

**PRIAM SMART AND SMART-E INTERFACE
PRODUCT SPECIFICATION**

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I. INTRODUCTION

A. Purpose

This specification describes the performance, the logical interface, the electrical interconnection, and the physical interconnection of the PRIAM SMART Interface and the PRIAM SMART-E Interface. This document provides the technical specifications required by users to connect the PRIAM SMART or SMART-E Interface to a host system with or without the use of a Direct Memory Access (DMA) port. For specific drive characteristics, see Table 1; for additional product detail, refer to the applicable product specifications.

B. Applicable Documents

PRIAM Product Specification 3350, 6650, and 15450
PRIAM Product Specification 3450 and 7050
PRIAM Product Specification 1070
PRIAM Interface Specification

C. General Description

For the purposes of this document and to eliminate text redundancies, the SMART and SMART-E will be referred to as the Interface, except where the two devices differ.

The Interface is a complete preprogrammed microprocessor based controller for the entire line of PRIAM Winchester disc drives. Up to four drives in any combination may be interconnected. The controller supports a variety of Read Sector, Write Sector, and Format commands. The data for the sector operations is transferred across an 8-bit parallel bidirectional data bus. The data transfers may be either programmed I/O or DMA transfers. Thus, the Interface performs the entire function of detailed disc control while presenting to the host a basic and cost effective interface. The Interface board may be mounted separately or attached to a PRIAM disc drive, either 8-inch or 14-inch.

The individual disc drive characteristics are shown in Table 1. Data capacities specified are based upon the number of eight bit bytes that may be recorded on a track. This unsectored capacity does not include any allowance for gaps or any format overhead. However, allowance is made for the 36 byte defect record.

TABLE 1 - PRIAM DISC DRIVE CHARACTERISTICS

Model	Disc Size	No. of Data Heads	No. of Servo Heads	Data Transfer Rate MB/Sec	Usable Bytes per Track	Bytes per Cyl.	Bytes per Drive	Cyl. per Drive
3350-10	14"	3	1	1.04	20,124	60,372	33,868,692	561
6650-10	14"	3	1	1.04	20,124	60,372	67,677,012	1121
15450-10	14"	7	1	1.04	20,124	140,868	157,913,028	1121
3450-10	8"	5	1	0.8	13,404	67,020	35,185,500	525
7050-10	8"	5	1	0.8	13,404	67,020	70,303,980	1049
1070-10	8"	4	None *	0.9	14,256	57,024	10,834,560	190

* Stepper motor controlled positioner.

D. Features

1. Controls up to four PRIAM disc drives.
2. Supports all PRIAM 8-inch and 14-inch disc products in any combination.
3. Designed for easy attachment to the typical microprocessor bus.
4. Does all bit serialization and format related functions. The host uses a simple byte-wide interface.
5. User-selectable sector sizes of 128, 256, 512, or 1024 bytes.
6. Full sector buffering which supports data transfers at any rate below 2 megabytes per second.
7. Both interrupt driven and polled operation are supported.
8. On-board 16-bit CRC on both ID header and data (SMART).
On-board 32-bit ECC on both ID header and data (SMART-E).
9. Automatic alternate sector assignment and read or write sector logic handle media defects transparent to the host.
10. Overlapped commands are supported. For example, three drives may be seeking, while seeking, reading, or writing on the fourth drive.

11. The Interface supports implied operations. For example, issuing a Read Command to a drive in which the disc is not turning will cause the drive to Sequence Up, Restore, Seek to the desired cylinder, Select the appropriate head, and Read the desired sector.
12. Versatile verify functions may be used for seek verification, sector data verification, track data verification, cylinder data verification, and complete disc data verifications.
13. Resident microdiagnostics.

E. Additional features of the SMART-E Interface

1. High performance microprocessor based.
2. Provides error correction (ECC).
3. Supports logical sector addressing.
4. Supports interleaving of sectors on drive.
5. Allows direct (non-buffered) data transfers.
6. Generates/tests parity on data bus.
7. 2K-byte disc data buffer (SMART is 1K-byte).

F. SMART-E Planned Enhancements

1. Daisychain capability to selected tape devices for straight-forward, inexpensive backup using common controller.
2. Full-track read and write (i.e., single-sector track) for large-block, high-speed data transfer.
3. Software user-selectable sector size for format flexibility.
4. On-track sector-sparing option for throughput efficiency.

NOTE: The SMART/SMART E Interfaces are not disc data format compatible. The drive must be formatted before use by the selected interface.

II. PRODUCT DESCRIPTION*

A. Physical Characteristics

The Interface is assembled on a single printed circuit board (13.75 by 8.30 inches) which may be mounted on either a 14-inch or 8-inch drive. There are three connectors: one for the host interface (40 pins), one for the drive interface (50 pins), and a third for DC power (2 pins). The host interface cable may be up to 25 feet in length.

The connector and cable types are as follows:

<u>Interface</u>	<u>Connector on SMART/SMART E</u>	<u>Connector on Interface Cable</u>	<u>Cable Type</u>
Host	3M 3432-1302 or Berg 65823-085	3M 3417-7040 or Spectra Strip 802-140-002	3M 3476/40 or Spectra Strip 455-276-40
Drive	3M 3433-1302 or Berg 65847-045	3M 3425-7050 or SAE RD6350-R5C	3M 3365-50
Power	AMP 640389-2 or Panduit HLAS156-2	Molex Series 2139 09-50-3021 with pins: Series 2478 08-50-0105 or Methode 3300-102 with pins: 3400-111	

B. Power Requirements

SMART: + 5 VDC, \pm 5%, 3 AMP maximum

SMART-E: + 5 VDC, \pm 5%, 3.5 AMP maximum

C. Environmental Characteristics

1. TEMPERATURE

a. Equipment Operational: 10° C to 40° C (57° F to 104° F).

b. Equipment Non-operational: -40° C to 60° C (-40° F to 140° F).

2. HUMIDITY

- a. Equipment Operational: 20% to 80% relative humidity, with a wet bulb temperature limit of 26° C (78° F) without condensation.
- b. Equipment Non-operational: 20% to 80% without condensation.

3. ALTITUDE

- a. Equipment Operational: From 1000 feet below sea level to 7000 feet above sea level.
- b. Equipment Non-operational: From 1000 below sea level to 40,000 feet above sea level.

* Specifications and characteristics provided in this document are subject to change without notice.

D. Reliability

1. MTBF

The Interface has an expected mean time between failures (MTBF) of 8000 power-on hours.

2. MTTR

The Interface is a field replaceable unit with a mean time to repair (MTTR) of less than 1/4 hour.

E. Control Jumpers for SMART Interface (See Figure 1)

1. W1

If jumper W1 is in the A position, PROM 12K is selected as a 2732; this jumper is selected by a PCB trace.

2. W2, W3, W4

If these jumpers are out, the PRIAM open loop write clock or A level interface is selected.

If these jumpers are installed, the PRIAM closed loop write clock or B level interface is selected.

3. W5

This jumper, when installed, enables the Head 4 line used on the DISKOS 3450 and the DISKOS 15450.

F. Control - Jumpers for SMART-E Interface (See Figure 2)

1. W1

If jumper W1 is in the A to B position, the SMART-E Interface becomes compatible with the SMART Interface with respect to the operation of the DTREQ/, HRD/, and HWR/ lines. This configuration does not support Direct Mode data transfers.

If jumper W1 is in the B to C position, the SMART-E Interface will support Direct Mode data transfers. However, in this configuration, the SMART-E Interface is not compatible with the SMART Interface with respect to the DTREQ/, HRD/, and HWR/ lines. Position B to C is the recommended position.

2. W2

Reserved for future use. This jumper is not required.

3. W3

This jumper, when installed, enables the Head 4 line, used on the DISKOS 3450 and the DISKOS 15450.

4. W4, W5, W6

If these jumpers are out, the PRIAM open loop write clock or A level interface is selected.

If these jumpers are installed, the PRIAM closed loop write clock or B level interface is selected.

5. W7

If jumper W7 is in the B to C position, even parity is enabled on the host interface bus.

If jumper W7 is in the A to B position, parity is disabled on the host interface bus.

6. W8

Reserved for future use. This jumper should be installed in the B position.

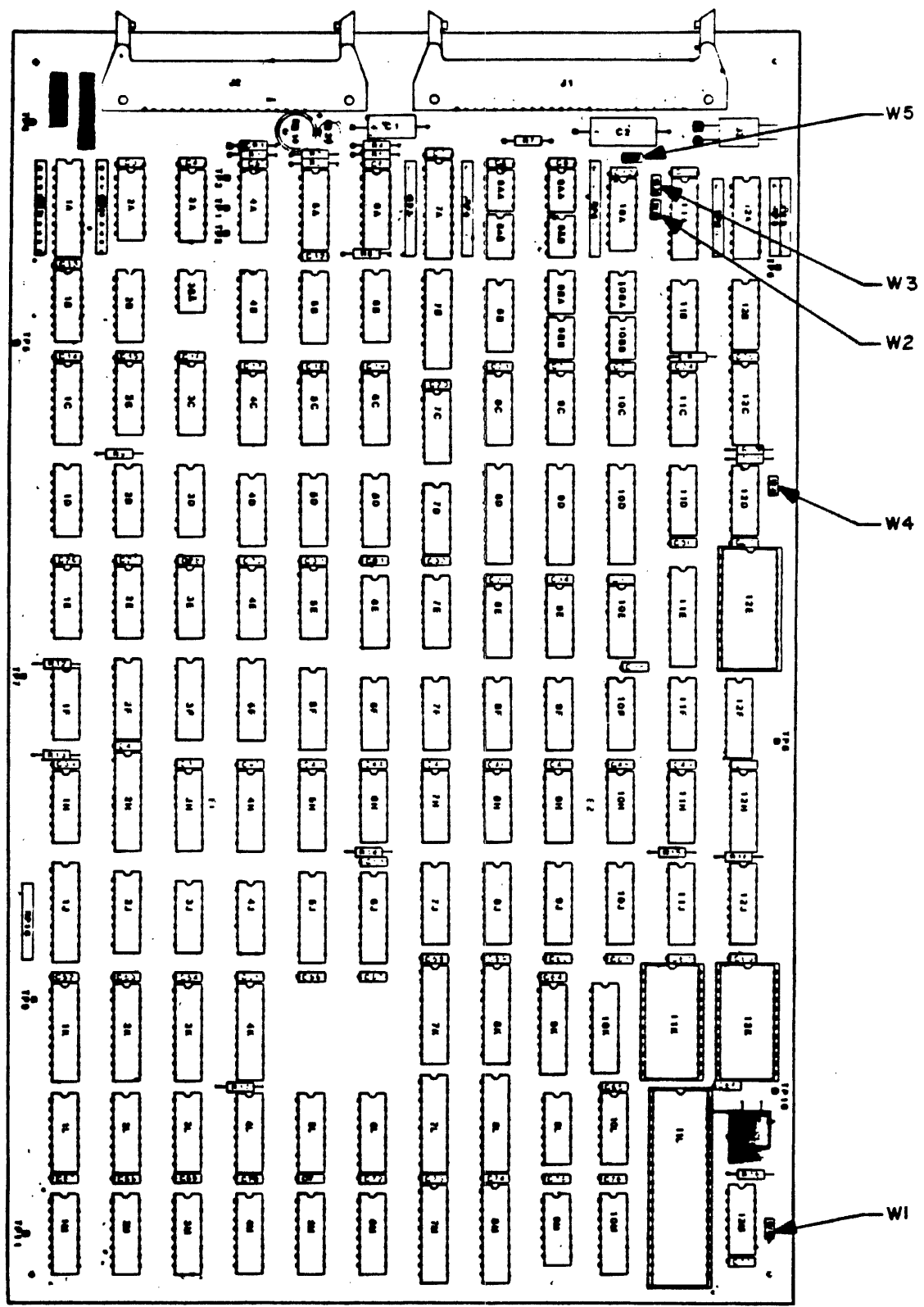


FIGURE 1. SMART Jumper Locations

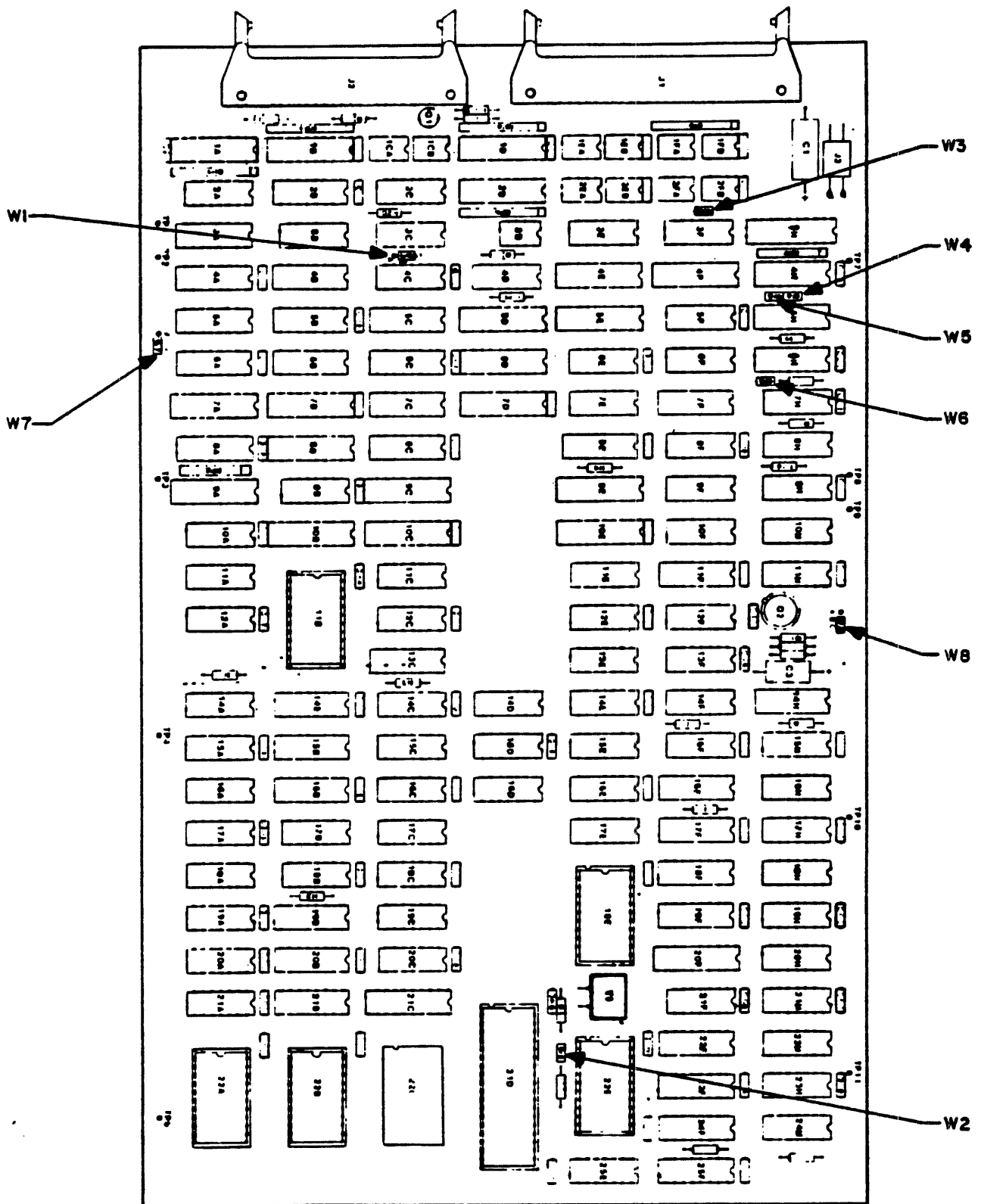


Figure 2. SMART-E Jumper Locations

III. ELECTRICAL INTERFACE

A. Interface Signals

The interface signals are defined in this section. Table 3 shows the connector pin assignment. All Interface signal connections are via a single 40 pin ribbon cable connector. See Table 2 for the recommended drivers and receivers.

1. HCBUS0 thru HCBUS7

This is the host bus. It is a high-active 8-bit wide bidirectional bus used to transfer control, status information and data. Data is transferred across this bus by successive operations with the Disc Data Register. The most significant bit is HCBUS7. The bus is TRISTATE bidirectional with the drivers enabled when the HRD signal is active. The receivers are enabled when the HRD signal is inactive.

Recommended termination for this bus is a 330 ohm resistor to +5 volts and a 390 ohm resistor to ground. Note: High current drivers (as listed in Table 2) are required to drive the HCBUS lines.

2. HCBUS8 (SMART-E Only)

This is the host bus parity line. If SMART-E jumper W7 is in the A position, data transfers across the host bus (HCBUS0 through HCBUS7 including HCBUS8) must have even parity.

Recommended termination for this signal is a 330 ohm resistor to +5 volts and a 390 ohm resistor to ground.

3. HRD/

This low-active signal gates the contents of the selected register (decode of HAD2, HAD1, HAD0) onto the HCBUS. See Table 5 for register decode assignment. This signal is terminated at the Interface with a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

4. HWR/

This low-active signal gates the contents of the HCBUS into the selected register (decode of HAD2, HAD1, HAD0). See Table 5 for register decode assignment. This signal is terminated at the Interface with a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

5. HAD2, HAD1, HAD0

This high-active, 3-bit-wide unidirectional address bus selects one of eight register pairs. One member of the pair stores the HCBUS contents while the contents of the other may be placed on the HCBUS, depending upon the host's manipulation of HRD and HWR.

These signals are terminated at the Interface with a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

6. RESET/

This low-active signal resets the Interface logic and places it into the initialized state. The Interface Busy bit will be set while initialization is in process.

The RESET/ signal should be used by the host hardware to ensure that the Interface is disabled during the host power-up phase. The minimum RESET/ pulse width is 500 ns.

This signal is terminated at the Interface with a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

7. HIR/

This low-active signal may be used by the host as an interrupt request. It is set active coincident with the setting of Command Completion bit in the Interface Status Register and it is cleared upon the receipt of the Completion Acknowledge Command.

Note: Interrupts are disabled by a power-up or controller reset. Interrupts are enabled by the first Command Acknowledge.

Recommended termination for this signal is a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

8. HREAD

This signal from the Interface indicates the direction of data transfer across the HCBUS. If this signal is high, a read (data from Interface to host) is the expected direction. When low, this line indicates that a write (data from the host to the Interface) is expected.

Recommended termination for this signal is a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

9. DBUSENA/

When low, this signal from the Interface to the host indicates that the Interface is enabled and ready to transfer data.

Recommended termination for this signal is a 220 ohm resistor to +5 volts and a 330 ohm resistor to ground.

10. DTREQ/

This low-active signal from the Interface to the host requests data transfers across the host bus (HCBUS).

This line is active when data is required and remains active until the proper number of bytes are transferred.

Recommended termination for this signal is a 220 ohm resistor to +5 volts and 330 ohm resistor to ground.

11. BUSREQ/ (SMART-E Only)

This active low signal is the bus request line. When the SMART-E is operated in direct mode (data is transferred at disc speed) this signal should be used to notify the host bus interface that a data transfer will be initiated.

TABLE 2 - Recommended Drivers/Receivers

<u>Signal</u>	<u>Driver/Receiver</u>
HCBUS7-HCBUS0	AMD, National 8304B or equivalent
All other receivers/HCBUS8	74LS14 or equivalent
All other drivers/HCBUS8	75461,75462,75463 or equivalent

TABLE 3 - Interface Connector Pin Assignment (J2)

<u>PIN Number</u>	<u>Signal</u>	<u>PIN Number</u>	<u>Signal</u>
1	Ground	31	Ground
2	HCBUS0	32	Reserved
3	HCBUS1	33	Reserved
4	HCBUS2	34	Reserved
5	HCBUS3	35	Reserved
6	HCBUS4	36	Reserved
7	HCBUS5	37	Reserved
8	HCBUS6	38	Reserved
9	HCBUS7	39	Reserved
10	Ground	40	Reserved
11	HRD/		
12	Ground		
13	HWR/		
14	Ground		
15	HAD2		
16	HAD1		
17	HADO		
18	Ground		
19	RESET/		
20	Ground		
21	HIR/		
22	Ground		
23	HREAD		
24	DBUSENA/		
25	Ground		
26	DTREQ/		
27	Ground		
28	BUSREQ/ (SMART-E only)		
29	Ground		
30	HCBUS8 (SMART-E only)		

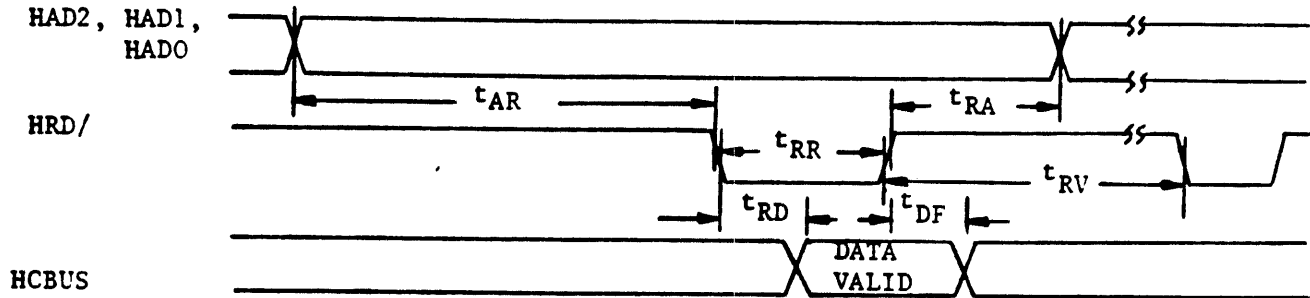
B. Data Transfer to or from the Interface

All data is transferred to or from the Interface on the HCBUS lines under the control of the host-generated HWR and HRD strobe lines. Figures 3 and 4 show the register Read and Write AC characteristics.

Commands and parameters are usually transferred to the Interface through the use of programmed I/O. Under programmed I/O the host processor is in direct control of the I/O operation.

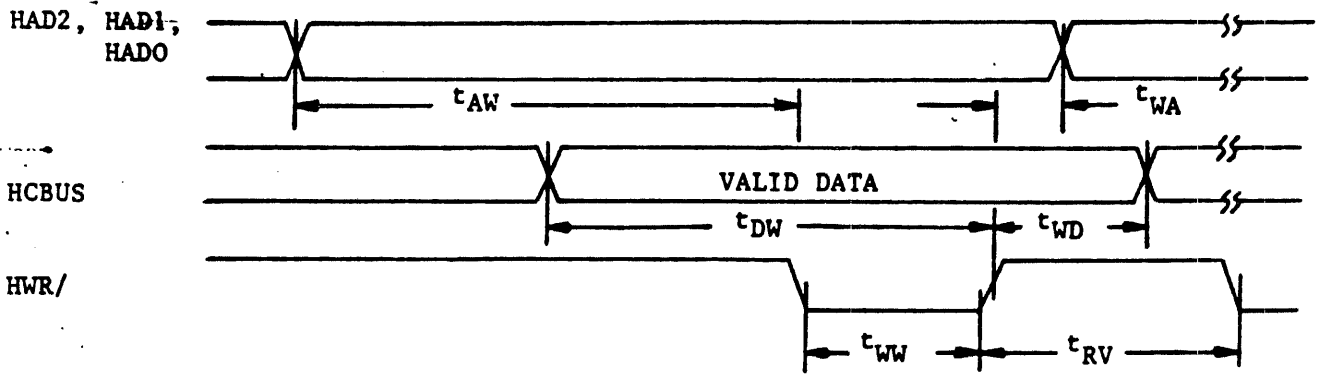
Many of the commands also contain a data transfer phase which may transfer large blocks of data. Some host interface designers may elect to implement Direct Memory Access (DMA) for the data transfer phase of the commands.

Figures 3, 4, and 5 are valid for SMART Interface command or data transfers using programmed I/O or DMA data transfers.



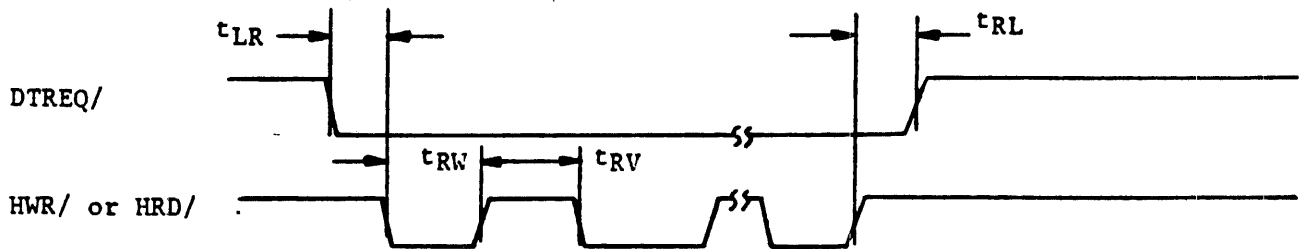
<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
tAR	Address stable before RD	60		ns
tRA	Address hold time for RD	30		ns
tRR	RD pulse width	250		ns
tRD	Data delay from RD		120	ns
tDF	RD to Bus Tristate condition		40	ns
tRV	RD recovery time	250		ns

Figure 3 - SMART Register Read AC Characteristics



<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
t_{AW}	Address stable before WR	60		ns
t_{WA}	Address hold time for WR	30		ns
t_{WW}	WR pulse width	250		ns
t_{DW}	Data set up time for WR	60		ns
t_{WD}	Data hold time for WR	30		ns
t_{RV}	Recovery time between WR	250		ns

Figure 4 - SMART Register Write AC Characteristics



<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
t_{LR}	Date Transfer Request HWR/ or HRD/	0		
t_{RL}	Data Transfer Release		200	ns
t_{RW}	HWR/ or HRD/ pulse width	250		ns
t_{RV}	Recovery Time between pulses	250		ns

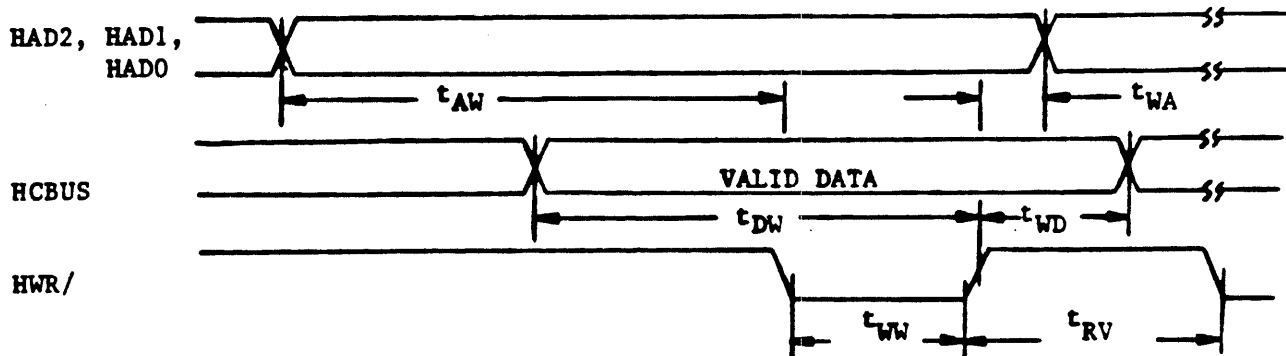
Figure 5 - SMART Data Request AC Characteristics

The SMART-E bus timing is compatible with the SMART timing. The follow differences apply to the SMART-E:

1. There is no Data hold time for write ($t_{wd} = 0$).
2. If jumper W1 is in the B position the data transfer request (DTREQ) line will become active for each data request and inactive when the data is transmitted/received.

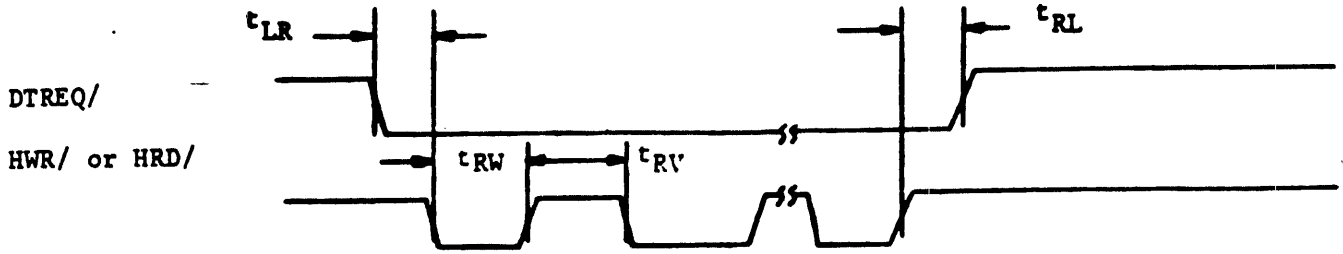
Figures 6, 7, 8, 9, and 10 are valid for SMART-E Interface command or data transfers using programmed I/O or DMA data transfers.

The SMART-E supports buffered and direct mode data transferred. If jumper W1 is in the B-C position and the SMART-E Mode Byte is initialized with bit 4 set, the SMART-E is placed in Direct Transfer mode (See Mode Byte discussion in Section V.A.). Under direct transfer mode the disc data is passed through to the host without going into the Interface buffer. Direct Mode requires a host bus interface that is capable of transmitting and receiving the data at disc speed.



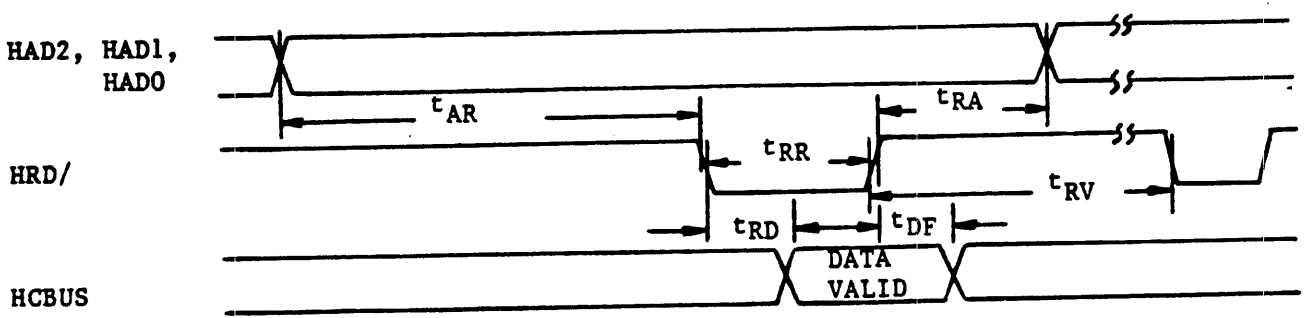
<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
t_{AW}	Address stable before WR	60		ns
t_{WA}	Address hold time for WR	0		ns
t_{WW}	WR pulse width	200		ns
t_{DW}	Data set up time for WR	200		ns
t_{WD}	Data hold time for WR	0		ns
t_{RV}	Recovery time between WR	30		ns

Figure 6 - SMART-E Register Write AC Characteristics



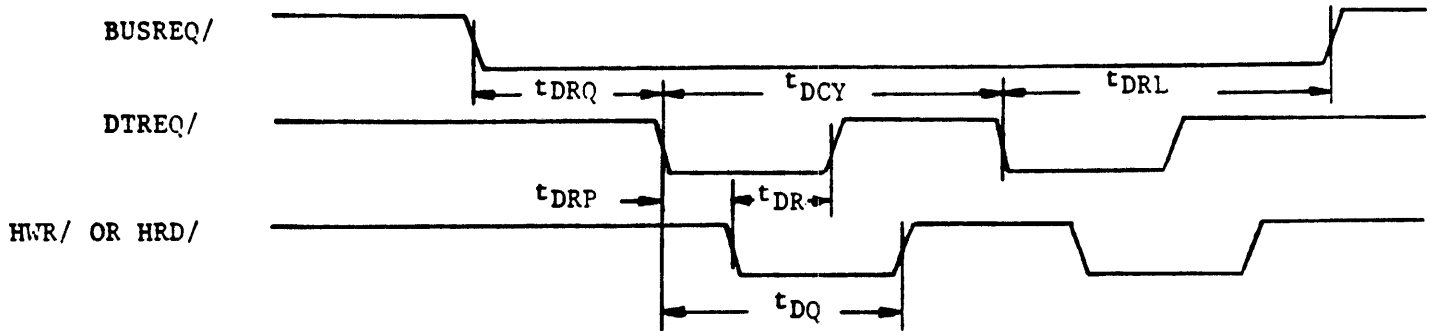
<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
t_{LR}	Data Transfer Request to HWR/ or HAO/	0		ns
t_{RL}	Data Transfer Release		0	ns
t_{RW}	HWR/ or HRD/ pulse width	200		ns
t_{RV}	Recovery Time between pulses	200		ns

Figure 7 - SMART-E Data Request AC Characteristics (Jumper W1 in A to B position)



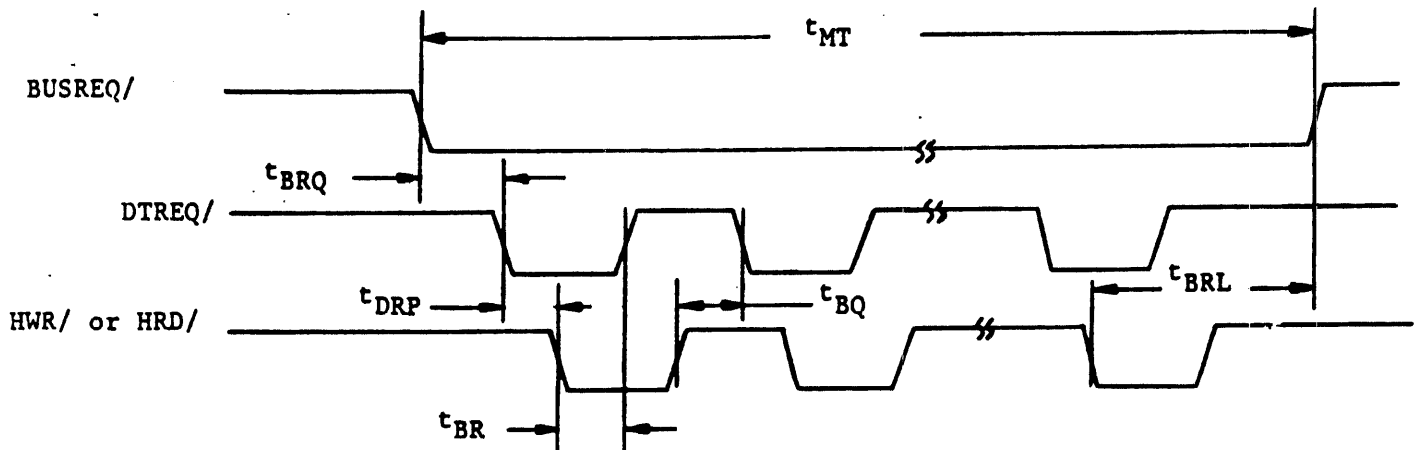
<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
t_{AR}	Address stable before RD	60		ns
t_{RA}	Address hold time for RD	0		ns
t_{RR}	RD pulse width	200		ns
t_{RD}	Data delay from RD		120	ns
t_{DF}	RD to Bus Tristate condition		40	ns
t_{RV}	RD recovery time	30		ns

Figure 8 - SMART-E Register Read AC Characteristics



<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
tDRQ	Bus Request before Data Request	12		us
tDRL	Last Data XFER Request to Bus Rels	4.0		us
tDCY	Byte Request to Byte Request	912	1500	ns
tDR	Request Release Time		250	ns
tDQ	Maximum Host Response Time		500	ns
tDRP	Data Transfer Request to HWR/ or HRD/	0		

Figure 9 - SMART-E - Direct Mode Data Request AC Characteristics (Jumper W1 in the B to C position)



<u>Symbol</u>	<u>Parameter</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
t_{BRQ}	Bus Request before Data Request	0		ns
t_{BRL}	Last Data XFER Request to Bus Rels			us
t_{MT}	Maximum Transfer Time		3	s
t_{BRL}	Bus Request Release Time		250	ns
t_{BQ}	Request Complete to Next Request		250	ns
t_{BR}	Buffered Request Delay		250	ns
t_{DRP}	Data Transfer Request to HWR/ or HRD/	0		ns

Figure 10 - SMART-E - Buffered Mode Data Request AC Characteristics (Jumper W1 in the B to C position)

IV. FUNCTIONAL INTERFACE

A. Command Initiation

Commands and data are transferred across an 8-bit bidirectional bus under control of host-generated HRD and HWR strobes. Registers within the controller are selected by decoding three address lines: HAD2, HAD1, and HAD0. Information is transferred over the TRISTATE bidirectional bus (HCBUS7 to HCBUS0). An active HRD signal places the bus in the transmit mode; an active HWR signal places the bus in the receive mode.

If the SMART-E is used with Jumper W7 in the B to C position the Interface will generate or check even parity on the HCBUS7 to HCBUS0 lines (HCBUS8 is the bus parity line). Parity is valid for all data transfer across the HCBUS except for host reads of the Interface Status Register. The Interface Status Register includes hardware generated signals that change asynchronous to HRD or HWR.

Table 5 shows the addressing required to select each of the registers.

A command is issued whenever the host loads the command register. Therefore, all the appropriate parameter registers must be loaded prior to loading the Command Register. When the Command Register is loaded, the Busy bit in the Interface Status Register will be set and will remain set until the command is validated and the parameter registers are copied into the Interface local memory.

After the SMART Interface has accepted the command the Busy bit is cleared. The Busy bit is cleared before the command is completed so that the host may issue overlapped seeks or other overlapped commands to other drives.

When using the SMART Interface the Command Reject will be set if any of the following errors occur:

1. The drive number is invalid.
2. The selected drive already has a command in process.
3. The command was written to the command register while Busy was set.

The Host Interrupt Request (HIR) is not activated if the command is rejected during the initial command validation phase of the SMART.

When using the SMART-E Interface the following errors will cause the SMART-E to abort all commands in process and set Host Interrupt Request (HIR) with the appropriate transaction status:

1. The drive number is invalid.
2. The selected drive already has a command in process.
3. The command was written to the command register while Busy was set.
4. A bus parity error was detected.

After a command has been completed, a command completion is indicated through the Command Completion Request bit in the Interface Status Register (see Table 6).

When the Command Completion Request Bit is set, the Host Interrupt Request line (HIR) is activated.

The Command Completion Request and the Host Interrupt Request are cleared by issuing the Completion Acknowledge command (see Command Descriptions).

Table 4 is a summary of the commands that are supported by the Interface. These commands are discussed in Section V of this specification.

TABLE 4 - Command Summary

<u>Command Code (Hex)</u>	<u>Command Name</u>
00	Completion Acknowledge
03	Read Buffer
04	Write Buffer
05	Read Internal Status
06	Read Drive Status
07	Software Reset
08	Specify SMART Mode (SMART-E Only)
09	Read SMART Mode
40	Drive Restore
# 44	Verify Data
# 48	Verify ID
# 51	Seek - Retry Enabled
# 41	Seek - Retry Disabled
# 52	Write Data - Retry Enabled
# 42	Write Data - Retry Disabled
# 53	Read Data - Retry Enabled
# 43	Read Data - Retry Disabled
# 55	Write ID - Retry Enabled
# 45	Write ID - Retry Disabled
# 56	Read ID - Retry Enabled
# 46	Read ID - Retry Disabled
# 57	Read ID Immediate - Retry Enabled
# 47	Read ID Immediate - Retry Disabled
# 59	Read Skip Defect Field - Retry Enabled
# 49	Read Skip Defect Field - Retry Disabled
# 5A	Write Skip Defect Field - Retry Enabled
# 4A	Write Skip Defect Field - Retry Disabled

TABLE 6 - Interface Status Register

<u>Bit</u>	<u>Name</u>	<u>Description</u>
7 (MSB)	Command Reject	An undefined or invalid command was received.
6	Command Completion Request	The Interface has performed the requested function and the transaction status is available in the Transaction Status Register.
5	Special Completion	The Special Completion bit is set (along with CS6) if the completion is for a command that may be overlapped with a drive command. Commands that set the Special Completion bit are identified in the command descriptions.
4	--	Reserved
3	Interface Busy	The Interface has received a command and is busy parsing the requested command.
2	Data Transfer Request	This bit indicates the state of the DTREQ/ interface line.
1	Read/Write Request	If this bit is active and the Data Transfer Request line is active, a read data operation is required. If this bit is not active and the Data Transfer Request line is active, a write data operation is required. This high active bit indicates the state of the HREAD interface line.

<u>Command Code (Hex)</u>	<u>Command Name</u>
81	Sequence Down
82	Sequence Up - Wait
83	Sequence Up - Return
85	Read Drive Parameters
86	Read Drive Type
A0	Format Disc
A1	Format Cylinder
A2	Format Track
A3	Verify Disc
A4	Verify Cylinder
A5	Verify Track
A6	Read Defect Directory
A8	Format Disc With Defect Mapping
# A9	Specify Bad Track
# AA	Specify Bad Sector
AB	Write Disc - Full Track
AC	Write Cylinder - Full Track
AD	Write Full Track
AE	Write Defect Directory
E0	Transfer Parameter to Result
E1	ID Buffer Transfer Test

In the SMART-E Interface, commands marked with '#' will accept a logical address if the Interface is in Logical Sector Mode.

B. User-Accessible Registers

Table 5 lists the registers that are directly accessible to the host, and shows the address and control signal values needed to access each register. Table 6 defines the bits of the Interface Status Register. Tables 5, 7, and 8 and the accompanying text define the fields of the Transaction Status (Result 0) Register. The text following Table 8 discusses the remaining parameter registers and result registers.

TABLE 5 - Control Register Assignment

<u>HAD2</u>	<u>HAD1</u>	<u>HADO</u>	<u>HRD</u>	<u>HWR</u>	<u>Register</u>
0	0	0	1	0	Interface Status
0	0	1	1	0	Read Disc Data
0	1	0	1	0	Result 0 (Transaction Status)
0	1	1	1	0	Result 1
1	0	0	1	0	Result 2
1	0	1	1	0	Result 3
1	1	0	1	0	Result 4
1	1	1	1	0	Result 5
0	0	0	0	1	Command
0	0	1	0	1	Write Disc Data
0	1	0	0	1	Parameter 0
0	1	1	0	1	Parameter 1
1	0	0	0	1	Parameter 2
1	0	1	0	1	Parameter 3
1	1	0	0	1	Parameter 4
1	1	1	0	1	Parameter 5

TABLE 6 - Interface Status Register (Cont'd)

<u>Bit</u>	<u>Name</u>	<u>Description</u>
0 (LSB)	Data Bus Enable	The Data Bus Enable bit indicates that the Interface has successfully completed its self test. This high active bit indicates the state of the DBUSENA interface line.

Transaction Status (Result Register 0)

The Transaction Status Register (Result 0) indicates the result of an Interface command. The format of the Transaction Status Register is shown in Table 7. When the Interface Status Register indicates that a Command Completion Request is pending, the host processor should read the Transaction Status Register to determine the outcome of the command. After the Host has read the Result Register the Host should issue the Completion Acknowledge command so that the Interface may post the next command completion.

The four major completion types are listed below:

1. Good Completion - 0

This type of completion indicates that the command was successfully completed. Some steps may have been retried.

The following codes are generated if the automatic retry logic is unable to recover from the error.

2. System Error - 1

These errors result from a system, controller or drive problem.

3. Operator Intervention - 2

These errors require human intervention for recovery.

4. Command or Drive Error - 3

Command errors are usually due to a user program error.

Table 8 provides more detailed information about completion types and completion codes.

TABLE 7 - Transaction Status Register

Bit Number:	7	6	5	4	3	2	1	0
Bit Designation:	D1	D0	T1	T0	CC3	CC2	CC1	CC0

<u>Bit</u>	<u>Name</u>	<u>Description</u>
D1, D0	Drive	This field indicates to which drive the transaction status applies.
T1, T0	Completion Type	This field defines the four major classes of completion. See Table 8.
CC3, CC2, CC1, CC0	Completion Code	The completion codes provide a detailed definition of the command termination. See Table 8.

TABLE 8 - Completion Code Summary

<u>Completion Type (Bits 5-4)</u>	<u>Completion Code (Bits 3-0)</u>	<u>Definition</u>
0	0	No Retries Performed
	1	Motion Retry Performed
	2	Data Retry Performed
	3	ECC Correction Performed (SMART-E Only)
1	0	Late Data Transfer
	1	CRC Error (SMART) or Uncorrectable ECC Error (SMART-E)
	2	Seek Fault - Drive Reported
	3	Drive Fault
	4	Not Used
	5	Seek Fault - Cylinder Mismatch
	6	Initialization Complete
	7	Stack Error
	8	Hardware Trap
	9	Read Loss Synchronization
	A	RAM Failure
	B	ID Buffer Failure
C	Bus Parity Error (SMART-E Only)	
D	PROM Checksum Error (SMART-E Only)	
2	0	Drive Not Ready
	1	Write Protect
	2	Drive Not Present
	3	Sector Size Invalid
	4	Alternate Area Overflow
	5	Defect Directory Full
	6	End of Defect Directory
	7	Defect Directory Not Present
3	0	Sector Not Found
	1	Command Reject
	2	Drive Busy Command Time-Out
	3	Data Transfer Time-Out
	4	Illegal Cylinder or Head Address
	5	Invalid Drive Number
	6	Sector Number Invalid
	7	Command Already In Progress
	8	Command Double Write
	9	Drive Command Reject
	A	Multisector Operation Error
B	Invalid Interleave Factor (SMART-E Only)	

The following section provides a summary of the completion codes and a detailed description of each code.

<u>Transaction Status (Bits 5-0)</u>	<u>Definition</u>
00	No Retries Required This status code indicates that the command completed successfully without any retries.
01	Motion Retries Performed This status code indicates that an automatic retry was used to recover from an error and then the command completed successfully.
02	Data Retries Performed This status code indicates that a data error occurred but an automatic retry recovered from the error and completed the command successfully.
03	ECC Correction Performed (SMART-E Only) This status code indicates that a hard read error occurred but the ECC logic was able to correct the bits in error.
10	Late Data Transfer (SMART-E Only) This error may occur when operating the SMART-E in direct mode. A late data transfer will occur if the host interface does not read/write data fast enough to match the disc transfer rate.
11	CRC Error (SMART) or Uncorrectable ECC Error (SMART-E) This status code indicates that a CRC error was detected on a read operation (SMART), or that an uncorrectable ECC error was detected (SMART-E).
12	Seek Fault - Drive Reported This status code indicates that a seek was attempted and the seek failed. The seek error was indicated in the disc drive status.
13	Drive Fault This status code indicates that the operation was terminated due to one of the conditions in Table 9.
15	Seek Fault - Cylinder Mismatch This status code indicates that a seek was performed and completed by the drive, but a comparison of the drive current cylinder registers with the intended address indicated that the wrong cylinder was selected.

Transaction Status
(Bits 5-0)

Definition

- 16 **Initialization Complete**
 This status code indicates that the Interface has successfully completed a restart operation (power up or interface line reset). This completion provides the following Result Register values:
- Result 1 = AA
Result 2 = 55
Result 3 = F0
Result 4 = 0F
Result 5 = 00
- This completion does not generate an interrupt request, but it must be acknowledged by a Completion Acknowledge command.
- 17 **Stack Error**
 This status code indicates that a hardware failure occurred that resulted in an instruction fetch from a nonexistent program memory location.
- 18 **Hardware Trap**
 This status code indicates that an unexpected processor interrupt (trap) occurred.
- 19 **Read Loss Synchronization**
 This status code indicates that read operation was terminated before the expected number of data bytes were read from the disc.
- 1A **RAM Failure**
 This status code indicates that the micro-diagnostics have detected a bad RAM location.
- The result registers have the following meanings:
- Result 1 = Expected Data
Result 2 = Received Data
Result 3 = Memory Address MSB
Result 4 = Memory Address LSB
- 1B **ID Buffer Failure**
 This status code indicates that the micro-diagnostics have detected an error in the ID buffer.
- The result registers have the following meanings:
- Result 1 = Expected Data
Result 2 = Received Data
Result 3 = Buffer Location

Transaction Status
(Bits 5-0)

Definition

- 1C Bus Parity Error (SMART-E Only)
 This status code indicates that the SMART-E Interface has detected a parity error (the HCBUS7-HCBUS0 and HCBUS8 should have even parity) on the host interface. This applies to both commands and data.
- 1D PROM Checksum Error (SMART-E Only)
 This status code indicates that the diagnostics have detected a program ROM failure.

 Result register 1 contains the PROM number in error:

 Result 1=0 PROM Location 22A
 Result 1=1 PROM Location 22B
 Result 1=2 PROM Location 22C
- 20 Drive Not Ready
 This status code indicates that the Interface attempted to sequence up the drive and the drive did not indicate that it was ready within the expected period of time.
- 21 Write Protect
 This status code indicates that a write operation was attempted on a write-protected drive.
- 22 Drive Not Present
 The drive specified is not connected or not powered up.
- 23 Sector Size Invalid
 The sector switches on the drive are set incorrectly.
- 24 Alternate Area Overflow
 This status code indicates that there are more defective sectors or tracks than there are spare sectors or tracks on the disc.
- 25 Defect Directory Full
 The defect mapping logic was unable to expand the size of the defect directory because all available space was in use.

Transaction Status
(Bits 5-0)

Definition

- 26 **End of Defect Directory**
 If the disc has been formatted with defect mapping enabled, there will be a Defect Directory located in the user alternate area. The directory is a linked list of 128 byte records that are numbered through N-1 where N is the number of 128 byte records in the directory. This error code will be received if a Read or Write Defect Directory command is issued that has specified a record number greater than N.
- 27 **Defect Directory Not Present**
 This error code indicates that a Read Defect Directory command was issued to a drive that was formatted without defect mapping.
- 30 **Sector Not Found**
 This code indicates that the specified logical sector could not be located.
- 31 **Command Reject**
 The received command is not supported by the Interface.
- 32 **Drive Busy Command Time-out**
 This status code indicates that the Interface issued a command to the drive and the drive did not properly complete the command.
- 33 **Data Transfer Timeout**
 This status code indicates that the Interface requested a data transfer to the host and the transfer was not completed within 3 seconds.
- 34 **Illegal Cylinder or Head Address**
 This code indicates that a head number or cylinder number greater than the maximum supported was specified as a parameter.
- 35 **Invalid Drive Number**
 This code indicates that a drive number greater than three was specified as a parameter.
- 36 **Sector Number Invalid**
 This code indicates that a physical operation (as distinguished from a logical operation) failed to find the specified sector.
- 37 **Command Already In Progress**
 This code indicates that the specified drive already had a command in progress.

38	Command Double Write This error occurs if the host writes to the command or parameter registers when the Interface Busy bit is set.
39	Drive Command Reject This error code indicates either a Interface or drive hardware failure.
3A	Multisector Operation Error This error code indicates that a read or write data command was issued with a multisector count equal to zero or greater than 7F HEX.
3B	Invalid Interleave Factor (SMART-E Only) This error code indicates that a command requiring an interleave factor was issued and that the interleave factor was incorrect. The discussion on interleaving describes the use of the interleave factor.

TABLE 9 - Drive Fault Conditions

1. WRITE GATE without write current at the head.
2. Write current at the head without WRITE GATE.
3. WRITE GATE without READY.
4. More than one head selected.
5. No transitions during write (MFM format).
6. WRITE GATE with WRITE PROTECT.
7. WRITE GATE between INDEX and the first SECTOR MARK (when the Skip Defect Record is write protected).

There is a common format for both parameter and result registers used in most commands.

Listed below are some commonly occurring formats for Parameter and Result Registers 0 to 4. These are used in many (though not all) commands. For purposes of illustration, physical addresses are shown for the contents of Parameter and Result Registers 1 to 3. When the SMART Interface is used, addresses on the disc must be specified by the host system as physical addresses. When the SMART-E Interface is used, the host system may specify either physical or logical addresses, in accordance with Bit 6 in the Mode Register. See the section on Disk Addressing Methods for more details.

Parameter Register 0

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	0	0	0	0	0	D1	D0

where:

<u>D1</u>	<u>D0</u>	
0	0	Drive 0
0	1	Drive 1
1	0	Drive 2
1	1	Drive 3

Parameter Register 1

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	H2	H1	H0	C11	C10	C9	C8

where: H2, H1, H0 define the target head address and C11, C10, C9, C8 are the upper binary bits of the target cylinder address. Both heads and cylinders are numbered consecutively, starting with 0.

Parameter Register 2

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	C7	C6	C5	C4	C3	C2	C1	C0

where: C7 through C0 are the 8 least significant bits of the target cylinder address. Cylinders are numbered consecutively, starting with cylinder 0.

Parameter Register 3

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	S6	S5	S4	S3	S2	S1	S0

where: S6 through S0 are the 7 binary bits defining the target sector. Within a given track, sectors are numbered consecutively, starting with sector 0.

Parameter Register 4

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	M6	M5	M4	M3	M2	M1	M0

where: M6 through M0 are the 7 binary bits defining the total number of consecutive logical sectors to be read or written. The valid range is from 1 to 7F (HEX) sectors.

The formats of the most common result registers are as follows:

Result Register 0

See Table 7 for the Result Register 0 definition.

Result Register 1

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	H2	H1	H0	C11	C10	C9	C8

where: H2, H1, H0 define the current selected head address and C11, C10, C9, are the upper binary bits of the current cylinder address. Both heads and cylinders are numbered consecutively, starting with 0.

Result Register 2

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	C7	C6	C5	C4	C3	C2	C1	C0

where: C7 through C0 are the 8 least significant bits of the current cylinder address. Cylinders are numbered consecutively, starting with cylinder 0.

Result Register 3

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	S6	S5	S4	S3	S2	S1	S0

where: S6 through S0 define the number of the last sector accessed. Within a given track, sectors are numbered consecutively, starting with sector 0.

Result Register 4

Bit Number	7	6	5	4	3	2	1	0
Bit Designation	0	M6	M5	M4	M3	M2	M1	M0

where: M6 through M0 indicate the residual sector count (non-zero if an unrecoverable error occurred).

C. Disk Addressing Methods

There are three types of addressing used to identify locations on the disc(s):

- Absolute Addressing
- Physical Addressing
- Logical Addressing

Absolute addressing identifies a location by specifying a head address, cylinder address, and sector address. The head addresses run from 0 to N-1, where N is the number of read/write heads on the drive; each possible value represents a particular head. The cylinder addresses run from 0 to T-1, where T is the number of tracks per disc surface; each possible value represents a particular cylinder, with 0 at the outer edge of the usable disc surface. The sector addresses run from 0 to S-1, where S is the number of sectors per track; each possible value represents a definite sector, and the sectors are numbered consecutively. The sector addresses increase as the disc rotates; Sector 0 is the first sector after the skip defect field.

Physical addressing uses the same format (head, cylinder, sector) as absolute addressing, but the physical address of a given sector may be different from that sector's absolute address. There are two factors leading to such differences -- defect mapping and interleaving. Defect mapping is the process through which a bad sector or track is identified, with an alternate assigned and used in its place. The defect directory is a list of these defective regions, with the corresponding alternate sectors or tracks also listed. When the Interface is processing a command which involves a read or write operation on a defective sector or track, the Interface automatically performs that operation on the corresponding alternate track. Except for the additional time required, this substitution is entirely transparent to the host system. The details of defect mapping are discussed in Section IV.E. of this specification. Interleaving (available only with the SMART-E interface) is a technique which may be used to enhance system performance under some conditions. It is a mapping performed on the sectors within each track. The user specifies an interleave factor (equal to the number of unaccessed absolute sectors between successively accessed physical sectors). For example, an interleave factor of 0 causes successive absolute sector addresses to be accessed, while an interleave factor of 1 causes every second absolute sector address to be accessed. The SMART-E Interface performs the interleaving in a manner that is transparent to the host system. More details on interleaving are given in the next section of this specification.

Logical addressing (supported only by the SMART-E Interface) allows the user to relate to the disc storage space as a list of sectors, numbered from 0 to the total usable storage capacity of the drive. The host system loads Parameter Registers 1, 2, and 3 with the logical sector address (Parameter Register 1 is the most significant

byte, and Parameter Register 3 is the least significant byte). The SMART-E Interface translates this into a physical sector address, and then proceeds in the manner described below. Defect mapping and interleaving (if required) are performed as part of the conversion between physical and absolute addressing. When the SMART-E reports results to the host system, it translates the physical address back into a logical address, before placing it in Result Registers 1, 2, and 3.

D. INTERLEAVING

Interleaving is a capability of the SMART-E Interface. It provides a means by which the host system may regulate the rate at which data passes between the host and the disc. Interleaving occurs within each track, and affects the sequence in which sectors are accessed during multi-sector operations.

The user controls the interleaving function by specifying an interleave factor. This is sent to the SMART-E interface as Parameter 3, prior to issuing one of the following commands:

- Format Disc with Defect Mapping
- Format Disc
- Format Cylinder
- Format Track

In the absence of interleaving the sectors are accessed sequentially; successive physical or logical sectors are also successive absolute sectors. If interleaving is not desired an interleave factor of 0 should be specified by the host. If interleaving is desired, the host may specify some other value. The SMART Interface does not support interleaving. An interleave value of 0 should always be specified when using the SMART Interface.

The value specified as the interleave factor is the number of unaccessed absolute sectors that lie between successive physical sectors. For example, if the user specifies an interleave factor of 3, then physical sectors 0, 1, 2, ... will correspond to absolute sectors 0, 4, 8, ...

During the formatting process, the SMART-E Interface writes a physical address of 0 into the ID field of the first absolute sector, then skips k absolute sectors (where k is the interleave factor), then writes physical address 1 into the ID field of the next absolute sector, and so on. The process continues until physical addresses have been assigned to all absolute sectors on the track(s) to be formatted. It is important to note that some interleave factors will not allow an assignment that results in k absolute sectors between some physical sectors. If during the setup of the ID fields the SMART-E detects that the next sector is already used the next available sector will be assigned instead (see example).

Example: Interleave factor/sector assignment

Sectors per track = 5
Interleave factor = 1

Absolute Sector Number: 0 1 2 3 4
Physical Sector Number: 0 3 1 4 2

Sectors per track = 6
Interleave factor = 1

Absolute Sector Number: 0 1 2 3 4 5
Physical Sector Number: 0 3 1 4 2 5

This example demonstrates a case where a sector per track/interleave factor combination does not result in proper sector spacing. Physical sector 3 is actually two sectors from physical sector 2.

The interleave factor may have any value from 0 up to half the number of sectors per track.

If the host system must implement custom interleave formats not supported by the standard algorithm, the user may specify the factor table directly.

When an interleave factor of OF0 HEX is specified the Interface will perform a data request for N bytes of data (where N is the number of sectors per track). The N bytes of data specify the physical sector numbers in absolute sector sequence. The first byte of data will be absolute sector zero's physical address, the second byte of data will be absolute sector one's sector address, etc.

The interleave factor is specified at the time of formatting, and can not be changed dynamically during normal operation.

In choosing an interleave factor the user should consider the following things concerning his system:

- Data transfer time across the host interface.
- Host processing time for this data.
- Number of sectors to be transferred on a single command.

Table 10 displays the basic timing parameters of the interface required to compute interleave factors.

Table 10 - SMART/SMART-E Command Delays

<u>OPERATION</u>	<u>SMART</u>	<u>SMART-E</u>
Completion ACK (Issue command to busy Clear)	80 us	30 us
Command Start (Issue command to busy Clear)	160 us	110 us
Initiate/Terminate Read/Write Data command	2 ms	1 ms

- NOTES:
1. All times are approximate
 2. All times assume non-overlapped command operation

E. DEFECT MAPPING

During the operation of the Format Disc with Defect Mapping Enabled command the Interface may encounter a defective sector on a track. The defect mapping capabilities of the Interface allow it to assign alternate areas for the defective areas. The Interface creates a defect directory described in the next section, during the format operation. Each drive has an area reserved for alternate sectors.

1. Defect Map Format

If the disc is formatted with defect mapping enabled the defect directory is created on the first good track of the alternate sector/track area. (See Tables 11 through 14.)

The Defect Map is a linked list of 128 byte records. Locations 1 and 2 of each record contain the address of the track that contains the next directory record. If a record is the last record in the directory, the link address will be zero.

TABLE 11 - Defect Directory Format

<u>Location (HEX)</u>	<u>Description</u>
0	Configuration Level
01, 02	Next entry link address
03	Interleave Factor (SMART-E Only)
04, 05	Interleave Factor Table Address (SMART-E Only)
06	Configuration Data (to be defined)
10-7F	Defect Directory Entries (see Table 12)

TABLE 12 - Defect Directory Entry Format

<u>Location</u>	<u>Description</u>
0	Defect Cylinder Address LSB
1	Defect Head/Cylinder Address MSB
2	Defect Physical Sector Address (If FF HEX = End of directory; if FE HEX = defective track.)
3	Alternate Cylinder Address LSB
4	Alternate Head/Cylinder Address MSB
5	Alternate Physical Sector Address

TABLE 13 - Alternate Areas (Cylinders) by Drive Type

<u>Drive Type</u>	<u>User Cylinder</u>	<u>Alternate Area (Cylinders)</u>
3350	0-554	555-560
6650/15450	0-1107	1108-1120
3450	0-514	515-524
7050	0-1038	1039-1048
1070	0-184	185-189

There are as many defect directory entries created as are required. The Format Disc with Defect Mapping command proceeds as follows:

- a. The entire disc is formatted including the alternate areas defined in Table 13.
- b. The skip defect records are read and the bad tracks and sectors are flagged by reformatting the sectors and tracks with the ID codes shown in Table 14.
- c. The first defect directory entry is created on the first available good track of the alternate area.
- d. The disc is scanned for flagged sectors or tracks and alternates are assigned.
- e. If the directory becomes full another record is added to the directory.

TABLE 14 - ID Control Field Definition

<u>ID Control Value (HEX)</u>	<u>Definition</u>
FF	User Data
FD	User Alternate
F5	Bad Track
FB	Bad Sector
F0	Defect Directory Entry
F3	Interleave Factor Table Entry

2. Read/Write Data Operations - Defect Handling

Read or Write requests that are performed on sectors that are not defective do not encounter any overhead due to the defect mapping feature. Defect mapping is only performed when the Interface cannot locate the specified sector. The major steps in the defect mapping logic are outlined below.

- a. Attempt to perform the operation on the sector as specified.
- b. If the specified sector is not found, read the defect map.
- c. Scan the defect map for the sector required.
- d. If the required sector is found, operate on the alternate sector specified.
- e. If the specified sector is a member of a bad track, complete the entire multisector operation. Otherwise seek back to the user data track.

3. Adding Defect Directory Entries

New entries may be added to the defect directory by using the Specify Bad Sector command or the Specify Bad Track command. For the SMART Interface, the user may specify the bad sector or track by giving its physical address. For the SMART-E Interface, the user may give a physical address (if the Interface is in physical mode) or a logical address (if the Interface is in logical mode).

It should be noted that adding a defect directory entry does not of itself amend the skip defect record on the corresponding track. This can be accomplished by using the Write Skip Defect Field command.

4. Interleave Factor Table

The Interleave Factor Table record is a 128 byte record that specifies the physical sector numbers in absolute sector sequence. The first N bytes are valid where N is the number of sectors per track.

The interleave factor table is generated when the disc is formatted with defect mapping enabled.

F. Error Retry Technique

If an error occurs during the execution of the command and the retry feature is selected (i.e., retries are enabled), the SMART Interface will automatically retry the command.

If retries are not enabled, the command is aborted and the appropriate transaction status is immediately returned to the host. Table 15 outlines the retry strategies employed.

All of the commands that require accessing data are preceded by a seek to the correct cylinder before the data transfer is begun. If the command is a logical or physical data access, the disc cylinder is verified by reading the ID field information.

TABLE 15 - Error Recovery Strategy

<u>Error Type</u>	<u>Retry Procedure</u>
CRC Error (SMART Interface)	b
ECC Error (SMART-E Interface)	f
Seek Fault	c
Drive Fault	d
Drive Not Ready	d
Write Protect	None
Sector Not Found	e
Command Reject	None
Command Timeout	d
Data Transfer Timeout	a
Illegal Cylinder/Head	None

1. Retry Procedures

- a. The command must be reissued by the host.
- b. The SMART Interface automatically performs four retries for any operation that results in a CRC error.
- c. If a seek fault occurs, the seek fault is reset and the seek is retried four times.
- d. A reset is issued to the drive and the command is retried four times.
- e. The defect mapping logic is initiated when a sector is not found.
- f. The SMART-E Interface automatically performs four retries for any operation that results in an ECC error. If the error persists, four additional retries are performed, and the syndrome pattern is checked for recurrence. If a given pattern appears two times, error correction is attempted, using the ECC.

2. SMART-E ECC

The SMART-E supports 32-bit computer generated code that is selected for insensitivity to short double bursts with good detection span. The ECC check characters/error syndromes are generated by hardware. ECC correction is performed under software control.

It should be noted that there is no performance penalty resulting from the use of the ECC error detection capability if error correction is not attempted.

When error correction is invoked, the SMART-E interface returns a 03 completion code in the Result 0 (transaction status) register. The recommended procedure in such a case is to rewrite the offending sector and read it again. If any errors persist, that sector should be flagged (and an alternate assigned) by issuing a Specify Bad Sector command.

TABLE 16 - SMART-E ECC Characteristics Summary

1. 32-bit computer-generated code.
2. Maximum correction span of 5 bits.
3. Single burst detection span of 32 bits.
4. Optimized for double burst detection.
5. No performance penalty unless ECC correction required.
6. Read retry recovery from soft errors.
7. ECC correction attempted only on hard errors with a repeatable syndrome.

3. SMART-E Special Considerations

The operation of the SMART-E error recovery logic is impacted by the Mode Byte specified by the host (see Section V).

If the interface is operating in direct mode the data has been transferred to the host memory before an ECC error is detected. The recommended error recovery is as follows:

1. Direct mode unrecoverable ECC error reported.
2. Change SMART-E mode to buffered operation.
3. Reissue read command.
4. If read successful rewrite sector.
5. If re-read error free restore mode.
6. If re-read in error specify bad sector and rewrite.
7. Restore mode.

V. COMMAND DESCRIPTION

This section defines each of the Interface commands.

The commands are presented in the following seven groups:

1. Interface Configuration and Control Commands (SMART-E Only)
2. Format Commands
3. Defect Mapping Commands
4. Data Transfer Commands
5. Disc Motion and Drive Control Commands
6. Disc Data Initialization and Verification Commands
7. Diagnostic Commands

A. Interface Configuration and Control Commands

The following two commands are used to read or write the SMART-E mode. This mode byte is used to select and control the additional features of the SMART-E. After a reset, the mode byte is set to zero. SMART-E users should always specify the mode byte after reset of the SMART-E if a mode other than mode zero is desired.

Table 17 outlines the mode byte values that most users should specify.

TABLE 17 - Common Mode Byte Values (SMART-E Only)

Mode Byte Value (HEX)	Meaning
00	Normal Read/Write physical sector buffered mode (same operation as the SMART).
40	Normal Read/Write logical sector buffered mode.
10	Read/Write physical sector direct data transfer mode.
50	Read/Write logical sector direct data transfer mode.

Command: Read Mode

Command Code: 09 HEX (Used with SMART-E only)

Parameters: Parameter 0 - Must be a valid drive address

Results: Result 0 - Transaction Status
 Result 1 - Mode Byte 0
 Result 2 - 0 (Reserved for Mode Byte 1)
 Result 3 - SMART Type (01 = SMART) (02 = SMART-E)
 (All other values reserved)

Data Transferred: None

Function: This command is used to read the Mode Register of the SMART-E Interface. In the present version of the SMART-E, the Mode Register is a one-byte register; future expansion may use a second byte. Refer to Table 18 for the contents of the Mode Register.

If this command is issued to a SMART Interface the mode byte is always returned as a zero.

Command: Specify Mode (SMART-E Only)

Command Code: 08 HEX (Used with SMART-E only)

Parameters: Parameter 0 - Must be a valid drive address
 Parameter 1 - Mode Byte 0
 Parameter 2 - Must be 0 (Reserved for Mode Byte 1)

Results: Result 0 - Transaction Status

Data Transferred: None

Function: This command is used to load the Mode Register of the SMART-E Interface. In the present version of the SMART-E, the Mode Register is a one-byte register; future expansion may utilize a second byte. Refer to Table 18 for the contents of the Mode Register.

TABLE 18 - Mode Register (SMART-E Only)

<u>Bit</u>	<u>Name</u>	<u>Description</u>
7(MSB)	Not Used	Must be 0.
6	Enable Logical Sector Mode	<p>When this bit = 1, the SMART-E Interface interprets the address information (Parameters 1, 2, and 3) as a logical sector address. (Also, Results 1, 2, and 3 are returned as logical sector addresses). Logical addresses may be used with the commands marked with '#' in the command code summary table.</p> <p>When this bit = 0, the SMART-E Interface interprets the address information as a physical address, and returns results as physical addresses.</p>
5	Inhibit ECC Correction	<p>When this bit = 1, ECC correction is inhibited.</p> <p>When this bit = 0, ECC correction is enabled.</p>
4	Enable Direct Mode	<p>When this bit = 1, Direct Mode (unbuffered data transfer) is enabled</p> <p>When this bit = 0, Direct Mode is disabled (buffered data transfer)</p>
3	Restrict Buffer (Multi-sector Operation)	<p>When this bit = 1, the use of the disc data buffer is restricted to single-sector operation during multi-sector transfers.</p> <p>When this bit = 0, the disc data buffer is not restricted during multi-sector transfers.</p>
2	Transfer If Error	<p>When this bit = 1, data is sent to the host even when an uncorrectable error has been detected (during a read data command).</p> <p>When this bit = 0, detection of an uncorrectable error causes the I/O transfer to abort.</p>

TABLE 18 - Mode Register (SMART-E Only) - Continued

<u>Bit</u>	<u>Name</u>	<u>Description</u>
1	Syndrome Disable	<p>When this bit = 1, the SMART-E interface does not calculate and test the syndrome bits for each ECC block.</p> <p>When this bit = 0, the SMART-E Interface calculates and tests the syndrome bits in the normal manner.</p>
0 (LSB)	Read/Write Extended	<p>When this bit = 1, the SMART-E Interface accepts both the data and (following the data) the ECC information from the host during a Write Data command. Similarly, during a Read Data command, the SMART-E Interface sends both the data and (following the data) the syndrome information to the host.</p> <p>When this bit = 0, the SMART-E Interface accepts only the data from the host during a Write Data command. The SMART-E Interface calculates the ECC bits and appends them to each block of data. Similarly, during a Read Data command, the SMART-E Interface sends only the data to the host.</p>

Bits 1 and 0 may be thought of as a field, since they both affect the handling of the ECC check bits. The following table considers these bits in combination:

<u>Bit 1</u>	<u>Bit 0</u>	<u>Function</u>
0	0	Normal write and read functions.
0	1	Read operations, calculate syndrome and return syndrome bits to user. This combination is used by diagnostic routines which test the ECC functions.
1	0	Not used.
1	1	Write data with user-supplied ECC check bits. On read operations, return these same check bits to the host. This combination is used by diagnostic routines which test the ECC functions.

NOTE: If Mode Byte bit 5, 4, 1 or 0 is set, ECC correction is disabled.

Command: Completion Acknowledge

Command Code: 00 HEX

Parameters: None

Results: None

Data Transfer: None

Function: Upon completion of a previously issued command the Command Completion Request bit in the Interface Status Register will be set. When this bit is set, the host system should read the appropriate result registers, and reset the Command Completion Request bit by issuing the Completion Acknowledge command.

In addition to resetting the Completion Request bit this command also clears the Host Interrupt Request. After a power up or controller reset (software or hardware), interrupts are disabled. Interrupts are enabled by the first Command Acknowledge issued by the host.

If a command for another drive has been completed, i.e., overlapped seeks, the bit will be set immediately after updating the result registers, requiring another Completion Acknowledge command to clear it.

After a power-up or an Interface reset interrupts are disabled and the Completion request bit is set. A Completion Acknowledge command must be issued to clear the Completion Request and enable interrupts.

Command: Read Drive Type

Command Code: 86 HEX

Parameters: Parameter 0 - Drive Address

Results: Result 0 - Transaction Status
Result 1 - Drive Type (see Table 18)
Result 2 - Physical Sector Size MSB
Result 3 - Physical Sector Size LSB

Data Transfer: None

Function: The interface may be used to control any of the various PRIAM drives.

This command is used to determine the type of drive attached to the Interface. (See Read Drive Parameters Command.)

The physical sector size returned in Result Registers 2 and 3 is expressed as the number of bytes between sector marks.

The drive type is not returned if the transaction status indicates that an error occurred. Table 19 lists the drive ID assignments.

TABLE 19 - Drive ID Assignment

<u>ID Code (HEX)</u>	<u>Drive Designation</u>
00	Invalid
01	DISKOS 3350-10 or -01 (20,160 bytes/track)
02-03	Reserved
04	DISKOS 3450 (13,440 bytes/track)
05	DISKOS 7050 (13,440 bytes/track)
06	DISKOS 6650 (20,160 bytes/track)
07	DISKOS 15450 (20,160 bytes/track)
08-10	Reserved
11	DISKOS 1070-1 (168 byte Skip Defect Record)
12-15	Reserved
16	DISKOS 1070-3 (336 byte Skip Defect Record)
17-1F	Reserved
20-FF	Reserved

Command: Read Drive Parameters

Command Code: 85 HEX

Parameters: Parameter 0 - Drive Address

Results: Result 0 - Transaction Status
Result 1 - Number of Heads/Number of Cylinders MSB
Result 2 - Number of Cylinders LSB
Result 3 - Number of Sectors Per Track
Result 4 - Logical Sector Size MSB
Result 5 - Logical Sector Size LSB

Data Transfer: None

Function: This command may be used by a software driver that is set up to handle multiple disc types. Through the use of this command, the driver can determine the parameters required to use the disc.

The Read Drive Parameters command returns the number of user data cylinders available. If defect mapping is enabled, the cylinders reserved for alternate sectors or tracks are not included in the number of cylinders reported.

The logical sector size is expressed as the number of usable data bytes within a physical sector.

Command: Read Internal Status

Command Code: 05

Parameters: None

Results: Result 0 - Transaction Status
Result 1 - Internal Status (Described below)

This command will set the Special Completion bit (CS5) in the Interface Status Register (see Table 6).

Data Transfer: None

Function: If the Command Reject bit in the Interface Status Register is set, the Read Internal Status command may be used to determine why the command was rejected. The Internal Status code returned in Result Register 1 will be one of the transaction status codes listed in Table 8.

The SMART-E does not set the Command Reject bit in the Interface Status Register, therefore this command is not required for SMART-E operation.

Command: Software Reset

Command Code: 07 HEX

Parameters: None

Results: Result 0 - Transaction Status

Data Transfer: None

Function: This command causes the Interface to abort all in-progress commands and run the microdiagnostics.

This command causes the Interface microprocessor to perform the same software reset sequenced initiated by a power up or hardware reset.

After a power-up or an Interface reset interrupts are disabled and the Completion request bit is set. A Completion Acknowledge command must be issued to clear the Completion Request and enable interrupts.

B. Format Disc Commands

The following set of commands are used to format the disc drive data tracks. Before the disc drive may be used to store data the data tracks must be initialized. The initialization process is performed by writing a specific pattern in each sector location (see Appendix A). The special pattern is used by the disc drive electronics to obtain synchronization and by the interface electronics to identify data areas.

The Interface command set is structured such that the host system may assume responsibility for formatting the drive by issuing primitive commands such as Write ID or to simply instruct the interface to perform the formatting function without host intervention.

Another consideration in disc formatting is the handling of disc defects. PRIAM disc drives contain Skip Defect records that indicate the location of defects on the disc surface. The host system may perform defect mapping or allow the Interface to perform defect mapping without host processing. The Interface defect mapping feature must be enabled at disc format time by selecting the correct format command.

Whenever a new sector size is selected through the sector switches on the disc drive, the drive must be reformatted using the appropriate set of the following commands.

Command: Format Disc With Defect Mapping

Command Code: A8 HEX

Parameters: Parameter 0 - Drive Address
Parameter 3 - SMART: Must be 0
SMART-E: Interleave Factor

Results: Result 0 - Transaction Status

Data Transfer: SMART: None
SMART-E: If the interleave factor is set to OF0 HEX the SMART-E will request that N bytes of data be transferred from the host to the interface (where N = the number of sectors per track). The N bytes of data are the interleave factor table defined in the interleaving discussion in Section IV.D.

Function: When the Format Disc With Defect Mapping command is issued the following major operations are performed:

1. Sector ID (identifier) fields are written for all sectors.
2. The Ship Defect Records are used to locate disc defects and flag the bad sectors/tracks.
3. An alternate area is defined and a defect directory is created.
4. Alternate areas are assigned for each of the bad sectors/tracks and entries are made in the defect directory so that the alternate areas may be used instead of the defective areas.

This command does not write any data fields. Before data may be read from the disc the user must issue a command that writes the data fields.

Command: Format Disc Without Defect Mapping

Command Code: A0 HEX

Parameters: Parameter 0 - Drive Address
Parameter 3 - SMART: Must be 0
SMART-E: Interleave Factor

Results: Result 0 - Transaction Status

Data Transfer: SMART: None
SMART-E: If the interleave factor is set to OF0 HEX the SMART-E will request that N bytes of data be transferred from the host to the interface (where N = the number of sectors per track). The N bytes of data are the interleave factor table defined in the interleaving discussion in Section IV.D.

Function: This command is used to format the disc without defect mapping.

The disc format is described in Appendix A. This format command does not write any data fields. Before data may be read from the disc, the user must issue a command that writes to the data fields.

Command: Format Cylinder Without Defect Mapping

Command Code: A1 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - SMART: Must be 0
SMART-E: Interleave Factor

Results: Result 0 - Transaction Status

Data Transfer: SMART: None
SMART-E: If the interleave factor is set to OF0 HEX the SMART-E will request that N bytes of data be transferred from the host to the interface (where N = the number of sectors per track). The N bytes of data are the interleave factor table defined in the interleaving discussion in Section IV.D.

Function: This command is used to format a single cylinder on the disc or discs (see Format Disc command). This format command does not write any data fields.

Command: Format Track Without Defect Mapping

Command Code: A2 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - SMART: Must be 0
SMART-E: Interleave Factor

Results: Result 0 - Transaction Status

Data Transfer: SMART: None
SMART-E: If the interleave factor is set to OF0 HEX the SMART-E will request that N bytes of data be transferred from the host to the interface (where N = the number of sectors per track). The N bytes of data are the interleave factor table defined in the interleaving discussion in Section IV.D.

Function: This command is used to format a single track on the disc (see Format Disc command). This format command does not write any data fields.

Command: Write ID

Command Code: 55 HEX - Retry Enabled
45 HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Absolute Sector Address
Parameter 4 - Multisector Count (1 to number of sectors/track)

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Absolute Sector Address
Result 4 - Residual Multisector Count

Data Transferred: The 4 byte ID field data is transferred from the host to the Interface.

Byte 0 - Logical Sector Address
Byte 1 - Head/Cylinder Address MSB
Byte 2 - Cylinder Address LSB
Byte 3 - ID Control Value = FF HEX (See Defect Mapping discussion)

A 4 byte ID field will be transferred for each ID field written.

Function: This command causes the 4 byte ID field to be written at the absolute sector location specified. The logical sector number is recorded from the buffer data. The command execution sequence is similar to the Write Data command with the following exception. The writing is enabled when the absolute sector count (number of sector marks past index) matches the Absolute Sector Address.

The multiple sector count shall not be greater than the number of sectors on a track.

Command Completion is set when the Multisector Count is zero.

Generally the disc is formatted using the Format Disc command. If a user requires a special format, the Write ID command may be used.

If an error occurs, the result registers specify which sector contains the error.

Command: Read ID

Command Code: 56 HEX - Retry Enabled
46 HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Absolute Sector Address
Parameter 4 - Multisector Count (1 to number of sectors/track)

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Absolute Sector Address
Result 4 - Residual Multisector Count

Data Transferred: The 4 byte ID field data is transferred from the SMART Interface to the host.

Byte 0 - Logical Sector Address
Byte 1 - Head/Cylinder Address MSB
Byte 2 - Cylinder Address LSB
Byte 3 - ID Control Value (see Defect Mapping discussion)

A 4 byte ID field will be transferred for each ID field read.

Function: This command causes the 4 byte ID field to be read from the absolute sector location specified.

The multisector count shall not be greater than the number of sectors on a track.

If an error occurs, the result registers specify which sector contains the error.

Command: Read ID Immediate

Command Code: 57 HEX - Retry Enabled
47 HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB

Results: Result 0 - Transaction Status

Data Transferred: The 4 byte ID field data is transferred from the Interface to the host.

Byte 0 - Logical Sector Address
Byte 1 - Head/Cylinder Address MSB
Byte 2 - Cylinder Address LSB
Byte 3 - ID Control Value (see Defect Mapping discussion)

Function: This command causes the ID field at the next physical sector encountered to be read.

Command: Read Skip Defect Field

Command Code: 59 HEX - Retry Enabled
49 HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 4 - Multisector Count = 1

Results: Result 0 - Transaction Status

Data Transferred: The 8 byte Skip Defect Record is transferred from the SMART Interface to the host. See Appendix A for the Skip Defect Field format.

Function: This command causes the 8 byte Skip Defect Field to be read from the location specified. If the record checksum is incorrect, a CRC Error/Uncorrectable ECC Error (Transaction Status 11) is reported .

Command: Write Skip Defect Field

Command Code: 5A HEX - Retry Enabled
4A HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSE
Parameter 4 - Multisector Count = 1

Results: Result 0 - Transaction Status

Data Transferred: The 8 byte Skip Defect Record is transferred from the host to the Interface. See Appendix A for the Skip Defect Field format.

Function: This command causes the 8 byte Skip Defect Field to be written to the location specified. The record checksum is automatically computed and appended to the record.

A Write Fault will occur if this command is attempted without disabling the drive's Skip Defect Field protection feature.

C. Defect Mapping Commands

The defect mapping command can be used if the disc has been previously formatted with defect mapping enabled. If the disc was formatted without defect mapping these commands are disabled.

Command: Specify Bad Sector

Command Code: AA HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Sector Address

Results: Result 0 - Transaction Status

Data Transfer: None

Function: If during operation of the disc the Host software determines that a sector on the disc is defective, the Host may use this command to flag the bad sector and assign an alternate.

When this command is issued the following operations are performed:

1. The bad sector is flagged.
2. An alternate sector is located.
3. The defect directory is updated to show the location of the alternate.

This command does not update the Skip Defect Record. Therefore if the disc is formatted again the bad sector must also be re-specified or the Skip Defect Record may be updated by the host.

This command may only be executed, for a disc that has previously been formatted with defect mapping enabled.

The user data field is not copied to the alternate location.

Command: Specify Bad Track

Command Code: A9 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB

Results: Result 0 - Transaction Status

Data Transfer: None

Function: This command is used by a host routine to request that the Interface flag a bad track and assign an alternate.

The operation of this command is the same as the Specify Bad Sector command except an entire track is flagged and mapped to an alternate. The Skip Defect Record is not updated nor is any data written to the newly assigned alternate track.

This command may only be executed, for a disc that has previously been formatted with defect mapping enabled.

Command: Read Defect Directory

Command Code: A6 HEX

Parameters: Parameter 0 - Drive Address
Parameter 3 - Directory Entry Number

Results: Result 0 - Transaction Status

Data Transfer: 128 bytes of data are transferred from the Interface to the host.

Function: This command may be used to read the Defect Directory if the disc has been formatted with defect mapping enabled (see Defect Mapping discussion).

The defect directory is a linked list of 128 byte records. The directory record are numbered from zero to the number of entries minus one. When reading the directory the host should read successive records from zero until an End of Directory status code is received.

Parameter 3 specifies the directory record that should be read. Directory entry number 0 is the first record, entry 1 is the second record, etc.

Command: Write Defect Directory

Command Code: AE HEX

Parameters: Parameter 0 - Drive Address
Parameter 3 - Directory Entry Number

Results: Result 0 - Transaction Status

Data Transfer: 128 bytes of data are transferred from the host to the Interface.

Function: This command may be used to write the Defect Directory (if the disc has been formatted with defect mapping enabled (see Defect Mapping discussion). See Read Defect Directory command discussion.

D. Data Transfer Commands

The Data Transfer Commands are the most commonly used commands supported by the Interface. It is important to note that the operation of these commands is modified by the Mode Byte (see Mode discussion in Section V.A.).

Command: Write Data

Command Code: 52 HEX - Retry Enabled
42 HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Sector Address
Parameter 4 - Multisector Count

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address
Result 4 - Multisector Count

Data Transfer: This command will cause data to be transferred from the host to the Interface.

If the user requested data will fit in the 1024-byte buffer, all the data is transferred in one block.

If the total data to be written is greater than 1024 bytes, the data transfer is broken into multiple 1024-byte block data transfers from the host with the data being written to the disc between block transfers.

If a Write Data Command requires a head switch or a seek because the multisector operation crossed a track boundary, the data transfer request is broken at the head switch or seek operation even if more data could have been placed in the buffer.

Function:

The Write Data command causes data to be written to the disc in accordance with the parameters specified. The parameters specify which drive, which cylinder, which head, which logical sector, and how many contiguous logical sectors. The command defines whether or not the write operation will be retried if the first attempt is unsuccessful. Also, Sequence Up, Seek, and Head Select are implied by this command.

The command execution sequence is described below:

- A. A Fault Reset is issued to the drive if the Drive Fault status bit is active.
- B. If the drive is not ready the Interface will issue a Sequence Up command to the drive and wait for a drive Ready or time-out. If time-out occurs, a retry or error termination will be performed.
- C. If the read/write head is not over the desired cylinder, a seek is issued to the drive to position the head at the target cylinder.
- D. Data is transferred from the host (see Data Transfer described in Section III.B.) to the Interface.
- E. The correct head is selected and consecutive ID fields on the target track are read until a match is found between the recorded physical sector number and the parameter-specified sector number.
- F. The data field is written from the buffer.
- G. The multiple sector count from Parameter Register 4 is decremented.
- H. If the multiple sector count has terminated, then command is complete and the appropriate Result Registers are updated.
- I. If the multiple sector count is non-zero, the sector number is incremented (modulo the number of sectors per track); then the buffer contents are checked. If the buffer is empty, then Step D is executed. Since the buffer is 1024 bytes, and sectors may be 128, 256, or 512 bytes; the ensuing sector data may be resident in the buffer. If the sector number is zero, then the next head is selected unless currently on the last head of the cylinder. If not, Step E is executed. If the last head is selected, the head address is set to zero and the cylinder address is incremented. Step C is then performed.

The Command Completion bit is set whenever the command is completed or an unrecoverable error occurs.

Command: Read Data

Command Code: 53 HEX - Retry Enabled
43 HEX - Retry Disabled

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Sector Address
Parameter 4 - Multisector Count

Results: Result 0 - Transaction Status
Result 1 - Heads/Cylinders Address MSB
Result 2 - Cylinders Address LSB
Result 3 - Sector Address
Result 4 - Multisector Count

Data Transfer: This command will cause data to be transferred from the Interface to the host.

If the user requested data will fit in the 1024 byte buffer, all the data is read into the buffer before a data transfer request is made to the host.

If the total data to be read is greater than 1024 bytes, the data transfers are broken into multiple 1024 byte blocks read from the disc and then transferred to the host.

If a Read Data Command requires a head switch or a seek because the multisector operation crossed a track boundary, the data transfer request is broken at the head switch or seek operation, even if more data could have been placed in the buffer.

Function: The Read Data command causes data to be read from the disc in accordance with the parameters specified.

The command execution sequence is described below:

- A. A Fault Reset is issued to the drive if the Drive Fault status bit is active.
- B. If the drive is not ready the controller will issue a Sequence Up command to the drive and wait for a drive Ready or time-out. If time-out occurs, a retry or error termination will be done.
- C. If the read/write head is not over the desired cylinder, a seek is issued to position the head at the target cylinder.
- D. The desired head is selected.

- E. Consecutive ID fields on the target track are read until a match is found between the recorded physical sector number and the parameter specified sector number.
- F. The data field is read from the disc into the buffer.
- G. The multiple sector count in Parameter Register 4 is decremented.
- H. If the multiple sector count is zero, then a data transfer request from the controller to the host is signalled. The controller waits for the data transfer to complete and when complete, the Command Completion bit is set and the Result Registers are updated.
- I. If the multiple sector count is non-zero, then the sector count is updated; also head and cylinder address are updated as required. If buffer space is available for the next sector, step E is repeated and the sequence is continued.

If the buffer is full, a data transfer operation is requested as discussed above. When the data transfer is done, Step C is repeated and the sequence is continued.

E. Disc Motion and Drive Control Commands

The following commands are supported so the host may have complete use of the disc drive motion control capability. The commands are implied by any other Interface command if required. During normal operation (with the exception of Sequence Down) the host should not need these commands to operate the interface.

Command: Sequence Up - Return
Command Code: 83 HEX
Parameters: Parameter 0 - Drive Address
Results: Result 0 - Transaction Status
Result 1 - Drive Status (see Table 19)

Data Transfer: None

Function: The Sequence Up - Return command causes the disc drive defined by the contents of Parameter Register 0 to power up its spindle motor. When the command is accepted by the selected drive, the Command Completion bit is set and the drive status will be in Result Register 1. The operation is similar to that in Sequence Up - Wait command, but the Interface does not wait until the drive is up to speed and the heads are positioned over Cylinder 0 before posting the command completion.

Command: Sequence Up - Wait
Command Code: 82 HEX
Parameters: Parameter 0 - Drive Address
Results: Result 0 - Transaction Status
Result 1 - Drive Status (see Table 19)

Data Transferred: None

Function: The Sequence Up - Wait command causes the disc drive defined by the contents of Parameter Register 0 to power up its spindle motor. The disc drive will monitor the rotational speed of the disc and when it is at speed and stable, the drive will position the heads at cylinder zero. When this is completed the Command Completion bit will be set with the drive status in Result Register 1.

The Sequence Up - Wait command is similar to the Sequence Up - Return command, except that the Sequence Up-Wait command requires about 30 seconds to complete.

Command: Sequence Down
Command Code: 81 HEX
Parameters: Parameter 0 - Drive Address
Results: Result 0 - Transaction Status
Result 1 - Drive Status (see Table 19)
Data Transferred: None

Function: The Sequence Down command causes the disc drive defined by the contents of Parameter Register 0 to position the heads over the landing zone. The spindle motor's dynamic braking is initiated. The drive will set the Write Protect status bit and clear the Ready bit. When dynamic braking is initiated the Command Completion bit will be set with the drive status in Result Register 1.

Command: Seek
Command Code: 51 HEX - Retry Enabled
41 HEX - Retry Disabled
Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Results: Result 0 - Transaction Status
Result 1 - Current Cylinder Address MSB
Result 2 - Current Cylinder Address LSB
Data Transferred: None

Function: The Seek Command uses the drive address defined in Parameter Register 0 and the contents of Parameter Registers 1 and 2 for the target cylinder address and head address.

The Interface will command the drive to seek to the target cylinder and select the specified head. When this is complete, the Command Completion bit will be set with the current cylinder MSB in Result Register 1 and current cylinder LSB in Result Register 2.

If the Retry bit is set, the seek will be retried if the first attempt is unsuccessful. This retry will be reported in the Transaction Status Register.

Also, Sequence Up is implied upon the receipt of this command, if the selected drive is sequenced down when this command is received by the Interface.

The seek command is automatically issued by the Interface as required.

Command: Drive Restore

Command Code: 40 HEX

Parameters: Parameter 0 - Drive Address

Results: Result 0 - Transaction Status

Data Transferred: None

Function: The Drive Restore command causes the access arm on the drive defined by the contents of Parameter Register 0 to be positioned over Cylinder 0.

Upon completion of the disc's restore operation, the Command Completion bit is set.

If the application program is using the Interface with retries enabled, the Drive Restore command is automatically issued when required.

Command: Read Drive Status

Command Code: 06 HEX

Parameters: Parameter 0 - Drive Address

Results: Result 0 - Transaction Status
Result 1 - Drive Status (see Table 20)
Result 2 - Current Cylinder Address MSB
Result 3 - Current Cylinder Address LSB

This command will set the Special Completion bit (CS5) in the interface status register (see Table 6).

Data Transfer: None

Function: The Read Drive Status command is used to obtain the status of the drive selected by Parameter Register 0.

Only one read status command may be outstanding at a time.

TABLE 20 - Drive Status Bit Definition

Result Register 1

<u>Bit</u>	<u>Name</u>	<u>Description</u>
7 (MSB)	Command Reject	Control or Register Load command received while drive is not ready, or improper command received.
6	Write Protect	The head selected is write protected. Write protection is set by switches in the drive or when the drive is not sequenced up.
5	Drive Fault	A fault was detected during a write operation, or a drive unsafe condition was detected.
4	Busy	The drive is in the process of executing a command.
3	Cylinder Zero	The access arm is set to Cylinder 0.
2	Seek Fault	A fault was detected during a seek operation.
1	Seek Complete	This bit is set when a seek operation is completed.
0 (LSB)	Ready	The drive is up to speed, servo system is locked onto a servo track, and the unit is in a state to read, write, or seek.

F. Disc Data Initialization and Verification Commands

The following set of commands are normally used by disc formatting routines and diagnostics.

Command: Write Disc - Full Track

Command Code: AB HEX

Parameters: Parameter 0 - Drive Address

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address

Data Transferred: This command causes data to be transferred from the host to the Interface.

128, 256, 512, or 1024 bytes of data are transferred depending upon the selected sector size.

Function: This command is used to initialize the disc data fields. The data pattern transferred is written to all data fields on the disc.

If an error occurs, the result registers indicate the sector that was being transferred when the error occurred.

Command: Write Cylinder - Full Track

Command Code: AC HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Cylinder Address MSB
Parameter 2 - Cylinder Address LSB

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address

Data Transferred: This command will cause data to be transferred from the host to the Interface.

128, 256, 512, or 1024 bytes of data are transferred depending upon the selected sector size.

Function: This command is used to initialize the disc data fields on a cylinder of the disc. The data pattern transferred is written to all data fields on the cylinder selected by Parameters 1 and 2.

Command: Write Full Track

Command Code: AD HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address

Data Transferred: This command will cause data to be transferred from the host to the Interface.

128, 256, 512, or 1024 bytes of data are transferred depending upon the selected sector size.

Function: This command is used to initialize the disc data fields on one track. The data pattern specified is written to all data fields on the track selected by Parameters 1 and 2.

Command: Verify Disc

Command Code: A3 HEX

Parameters: Parameter 0 - Drive Address

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address

Data Transferred: None

Function: This command is used to verify that a disc is formatted properly. Every ID and sector on the disc is read and the CRC/ECC is performed. If an error is detected, the operation is terminated and the result registers indicate which sector contains the error.

Command: Verify Cylinder

Command Code: A4 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Cylinder Address MSB
Parameter 2 - Cylinder Address LSB

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address

Data Transferred: None

Function: This command is used to verify that a single cylinder of the disc is formatted properly. Every ID and sector on the specified cylinder is read and the CRC/ECC is checked. If an error occurs, the operation is terminated and the result registers indicate which sector contains the error.

Command: Verify Track

Command Code: A5 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address

Data Transferred: None

Function: This command is used to verify that a single track of the disc is formatted properly. Every ID and sector on the specified track is read and the CRC/ECC is performed. If an error is detected, the operation is terminated and the result registers indicate which sector contains the error.

Command: Verify Data

Command Code: 44 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Sector Address
Parameter 4 - Multisector Count

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Sector Address
Result 4 - Residual Multisector Count

Data Transferred: None

Function: This command is used to verify that the specified sectors indicated by the parameter registers are formatted properly. Every ID and data sector specified is read and the CRC/ECC is performed. If an error occurs, the operation is terminated and the result registers indicate which sector contains the error.

Command: Verify ID

Command Code: 48 HEX

Parameters: Parameter 0 - Drive Address
Parameter 1 - Head/Cylinder Address MSB
Parameter 2 - Cylinder Address LSB
Parameter 3 - Absolute Sector Address
Parameter 4 - Multisector Count

Results: Result 0 - Transaction Status
Result 1 - Head/Cylinder Address MSB
Result 2 - Cylinder Address LSB
Result 3 - Absolute Sector Address
Result 4 - Residual Multisector Count

Data Transferred: None

Function: This command is used to verify that the ID fields on a track are readable. Every ID field specified by the parameter registers is read and the CRC/ECC is performed. If an error is detected, the operation is terminated and the result registers indicate which ID field contains the error.

G. Diagnostic Commands

The Interface performs three distinct types of diagnostic procedures:

Power Up Diagnostics -- Those performed automatically upon power up or software reset.

User-invoked Diagnostics -- Those which are performed in response to a diagnostic command sent by the host to the Interface.

In-process Diagnostics -- Those which are inherent in the execution of individual commands.

1. Power Up Diagnostics

Upon power up (or software reset) the Interface performs an initialization routine. The initialization sequence includes a RAM test, an ID buffer test and a PROM test. If the initialization is complete and normal the value 16 is returned for Result 0 (the transaction status), and the following values are placed in the remaining result registers:

Result 1 = AA
Result 2 = 55
Result 3 = F0
Result 4 = 0F
Result 5 = 00

The RAM test is performed on the microprocessor scratch pad RAM and the disc data buffer. In the SMART Interface, each of these two memories is 1K x 8 bits; in the SMART-E Interface each is 2K x 8. The RAM test is performed by writing each memory location with a data value equal to its own address (LSB), then reading the RAM and comparing the values read with those written. The entire process is then repeated, using data values equal to the complement of the respective addresses. If an error occurs the value 1A is returned for the transaction status, and Result Registers 1-4 are loaded with the following information:

Result 1 = Expected Data
Result 2 = Received Data
Result 3 = Memory Address MSB
Result 4 = Memory Address LSB

From the memory address the host may determine whether the error occurred in the microprocessor scratch pad RAM or in the disk data buffer. Table 21 shows the respective address ranges.

TABLE 21 - Memory Address Ranges

<u>Memory Function</u>	<u>SMART</u>	<u>SMART-E</u>
Microprocessor Scratch Pad	4000 - 43FF	6000 - 67FF
Disc Data Buffer	8000 - 83FF	8000 - 87FF

The ID buffer test consists of a series of paired write/read operations to/from the four byte locations of the ID buffer:

	<u>ID Buffer Location</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
First write/read:	00	01	02	03
Second write/read:	01	02	03	04
Third write/read:	02	03	04	05
.				
.				
Last write/read:	FF	01	02	03

If a discrepancy is found, the value 1B is returned for the transaction status, and Result Registers 1-4 are loaded with the following information:

- Result 1 = Expected Data
- Result 2 = Received Data
- Result 3 = Buffer Location

The SMART-E PROM test is performed on the microprocessor program area. Each PROM contains a 16-bit checksum in the last two locations. At power-up the checksum is computed and compared with the stored value. If a PROM failure is detected the PROM number is reported in Result 1 as follows:

- Result 1=0 SMART-E PROM Location 22A
- Result 1=1 SMART-E PROM Location 22B
- Result 1=2 SMART-E PROM Location 22C

2. User-invoked Diagnostics

The user-invoked diagnostics include the following commands:

- 04 Write Buffer
- 03 Read Buffer
- E0 Transfer Parameter to Result
- E1 ID Buffer Transfer Test

The Write Buffer command is used in conjunction with the Read Buffer command to test the disc data buffer RAM. Refer to the individual command descriptions for details.

3. In-process Diagnostics

The execution of individual commands often involves various levels of error checking. When an error is detected, the appropriate bits are set in the Result 0 (transaction status) register. Relevant parametric information is also made available to the host via Result Registers 1-4. Refer to the individual command descriptions for details.

Command: Write Buffer

Command Code: 04 HEX

Parameters: None

Results: Result 0 - Transaction Status

This command will set the Special Completion bit (CS5) in the Interface Status Register (see Table 6).

Data Transferred: 1024 bytes of data are transferred from the host to the SMART Interface. 2048 bytes of data are transferred from the host to the SMART-E Interface.

Function: The Write Buffer command is used to transfer data from the host to the Interface data buffer. This command may be used in conjunction with the Read Buffer command to test the Interface data buffer. The Command Completion bit is set when the last byte required to fill the buffer is transferred.

The Write Buffer command is not required for normal Interface operation.

Command: Read Buffer

Command Code: 03 HEX

Parameters: None

Results: Result 0 - Transaction Status

This command will set the Special Completion bit (CS5) in the Interface Status Register (see Table 6).

Data Transferred: 1024 bytes of data are transferred from the SMART Interface to the host. 2048 bytes of data are transferred from the SMART-E Interface to the host.

Function: The Read Buffer command may be used to list the buffer contents, to verify the buffer or in error recovery operations. The Command Completion bit is set when the last byte in the buffer is read.

The Read Buffer command is not required for normal Interface operation.

Command: Transfer Parameter to Result

Command Code: E0 HEX

Parameters: Parameter 0 - Must be 0
Parameter 1 - User Test Byte 1
Parameter 2 - User Test Byte 2
Parameter 3 - User Test Byte 3
Parameter 4 - User Test Byte 4
Parameter 5 - User Test Byte 5

Results: Result 0 - Transaction Status
Result 1 - User Test Byte 1
Result 2 - User Test Byte 2
Result 3 - User Test Byte 3
Result 4 - User Test Byte 4
Result 5 - User Test Byte 5

Data Transferred: None

Function: The Transfer Parameter to Result command may be used to test the operation of Parameter Registers 1-5 and Result Registers 1-5. The user writes any five bytes to the five parameter registers, issues Command E0, and then reads these five bytes from the corresponding result registers.

Command: ID Buffer Transfer Test

Command Code: E1 HEX

Parameters: Parameter 0 - Must be 0
Parameter 1 - User Test Byte 1
Parameter 2 - User Test Byte 2
Parameter 3 - User Test Byte 3
Parameter 4 - User Test Byte 4

Results: Result 0 - Transaction Status
Result 1 - User Test Byte 1
Result 2 - User Test Byte 2
Result 3 - User Test Byte 3
Result 4 - User Test Byte 4

Data Transferred: None

Function: The ID Buffer Transfer Test command may be used to test the operation of the ID buffer. The user writes any four bytes to the four parameter registers, and issues Command E1. The four bytes are transferred, via the ID buffer, to the corresponding four result registers. The user then reads the result registers and compares each byte with its respective original input.

APPENDIX A - DISC FORMAT

1. Sector Format

The sector format used by the Interface is shown in Figure A1.

Each track starts with an INDEX pulse, which corresponds to a certain position on the servo track. The servo track also provides rotational position information for the generation of SECTOR pulses. A sector pulse precedes each record, and successive records are separated by gaps within which the sector pulses occur.

a. Pre-Record Gap (Gap 1)

The Pre-Record Gap, or Gap 1, appears at the beginning of every record. It consists of 23 bytes of zeros. The length of Gap 1 never varies. The first Gap 1, after INDEX, is followed by the Skip Defect Record. All other Gap 1's, after SECTOR pulses, are followed by ID records.

b. Skip Defect Record

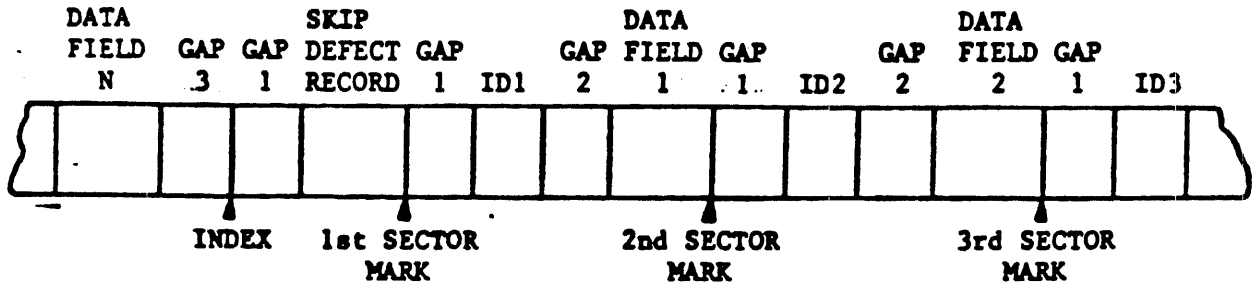
The Skip Defect Record (Table A1) consists of 11 bytes: a Data Sync using the hexadecimal pattern FB, the address of the first defect using 2 bytes, the address of the second defect using 2 bytes, the address of the third defect using 2 bytes, a checksum across the previous 3 words (2 bytes) using 2 bytes, and fill characters of zeros using 2 bytes.

If an address is 0000, then there are not any additional defects on the track.

If the address of the first defect is FFFF HEX, the whole track is defective.

TABLE A1 - Defect Record Format

<u>Decimal Location</u>	<u>Data</u>
000-022	Gap 1 - 23 Zeros
023	Defect Record Sync (FB Hex)
024	1st Address MSB
025	1st Address LSB
026	2nd Address MSB
027	2nd Address LSB
028	3rd Address MSB
029	3rd Address LSB
030	Checksum MSB
031	Checksum LSB
032-035	Fill (Zero)



Index:	Derived from servo track	
Gap 1:	Zeros	23 Bytes
Skip Defect Record:	Data Sync, FB Hex	1 Byte
	1st defect address	2 Bytes
	2nd defect address	2 Bytes
	3rd defect address	2 Bytes
	Checksum	2 Bytes
	Fill characters - zeros	2 Bytes
Gap 1:	Zeros	23 Bytes
Sector Mark:	Derived from INDEX and servo clock	
ID Field:	ID Sync, F9 Hex	1 Byte
	Sector address	1 Byte
	Head and cylinder address MSB	1 Byte
	Cylinder address LSB	1 Byte
	ID Control	1 Byte
	CRC/ECC	2/4 Bytes
	Fill characters (zeros)	2 Bytes
Gap 2:	Zeros	11 Bytes
Data Field:	Data Sync, FD Hex	1 Byte
	Data	128, 256, 512, or 1024 Bytes
	CRC/ECC	2/4 Bytes
	Fill characters (zeros)	2 Bytes
Gap 3:	Zeros (size depends on data field size)	

TABLE A2 - Sector Format

c. ID Field

The Identification Field contains 9 (SMART) or 11 (SMART-E) bytes: an ID sync using the hexadecimal pattern F9, the sector number of 1 byte, the head address and high order cylinder address of 1 byte, the low order cylinder address of 1 byte, an ID control field of 1 byte, 2 CRC (cyclic redundancy check) bytes (SMART) or 4 ECC (Error Correction Code) bytes (SMART-E), and 2 bytes of zeros for filling. The cylinder and head address, along with the sector number, verify that the drive has addressed the correct track and sector. The ID control field is discussed in the Section IV.E.

d. ID Gap (Gap 2)

The ID Gap, or Gap 2, separates each successive Identification Field (ID) from its Data Field. It contains 11 bytes of zeros.

e. Data Field

Following Gap 2, the Data Field consists of 133/135, 261/263, 517/519, or 1029/1031 bytes depending on the selected data length. The first byte is the data sync (hexadecimal pattern FD), while the last bytes consist of 2 bytes of CRC and 2 bytes of zeros for filling (SMART), or 4 bytes of ECC and 2 bytes of zeros (SMART-E).

f. Pre-Index Gap (Gap 3)

The Pre-Index Gap, or Gap 3, is used only once on a track. It appears at the end of the last data field and persists until INDEX. This gap contains zeros.

The sector size is selected by setting the sector switches on the drive according to the decimal physical sector size.

The following tables define the sector switch settings required to select 128, 256, 512, or 1024 byte logical sector sizes on each of the PRIAM drive types.

TABLE A3 - Sector Format Summary - 3350/6650/15450

<u>Logical Size</u>	<u>Physical Size</u>	<u>Sectors Per Track</u>	<u>Switch Setting</u>
128	181	111	7, 6, 4, 3, 2, 1
256	309	65	7, 1
512	574	35	6, 2, 1
1024	1118	18	5, 2

NOTE: Switch 8 should be off.

TABLE A4 - Sector Format Summary - 3450/7050

<u>Logical Size</u>	<u>Physical Size</u>	<u>Sectors Per Track</u>	<u>Switch Setting</u>
128	181	74	7, 4, 2
256	311	43	6, 4, 2, 1
512	582	23	5, 3, 2, 1
1024	1117	12	4, 3

TABLE A5 - Sector Format Summary - 1070

<u>Logical Size</u>	<u>Physical Size</u>	<u>Sector Per Track</u>	<u>Switch Setting</u>
256	324	44	3, 2
512	648	22	4, 2
1024	1296	11	4, 3

NOTE: Once a Sector Switch is set the disc must be powered down, then powered back up in order to initialize the Sector Mark generator to the newly selected value.