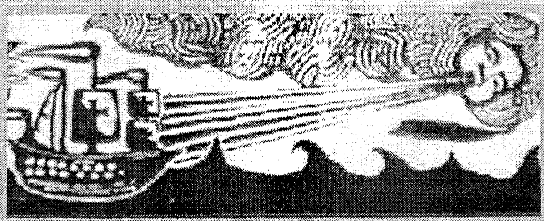

Tempest

FIRMWARE MANUAL

May, 1996

Rev. A

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Chapter 1 General Information

1.1 Revision History

REVISION	CONTACT	DATE	DESCRIPTION
A	Joe Liu	5/24/96	Initial Release

1.2 Scope

The purpose of this manual is to document the Tempest firmware commands. This manual documents deviations from the SCSI and AT specifications. In addition to documenting the external interface, certain internal features of the firmware and its architecture are described.

1.3 Tempest Firmware Features

- K7 CPU
  - 32 bit CPU
  - 33.33 MHz internal system clock
  - General purpose register architecture
  - 16 M byte linear address space

- µCode download
  - ATA CAM compatible
    Opcode 92h

  - SCSI-2 compatible
    Write buffer opcode 3Bh

  - µCode verification
    µCode checksum and valid product code
    Rom checksum and version stamp

- Double burst correction on the fly
- Triple burst offline correction
- Dynamic cache segments
- Up to 26 pending random write command cache
- Concurrent read / write cache process
- DPA phase 3 error logging and reporting

- New AT block
  - Enhanced auto features
    Supports LBA and MULTIPLE command mode of operation
    Multiple sector auto read/write transfer
    Auto reads across commands
  - PIO mode 4
  - DMA multiword mode 2

- New SCSI block
  - Automated SCSI protocol handling controlled via WCS
  - Auto reads across commands
  - Supports Ultra SCSI 20MB/s transfers

- SCSI-3 power saving mode support
- SCAM support
  - Power - on configurable ID's

1.4 Applicable Documents

SCSI-II Specification
CAM ATA Specification
AKBAR Specification.
Tempest Selfscan User's Guide (QNTM P/N)
Tempest SCSI Product Manual (QNTM P/N)
Tempest AT Product Manual (QNTM P/N)
Quantum DPSG Unified Superset Command Manual
Quantum DPA Implementation Guide
Compaq ATA Drive Failure Prediction Spec. Version 1.30 Proposal

Chapter 2 Defect Management

2.1 The Defect List

Two different lists are stored on system cylinder -2 and -3:

1. Primary defect list (P list) - this list contains the defects found in defect scans at the factory. Only the factory test software has the capability to define the P list. The P list contains the description for defects only. No information regarding their replacement is included.

2. Working list (W list) - typically, the W list is a union of the P and G lists, plus it contains all information necessary to locate the replacement to all defects.
   Grown defect list (G list) - this list contains the defects found in the field during operation of the drive. All user's reassigned defects (i.e. with Reassign Block) and auto-reallocated defects are recorded in this list.

The host may access the P and G lists with the Read Defect Data SCSI command (Read Defect AT Extended command). The G list is decoded from information stored in the W list.

The W list is used by defect management whenever a logical-to-physical address conversion is called for. This list is accessible with the "Real Normalized Defect Data" super command. For its data structure, refer to the Systems Engineering's documentation, "Proposal For Real Defect List Command".

2.1.1 Defect List Data Structure

The defect lists maintained and accessed by the defect management system consist of 5 byte defect entries. The P list contains only defect entries while the W list contains both defect and replacement cylinder information. The defect list structure is illustrated below.

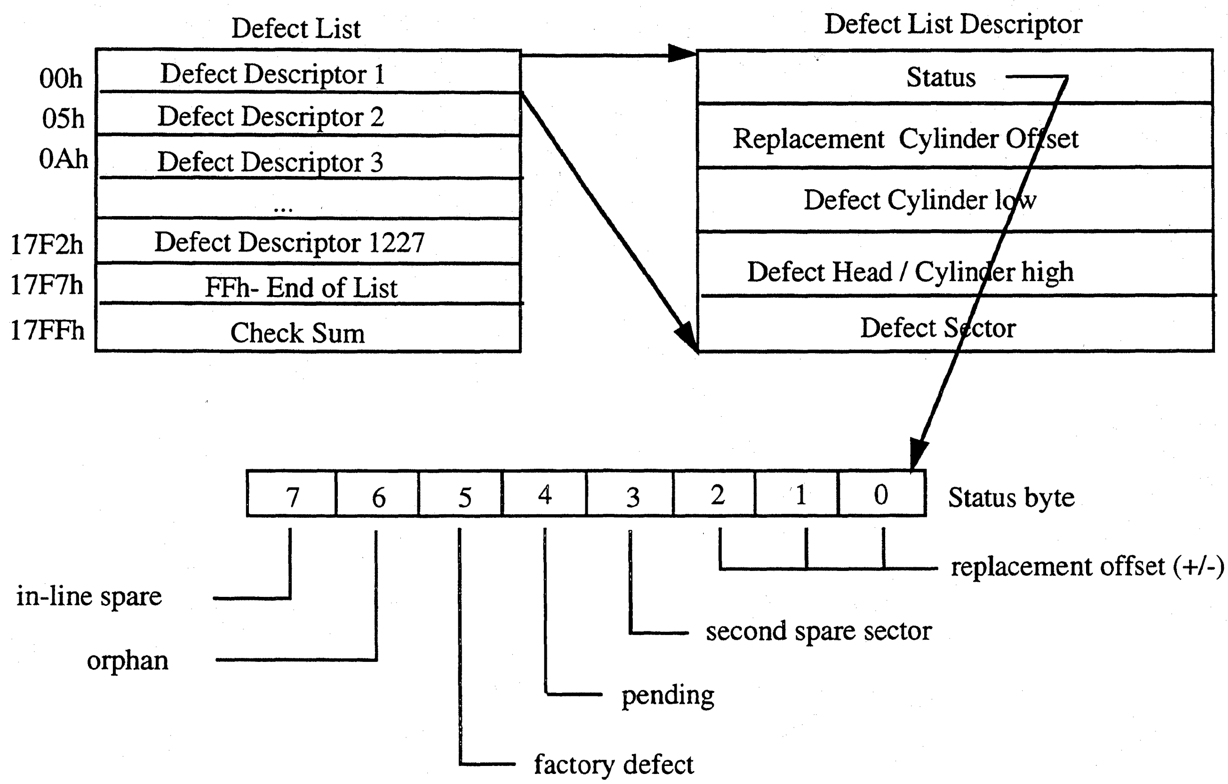

Figure 2-1 Defect List Data Structure

The end of list marker is placed after the last entry in the list.

The checksum is placed at the end of the list, and the empty area in the list is filled with zeros. When this byte is added to the rest of the bytes in the list, the **lsb** of the checksum will equal ascii "T".

Defect type is used to distinguish between P list entries (factory defect) and G list entries (auto reallocated and user reassigned).

Replacement type is used by defect management to find the correct physical sector for a given LBA.

2.2 Replacement Strategy

Tempest reserve two spare sectors per cylinder for all models. It utilizes two methods for sector replacement - inline and offline sparing.

2.2.1 Inline Sparing

Inline sparing is where a defective sector is replaced by the next immediate sector; all sectors thereafter within the same cylinder is shifted, logically, by one. (see figure 2.2) The access penalty is very small for inline replacement which is one sector time. Whenever possible, defects are spared with inline replacement at the factory. In the unlikely event where there are more than two defects on the same cylinder, additional spare sectors must be allocated from adjacent cylinders. This is defined as offline replacement. Accessing the defective sector requires a short seek and latency. All grown defects are offline spared during drive operation. However, the drive will attempt to inline spare all known defects when a Format Unit command is issued.

2.2.2 Offline Sparing

Off line sparing is where a defective sector is replaced by a spare sector located at the end of a cylinder. Defect management will try to replace the defective sector with a spare on the same cylinder. If this is not possible, as in the case of the spare is already in use, defect management will find a spare sector located on an adjacent cylinder. The disadvantage to this is the performance hit caused by the seek. Figure 2.2 contains an example of an offline spare.

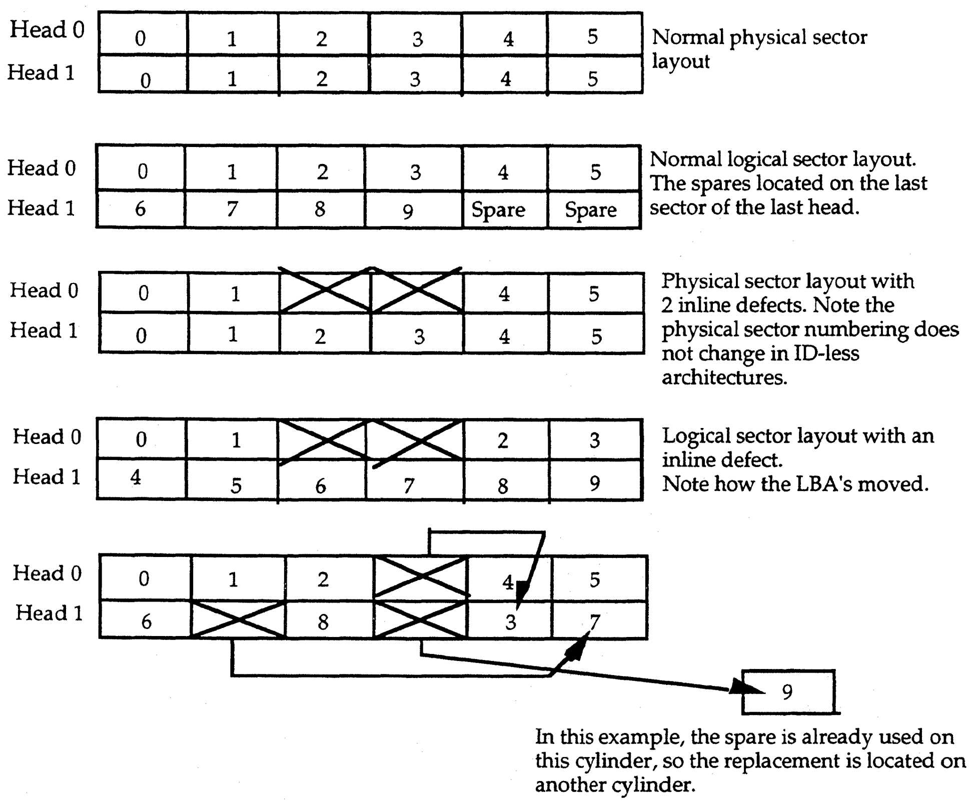

Figure 2-2 Inline and Offline Examples

2.2.3 Orphans

An orphan occurs when a replacement sector goes bad. The replacement is assigned a new sector and the original replacement sector is tagged as an orphan in the defect list. It is no longer used. Defect management skips over defect entries that are tagged orphans.

2.3 Defect List Storage

Up-to-date versions of the P and W lists are saved on the disk, only the W list needs to be resident in RAM during drive operation. Each defect list may require up to 6144 bytes of storage, therefore, a total of 12 sectors per list are reserved to hold the defect lists on a system track. See section 3 for System Cylinder layout for the location of the lists. Since the W list is limited to 6144 bytes in size, a maximum of 1,227 defects may be recorded in a Tempest drive.

2.4 LBA to CHS Conversion

There are two entry points for performing the LBA to CHS conversion. Given an LBA, the caller invokes INIT_LBA_TO_CHS to initiate the conversion process.

INIT_LBA_TO_CHS determines the destination cylinder for the logical block and scans for known defects from the beginning of that cylinder. The function returns the CHS of the first valid sector plus a value indicating the number of consecutive data sectors starting from the first accessible sector.

It is left to the caller to decide how many sectors are actually required to complete its operation. If sectors are needed in addition to the first series of consecutive sectors, the caller uses the INIT_LBA_TO_CHS function to locate the next series of sectors. NEXT_LBA_TO_CHS requires no input parameter and returns the same information as INIT_LBA_TO_CHS. Since media defects are spares, there should be large number of contiguous cylinders with no defects for a typical drive. Basing on this fact, when a location on the disk is accessed, defect management firmware locates a rang of "defect - free" cylinders in both directions of the current position. Once the range is defined, subsequent access made within the range will not require any reference to the defect list.

2.5 Auto Reallocation

Reallocation during read operation is processed on sector-by-sector basis (not necessarily the whole logical block). When a sector is determined to be defective by the read or write firmware, it is then subjected to write/verify test before it will be reallocated. Using the data read from the defective sector and /or different data patterns, the drive writes to and reads the sector for up to ten times. If any of the ten tests fail, the defect is considered repeatable and the sector is reallocated. If all ten tests pass, then the failure is considered non-repeatable and the sector is left as is.

The exception to the above rule is when an uncorrectable read error occurs. At such incidences the write/verify test is not performed immediately, but the sector is marked "Pending Defect" in the defect list. No recovery actions are taken until a write is attempted on the sector, then the same write/verify recovery steps as described above are done. This is known as the Transparent Autoreallocation.

Chapter 3 System Cylinders

3.1 General Information

Six cylinders on all drives are reserved for system and test usage. These cylinders contain drive configuration information, drive test information, and diskware. Customers cannot access these reserved cylinders. The reserved cylinders are only accessible with physical address commands which are protected diagnostic commands.

Data is stored on heads 0 and 1 in the OD system area.

The reserved cylinders are assigned as follows:

Cylinder	Description Outer System Area
-1	Test Equipment / Error logging
-2	System
-3	Copy of cylinder -2
-4	Diskware
-5	Copy of cylinder -4
-6	Test data

Note : The data on the system cylinder, unless specified otherwise, will use the following rules:

ASCII fields must be left justified, terminated with binary 0, and padded with binary 0's.
ASCII fields read by the drive firmware, such as the serial number, must be right justified with spaces and terminated with 0.

3.2 Test Equipment / Error logging Cylinders

The test equipment cylinder is reserved for test process usage. This cylinder contains test parameters and data collected during production test.

The sector usages are as follows:

Sector	Description
0	Copy of Servo Writer serial number data
1	Test process interlock
2	Reserved
3	Configuration center control
4	Reserved
5 - 14	Test process history queue
15 - 30	Process tset defect list
31	Error log(Header and count need for Apple burn -in)
32 - 40	Self Scan results
41 - 49	Self Scan test parameters
50 - 51	Self Scan command history
52 - 62	Self Scan defect list
63	Servo defect map
64 - 65	Adaptive results
66	Tail
67	Sofe error table
68 - 70	Sofe error list
71 - 118	Self Scan overlay number 1
119 - 120	Self Scan overlay number 2
121	Self Scan variables
122 - 151	Reserved for in-line defect sparing

3.3 System / Firmware Cylinders

This cylinder is reserved for system and firmware usage. It contains modepage information, configuration information, defect list, and format information for the drive.

Sector usages of cylinder -1 are not used.

Sector usages of cylinder -2 and -3 (for Firmware, System Infos) are as follows :

Sector	Description
0	System defect list
1	Reserved
2	Saved mode pages
3 - 14	Configuration pages
15 - 34	Working defect list
35 - 44	Primary defect list
45 - 46	Servo defect list
47	Apple system sector for read/write of OS information
48 - 51	ID-less descriptor table
52 - 65	Reserved
66 - 81	Selfscan - resident
82 - 97	Selfscan - overlay 1
98 -113	Selfscan - overlay 2
114 - 129	Selfscan - overlay 3
130	Reserved
131 - 134	Spares

Sector Usages of cylinder -4 and -5 (for Diskware) are as follows:

Sector	Description
0-1	Boot loader
2 - 57 / 2 - 65	AT / SCSI resident diskware (28 / 32 K)
58 - 113 / 66 - 121	AT / SCSI overlay (4K x 7)
114 - 130 / 122 - 130	Reserved
131-134	Spares

Sector Usages of cylinder -6 (for Selfscan, DPA, and Test process logs) are as follows:

Sector	Description
0	Test process - copy of servo writer data including drive serial number
1	Test process - interlock
2	Test process - reclassification
3	Configuration center control
4	Reserved for expansion
5 - 14	Test process - history queue
15 - 30	Test process - defect list
31 - 32	Test process - reserved
33 - 38	Selfscan - script / parameters
39 - 48	Selfscan - results
49 - 50	Selfscan - results tail
51 - 82	Selfscan - defect list
83 - 86	Selfscan - servo defect map
87 - 95	Selfscan - adaptive data
96 - 97	Selfscan - microjog
98	Selfscan - variables
99	Selfscan - input attenuation
100	Selfscan - MR Bias data
101 - 102	Selfscan - Short Head Stability data
103 - 111	Reserved
112 - 114	Drive Failure Prediction (DPA) results
115 - 127	Log dump (11), log sense and log select (2)
128	Error log (header & count for Apple burn-in)
129 - 130	Reserved
131 - 134	Spares

Sector Usages of cylinder -6 (for Selfscan CSS output) are as follows:

Sector	Description
0 - 124	CSS Test Data
125 - 134	Reserved

Sector Usages of cylinder -6 (for Selfscan Detailed Head Stability output) are as follows:

Sector	Description
0 - 19	HS run 1 bias setting 1
20 - 39	HS run 1 bias setting 2
40 - 59	HS run 1 bias setting 3
60 - 79	HS run 2 bias setting 1
80 - 99	HS run 2 bias setting 2
100 - 119	HS run 2 bias setting 3
120 - 134	Reserved

- **Saved Mode Pages**

  The data stored on these sectors is only the changeable part of the mode pages. See the section on Mode Pages for more details.

- **Configuration Pages**

  This area contains the drives configuration information such as the revision level, number of heads, etc. See the Read Configuration superset command for a detailed explanation of the data contained in this sector.

- **Defect List Sectors**

  These sectors contain the defect lists used during the drives normal operation. See the chapter on Defect Management for more information.

- **Format Header Sectors**

  In order for the firmware to format the drive, it needs to know the count byte information for the split sector data fields. Since there is no simple algorithm to generate this information, the count bytes must be stored in a table. We allocated 16 sectors on the system cylinder to hold this information. Each sector contains the count byte information for a particular zone.

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Chapter 4 Diskware

4.1 Introduction

The Tempest architecture is designed to support diskware. Part of the Buffer memory is used to load firmware from disk and the processor is able to execute the firmware directly from the buffer.

4.2 K7 Memory Map & RAM Usage

The K7 Memory Map for Tempest is organized as follows:

K7 ADDRESS	Usage	Size
900000 - FFFFFF	IMAGES OF 800000 - 8FFFFF	7,168K
8FFE00 - 8FFFFF	K7 INTERNAL SFR	512
8FFA00 - 8FFDFF	K7 INTERNAL RAM	1,024
8F8400 - 8FF9FF	NON-ADDRESSABLE	29.5K
8F8000 - 8F83FF	AKBAR REGISTERS	1K
800000 - 8F7FFF	NON-ADDRESSABLE	992K
100000 - 7FFFFF	IMAGES OF 000000 - 0FFFFF	7,168K
028000 - 0FFFFF	NON-ADDRESSABLE	864K
008000 - 027FFF	128K EXTERNAL RAM	128K
000000 - 007FFF	K7 INTERNAL CODE ROM	32K

The AT Buffer RAM Usage for Tempest is organized as follows:

K7 ADDRESS	Usage	Size
14E00 - 27FFF	CACHE MEMORY	76.5K
14A00 - 14DFF	TEMP BUFFER 1	1,024
14800 - 149FF	TEMP BUFFER 2	512
14600 - 147FF	SERVO DEFECT LIST	512
12E00 - 145FF	WORKING DEFECT LIST	6,144
11AA6 - 12DFF	VARIABLES	4,954
116A6 - 11AA5	COMMAND HISTORY	1,024
115AA - 116A5	CACHE TABLE	252
112B0 - 115A9	ACTIVE DESCRIPTOR TABLE	762
10AB0 - 112AF	DESCRIPTOR TABLE (COMPRESSED)	2,048
10894 - 10AAF	SAM to SAM TABLE	540
1034E - 10893	SERVO ADAPTIVE VARIABLES (CP21)	1,350
10092 - 1034D	SERVO VARIABLES (CP18)	700
10000 - 10091	SYSTEM DEFECT LIST	146
0F000 - 0FFFF	OVERLAY DISKWARE	4,096
08000 - 0EFFF	RESIDENT DISKWARE	28,672

The SCSI Buffer RAM Usage for Tempest is organized as follows:

K7 ADDRESS	Usage	Size
16800 - 27FFF	CACHE MEMORY	70.0K
16400 - 167FF	TEMP BUFFER 1	1,024
16200 - 163FF	TEMP BUFFER 2	512
16000 - 161FF	SERVO DEFECT LIST	512
14800 - 15FFF	WORKING DEFECT LIST	6,144
132A6 - 147FF	VARIABLES	5,466
12EA6 - 132A5	COMMAND HISTORY	1,024
12DAA - 12EA5	CACHE TABLE	252
12AB0 - 12DA9	ACTIVE DESCRIPTOR TABLE	762
122B0 - 12AAF	DESCRIPTOR TABLE (COMPRESSED)	2,048
12094 - 122AF	SAM to SAM TABLE	540
11B4E - 12093	SERVO ADAPTIVE VARIABLES (CP21)	1,350
11892 - 11B4D	SERVO VARIABLES (CP18)	700
11092 - 11891	COMMAND QUEUE BUFFER	2,048
11000 - 11091	SYSTEM DEFECT LIST	146
10000 - 10FFF	OVERLAY DISKWARE	4,096
08000 - 0FFFF	RESIDENT DISKWARE	32,768

* This DRAM address is mapped at 00000h - 07FFFh (upper bit is ignored).

The firmware is partitioned between the CPU ROM and the Diskware. The CPU ROM code contains all of the routines necessary to power up the drive and read the diskware into the Buffer. It also contains routines that allow the Diskware to be written to the disk via the host interface. All time critical code is located in the CPU ROM because the processor is able to execute CPU ROM code much faster than Diskware code. The Diskware code contains non time critical code that is not required for powering up the drive. The Diskware code also contains provisions to allow firmware bugs in the CPU ROM code to be corrected by mapping erroneous subroutines from CPU ROM into the Diskware.

4.3 Diskware Code Organization

The diskware code space is partitioned into two parts, a resident part and an overlay part. The Resident diskware is loaded during the drive power up initialization and remains in memory while the drive is powered on. The Overlay diskware is loaded on an as needed basis.

AT

Address Range	Description
8000h - F7FFh	Resident Diskware (Vector Table; Code)
F800h - FFFFh	Overlay Diskware

SCSI

Address Range	Description
8000h - FFFFh	Resident
10000h - 10FFFh	Overlay

The Resident Diskware contains a vector table which is used by the CPU ROM code for accessing Diskware subroutines and data, and for mapping erroneous CPU ROM subroutines into Diskware subroutines. During power up initialization a default vector table is copied from CPU ROM, this is replaced by the actual vector table when the Diskware is loaded from disk.

4.4 Diskware Storage Requirements

The diskware is stored on reserved system cylinders in memory image format. Configuration page 15 specifies where the overlays are stored on the system cylinders and where the overlays are loaded into the processor memory. Generally system cylinder information is stored in multiple places for redundancy, although the overlay configuration page only specifies where the first copy of the diskware is stored. Redundant copies of the diskware are stored according to the firmware redundancy algorithm for system cylinder information. The Tempest firmware stores redundant system cylinder information on physical head 0 and 1 in system cylinder areas.

Configuration Page 15 - Overlay Page

Field Offset	Description
0	Element number definition
1	Load address
4	Size- number of sectors
5	Cylinder
7	Alternate Cylinder
9	Starting Sector
11	Element number definition
12 - 21	Same fields as above
:	:
165	FFh - End marker

4.5 Write Buffer Command

Write Buffer command with the download option for SCSI and ATA is used to update the diskware. The Write Buffer command is described in the respective interface documents (SCSI ANSI X3T9.2/375R, ATA ANSI X3T9.2/791D). The download options are vendor specific, this specification will define the Quantum implementation of this option.

4.5.1 SCSI Write Buffer Command

	7	6	5	4	3	2	1	0
0	Opcode = 03Bh							
1	LUN = 0			Reserved		Mode		
2	Q	Reserved = 0						
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Parameter list length (MSB)							
7	Parameter list length							
8	Parameter list length (LSB)							
9	Reserved = 0						F	L

Mode 100 - Download Diskware. (Ramware)
Q 0 - Servo recal
1 - No servo recal (Quiet mode)

101 - Download Diskware and save.
Q x - ignored

4.5.2 ATA Write Buffer Command

The command is an optional, class 3 command. The op code used is 92h. Parameters used are the FR, SC, SN, CY registers. (see table 9-1 of the ATA specification). It is also a PIO Data Out command (see section 10.2 of the ATA specification). The head bits of the Drive/Head register shall always be set to zero. The Sector register shall be used to extend the Sector Count register, creating an effective sector count 16 bits long. The Cylinder High and Low registers are reserved.

The value of the Features register shall be used to determine the time the update takes effect, whether it is saved for future use, and any future functions:

Feature register values for Download diskware.

bit 2 1 0	
0 0 1	download is for immediate, temporary use. (Ramware)
1 1 1	save downloaded code for future reference by value of cylinder and specify it as the default for immediate and future use.

Feature register value of 0FEh specifies a download for immediate temporary use with no servo recal.

4.6 Diskware Download Theory of Operation

The write buffer command will download diskware. The download elements are a diskware downloader, an optional diskware boot loader, diskware control page, and diskware overlay entries. The diskware downloader shall be validated by a good checksum, valid product code, compare of the ROM version stamp and ROM checksum. Once the diskware downloader is validated, the diskware downloader will execute.

The diskware downloader will validate the diskware control page and diskware overlay entries by a good checksum, valid product code, compare of the ROM version stamp and ROM checksum. The diskware downloader will put the drive in a "ROM only" state (servo and spindle to run out the ROM) and move the overlay entries to the locations directed to by the diskware control page. The last overlay entry to move is the vector table. Care must be exercised to disable the currently running functions when this table is loaded (i.e. servo and spindle functions that are currently running in "ROM only" mode). Upon completion of the vector table move, the handler will initialize drive mode and configuration page parameters with the ROM defaults. The handler will start execution of the diskware in ram.

The download and save mode will additionally save the diskware data to the reserved cylinders as specified in the diskware control page.

The optional diskware boot loader is firmware that at power up will be read from disk and it will read and validate the remaining diskware elements.

4.7 Diskware Elements

All the diskware elements have a common header at the beginning of each element. The diskware element header is defined as follows:

Byte	Definition of field
0	Element Type
1	Product Code
2-4	ROM Version Stamp
5-6	ROM Checksum
7	Length of the element
8-14	Element dependent
15	Checkbyte
16	Start of element data
n	End of element data

Description of the bytes in the page

Byte 0	Type of element. 80h - Diskware downloader 81h - Diskware control page 82h - Diskware boot loader 00h - Vector Table 01h - Resident 1xh - Resident overlay x 03h - Self Scan resident 3xh - Self Scan overlay x
Byte 1	Product code unique to each product.
Byte 2-4	Copy of the ROM version stamp.
Byte 5-6	Copy of the ROM checksum.
Byte 7	Length of this data page in 512 sectors.
Byte 8-14	Element dependent.
Byte 15	Checkbyte of the element.
Byte 16	Start of the diskware element data.
Byte n	End of the diskware element data.

4.8 Diskware Downloader

The diskware downloader consists of element header and data. The downloader definition is defined as follows:

Byte	Definition of field
0	Element type (080h).
1	Product Code
2-4	ROM Version Stamp
5-6	ROM Checksum
7	Size of the downloader
8-11	Downloader execution address
12-14	Reserved
15	Checkbyte
16	Start of downloader code
n	End of downloader code

Description of the bytes in the diskware downloader.

Byte 0	Element type for the diskware downloader.
Byte 1	Product code unique to each product.
Byte 2-4	Copy of the ROM version stamp.
Byte 5-6	Copy of the ROM checksum.
Byte 7	Length of this data page in 512 sectors.
Byte 8-11	Downloader start of execution address.
Byte 12-14	Reserved.
Byte 15	Checkbyte of the diskware downloader.
Byte 16	Start of the diskware downloader program.
Byte n	End of the diskware downloader program.

4.9 Diskware Control Page

The Diskware control page contains diskware entries. A maximum of twenty entries are available in this page. The diskware control page is 512 bytes long and is defined as follows:

Byte	Definition of field
0	Element Type (81h)
1	Product Code
2-4	ROM Version Stamp
5-6	ROM Checksum
7	Length of the page (01h)
8-14	Reserved
15	Checkbyte
16	Element type 0
17-19	Load Address
20	Size
21-22	Cylinder
23-24	Alternate Cylinder
25-26	Starting Sector
27	Element type 1
28-37	Definitions same as bytes 17-26
38	Element type 2
39-48	Definitions same as bytes 17-26
49	Element type 3
50-59	Definitions same as bytes 17-26
60	Element type 4
61-70	Definitions same as bytes 17-26
71	Element type 5
72-81	Definitions same as bytes 17-26
82	Element type 6
83-92	Definitions same as bytes 17-26
93	Element type 7
94-103	Definitions same as bytes 17-26
104	Element type 8
104-114	Definitions same as bytes 17-26
115	Element type 9
116-125	Definitions same as bytes 17-26
n	End of overlay entries (0FFh)
n+1-511	Fill (00h)

Description of the bytes in the page

Byte 0	Element type overlay control page (081h)
Byte 1	Product code unique to each product.
Byte 2-4	Copy of the ROM version stamp.
Byte 5-6	Copy of the ROM checksum.
Byte 7	Length of this data page in 512 sectors.
Byte 8-14	Reserved.
Byte 15	Checkbyte of diskware control page.
Byte 16	Element number definition.
Byte 17-19	Load address is the memory address of the overlay. The load address is three bytes of a four byte address with the least significant byte zero.
Byte 20	Size in 512 sectors
Byte 21-22	Cylinder is where primary copies of the overlay will be stored.
Byte 23-24	Alternate Cylinder is where alternate copies of the overlay will be stored.
Byte 25-26	Starting sector is where the overlay starts.
Byte 27-n	Additional overlay entries.
Byte n+1	End of overlay entries (0FFh marks the end of the entries).
Byte n+2-511	Fill pads out from the End of overlay marker to byte 511.

4.10 Diskware Overlay Entry Data

All the disk parameters for the diskware data are defined in the diskware control page. Each overlay has a element header. The overlay data is defined as follows:

Byte	Definition of field
0	Element Type
1	Product Code
2-4	ROM Version Stamp
5-6	ROM Checksum
7	Size
8-14	Reserved
15	Checkbyte
16	Start of overlay data
n	End of overlay data

Description of the bytes in the page

Byte 0	Element type.
Byte 1	Product code unique to each product.
Byte 2-4	Copy of the ROM version stamp.
Byte 5-6	Copy of the ROM checksum.
Byte 7	Length of this data page in 512 sectors.
Byte 8-14	Reserved.
Byte 15	Checkbyte of the overlay entry data.
Byte 16	Start of the overlay entry data.
Byte n	End of the overlay entry data.

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Chapter 5 New / Modified Super Commands

5.1 Read / Write Descriptor

Byte	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			0	HDR	R/W	ALL	SV
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Zone							
6	Sub Opcode = 3Ah							
7	Descriptor length - MSB							
8	Descriptor length - LSB							
9	Reserved = 0						F	L

This command writes (downloads) and reads (uploads) ID-less descriptors to and from the drive.

When **R/W** is set to 1, the drive will perform a Write Descriptor operation. The data to be sent to the drive are the sector descriptors, contained in a binary file, output from the ITF program. The Descriptor length specifies the number of bytes the drive will accept in the data phase.

If the option bit **ALL** is set, the drive will interpret the data as the descriptors for all recording zones. If **ALL** is not set, the drive will interpret the data for a single zone, as indicated by the **Zone** byte (CDB5). A zone value of $0FF_H$ indicates the system cylinder zone.

If the **SV** bit is set, the drive will save the descriptors onto the system cylinder.

When **R/W** is set to 0, the drive will perform a Read Descriptor operation. In this case, the drive will return the current descriptor structure to the host. Similar to the write descriptor operation, a single zone may be specified with the **Zone** byte.

If the **SV** bit is set, the drive will return the descriptors as saved from the system cylinder; otherwise, the descriptors in the buffer RAM will be returned.

If the **HDR** bit is set, the drive will return *only* the 32-byte header for the descriptors.

Note: When the **ALL** option is not selected, Tempest currently allows access to zone FF_H only.

5.2 Read Serial Number

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			0	0	0	0	ALL
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 3Bh							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

\+ *New for Tempest*
This command causes the drive to return the 12-digit BCD serial number (in 6 bytes) as written on the super cylinders.

Byte	Contents
0	First and second digits (MSB) of the serial number.
.	...
5	Second last and last digits (LSB) of the serial number.

If the option bit **ALL** is clear, then only the six bytes of data are transferred to the host. If **ALL** is set then a total of 14 bytes of data are returned (the first six are the serial number, the remaining eight are the other servo writer information bytes).

5.3 Read Spindle ETM

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			0	0	0	0	0
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 3Ch							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

This command causes the drive's spindle controller to perform an Electronic Torque Measurement (ETM) on the spindle and return the result. This information is used for CSS testing.

Prior to sending this command the drive must be running RAMware (see Set RAMware Mode command) and the spindle motor must be stopped. If these conditions aren't met the drive may hang.

Byte	Contents
0	ETM value. (this is a DAC value)

To convert to current (milliamps): (ETM value * (0.348 / 255)) / 0.25
(or approximately ETM value * 0.00546)

5.4 Microjog Calibration

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			0	0	SV	0	0
2	Start Offset - MSB							
3	Start Offset - LSB							
4	HEAD							
5	Microjog Zone Number							
6	Sub Opcode = 3Dh							
7	Min. Good Samples							
8	Step Value							
9	Num of Revs						F	L

This command causes the drive to perform a microjog calibration on all its heads over the specified region--i.e. microjog zones. Microjog zones in Tempest are defined as follows: Zone 0 is the system area. Zones 1 through 16 are sixteen evenly divided segments among the user's cylinders starting with cylinder 0.

The **SV** flag determines whether the config pages should be updated with the calibrated values. If it is set, the parameters will be saved to the RAM copy of configuration page 23 on the drive and sent to the host. If clear, data is transferred to the host only and NOT to the RAM copy of config Page 23.

The **Zone Number** will specify which one of the 17 microjog zones (0 thr. 16) is to be calibrated.

Start Offset defines the maximum offset to step from track center to begin the calibration. The next step would be the same offset but in the negative direction. The magnitude of each step is defined by the **Step Value** field, i.e. the step size to be taken between two microstep measurements.

The **Min. Good Sample** field specifies the minimum number of good samples needs to be collected over all the revolutions (not per revolution). The **Number of Revs** field sets the number of revolutions in which samples are taken when determining the average VGA.

5.5 Set RAMware Mode

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			Reserved = 0				RAM
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 3Eh							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

\+ *New for Tempest*

This command is used to switch between Diskware and RAMware operational modes. If **RAM** is set to 1, the drive will switch to RAMware mode. The purpose of RAMware mode operation is to eliminate any system cylinder access during super command execution--i.e. the implicit seek and read operations required to read an overlay. If **RAM** is set to 0, the drive will switch to Diskware mode. In either case, the drive must have booted up with Diskware. This command will also reinitialize the cache and disable Servo Records, although the user may subsequently re-enable Servo Records.

Diskware mode is the normal operating mode of the drive. Overlays are loaded from disk into memory as needed. As most Super mode commands are in overlays, executing a super mode command often requires a system cylinder access to load the required overlay into memory. Note that it is sometimes undesirable or unacceptable to have the actuator move from its original position. This is where operating in RAMware mode is useful.

RAMware mode differs in that all the overlays are stored in the cache buffer, so that "loading an overlay" when in this mode simply means copying the overlay image from the cache buffer to the overlay area. No disk activity is required to load an overlay when operating in RAMware mode. The main advantage to operating in RAMware mode is that there are no hidden side-effects of the actuator moving around unexpectedly. Note that cache size is reduced by 28K, however.

5.6 Read BHV

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			0	0	0	0	0
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 3Fh							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

+ *New for Tempest*

This command causes the drive to measure the Buffer Head Voltage (BHV) from each of its MR heads and return the results. The analog-to-digital conversion of the voltages will take place while the drive is up and running, therefore, the host should execute this command only when the drive is ready. The returned data is as follows:

Byte	Contents
0	8-bit digitized BHV value for head 0.
1	BHV for head 1.
.	. . .
5	BHV for head 5.

Note that the command will return 6 bytes of data regardless of the number of heads the drive may contain; e.g. for a four-headed drive, bytes 4 and 5 will be invalid and should be dismissed.

5.7 Read Current Cylinder

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			0	0	0	SVO	SN
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 82h							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

This command causes the drive to return the current track ID over which the actuator is located. If the **SN** (serial number) flag is clear, the drive will read the track ID from the first available wedge and return it. Note: If the first available wedge is a wedge with the serial number data encoded, it will pass this info as the current cylinder.

Byte	Contents
0	Current track ID (LSB).
1	Current track ID (MSB).

\+ *New for Tempest*
If **SVO** is set, the command will return the cylinder number in term of *servo cylinder*. When SVO is clear, the command will convert its output to *data cylinder*.

If **SN** is set, a three-digit BCD serial number code (3 out of the 12-digit number) as written on the current cylinder will be returned, assuming the actuator is positioned over a Super cylinder. In Tempest, the serial number is coded on every 4th wedge starting with wedge 2 on the Super cylinders. Note: The preferred method for the host to retrieve the serial number is by using the Read Serial Number command.

Byte	Contents
0	Serial number code (LSB).
1	Serial number code (MSB).

5.8 Write and Read Wedge-to-Wedge

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			SKW	ECC	U/D	B	R/W
2	Reserved = 0							
3	Pattern (Byte Mode)							
4	Starting Wedge Number							
5	Number of Wedges							
6	Sub Opcode = 90h							
7	Bytes per Wedge - MSB							
8	Bytes per Wedge - LSB							
9	Reserved = 0						F	L

This command reads or writes *wedge to wedge sectors* as specified by the command, instead of using the conventional 512-byte sector size.

With the **R/W** flag set to 1, the drive will perform a *write* operation. In which case, the **B** flag may be used to indicate the source of write data pattern. If **B** is 0, the drive will expect the data pattern to be transferred from the host. When **B** is set to 1, the drive will use the byte from CDB3 as the fill pattern for the entire sector.

With **R/W** set to 0, the drive will perform wedge-to-wedge *read*.

The **ECC** flag is used to select whether the write/read operation should generate/verify ECC. To disable ECC generation and checking, set **ECC** to 0.

With the **SKW** flag set to 1, the drive will use skewing when performing the operation.

With **SKW** set to 0, the drive will not use skewing.

+ *New for Tempest*

1. **Bytes per Wedge** (CDB7 and CDB8) specifies sector size (number of bytes) to be written. i.e. 512 bytes/wedge (Previously this specified total bytes to write. i.e. 512 bytes/wedge * 90 wedges).

2. With **U/D** set to 1, **Starting Wedge Number** (CDB4) specifies wedge number to begin write/read. **Number of Wedges** (CDB5) specifies the number of wedges to write/read. (Fireball would write/read the entire track). If **U/D** is 0, write/read will take place over the entire track (all wedges), CDB4 and CDB5 are ignored (also the writing/reading will begin on the current wedge + 5 the command will not wait for wedge 0 to start the command).

3. As with Fireball, the Read W-to-W command does not transfer data to the host, but it *does* transfer it to the drive's buffer (Fireball did not transfer data to the drives buffer, it performed byte to byte comparison of the data read with the data specified in CDB3). The Akbar controller does not support read & compare, therefore, Tempest ignores the byte specified in CDB3 during Read W-to-W.

4. If generation/verification of ECC is desired, CDB1.3 needs to be set. With Fireball, ECC was never generated when performing a W-to-W command.

> Caution: Read/Write Wedge-to-wedge do *not* contain implied seek--they begin operation wherever the head is located at the time. Use Config. Page 7 to disable microjogging prior to seeking to the desired position for these commands.

5.9 Channel Register Sampling (Read and Sample Shiva)

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			SKW	0	0	R/W	F/Q
2	Shiva Reg. 1							
3	Shiva Reg. 2							
4	Shiva Reg. 3							
5	Shiva Reg. 4							
6	Sub Opcode = 92h							
7	Starting Wedge Number							
8	Number of Wedges / Revs							
9	Reserved = 0						F	L

This command samples four read channel registers following the data area.

With the **SKW** flag set to 1, the drive will use skewing when performing the operation.

With **SKW** set to 0, the drive will not use skewing.

+ *New for Tempest*
If the **F/Q** flag is clear, 512 bytes will be read before Shiva is sampled. If **F/Q** is set, only a 1/4 sector (128 bytes) will be read before sampling Shiva.

If the **R/W** flag is clear, CDB8 specifies the number of wedges to sample. If **R/W** is set, CDB8 specifies the number of revs to sample (all wedges will be sampled for the number of revs specified in CDB8). When sampling multiple revs, the formatter will be restarted after each rev of data is collected until all revs have been taken. A limit of **5 revs** is allowed due to buffer size. If more than 5 revs are specified, only 5 revs will be sampled.

Data returned to the host is no longer in wedge order. The data is in order of samples (i.e. if wedge 10 is sampled first, its data will be stored at the top of the buffer).

5.10 Reassign Physical

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			SKW	0	0	0	CSD
2	Cylinder - MSB							
3	Cylinder - LSB							
4	Head							
5	Sector							
6	Sub Opcode = 10h							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

This command causes the drive to reassign the physical sector with the given cylinder, head and sector.

+ <u>New for Tempest</u>
The drive will interpret a negative cylinder as system cylinder number. For ID-less design, the drive maintains a defect list for system defect as well; this command can be used for mapping out defects found in the system area. If the **CSD** bit is set, the drive will clear its system defect list.

5.11 Erase Track

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			SKW	0	0	0	0
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 16h							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

With the **SKW** flag set to 1, the drive will use skewing when performing the operation.

With **SKW** set to 0, the drive will not use skewing.

5.12 Read SCSI Sequencer WCS

Tempest:

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			Reserved = 0				
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 1Ah							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

This command causes the drive to return the 228 bytes of microprogram in the SCSI sequencer's Writable Control Store. The data is organized as 76 words of 3-byte instructions .

5.13 Write SCSI Sequencer WCS

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			Reserved = 0				
2	Reserved = 0							
3	Reserved = 0							
4	Reserved = 0							
5	Reserved = 0							
6	Sub Opcode = 1Bh							
7	Reserved = 0							
8	Reserved = 0							
9	Reserved = 0						F	L

This command causes the drive to accept 228 bytes of microprogram from the host and download it to the SCSI sequencer's Writable Control Store. The data is organized as 76 words of 3-byte instruction

5.14 Tempest Servo Verify

Tempest:

	7	6	5	4	3	2	1	0
0	Opcode = 0FFh							
1	LUN = 0			reserved= 0		NS	C	A
2	Cylinder - MSB							
3	Cylinder - LSB							
4	Head							
5	Reserved = 0							
6	Sub Opcode = 81h							
7	Bump Limit MSB							
8	Bump Limit LSB							
9	Reserved = 0						F	L

This subroutine is used to verify servos on a single track of the drive. It has three modes; if the ALL WEDGES flag is (0), then it will return the wedge number and error code for the first wedge with a non-zero servo status. This mode isn't too useful for general use, since the multiple servo errors on the same track will not be reported. If the ALL WEDGES flag is (1), then the status's for all wedges will be read and returned to the host.

(A)LL WEDGES flag - read and return ALL wedge status's
(C)ollect burst data flag
(NS) don't issue seek
BUMP LIMIT (0 = use default write limit)

The following is t format of the host servo verify data:

Wedge number	Offset	Format	Descriptions	
	00h	BYTE	Servo error flags	
			BIT	*STATUS*
			0	Mapped defect
			1	Wrong track ID
			2	Servo defect
			3	Speed out of range
			4	PERR bump
			5	Track data error
			6	Servo sync error
			7	Servo AM bad
0	01h	BYTE	Flags Bit 7 = Set indicates Index Bit 6 = Set indicates first sector found.	
0	02h	WORD	SAM-TO-SAM time (LSB, MSB)	
0	04h	BYTE	B Burst	
0	05h	BYTE	A Burst	
0	06h	BYTE	C Burst	
0	07h	BYTE	Physical Burst number	

Chapter 6 ID-less Format File

6.1 ID-less Descriptor File (TMITF.BIN)

The descriptor binary file contains the sector descriptors for all recording zones (system and data), related parameters for programming the formatter plus the information necessary to access the descriptors. The .BIN file is generated by the *ITF* program and to be passed to the drive via the Write Descriptor command. The binary file is divided in five sections as follows:

6.2 The Header Block

The 32-byte header of the binary descriptor file:

Bytes	Content	Default
0	Checksum byte	[1]
1	File type	[2]
2-3	*ITF* output revision code (major/minor ver)	0051_h
4-7	Size of this descriptor file (LSB first)	[3]
8	Descriptor revision	[4]
9	Number of zones	16
$0A_h$	Number of sector sizes	1
$0B_h$	Size of index entry	2
$0C\text{-}0D_h$	Offset to global parameter block	0020_h
$0E\text{-}0F_h$	Offset to zone parameter block	0028_h
$10\text{-}11_h$	Offset to index block	$014A_h$
$12\text{-}13_h$	Offset to descriptor block	$016C_h$
$14\text{-}1F_h$	Reserved	0

[1] Checksum byte is the 8-bit sum of all the bytes within the current file (header, index and descriptor sections) excluding itself.

[2] Bit 0 indicates "expanded parameter blocks" (not used in Tempest);
Bit 1 indicates "compact" descriptors output (see Section 1.5).

[3] Total number of bytes in the current file.

[4] Value is entered by user at time of descriptors generation. To distinguish the types of Tempest format files--1080 vs. 1280: For the Tempest 1080 series, the value of this byte will be less than 10. For the 1280 series, it will be 10 or higher.

6.3 The Global Parameter Block

Along with the sector descriptors, there exists a collection of *ITF*'s input and output parameters that are closely linked to the descriptors being generated; it makes sense to co-locate these information. The *Global* parameter block carries the following parameters which may be accessed by the firmware to set up the ASIC.

Bytes	Content
20_h	PW read gate delay
21_h	Skip write splice
22_h	Write gate extension
23_h	Just-in-case size
24_h	Just-in-case data
$25\text{-}27_h$	Reserved

6.4 The Zone Parameter Block

The *Zone* block has similar purpose as the Global block, except it carries zone-dependent parameters, thus the data structure is repeated for each existing zone.

Bytes	Content
$28\text{-}29_h$	Read pre-wedge signal (LSB first)
$2A\text{-}2B_h$	Write pre-wedge signal
$2C\text{-}2D_h$	# of cylinders
$2E\text{-}2F_h$	Wedge-to-wedge bytes/sector
$30\text{-}31_h$	Sector start time w/ break count [5] Zone 0
$32\text{-}33_h$	Formatter wedge
$34\text{-}35_h$	Formatter wedge for wiggle
36_h	Negnum
37_h	Reserved
$38\text{-}47_h$	Above information for zone 1
$48\text{-}127_h$	Above information for zones 2-15

[5] These two bytes are the second and third bytes of a wedge-to-wedge sector descriptor, the wedge number (first byte) of the descriptor is expected to be synthesized by firmware.

The second part of the Zone parameter block is the sectors per track table. The first word specifies the sector size, followed by sectors per track values for the 16 zones.

Bytes	Content
$128\text{-}129_h$	Bytes per sector (i.e. 512)
$12A\text{-}12B_h$	Sectors per track for zone 0 (LSB first)
$12C\text{-}149_h$	Sectors per track for zones 1-15

6.5 The Index Block

Following the Zone parameter block is the *Indexes* block, it contains 17 indexes, one for each zone; each index points to the first byte of the descriptor (wedge 0) for the given zone. There is also a trailing index which points to the end of all the descriptors. The size of this section may be variable, based on the number of zones in use; the test software should examine the header field to determine the actual number. Another variable in this section is the size of indexes. Tempest employs 2-byte indexes (as denoted in byte $0B_H$ of the header block).

Bytes	Content
$14A\text{-}14B_h$	Index to descriptor for zone 0 (LSB first)
$14C\text{-}169_h$	Index to descriptor for zones 1-15
$16A\text{-}16B_h$	Index to the byte after the last zone

6.6 The Descriptor Section

Finally, the 3-byte descriptors are packed into the .BIN file beginning with zone 0. The number of descriptors in a zone varies from zone to zone. The format of these descriptors comes in one of two versions. The "full-size" output version generates the full number of descriptors for the given track, i.e. equal to the number of sectors per track. In the "compact" version, *ITF* takes advantage of the *harmonic* nature of the format in which the split-sector relationship of sectors-to-wedges typically repeats many times within a track. In this mode, ITF will only output the first sequence of the sector descriptors and stop before they repeat. Tempest utilizes the "compact" descriptor format (as denoted in byte 1 of the header block); the firmware replicates the descriptors to fulfill the full track as needed in run-time.

Example of a .BIN file:

```
0000  74 02 00 53 1F 06 00 00-0A 10 01 02 20 00 28 00      ; Header block
0010  4A 01 6C 01 00 00 00 00-00 00 00 00 00 00 00 00
0020  02 02 09 00 00 04 B9 19-                           ; Global parameter block
0020                          -D2 0A C6 0A 00 00 78 03   ; Zone parameter block
0030  80 69 D4 00 CE 00 EC 00-E7 0A E0 0A B7 01 B2 05
0040  40 67 CF 00 CC 00 EC 00-E6 0A DE 0A B7 01 77 05
0050  70 67 D0 00 CC 00 EC 00-E5 0A DD 0A B7 01 51 05
......
0120                          -00 02 87 00 DE 00 D4 00   ; Sectors/trk
0130  CF 00 C6 00 BE 00 B4 00-AA 00 A0 00 97 00 90 00
0140  87 00 7E 00 78 00 70 00-68 00
014A                          -     6C 01 75 01 E4 01   ; Index block
0150  32 02 77 02 98 02 D2 04-D8 04 0B 05 3B 05 8C 05
0160  A4 05 AD 05 C2 05 CE 05-DD 05 1F 06
016C                                      00 D0 69 00   ; Descriptors for zone 0
0170  93 B9 01 D2 21
0175                 80 D0 67-00 D2 6E 00 44 75 01 D1   ; Descriptors for zone 1
0180  7E 81 93 85 82 D0 8E 02-D2 95 82 F4 9C 03 D1 A4
0190  83 43 AB 84 D0 B4 04 D2-BB 04 A4 C2 85 D1 CA 85
01A0  F3 D1 86 D0 DA 86 D2 E1-06 54 E8 07 D1 F0 87 A3
01B0  F7 08 D1 00 08 D3 07 88-05 0E 09 D2 16 09 54 1D
01C0  0A D1 26 0A D3 2D 0A A5-34 8B D2 3D 8B 04 44 0C
01D0  D1 4C 0C D3 53 8C 55 5A-0D D2 63 8D A4 6A 8E D1
01E0  73 0E D3 7A
01E4              80 D0 67 80-D2 84 00 74 A1 01 D1 C0   ; Descriptors for zone 2
01F0  01 F3 DD 02 D0 FD 02 D3-1A 02 75 37 83 D2 56 83
......
```

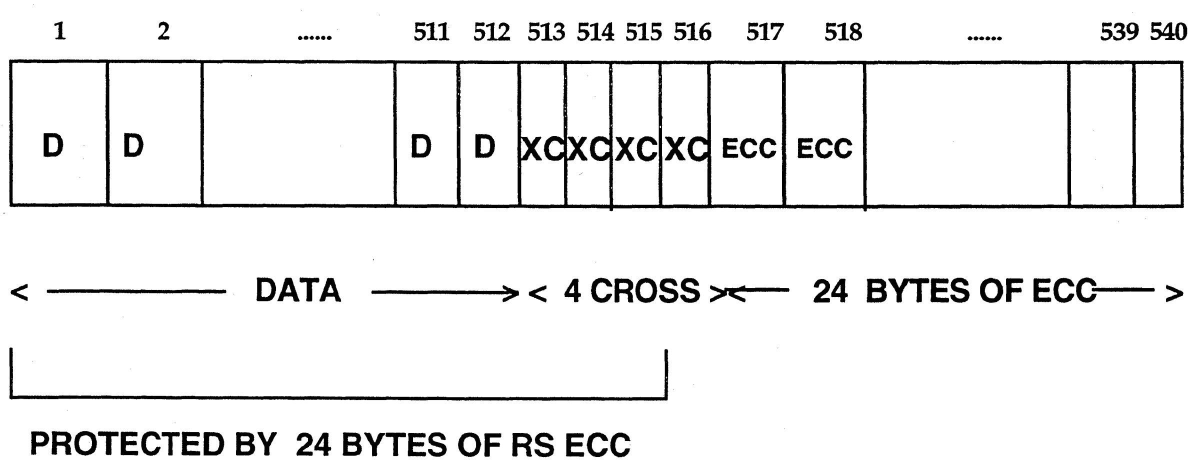
Chapter 7 Error Correcting Code

7.1 ASIC ECC Comparsion

Tempest AKBAR	vs	Fireball LEO
• 8 bits per symbol		Same
• 4 interleaves		3 interleaves
• 6 redundancy bytes per interleave		6 redundancy bytes per interleave.
• 4 cross-check bytes		2 cross-check bytes
• 24 ECC bytes and 4 CRC bytes		18 ECC bytes and 2 CRC bytes
• Single-Error Correction on-the-fly		Same
• Double-Error Correction on-the-fly		Same
• Triple-Error Correction		Same
• None		3 Bytes CRC per ID field

7.2 AKBAR ASIC

7.2.1 1 Sector Data Field with ECC Bytes



7.2.2 Bytes Interleaving

Interleave 1 ⇨	d1	d5	••••	d509	xc1	ecc1	ecc5	ecc9	ecc13	ecc17	ecc21	ecc25
Interleave 2 ⇨	d2	d6	••••	d510	xc2	ecc2	ecc6	ecc10	ecc14	ecc18	ecc22	
Interleave 3 ⇨	d3	d7	••••	d511	xc3	ecc3	ecc7	ecc11	ecc15	ecc19	ecc23	
Interleave 4 ⇨	d4	d8	••••	d512	xc4	ecc4	ecc8	ecc12	ecc16	ecc20	ecc24	

7.3 ECC Principles of Operation

- ECC hardware includes REED-SOLOMON (RS) Encoder/Decoder circuit that is used to generate redundancies during write mode and syndromes during read mode.
- ECC hardware also checks the values of the syndromes to detect errors.
- All corrections will be done in Firmware.

7.4 Cross Check Bytes

- There are 4 cross check bytes per data filed.
- Used to " Double Check" the main correction, and therefore reduced the miscorrection probability of the REED-SOLOMON (RS) ECC correction.

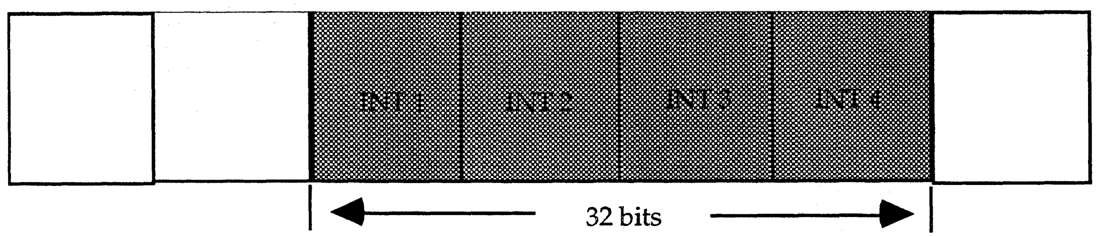
7.5 ECC Correction On - the - Fly

- The expression "On - the - Fly" means an error correction process which is carried out with minimized data flow interruption, and which does not requires one or more disk rotation latencies (revolutions) for carrying out the correction process.
- In order to perform ECC "On - the - Fly", it is necessary to detect and correct the data errors in the background while the sequencer is still active, so that is does not stop the flow of data block during a typical transfer of multiple blocks.

7.6 Single-Burst Error

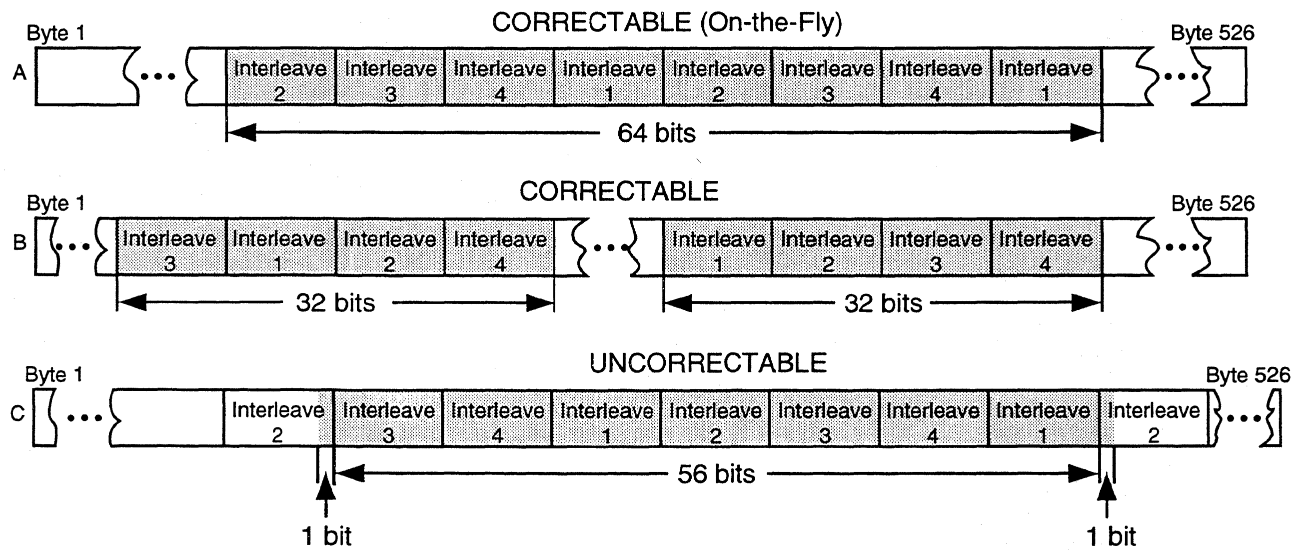
- Single burst error is defined as an error occurring in one byte within one of the interleaves.
- Can have up to three erroneous bytes within a sector, provided that each byte of the three occupies a different interleave.
- Correct up to 32bits i.e., 1 byte per interleave. Guarantee to correct 25 bits.

7.6.1 Correctable of 32 Bit Single Burst Error



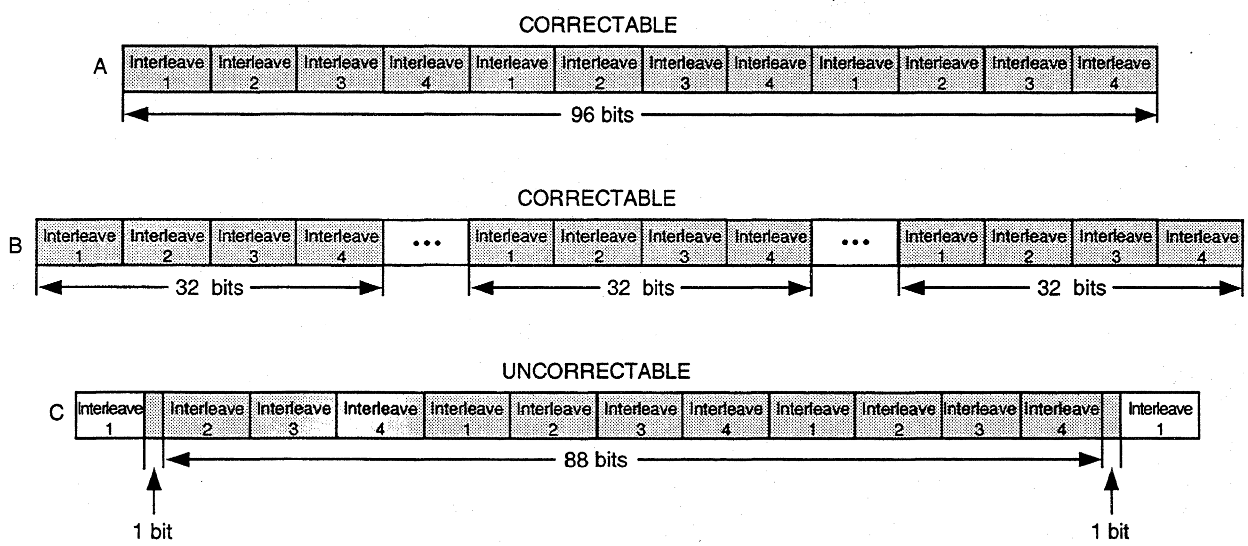
7.7 Double Burst Error

- A double burst error is defined as an error occurring in two bytes within one of the interleaves.
- Correctable double burst errors must have two or fewer erroneous bytes per interleaves.
- Correct up to 64 bits i.e., 2 bytes per interleave. Guarantee to correct 57 bits.



7.8 Triple Burst Error

- Triple burst error is defined as an error occuring in three bytes within one of the interleaves.
- Correctable triple burst errors must have three or fewer erroneous bytes per interleaves.
- Correct up to 96 bits i.e., 3 bytes per interleave. Guarantee to correct 89 bits.



Chapter 8 Miscellaneous Information

8.1 Programmable Trigger

Firmware allows certain conditions to generate a scope trigger. The conditions under which a trigger pulse is generated is controlled by Configuration Page 12 which consists of one byte. The eight bits are used to control whether a pulse is to be generated on an associated condition. If the bit is set and the condition occurs, a 1 microsecond (approximately) pulse is generated. Multiple trigger conditions may be specified at a time. The supported bits and associated conditions are as follows:

Bit	Description
0	True bump, not a sync\sam\data or speed
1	Seek time out
2	Seek fault
3	Any Tunafish error
4	ECC error
5	Sequencer read/write error
6	Sequencer overrun/underrun
7	Sequencer time out

As as example, to enable a pulse on either a seek time-out or ECC error, enter the following DIAG command line: DEPB 0 18 , WRCONF 12

The programmable scope trigger magically appears on microprocessor port P0.7.

8.2 Drive Parameter Analysis

Drive Parameter Analysis (DPA) feature has been implemented on Tempest At drives. The DPA feature can be turned on by setting bit 7 byte 1 of config page 19 to one. Once the DPA feature is turned on the user can send **dpa enable** command to start monitoring some parameters of the Tempest\AT drive.

A set of two sectors (55, 56) have been reserved on Cylinder -2 and -3 to store DPA related data and variables. Sector 55 to store DPA related variables and sector 56 is used to store Warranty Threshold Values.

An opcode B0H has been defined for DPA related commands. This command has a number of separate functions which are selectable by a subopcode via the Features Register. The drive checks a specific password in Cylinder Low & High Registers before it accepts a DPA Command as valid.

Password for a valid DPA Command is:

0x4F	Cylinder Low
0xC2	Cylinder High
0xB0	Command Opcode

The Tempest drive supports following DPA commands:

DPA Subcode	Function
0xD0	Returns Drive Attribute Values. The drive returns 512 bytes and saves the attributes to disk (sector 91 Cylinder -1)
0xD1	Read Warranty Threshold Values. The drive returns 512 bytes of data from Warranty Threshold values sector (sector 56 Cylinder -2, -3)
0xD2	Enable/ Disable Autosave
0xD3	Write Current Attribute Values to the disk (sector 55 Cylinder -2, -3)
0xD7	Write Warranty Threshold values to the disk (sector 56 Cylinder -2, -3)
0xD8	Enable DPA data collection and DPA Command decode
0xD9	Disable DPA data collection and DPA Command decode
0xDA	Check Warranty

8.2.1 Drive Attributes Supported

Attribute ID Number	Attribute Name
1	Read Error Rate
3	Spin Up Time
4	Start/stop Count
5	Reallocated Sector Count (grown defects)
7	Seek Error Rate
9	Power On Hours Count
11	Recal Retry Count
12	Drive Power Cycle Count

8.2.2 Drive Attribute Value Data Structure

The following data structure defines the 512 bytes that make up the Drive Attribute Value information.

Bytes	Drive Attribute Data Structure Description
2	Data Structure Revision Number
12	First of the supported Drive Attributes
12	Second of the supported Drive Attribute
	..
	..
	..
12	30th of the supported Drive Attributes
6	Off - line data collection status byte (Not Supported)
2	Drive Failure Prediction Capability Word **Bit** 0 = Attributes Saved by Drive before Entering Power Mode 1 = Attributes Auto Save Capability
92	Reserved (0x00)
48	Vendor Unique (0x00)
1	Quantum Checksum Byte
1	Data Structure Checksum Byte
Total 512	

The Data Structure Revision Number identifies which version of this data structure is implemented.

Quantum Checksum Byte is calculated so that sum of all bytes in Data Structure is 'C'.
The Data Structure Checksum is a simple 8 bit addition of the first 511 bytes in the data structure with the Checksum value being the two's complement of this sum.

8.2.3 Drive Attribute Format

Bytes	Drive Attribute Description
1	Attribute ID Number
2	Status Flags
1	Normalized Attribute Value
1	Worst Ever Normalized Attribute Value
6	Raw Attribute Value
1	Reserved (0x00)
Total 12	

8.2.4 Status Flags

Bit	Description
0	If set to 1, an Attribute value exceeding Threshold constitute a failure
1	If set to 1, the Attribute value is updated during on line testing
2	If set to 1, it's a performance Attribute
3	If set to 1, it's an error rate Attribute
4	If set to 1, it's an event count Attribute
5	If set to 1, it's self preserving Attribute
6	Reserved
7	Reserved
8-15	Reserved

8.2.5 Normalized Attribute Value

Valid numbers are 0x01 - 0xFE

Normalized Value	Description
0x01	Minimum value
0x64	Initial value prior to data collection
0xFE	Maximum value. Data count is saturated. Value not valid

8.2.6 Worst Ever Normalized Attribute Value

Valid numbers are 0x01 - 0xFE

Normalized Value	Description
0x01	Minimum value
0x64	Initial value prior to data collection
0xFE	Maximum value. Data count is saturated. Value not valid

8.3 AT Configuration Command Format

BYTE	BITS								DEFAULT
	7	6	5	4	3	2	1	0	
0-31	QUANTUM CONFIGURATION KEY								
32	RESERVED = 0						PE	CE	03h
33	RESERVED = 0								00h
34	RESERVED = 0								00h
35	RESERVED = 0								00h
36	AWRE	ARRE	N/A	RC	ECC	N/A	N/A	DCR	C0h
37	NUMBER OF RETRIES								08h (1)
38	ECC CORRECTION SPAN								18h (2)
39	RESERVED = 0					WCE	RUEE	0	06h
40-511	RESERVED = 0								00h

KEY:

PE	Prefetch Enable
CE	Cache Enable
AWRE	Automatic Write Reallocation Enable
ARRE	Automatic Read Reallocation Enable
RC	Read Continuous
ECC	Enable Early Correction
DCR	Disable Correction
WCE	Write Cache Enable
RUEE	Reallocation Uncorrectable Error Enable

COMMENTS:
1. This number reflects number of times through group retry sequence.
2. Triple burst correction and double burst on the fly enabled.

8.4 Configuration Pages

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 0	0	0	Customer no.		1	1	0
Pg 1	0	1	Jumper settings		2	2	4006h
Pg 2	0	15	Vendor name		16	16	"QUANTUM"
Pg 3	0	15	Product ID	Model dependent	16	16	"FIREBALL_TM1080 A" for 1-D
							"FIREBALL_TM2100 A" for 2-D
							"FIREBALL_TM3200 A" for 3-D
Pg 4	0	7	Drive revision level	Current version ("XRR.DDCS")	8	8	none
Pg 5	0	11	Drive serial number	Drive's S/N in ASCII	12	12	none
Pg 6	0	31	Customer name		32	32	"GENERIC"+blanks
Pg 7	0	0	AT configuration	Misc1	1	10	60h
				Bit 7: Idle pwr down enable			
				Bit 6,5 : Auto read, transfer enable			
				Bit 4: Command history enable			
				Bit 3: Cache debug			
				Bit 2: Wiggle retry disable			
				Bit 1: DASP spike			
				Bit 0: T.A. mode 2 retry enable			
	1	1		Misc2	1		81h
				Bit 7,6 : DMA mode			("Demand mode" on)
				Bit 5,4 : IOR delay			(0 nS IOR delay)
				Bit 3 : Microjog disable			
				Bit 1 : Seek with offset enable			
				Bit 0: T.A. mode 1 recovery enable			
	2	3		Logical cylinders/drive	2		2112 for 1-D
							4092 for 2-D
							6232 for 3-D
	4	4		Logical heads/cylinder	1		16
	5	5		Logical sector/track	1		63
	6	6		Min power time	1		0
	7	7		Transfer read delay	1		32h
	8	8		Transfer write delay	1		32h
	9	9	Page Revision Number		1		

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 8	0	0	Number of heads	Model dependent	1	1	2/4/6
Pg 9	0	15	Configuration validation field	0,1,FF,2,FE,3,FD,4,FC,5, FB,6,FA,7,F9,8	16	16	<- as shown
Pg 10	0	1	Starting Cylinder		2	507	0
	2	5	Starting Logical Sector Address		4		0
	6	6	Sectors/track		1		87h
	7	9	Sectors/zone		3		0
	10	10	Z0_10	M value for Clock Synthesizer	1		
	11	11	Z0_11	N value for Clock Synthesizer	1		
	12	12	Z0_12	Clock Synthesizer Loop Res/multiplier	1		
	13	13	Z0_17	Servo Continuos Filter Cutoff Freq	1		
	14	14	Z0_19	Tune	1		
	15	15	Z0_1A	TWAI/TWAO	1		
	16	16	Z0_1B	8 LSBs flash digitizer output latch counter	1		
	17	17	Z0_1D	AGC internal Capacitor	1		
	18	18	Z0_1E	Servo Control	1		
	19	19	Z0_21	TST1/TST2 output port select	1		
	20	20	Z0_23	Frequency	1		
	21	21	Z0_26	Quality Monitor Control	1		
	22	22	Z0_27	ENDEC Control	1		
	23	23	Z0_28	ENDEC Control	1		
	24	24	Z0_29	RD/WR Gate Logic/Extended WR gate	1		
	25	25	Z0_2A	Mode Select	1		
	26	26	Z0_2D	Read Path test	1		
	27	27	Z0_2E	Digital Test	1		
	28	28	Z0_2F	Test Mode Select	1		
	29	29	Z0_35	Shiva reg 35h	1		
	30	30	Z0_36	Shiva reg 36h	1		
			Zone				
	31	61	1	Same as 0-28	31		
	62	92	2	Same as 0-28	31		
	93	123	3	Same as 0-28	31		
	124	154	4	Same as 0-28	31		
	155	185	5	Same as 0-28	31		
	186	216	6	Same as 0-28	31		
	217	247	7	Same as 0-28	31		

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 10	248	278	8	Same as 0-28	31		
	279	309	9	Same as 0-28	31		
	310	340	10	Same as 0-28	31		
	341	371	11	Same as 0-28	31		
	372	402	12	Same as 0-28	31		
	403	433	13	Same as 0-28	31		
	434	464	14	Same as 0-28	31		
	465	495	15	Same as 0-28	31		
	496	497	Maximum Cylinder		2		6,810
	498	501	Total Log. Sectors (not MAXLBA)		4		2,128,896 for 1-D
							4,124,736 for 2-D
							6,281,856 for 3-D
	502	502	Head (track) wedge skew		1		21
	503	503	Cylinder wedge skew		1		28
	504	504	Number of Zones		1		16
	505	505	Wedges Per Track		1		90
		506	Page Revision Number		1		
Pg 11	0	3	Total no. of accessible sectors	LSB first	4	4	0FFh, 0FFh, 0FFh, 0FFh
Pg 12	0	0	Trigger mask		1	1	0
Pg 13	0	1	Family & model ID numbers	Family=18H, Model=depends on # of heads	2	2	18h, 12h for 1-D
				Model no. 1XH for 1080 format			18h, 14h for 2-D
				Model no. 2XH for 1280 format			18h, 16h for 3-D
Pg 14	0	5	Head mapping	Hardware head map, user head map	6	6	03h,0,0, 03h,0,0 for 1-D
							0Fh,0,0, 0Fh,0,0 for 2-D
							3Fh,0,0, 3Fh,0,0 for 3-D
Pg 15	0	0	Overlay number: 0	Vector Table	1	178	0
	1	3	RAM load start address		3		80h,0,0
	4	4	Size in sectors		1		3
	5	6	Cylinder		2		0FCh,0FFh

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 15	7	8	Alternate cylinder		2		0FBh,0FFh
	9	10	Sector		2		2
	11	21	Overlay 1	FW Resident Overlay	11		
	22	32	Overlay 2	FW Overlay 0	11		
	33	43	Overlay 3	FW Overlay 1	11		
	44	54	Overlay 4	FW Overlay 2	11		
	55	65	Overlay 5	FW Overlay 3	11		
	66	76	Overlay 6	FW Overlay 4	11		
	77	87	Overlay 7	FW Overlay 5	11		
	88	98	Overlay 8	FW Overlay 6	11		
	99	109	Overlay 9	FW Overlay 7	11		
	110	120	Overlay 10	SS Resident Overlay	11		
	121	131	Overlay 11	SS Overlay 0	11		
	132	142	Overlay 12	SS Overlay 1	11		
	143	153	Overlay 13	SS Overlay 2	11		
	154	164	Overlay 14	Reserved	11		
	165	175	Overlay 15	Reserved	11		
	176	176	End of overlays marker		1		
		176	Page Revision Number	RAM load start address	1		
Pg 16	0	0	HDA control flags	Bit 7: Enable fast seek seq	1	2	5Ch
				Bit 6: Read-on-Arrival enable			
				Bit 5: Record taking enable			
				Bit 4: Active braking			
				Bit 3: Kill low-power			
				Bit 2: No multi-wedge sets			
				Bit 1: Recal on fatal error			
				Bit 0: Disable spin down on recal failure			
	1	1	Page Revision Number		1		
Pg 17	0	0	Z0_HD0_00	DC Tap	1	2887	(Adaptive)
	1	1	Z0_HD0_01	TAP 1	1		
	2	2	Z0_HD0_02	TAP 2	1		
	3	3	Z0_HD0_03	TAP 4	1		
	4	4	Z0_HD0_04	TAP 5	1		
	5	5	Z0_HD0_05	TAP6	1		
	6	6	Z0_HD0_06	TAP 7	1		
	7	7	Z0_HD0_07	TAP 8	1		
	8	8	Z0_HD0_08	TAP 9	1		

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 17	9	9	Z0_HD0_09	TAP 10	1		
	10	10	Z0_HD0_0A	NLF	1		
	11	11	Z0_HD0_0B	DFE TAP 1	1		
	12	12	Z0_HD0_0C	DFE TAP 2	1		
	13	13	Z0_HD0_0D	DFE TAP 3	1		
	14	14	Z0_HD0_0F	VGA	1		
	15	15	Z0_HD0_13	Read Continuous Filter Cutoff Freq	1		
	16	16	Z0_HD0_14	Read Continuous Filter Zero Frequency	1		
	17	17	Z0_HD0_15	ACC/ATT	1		
	18	18	Z0_HD0_18	Servo Zero frequency	1		
	19	19	Z0_HD0_1F	Servo Amplitude	1		
	20	20	Z0_HD0_20	Write Precomp	1		
	21	21	Z0_HD0_22	GUG/TDFEOFF/TWUG	1		
	22	22	Z0_HD0_24	FUG/PHUG	1		
	23	23	Z0_HD0_30	Version 3 Only-Leading DFE control	1		
	24	24	Z0_HD0_31	Version 3 Only-Leading DFE Tap 1	1		
	25	25	Z0_HD0_37	**Blue**-IDAC (1_in_doz, enidac, idac 0-4) *NOTE:* IDAC setting is used to set MR bias current on the latest PCBs.	1		
	26	26	Z0_HD0_38	**Blue**-(ta_bline, ta_coast, ta_dio 0-1, ta_insrv, tst1_pu, ta_len 0-1)	1		
	27	27	Z0_HD0_39	**Blue**-(ta_famt 7-0)	1		Possibly obsolete
	28	28	Z0_HD0_3A	**Blue**-(ta_fam,nlpos,nlinsrv,nladapt,nlc 0-1)	1		Possibly obsolete
	29	29	Z0_HD0_WCR	Write Current Reduce; upper 2 bits only (Current reduction mux, not shiva reg)	1		Possibly obsolete
			Head				
	30	59	HD1	Same as 0-30	30		
	60	89	HD2	Same as 0-30	30		
	90	119	HD3	Same as 0-30	30		
	120	149	HD4	Same as 0-30	30		
	150	179	HD5	Same as 0-30	30		
			Zone				
	180	359	1	Same as 0-185	180		
	360	539	2	Same as 0-185	180		
	540	719	3	Same as 0-185	180		

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 17	720	899	4	Same as 0-185	180		
	900	1079	5	Same as 0-185	180		
	1080	1259	6	Same as 0-185	180		
	1260	1439	7	Same as 0-185	180		
	1440	1619	8	Same as 0-185	180		
	1620	1799	9	Same as 0-185	180		
	1800	1979	10	Same as 0-185	180		
	1980	2159	11	Same as 0-185	180		
	2160	2339	12	Same as 0-185	180		
	2340	2519	13	Same as 0-185	180		
	2520	2699	14	Same as 0-185	180		
	2700	2879	15	Same as 0-185	180		
			Head				
	2880	2880	0	Bias current	1		0
	2881	2881	1	Bias current	1		0
	2882	2882	2	Bias current	1		0
	2883	2883	3	Bias current	1		0
	2884	2884	4	Bias current	1		0
	2885	2885	5	Bias current	1		0
		2886	Page Revision Number		1		
Pg 18	0	415	Servo variables (non-adaptive)		416	428	
Pg 19	0	0	EL_PERIOD	Time between logging to disk	1	23	0
	1	1	EL_PERIOD	Turns on DPA	1		80h
	2	5	SEEK_DR	Seek sample size	4		3E80h
	6	6	MAX_SK_ERROR_DR	Seek error saturation point	1		0Dh
	7	10	READ_DR	Read sample size	4		17D78h
	11	11	MAX_RD_ERROR_DR	Read error saturation point	1		0Dh
	12	13	SPINUP_DR	Spinup sample size	2		14h
	14	15	MAX_SPINUP_TIME_DR	Spinup error saturation point	2		30D4h
	16	16	RECAL_DR	Recal sample size	1		0Ah
	17	17	EL_SPARE		1		0
	18	19	MAX_OFFLINE_BLK_DR	Offline read sample size	2		9C4h
	20	20	MICRO_OFFLINE_BLK	Max block size for offline read	1		0FFh
	21	21	MAX_OFFLINE_ERR_DR	Offline saturation point	1		0FAh
		17	Page Revision Number		1		0

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 20				Dummy page (not used by AT or SCSI)	1	1	0
Pg 21	0	5	A equal B high	1 byte per head for servo zone 0	6	1346	(Adaptive)
	6	161	" "	repeat for servo zones 1-26	156		
	162	167	A equal B low	1 byte per 27 servo zones	6		
	168	323	" "	repeat for servo zones 1-26	156		
	324	335	AB slope	1 word per 27 servo zones (LSB first)	12		
	336	647	" "	repeat for servo zones 1-26	312		
	648	659	AC slope	1 word per 27 servo zones	12		
	660	971	" "	repeat for servo zones 1-26	312		
	972	983	Kloop calibration	1 word per 27 servo zones	12		
	984	1295	" "	repeat for servo zones 1-26	312		
	1296	1296	Page Revision Number		1		
	1297	1297		slack space	239		
Pg 22	0	0	**SCSI only** parameters	QCP flags	1	3	0
	1	1		ACK glitch filter	1		0
	2	2		Active pull-up, parity check control	1		2Dh
	0	0	Dummy page 23 for AT	(dummy data)	1	1	*** not used; dummy page for AT
Pg 23	0	1	Valid page length	Number of valid bytes in this page	2	206	206
	2	3	MicroJog offset for band 0	Head 0 (2's compl. LSB first)	2		0 (Adaptive)
	4	5	MicroJog offset for band 1	"	2		0
	6	7	MicroJog offset for band 2	"	2		0
	8	9	MicroJog offset for band 3	"	2		0
	10	11	MicroJog offset for band 4	"	2		0
	12	13	MicroJog offset for band 5	"	2		0
	14	15	MicroJog offset for band 6	"	2		0

Page	From byte	To byte	Function	Description	Bytes	Leng	Default value LCP
Pg 23	16	17	MicroJog offset for band 7	"	2		0
	18	19	MicroJog offset for band 8	"	2		0
	20	21	MicroJog offset for band 9	"	2		0
	22	23	MicroJog offset for band 10	"	2		0
	24	25	MicroJog offset for band 11	"	2		0
	26	27	MicroJog offset for band 12	"	2		0
	28	29	MicroJog offset for band 13	"	2		0
	30	31	MicroJog offset for band 14	"	2		0
	32	33	MicroJog offset for band 15	"	2		0
	34	35	MicroJog offset for band 16	"	2		0
	36	69	MicroJog offset for all bands	17 bands for head 1	34		0
	70	103	MicroJog offset for all bands	17 bands for head 2	34		0
	104	137	MicroJog offset for all bands	17 bands for head 3	34		0
	138	171	MicroJog offset for all bands	17 bands for head 4	34		0
	172	205	MicroJog offset for all bands	17 bands for head 5	34		0
Pg 24	0	137	**AT only**	Parameters for AT Identify Drive command	138	138	
	0	0	Dummy page 24 for SCSI	(dummy data)	1	1	*** not used; dummy page for SCSI
Pg 25	0	0	IGNWUS	Ignore Write Unsafe	1	3	10
	1	1	BRKENTD	Delayed Break Count	1		0
	2	2	SECMRKD	Delayed Sector Mark	1		0
					Total:	6030	
			- END -				

8.5 ECC Status Format

Data returned by the Read ECC Status command

Bytes	Content	Description
0-3	ECC Status	Correction Status Words (see below)
4-5	ECC Sector	Sector Number / Physical
6- 8	ECC Correct	Forward displacement / Error Correction Byte 0
9 -11		Forward displacement / Error Correction Byte 1
12-14		Forward displacement / Error Correction Byte 2
15-17		Forward displacement / Error Correction Byte 3
18-22		Forward displacement / Error Correction Byte 4
21-23		Forward displacement / Error Correction Byte 5
24-26		Forward displacement / Error Correction Byte 6
27-29		Forward displacement / Error Correction Byte 7
30-32		Forward displacement / Error Correction Byte 8
33-35		Forward displacement / Error Correction Byte 9
36-38		Forward displacement / Error Correction Byte 10
39-41		Forward displacement / Error Correction Byte 11
42-45	ECC Symbol Blk	Symbol Block Index

Correction Status Word 1 (bits 16 - 31)

31	UC	Uncorrectable Error UC = U3 or U2 or U1 or U0
30	PD	Pending Correctable/uncorrectable
29	Ab	ECC Calculation Aborted (ECC on the fly only)
28	Dib	DIB error detected, always returns with uncorrectable error
16-27	Reserved	Unused

Correction Status Word 0 (bits 0 - 15)

15	U3	uncorrectable error/interleave 3
12-14	Errors 3	bit significant number of errors in interleave 3
11	U2	uncorrectable error/interleave 2
8-10	Errors 2	bit significant number of errors in interleave 2
7	U1	uncorrectable error/interleave 1
4-6	Errors 1	bit significant number of errors in interleave 1
3	U0	uncorrectable error/interleave 0
0-2	Errors 0	bit significant number of errors in interleave 0

8.6 Cache Tables Format

Bytes	Content	Description
0-3	LOWER_CACHE_LBA	Lowest LBA in this segment
4-7	UPPER_CACHE_LBA	Highest LBA in this segment
8-9	START_SEG_ADRS	Bottom of ring buffer
10-11	END_SEG_ADRS	Top of ring buffer
12-13	NS_IN_SEGMENT	Number of sectors in use in this cache segment
14-15	CACHE_FLAGS	Cache entry status/flags bit
16-17	START_BUF_ADRS	Beginning address of the cache segment

8.7 Firmware Error Code

Error Code	Sense Key	Sense Code	Qualifier	Description
0	0	00	00	No Error detected at Drive level
1	3	20	00	Medium error, all overlay copies were bad
2	3	82	00	Error during reading of diskware
3	4	40	00	RAM error (most likely found in a diagnostic)
4	4	42	00	Internal ROM checksum error
5	4	42	01	Marker for resident code checksum
6	4	42	03	Marker for ROM and resident code are incompatible
7	4	42	04	Marker for ROM and overlay are incompatible
8	4	42	05	Marker for overlay checksum
9	4	42	06	Marker for diskware vector table checksum
A	4	42	08	ROM and vector table versions are incompatible
B	4	84	00	SCSI WCS RAM failure
C	0	00	00	Unused
D	1	C	00	Requested format in Read Defect Data not available
E	5	20	00	Invalid command
F	5	21	00	Invalid lba
10	5	24	00	Invalid bits set in CDB
11	5	26	00	Invalid fields in parameters
12	5	8A	00	Invalid head specified
13	5	8B	00	Invalid cylinder specified
14	5	8F	00	Invalid sector specified
15	5	AE	00	Some param(s) in the mode pages found to be bad during init
16	5	19	00	Invalid defect list format
17	0	00	00	Unused
18	0	00	00	Unused
19	0	00	00	Unused
1A	2	04	01	Bad defect list
1B	3	32	00	Defect list is full
1C	3	32	00	No more alternate sectors available
1D	3	80	00	Error in writing to system sector
1E	3	81	00	Error in reading from a system sector
1F	6	87	00	Logical assertion (firmware consistency check) error
20	6	29	00	Reset occurred
21	B	47	00	SCSI bus parity error
22	6	87	01	Invalid or duplicate defect CHS specified
23	0	00	00	Unused
24	0	00	00	Unused
25	0	00	00	Unused
26	1	17	09	Correctable data field via on the fly algorithm
27	1	18	00	Data error recovered via ECC w/ 2 consecutive = syndromes
28	1	18	01	Data error recovered via ECC on last retry
29	3	03	00	Write fault
2A	1	03	00	Recovered - Write fault
2B	3	03	01	Write gate still asserted when wedge detected
2C	1	03	01	Recovered - Write gate still asserted when wedge detected
2D	3	11	00	Uncorrectable data field ECC error

Error Code	Sense Key	Sense Code	Qualifier	Description
2E	1	17	01	Recovered via retries - Uncorrectable data field ECC error
2F	0	00	00	Unused
30	0	00	00	Unused
31	0	00	00	Unused
32	0	00	00	Unused
33	0	00	00	Unused
34	0	00	00	Unused
35	3	13	04	Data field sync timeout
36	1	13	04	Recovered - Data field sync timeout
37	3	14	01	No record found
38	1	14	01	Recovered - No record found
39	4	03	02	WUS Write fault (bump)
3A	1	03	02	Recovered - WUS Write fault (bump)
3B	4	86	00	Unexpected formatter error
3C	1	86	01	Recovered - Unexpected formatter error
3D	0	00	00	Unused
3E	0	00	00	Unused
3F	0	00	00	Unused
40	0	00	00	Unused
41	4	97	03	Underrun error
42	1	97	04	Recovered Underrun error
43	0	00	00	Unused
44	0	00	00	Unused
45	0	00	00	Unused
46	0	00	00	Unused
47	2	04	00	Drive is up to speed and recalibrating
48	2	04	02	Drive has not been told to spin up
49	3	31	01	Track format is invalid during PES measurement
4A	4	09	04	Bad Servo Sync
4B	1	09	04	Recovered - Bad Servo Sync
4C	4	09	05	Bad Servo Address Mark
4D	1	09	05	Recovered - Bad Servo Address Mark
4E	4	09	06	Bad Track Number Data (Gray Code Error)
4F	1	09	06	Recovered - Bad Track Number Data (Gray Code Error)
50	4	09	07	Servo Defect (Bad Servo Sample)
51	1	09	07	Recovered - Servo Defect (Bad Servo Sample)
52	4	09	08	Bump Detected
53	1	09	08	Recovered - Bump Detected
54	0	00	00	Unused
55	0	00	00	Unused
56	4	15	03	Fatal Servo Error: Multiple bad Sync/SAM during SETTLE/ON_TRK
57	1	15	03	Recovered - Fatal Servo Error: Multiple bad Sync/SAM during SETTLE/ON_TRK
58	4	15	06	Failure to enter servo oversampling mode
59	4	15	07	Fatal Servo Error: Missing Servo Interrupts Without Mask
5A	4	15	08	Fatal Servo Error: Missing Servo Interrupts With Mask
5B	4	8A	00	Head read from ID not equal to selected head
5C	4	9E	01	Speed is out of range
5D	1	9E	01	Recovered - Speed is out of range

Error Code	Sense Key	Sense Code	Qualifier	Description
5E	4	15	09	Too many SAM
5F	1	15	09	Recovered - Too many SAM
60	4	15	05	Estimator Error too large
61	1	15	05	Recovered - Estimator Error too large
62	4	15	00	Seek error
63	1	15	00	Recovered - Seek error
64	4	15	01	Seek error
65	1	15	01	Recovered - Seek error
66	4	15	04	Seek timeout with no servo fault
67	1	15	04	Recovered - Seek timeout with no servo fault
68	0	00	00	Unused
69	0	00	00	Unused
6A	0	00	00	Unused
6B	0	00	00	Unused
6C	4	06	01	Recal fault: Coarse Slope PES Gain calibration
6D	1	06	01	Recovered - Recal fault: Coarse Slope PES Gain calibration
6E	4	06	02	Recal fault: Fine Slope PES Gain calibration at AEQBH
6F	1	06	02	Recovered - Recal fault: Fine Slope PES Gain calibration at AEQBH
70	4	06	03	Recal fault: Fine Slope PES Gain calibration at AEQBL
71	1	06	03	Recovered - Recal fault: Fine Slope PES Gain calibration at AEQBL
72	4	06	04	Recal fault: Cannot lock to track
73	1	06	04	Recovered - Recal fault: Cannot lock to track
74	4	06	05	Recal fault: Cannot detect SAM during un_parking
75	1	06	05	Recovered - Recal fault: Cannot detect SAM during un_parking
76	4	06	07	Recal fault: Cannot seek to OD area to get near system cylin
77	1	06	07	Recovered - Recal fault: Cannot seek to OD area to get near system cylin
78	4	06	08	Recal fault: Cannot seek to Fine Slope PES Gain calib
79	1	06	08	Recovered - Recal fault: Cannot seek to Fine Slope PES Gain calib
7A	4	06	09	Recal fault: Seek failure during Nulli calibration
7B	1	06	09	Recovered - Recal fault: Seek failure during Nulli calibration
7C	4	06	0A	Recal fault: Seek failure during V_SCALE adaptation
7D	1	06	0A	Recovered - Recal fault: Seek failure during V_SCALE adaptation
7E	4	06	0B	Recal fault: Seek failure during KLOOP calibration
7F	1	06	0B	Recovered - Recal fault: Seek failure during LOOPK calibration
80	4	06	0C	Recal fault: Seek failure during Repeatable Run-Out calibra
81	1	06	0C	Recovered - Recal fault: Seek failure during Repeatable Run-Out calibra
82	4	06	0D	Recal fault: Seek failure to track 0 during rezero
83	1	06	0D	Recovered - Recal fault: Seek failure to track 0 during rezero

Error Code	Sense Key	Sense Code	Qualifier	Description
84	4	06	0E	Recal fault: Unable to complete KLOOP calibration
85	1	06	0E	Recovered - Recal fault: Unable to complete KLOOP calibration
86	4	06	0F	Recal fault: Unable to complete Repeatable Run-Out calibration
87	1	06	0F	Recovered - Recal fault: Unable to complete Repeatable Run-Out calibration
88	4	06	10	Recal fault: Cannot detect reliable SAM on one or more heads
89	1	06	10	Recovered - Recal fault: Cannot detect reliable SAM on one or more heads
8A	4	9E	00	Motor unable to get up to speed
8B	1	9E	00	Recovered - Motor unable to get up to speed
8C	0	00	00	Unused
8D	0	00	00	Unused
8E	0	00	00	Unused
8F	0	00	00	Unused
90	1	5B	00	Log counter at maximum
91	1	5D	80	The spinup time threshold is exceeded
92	1	5D	81	The media defects threshold is exceeded
93	1	5D	82	The Start/Stop threshold is exceeded
94	1	5D	84	The Compaq attribute threshold is exceeded
95	6	5B	00	Threshold condition met
96	0	00	00	Invalid revision in the Failure Prediction structure
97	0	00	00	Invalid function in the Features register
98	0	00	00	Failure prediction operations are disabled
99	0	00	00	Can't read any of the FP sectors from the media
9A	0	00	00	Can't write any of the FP sectors to the media
9B	0	00	00	Invalid attempt to execute FP command without necessary key
9C	0	00	00	The checksum in a Warranty Threshold Data structure sent to
9D	0	00	00	Unused
9E	0	00	00	Unused
9F	0	00	00	Unused
A0	3	31	00	Medium Format Corrupted
A1	4	1B	00	Synchronous transfer error
A2	4	43	00	Message reject error
A3	4	49	00	Undocumented SIC error
A4	4	4A	00	Undocumented SIC error
A5	4	4B	00	Undocumented SIC error
A6	4	85	00	Reject of message that should never have been sent
A7	4	90	00	Synchronous acknowledge error
A8	4	91	00	Synchronous acknowledge error
A9	4	94	00	Undocumented SIC error
AA	5	1A	00	Parameter overrun
AB	5	25	00	Invalid lun specified
AC	5	8C	00	Attempt by intruding initiator to select drive a second time
AD	5	9B	00	Invalid period or offset in synchronous message
AE	B	4E	00	Overlapped commands attempted by initiator
AF	6	2A	00	Mode select parameters were changed

Error Code	Sense Key	Sense Code	Qualifier	Description
B0	6	2A	01	Log parameters changed
B1.	6	2F	00	Command queue was cleared
B2	6	9A	00	A target attempted to re-select
B3	B	00	00	Response for an Abort message
B4	B	29	00	Undocumented SIC error
B5	B	45	00	Initiator did not reselect
B6	B	48	00	Initiator detected error
B7	5	3D	00	Invalid ID message
B8	5	20	FF	Invalid Super Command
B9	0	00	00	Unused
BA	0	00	00	Unused
BB	0	00	00	Unused
BC	0	00	00	Unused
BD	0	00	00	Unused
BE	0	00	00	Unused
BF	0	00	00	Unused
C0	4	02	00	Formatter servo fault
C1	1	02	00	Recovered formatter servo fault
C2	3	10	00	Formatter wedge counter & number read from TNA sync error
C3	1	10	00	Recovered formatter wedge counter & number read from TNA sync error
C4	3	10	01	Formatter wedge counter & index sync error
C5	1	10	01	Recovered formatter wedge counter & index sync error
C6	4	88	00	Parity error when reading sector or defect descriptor from buffer
C7	1	88	00	Recovered parity error when reading sector or defect descriptor from buffer
C8	3	13	00	Formatter detected data address mark timeout error
C9	1	13	00	Recovered formatter detected data address mark timeout error
CA	3	13	01	Address mark not found for second half of split sector error
CB	1	13	01	Recovered address mark not found for second half of split sector error
CC	3	11	00	Second ECC error found before syndrome latches were read
CD	1	18	00	Recovered second ECC error found before syndrome latches were read
CE	3	01	00	Formatter index timeout
CF	1	01	00	Recovered formatter index timeout
D0	4	96	00	Read fault bit set in formatter status register
D1	1	96	00	Recovered read fault bit set in formatter status register
D2	4	95	00	Formatter timeout error
D3	1	95	00	Recovered formatter timeout error
D4	2	04	D4	Bad formatter descriptor table error
D5	3	75	00	Bad system defect list error
D6	1	17	09	Corrected data field ECC via on the fly caused by Thermal Asperity
D7	3	76	00	System defect list full error
D8	3	13	02	Data AM timeout caused by Thermal Asperity

Error Code	Sense Key	Sense Code	Qualifier	Description
D9	1	13	02	Recovered data AM timeout caused by Thermal Asperity
DA	3	13	03	AM timeout on split sector's 2nd half by Thermal Asperity
DB	1	13	03	Recovered AM timeout on split sector's 2nd half by Thermal Asperity
DC	3	11	01	Data field ECC caused by Thermal Asperity
DD	1	11	01	Recovered data field ECC caused by Thermal Asperity
DE	3	11	01	Second ECC error found where the first was caused by Thermal Asperity
DF	1	11	01	Recovered second ECC error where the first was caused by Thermal Asperity
E0	3	14	00	General Formatter error
E1	4	06	00	General Servo/Seek/Recal error

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