Firmware Manual

May 1995

Rev. A

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GERALD LEGOTETA - APG

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Chapter 1 General Information

1.1 Revision History

REVISION	CONTACT	DATE	DESCRIPTION
A	Roy Kozen	5/05/95	Initial Release

1.2 Scope

The purpose of this manual is to document the Fireball 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 Fireball 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

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

1.4 Applicable Documents

SCSI-II Specification
CAM ATA Specification
LEO Specification.
Fireball Selfscan User's Guide (QNTM P/N)
Fireball SCSI Product Manual (QNTM P/N)
Fireball 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

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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 not accessible with standard SCSI commands.

2.1.1 Replacement Strategy

Fireball reserve one spare sector per cylinder for 540 Mb and 1080 Mb drives. It utilizes two methods for sector replacement - inline and offline sparing.

2.1.1.1 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 2.1) 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 multiple 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.

2.1.1.2 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 2.1 contains an example of an offline spare.

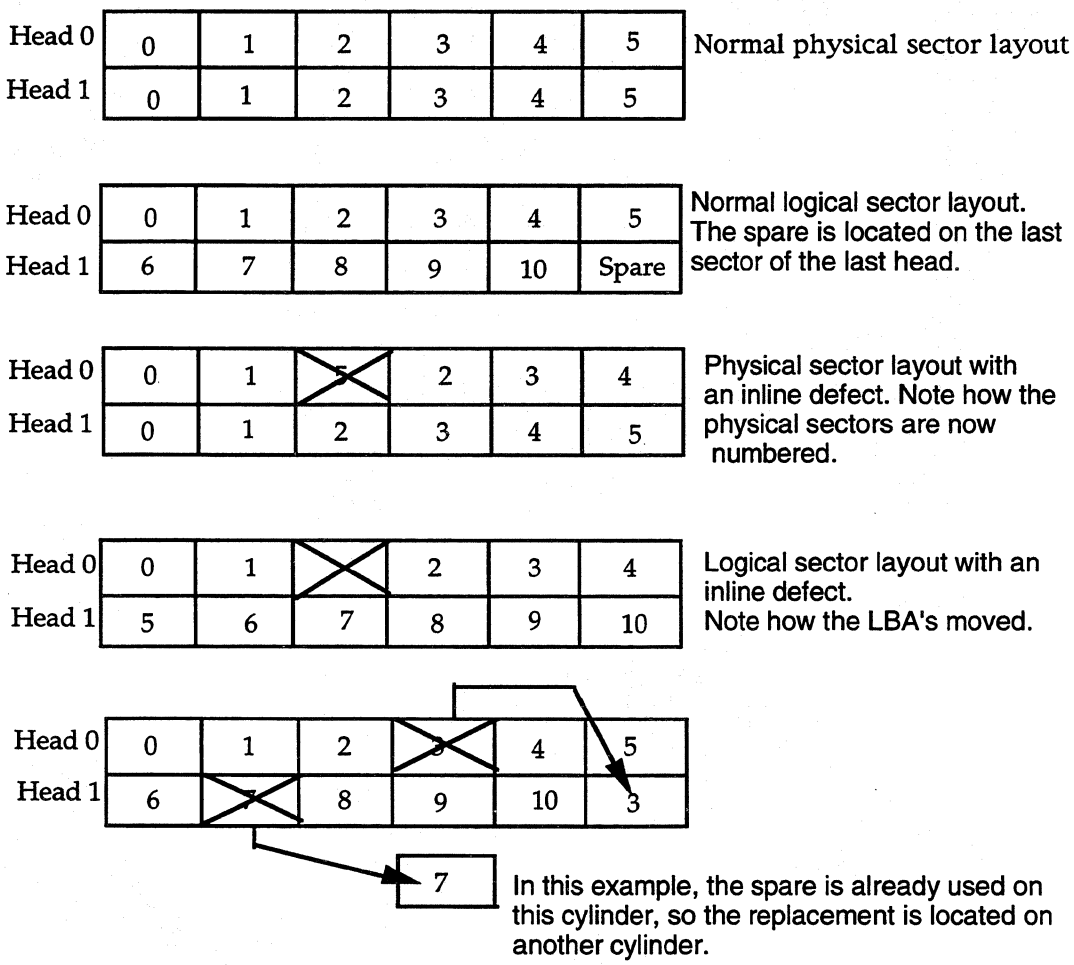

Figure 2-1 Inline and Offline Examples

2.1.1.3 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.

2.1.2 Defect List Data Structure

The defect lists maintained and accessed by the defect management system consist of 7 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.

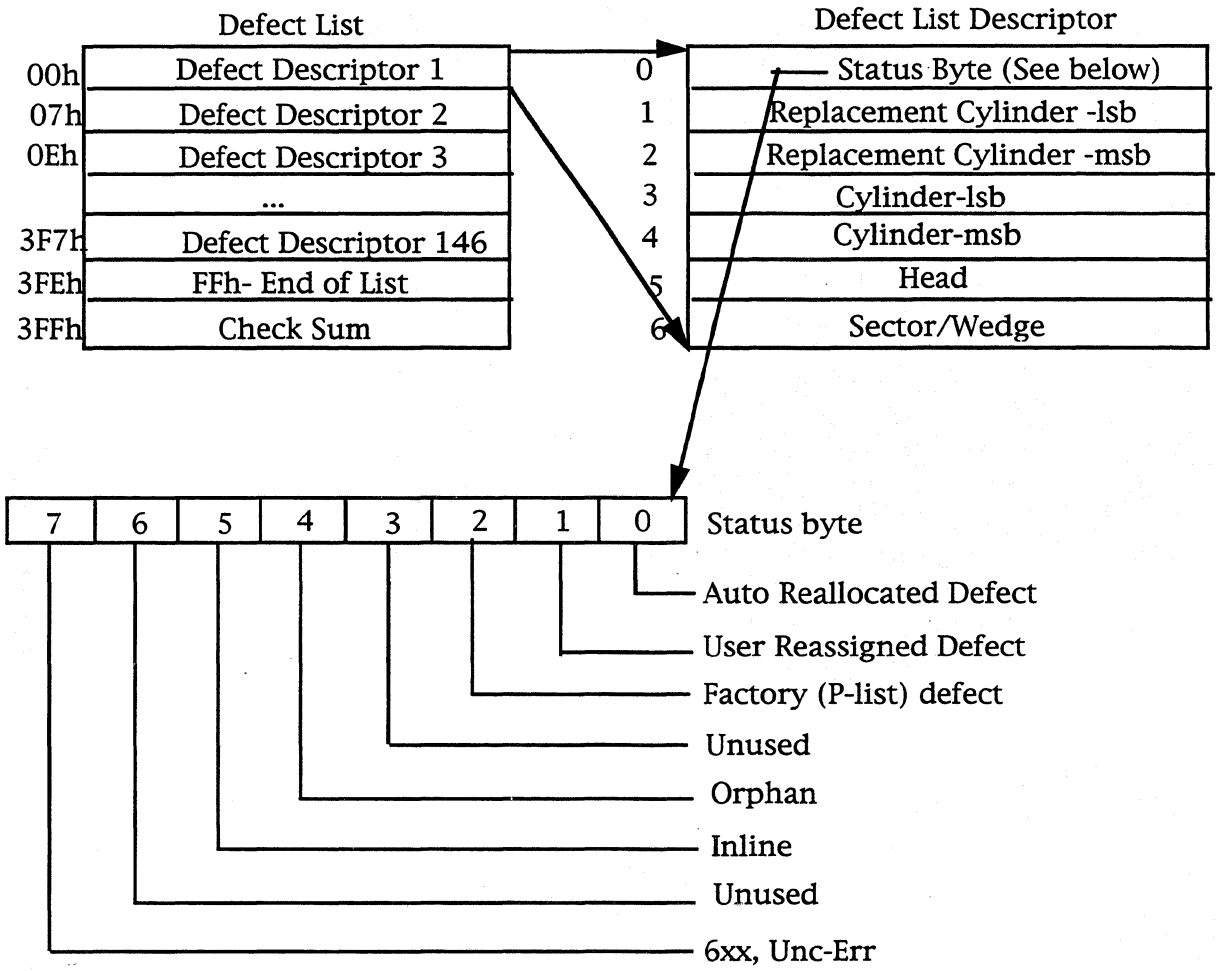

Figure 3-2 Defect List Data Structure

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 "L".

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 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 3584 bytes of storage, therefore, a total of 7 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 3584 bytes in size, a maximum of 511 defects may be recorded in a Fireball drive.

2.3 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.

2.4 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.

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 -2 and -3 are as follows :

Sector	Description
0	Saved mode page
1 - 8	Configuration pages
9 - 15	Working defect list
16 - 22	Primary defect list
23 - 29	Unused
30 - 45	Format header bytes zone 0-15
46	Apple system sector for rd/wr of OS information
47	Passport sector
48	Servo defect list
49 - 53	Log sense and log select
54 - 59	DPA variable sectors
60 - 101	DPA log dump sectors
102 - 121	Spared
122 - 151	Reserved for in-line defect sparing

Sector Usages of cylinder -4 and -5 are as follows:

Sector	Description
0 - 1	Boot loader
2 - 61	Diskware 30K segment
62 - 121	Overlay
122- 151	Reserved for in-line defect sparing

Sector Usages of cylinder -6 are as follows:

Sector	Description
0 - 121	Test. Out
122- 151	Reserved for in-line defect sparing

- **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.

Chapter 4 Diskware

4.1 Introduction

The Fireball 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 Memory Map

The DRAM memory map for Fireball is organized as follows:

K7 ADDRESS		DRAM ADDRESS
27FFFh - 20000h	CACHE 32 K*	27FFFh - 20000h
1FFFFh - 13200h	CACHE 51.5 K	1FFFFh - 13200h
131FFh - 13000h	TEMP BUFFER 2 0.5 K	131FFh - 13000h
12FFFh - 12C00h	TEMP BUFFER 1 1 K	12FFFh - 12C00h
12BFFh - 11E00h	W LIST 3.5 K	12BFFh - 11E00h
11DFFh - 11C00h	CACHE TABLE 0.5 K	11DFFh - 11C00h
11BFFh - 11800h	COMMAND HISTORY 1 K	11BFFh - 11800h
117FFh - 10800h	VARIABLES AND CONFG PAGE 4 K	117FFh - 10800h
107FFh - 10600h	SERVO DEFECT LIST 0.5 K	107FFh - 10600h
105FFh - 10400h	RUNOUT TABLE 0.5 K	105FFh - 10400h
103FFh - 10200h	SERVO ADAPTIVE VARIABLES 0.5 K (confg pg 21)	103FFh - 10200h
101FFh - 10000h	SERVO NON ADAPTIVE VARIABLES 0.5 K (confg pg 18)	101FFh - 10000h
0FFFFh - 0F800h	OVERLAY DISKWARE 2 K	0FFFFh - 0F800h
0F7FFh - 08000h	RESIDENT DISKWARE 30 K	0F7FFh - 08000h
07FFFh - 00000h	ROM CODE 32 K	

* 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.

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

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 Fireball 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 Error Correcting Code

5.1 ASIC ECC Comparsion

Fireball LEO	vs	Thunderbolt KONI
• 8 bits per symbol		Same
• 3 interleaves		Same
• 6 redundancy bytes per interleave		4 redundancy bytes per interleave.
• 2 cross-check bytes		Same
• 18 ECC bytes and 2 CRC bytes		12 ECC bytes and 2 CRC bytes
• Single-Error Correction:		Same
• Double-Error Correctionon the fly		Not on the fly
• Triple-Error Correction		Not available
• 3 Bytes CRC per ID field		Same

5.2 Reed Solomon Generator Polynomial in LEO ASIC

5.2.1 ECC Polynomial

The ECC polynomial is defined as follows:

$$G(X) = X^6 + \alpha^{169} X^5 + \alpha^{179} X^4 + \alpha^{25} X^3 + \alpha^{184} X^2 + \alpha^{179} X + \alpha^{15}$$

$$= (X + 1)(X + \alpha^1)(X + \alpha^2)(X + \alpha^3)(X + \alpha^4)(X + \alpha^5)$$

5.2.2 Cross Check Polynomial

The Cross - Check Polynomial is defined as follows:

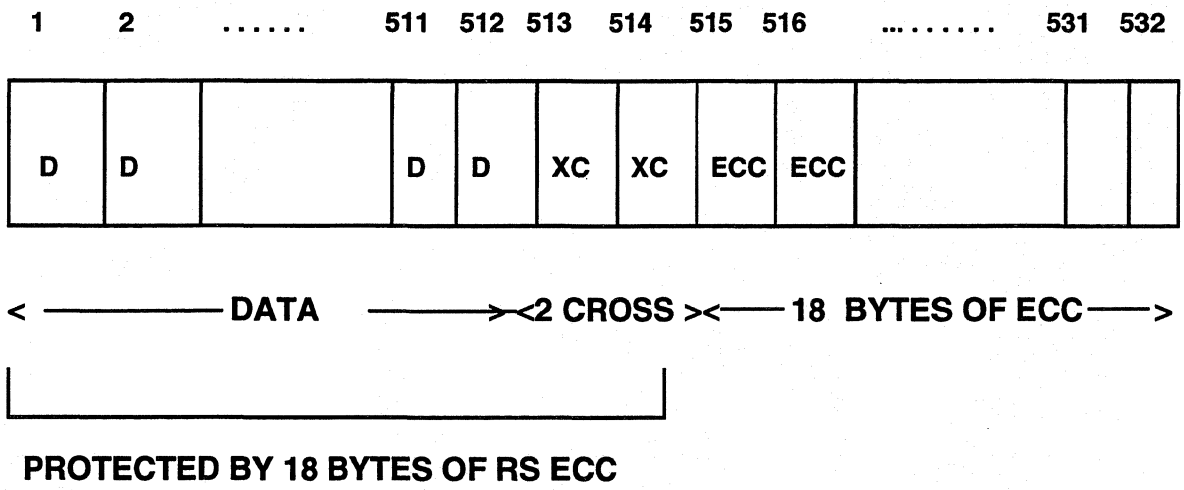
$$XC(X) = X^2 + \alpha^{143} X + 1$$
$$= (X + \alpha^{127})(X + \alpha^{128})$$

5.2.3 CRC Polynomial

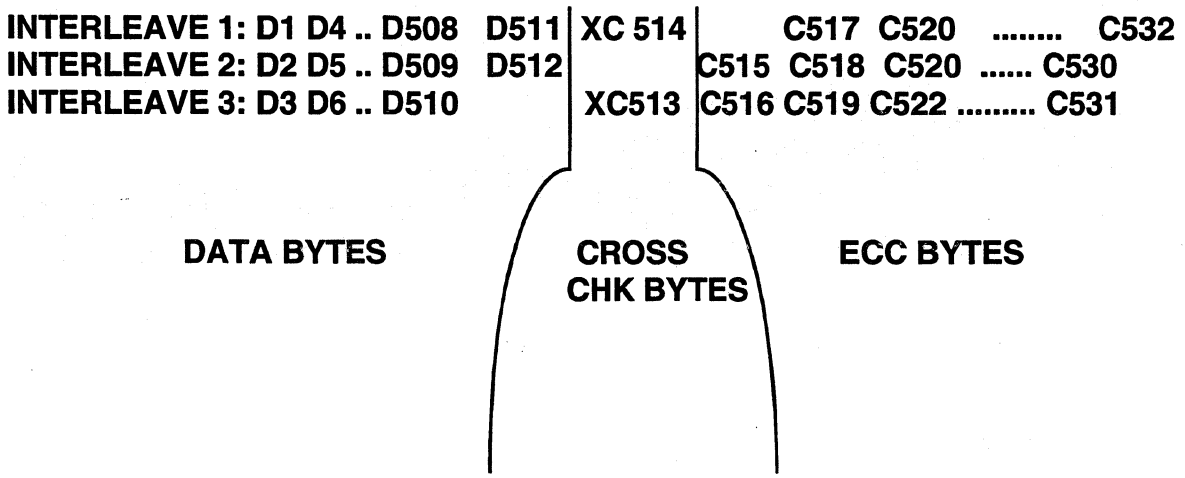
$$CRC(X) = X^3 + \alpha^{203} X^2 + \alpha^{203} X + 1$$
$$= (X + \alpha^{-1})(X + \alpha^0)(X + \alpha^1)$$

5.3 LEO ASIC

5.3.1 1 Sector Data Field with ECC Bytes



5.3.2 Bytes Interleaving



5.4 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.

5.5 Cross Check Bytes

- There are 2 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.

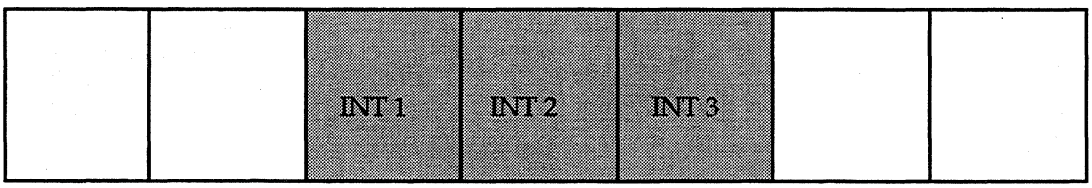
5.6 ECC Correction On - the - Fly

- 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.

5.7 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 24 bits I.E., 1 byte per interleave. Guarantee to correct 17 bits.

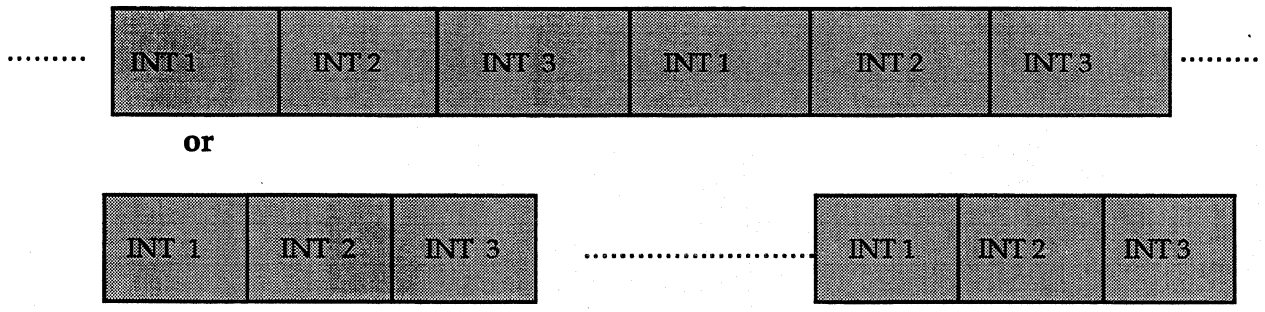
5.7.1 Correctable of 24 Bit Single Burst Error



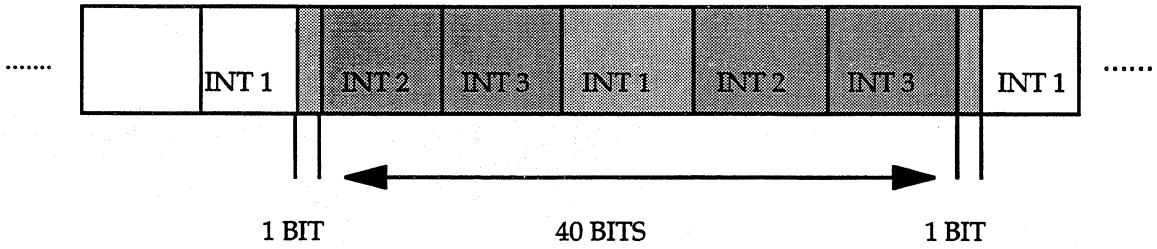
5.8 Double Burst Error

- 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 48 bits I.E., 2 bytes per interleave. Guarantee to correct 41 bits.

5.8.1 Correctable 48 Bit of Double Burst Error



5.8.2 Uncorrectable (On - the -Fly) 42 Bit of Double Burst Error

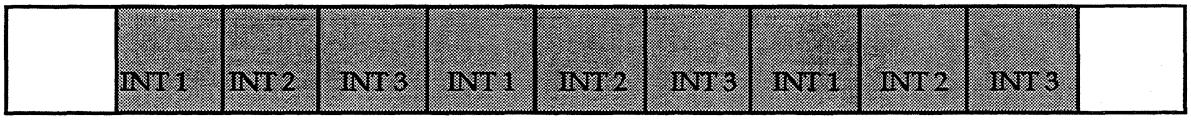


Note :
The 42 bit error is uncorrectable, while the other two 48 bit errors are correctable. The reason for the 42 bit error is uncorrectable is that occupies two interleave 2S, and two interleave 3S, but occupies three interleave 1S, where as the limit is two bytes per interleave. This 42 bit error can be corrected if the drive rereads the sector and applies triple burst error correction techniques.

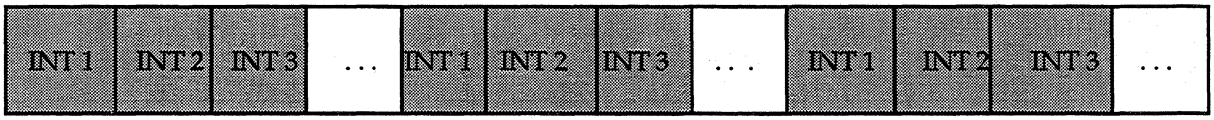
5.9 Triple Burst Error

- 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 72 bits I.E., 3 bytes per interleave. Guarantee to correct 65 bits.

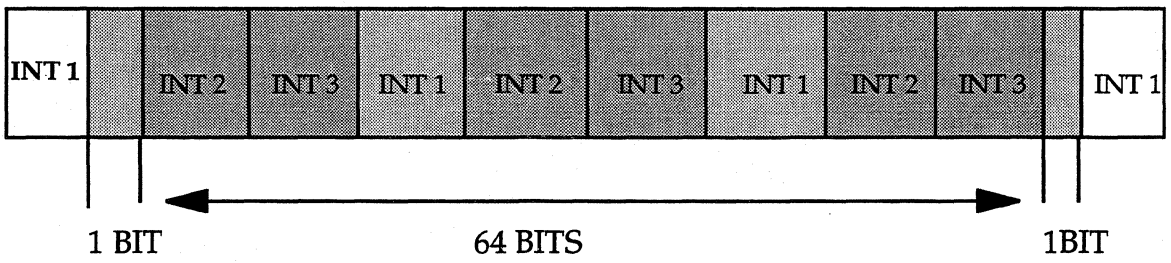
5.9.1 Correctable 72 Bit of Triple Burst Error



or



5.9.2 Uncorrectable 72 Bit of Triple Burst Error



5.10 Multiple Random Burst Errors

- Can correct up to 72 bits of multiple random errors, provided that the bytes in error follow the guidelines for correctable triple burst errors. Up to 48 bits of multiple random errors can be corrected On- the -Fly if two or fewer bytes per interleave.

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Chapter 6 Miscellaneous Information

6.1 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	---
1	Seek time out
2	Seek fault
3	---
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.

6.2 Drive Parameter Analysis

Drive Parameter Analysis (DPA) feature has been implemented on Fireball 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 Fireball 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 Fireball 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

6.2.1 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

6.2.2 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.

6.2.3 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	

6.2.4 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

6.2.5 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

6.2.6 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

6.3 Mode Pages

The following is information on the mode pages. Some of the pages contain information that can be configured by the customer, and this information is denoted by a value in the Mask column of the lists. If a bit is set to 1 in the mask, then that bit can be configured by the customer.

Page 1h Error recovery parameters.

Byte	Mask	Default	Description
0		81h	Page code.
1		0Ah	Page length.
2	FFh	C0h	AWRE, ARRE.
3	FFh	08h	Retry count.
4	FFh	18h	Maximum ecc error burst on which to perform corrections.
5		0Ah	Head offset count.
6		00h	Data strobe offset count.
7		00h	Reserved.
8	FFh	08h	Write retry count.
9		00h	Reserved.
10 - 11		00h	Recovery time limit in units of 10 ms.

Page 2h Disconnect/reconnect control parameters.

Byte	Mask	Default	Description
0		82h	Page code.
1		0Ah	Page length.
2	FFh	C0h	On reads, how full buffer should be before reconnecting.
3	FFh	40h	On writes, how empty buffer should be before reconnecting.
4		00h	Bus inactivity limit - msb.
5		00h	Bus inactivity limit - lsb.
6		00h	Disconnect time limit - msb.
7		00h	Disconnect time limit - lsb.
8		00h	Connect time limit - msb.
9		00h	Connect time limit - lsb.
10		00h	Maximum burst size - msb.
11		00h	Maximum burst size - lsb.

Page 3h Direct access device format parameters.

Byte	Mask	Default	Description
0		03h	Page code.
1		16h	Page length.
2		00h	Tracks per zone as defined in CCS - msb.
3	00h	02h	Tracks per zone as defined in CCS - lsb.
4		00h	Alternate sectors per zone - msb.
5		01h	Alternate sectors per zone - lsb.
6		00h	Alternate tracks per zone - msb.
7		00h	Alternate tracks per zone - lsb.
8		00h	Alternate tracks per volume - msb.
9		00h	Alternate tracks per volume - lsb.
10	00h	00h	Sectors per track - msb.
11		8Bh	Sectors per track - lsb.
12	00h	02h	Bytes per sector - msb.
13		00h	Bytes per sector - lsb.
14		00h	Interleave - msb.
15		01h	Interleave - lsb.
16		00h	Track skew factor - msb.
17	00h	28h	Track skew factor - lsb.
18		00h	Cylinder skew factor - msb.
19	00h	2Bh	Cylinder skew factor - lsb.
20		80h	Drive type definition bits. (40H = hard sector format).
21		00h	Reserved.
22		00h	Reserved.
23		00h	Reserved.

Page 4h Rigid disk drive geometry parameters.

Byte	Mask	Default	Description
0		04h	Page code - 04h.
1		16h	Page length.
2	00h	00h	Number of cylinders - msb.
3		0Eh	Number of cylinders - middle.
4		FBh	Number of cylinders - lsb.
5	00h	02h	Number of heads.
6		00h	Starting cylinder for write precompensation.
7		00h	Starting cylinder for write precompensation.
8		00h	Starting cylinder for write precompensation.
9		00h	Starting cylinder for reduced write current.
10		0Eh	Starting cylinder for reduced write current.
11		FBh	Starting cylinder for reduced write current.
12		00h	Drive step rate.
13		00h	Drive step rate.
14		00h	Landing zone cylinder.
15		00h	Landing zone cylinder.
16		00h	Landing zone cylinder.
17		00h	Reserved.
18		00h	Reserved.
19		00h	Reserved.
20		15h	Medium rotation rate - msb.
21		18h	Medium rotation rate - lsb.
22 - 23		00h	Reserved.

Page 8h Cache page.

Byte	Mask	Default	Description
0		88h	Page code.
1		0Ah	Page length.
2	07H	04h	Write cache enable (bit 4 = 1); Read Cache Disable (bit 0) = 0.
3		00h	None of the features in the Priority byte is supported.
4		FFh	Disable Prefetch Transfer Length - msb.
5		FFh	Disable Prefetch Transfer Length - lsb.
6		00h	Minimum number of blocks to prefetch - msb.
7		00h	Minimum number of blocks to prefetch - lsb.
8		FFh	Maximum number of blocks to prefetch - msb.
9		FFh	Maximum number of blocks to prefetch - lsb.
10		00h	Maximum Prefetch Ceiling - msb.
11		00h	Maximum Prefetch Ceiling - lsb.

Page 9h Peripheral Device Page.

Byte	Mask	Default	Description
0		09h	Page code.
1		0Eh	Page length.
2 -11		00h	Vendor unique.
12 - 13		00h	Compaq reserved.
14	FFh	01h	Failure Analysis and Prediction version.
15	4Eh	04h	Failure Analysis and Prediction disable (bit 2). Failure Analysis and Prediction group OP code (bits 5>).

Page Ah Control Mode.

Byte	Mask	Default	Description
0		0Ah	Page code.
1		06h	Page length.
2	01h	00h	Report log exception condition (bit 0).
3		00h	Queue algorithm modifier (bit 4 -7). Queue error management (bit 1). Disable queue (bit 0).
4		00h	Error AEN permission (bit 0). Unit attention AEN permission (bit 1). Ready AEN permission (bit 1). Enable extended contingent allegiance (bit 7).
5 - 7		00h	Ready AEN hold off period.

Page Dh Power Condition Page.

Byte	Mask	Default	Description
0		8Dh	Page code.
1		0Ah	Page length.
2		00h	Reserved.
3	03h	00h	Power condition flag.
4	FFh	00h	Idle condition timer.
5	FFh	00h	"
6	FFh	00h	"
7	FFh	00h	"
8	FFh	00h	Standby condition timer.
9	FFh	00h	"
10	FFh	00h	"
11	FFh	00h	"

Page Ch Notch page.

Byte	Mask	Default	Description
0		0Ch	Page code.
1		16h	Page length.
2		80h	Device is notched, with physical boundaries.
3		00h	Reserved.
4		00h	Maximum number of notches - middle.
5		0Fh	Maximum number of notches - lsb.
6	FFh	00h	Active notch high not used.
7	FFh	00h	Active notch low by default is 0 (entire device).
8		00h	Starting cylinder - msb.
9	00h	00h	Starting cylinder - middle.
10		00h	Starting cylinder - lsb.
11		00h	Starting head 0.
12		00h	Ending at cylinder max minus 1.
13	00h	0Eh	Ending cylinder middle.
14		FAh	Ending cylinder lsb.
15	00h	01h	Ending head.
16		00h	Indicate pages 3, 4 and C are notched.
17		00h	Indicate pages 3, 4 and C are notched.
18		00h	Indicate pages 3, 4 and C are notched.
19		00h	Indicate pages 3, 4 and C are notched.
20		00h	Indicate pages 3, 4 and C are notched.
21		00h	Indicate pages 3, 4 and C are notched.
22		10h	Indicate pages 3, 4 and C are notched.
23		18h	Indicate pages 3, 4 and C are notched.

Page 32h Auto power down page. (Apple only)

Byte	Mask	Default	Description
0		B2h	Page code.
1		02h	Page length.
2	FFh	00h	Standby mode disabled with 0.
3	FFh	00h	Shutdown mode disabled with 0.

Page 39h Quantum Page.

Byte	Mask	Default	Description
0		89h	Page code.
1		06h	Page length.
2	FFh	10h	Quantum flags.
3	FFh	00h	Soft ID.
4	FDh	00h	Soft jumper.
5	FFh	00h	Motor delay value.
6		00h	Reserved.
7		00h	Reserved.

6.4 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.

6.5 Configuration Pages

Page	Function	Size	Byte #	Description	Default
Pg 0	Customer no.	1 bytes	byte 0	0 - generic 1 - Apple 2 - Compaq 3 - DEC	0
Pg 1	Jumper setting	2 bytes			AT = 00 00 SCSI = 00 26
Pg 2	Vendor ID	16 bytes		16 bytes ASCII characters	"QUANTUM "
Pg 3	Product ID	16 bytes		16 bytes ASCII characters	"FIREBALL540A " "FIREBALL540S " "FIREBALL1080A " "FIREBALL1080S "
Pg 4	Drive Revision	8 bytes		where I = interface (A/S) rr = rom rev dd = diskware rev c = fmt/conf rev s = selfscan rev	Irr.ddci
Pg 5	Drive Serial No.	12 bytes		12 bytes of drive serial # in ASCII	
Pg 6	Customer Name	32 bytes		32 bytes customer name in ASCII	"GENERIC" padded with " "
Pg 7	AT Config Flags	10 bytes	byte 0	0 - Not used 1 - Not used 2 - Disable wiggle 3 - Cache debug enb 4 - Save cmd history 5 - Enable auto arm 6 - Auto read enabled 7 - Spin down control (AT only)	AT = E0h SCSI = 60h auto features enabled
			byte 1	0 - Use 528mb chs for default chs field of identify information. 1 - Seek with offset 2 - Not used 3 - Not used 4-5 IO read delay 6-7 DMA mode	80h DMA mode demand
			bytes 2-3	AT logical cyls	1056/2112
			byte 4	AT logical heads	16
			byte 5	AT logical secs	63
			byte 6	IBM power mode	1 (min. of 1 minute)
			byte 7	Transfer read delay	50 (5us)
			byte 8	Transfer write delay	50 (5us)
			byte 9	page revision number (currently not used)	
Pg 8		1 byte		number of head	
Pg 9		16 bytes	bytes 0-15	0,1,ff,2,fe,3,fd,4,fc,5,fb,6,fa,7,f9,8	

Page	Function	Size	Byte #	Description	Default
Pg 10	Non Adaptive Zone Table	491 bytes	byte 0	starting cylinder	
			byte 2	starting logical sector address	
			byte 6	sectors per track	
			byte 7	sectors per zone	
			byte 9	track skew	
			byte 10	cylinder skew	
			byte 11	Z0_10	
			byte 12	Z0_11	
			byte 13	Z0_12	
			byte 14	Z0_17	
			byte 15	Z0_19	
			byte 16	Z0_1A	
			byte 17	Z0_1B	
			byte 18	Z0_1D	
			byte 19	Z0_1E	
			byte 20	Z0_21	
			byte 21	Z0_23	
			byte 22	Z0_26	
			byte 23	Z0_27	
			byte 24	Z0_28	
			byte 25	Z0_29	
			byte 26	Z0_2A	
			byte 27	Z0_2D	
			byte 28	Z0_2E	
			byte 29	Z0_2F	
				REPEAT BYTES 0 TO 29 FOR ZONES 1 TO 15	
			byte 480	# of cylinder	3835 (0 - 3834)
			byte 482	# of logical sector address (from 0 to max-1)	* 540 = 1065235 * 1080 = 2134305
			byte 486	track wedge skew	
			byte 487	cylinder wedge skew	
			byte 488	number of zones	
			byte 489	wedges per track	
			byte 490	page revision number (currently not used)	
Pg 11	Number of User Sectors	4 bytes		# of user accessable sector at ROM default	16777215
Pg 12	Trigger Msk	1 byte		0 - true bump 1 - seek timeout 2 - servo fault 3 - tunafish error 4 - ecc error 5 - sequencer r/w error 6 - sequencer underrun/over 7 - sequencer timeout	00
Pg 13	Drive family and Model	2 bytes	byte 0	family	Fireball - 12h

Page	Function	Size	Byte #	Description	Default
			byte 1	model	540 - 0 1080 - 1
Pg 14	HW head map	6 bytes	bytes 0-2	map of available heads	
			bytes 3-5	repeat of bytes 1-3	
Pg 15	Diskware	167 bytes	byte 0	overlay number	
			byte 1	ram load address	
			byte 4	size in sectors	
			byte 5	cylinder	
			byte 7	alternate cylinder	
			byte 9	sector	
				REPEAT BYTE 0 TO 10 FOR 14 MORE OVERLAYS	
			byte 165	end of list pad (FF)	
			byte 166	page revision number (currently not used)	
Pg 16	HDA control Flags	2 bytes	byte 0	0 - no_spin_down 1 - rcal_on_fatal_err 2 - not used 3 - kill_low_pwr 4 - enable_active_brake 5 - not used 6 - rd_on_arrival 7 - not used	40h Read on arrival enabled.
			byte 1	page revision number (currently not used)	
Pg 17	Adaptive Zone Table	1985 bytes	byte 0	Z0_HD0_00	
			byte 1	Z0_HD0_01	
			byte 2	Z0_HD0_02	
			byte 3	Z0_HD0_03	
			byte 4	Z0_HD0_04	
			byte 5	Z0_HD0_05	
			byte 6	Z0_HD0_06	
			byte 7	Z0_HD0_07	
			byte 8	Z0_HD0_08	
			byte 9	Z0_HD0_09	
			byte 10	Z0_HD0_0A	
			byte 11	Z0_HD0_0B	
			byte 12	Z0_HD0_0C	
			byte 13	Z0_HD0_0D	
			byte 14	Z0_HD0_0E	
			byte 15	Z0_HD0_0F	
			byte 16	Z0_HD0_13	
			byte 17	Z0_HD0_14	
			byte 18	Z0_HD0_15	
			byte 19	Z0_HD0_18	
			byte 20	Z0_HD0_1F	
			byte 21	Z0_HD0_20	

Page	Function	Size	Byte #	Description	Default
			byte 22	Z0_HD0_22	
			byte 23	Z0_HD0_24	
			byte 24	Z0_HD0_30	
			byte 25	Z0_HD0_31	
			byte 26	Z0_HD0_32	
			byte 27	Z0_HD0_33	
			byte 28	Z0_HD0_34	
			byte 29	Z0_HD0_35	
			byte 30	Z0_HD0_WCR	
				Repeat Bytes 0 to 30 for heads 1 to 3	
				Repeat Bytes 0 to 123 for zones 1 to 15	
			byte 1984	page revision number (currently not used)	
Pg 18	Non Adaptive Servo	399 bytes	byte 398	page revision number (currently not used)	FLL PORT [USES NEW VALUES FROM CPIB/DMLIB]
Pg 19	DPA (phase 3)	18 bytes	byte 0	Period of logging DPA to disk	0
			byte 1	0 - 6 Period between logging the DPA to disk 7 - DPA is enabled	80h
			bytes 2-5	Seek sample size (Number of seeks)	3E80h
			byte 6	Seek error saturation point per sample size	0Dh
			bytes 7-10	Read sample size (Number of sectors read)	17D78h
			byte 11	Read error saturation point per sample size	0Dh
			bytes 12 - 13	Spinup sample size (Number of spinup)	14h
			bytes 14 -15	Spin up time saturation time per sample size	30D4h
			byte 16	max. # of recal for 1 data range	0Ah
			byte 17	page revision number (currently not used)	1
Pg 20	Not Used	1 byte			
Pg 21	Adaptive Servo	513 bytes	byte 512	page revision number (currently not used)	
Pg 22	E2prom	4 bytes	byte 0	0 QCP configuration 1-7 unused	0
			byte 1	0 ~~req filter~~ ACK DIGITAL Glitch 1-7 unused	0 1
			byte 2	0-1 req slew rate 2-3 data slew rate 4-5 data/req pull up 6-7 unused	10h
			byte 3	page revision number (currently not used)	

6.6 Firmware Error Code

Error Code	Sense Key	Sense Code	Qualifier	Description
0	0	00	00	No Error detected at Drive level
1	2	04	00	Drive is up to speed and recalibrating
2	2	04	02	Drive has not been told to spin up
3	4	42	05	Marker for overlay checksum
4	3	11	00	Uncorrectable data field ECC error
5	1	17	01	Recovered data field ECC error
6	6	9A	00	A target attempted to re-select
7	3	13	00	Data field sync timeout
8	1	13	00	Recovered data field sync timeout
9	3	14	01	No record found
A	1	14	01	Recovered no record found
B	4	15	00	Seek error
C	1	15	00	Recovered seek error
D	1	18	00	Recovered data error via ECC w/2 = syndromes
E	1	18	01	Recovered data error via ECC on last retry
F	5	1A	00	Parameter overrun
10	5	20	00	Invalid command
11	5	21	00	Invalid LBA
12	5	24	00	Invalid bits set in CDB
13	5	26	00	Invalid field in parameters
14	6	29	00	Reset occurred
15	6	2A	00	Mode select parameters were changed
16	4	40	00	RAM error (most likely found in a diagnostic)
17	4	87	00	Logical assertion/firmware consistency check err
18	4	42	00	Internal ROM checksum error
19	B	47	00	SCSI Bus parity error
1A	4	42	01	Marker for resident code checksum
1B	3	80	00	Error in writing to system sector
1C	3	81	00	Error in reading from system sector
1D	4	9E	00	Motor unable to get up to speed
1E	1	9E	00	Recovered motor unable to get up to speed
1F	4	84	00	Failure in writing to sequencer format table
20	4	86	00	Unexpected sequencer error
21	1	86	00	Recovered unexpected sequencer error
22	4	8A	00	Head read from ID not equal to selected head
23	5	8A	00	Invalid head specified
24	5	8B	00	Invalid cylinder specified
25	5	8D	00	Bytes per block/bytes per sector gives a remaindr
26	3	03	00	Write fault
27	1	03	00	Recovered Write Fault
28	3	32	01	No more alternate sectors available
29	5	8F	00	Invalid sector specified
2A	4	95	00	Sequencer timeout
2B	1	95	00	Recovered sequencer timeout
2C	E	1D	00	Read buffer miscompare
2D	4	A1	00	Sequencer rollover register failure
2E	3	A3	00	Failure reading sector in Reassign Blocks command
2F	5	AE	00	Bad parameter(s) found in mode pages during init
30	3	31	01	FDPE write failed during format unit command
31	3	10	00	ID ECC error

Error Code	Sense Key	Sense Code	Qualifier	Description
32	1	10	00	Recovered ID ECC error
33	3	12	00	AM mark not found for ID field
34	1	12	00	Recovered AM mark not found for ID field
35	3	AA	00	Read Data written on realloc of uncorrectbl data
36	1	AA	00	Recovrd Rd data Wr on realloc of uncorrctbl data
37	3	19	00	Bad defect list
38	3	32	00	Defect list is full
39	1	AB	00	Requested format in Read Defect Data not avail
3A	4	97	00	Underrun error
3B	1	97	00	Recovered underrun error
3C	4	06	01	RCL FLT- Coarse Slope PES Gain calibration
3D	1	06	01	Recovered RCL FLT- Coarse Slope PES calibration
3E	4	06	02	RCL FLT- Fine Slope PES Gain calibration at AEQBH
3F	1	06	02	Recovered RCL FLT- Fine Slope PES calib at AEQBH
40	4	06	03	RCL FLT- Fine Slope PES Gain calib at AEQBL
41	1	06	03	Recovered RCL FLT- Fine Slope PES calib at AEQBL
42	4	06	04	RCL FLT- Cannot Lock to track
43	1	06	04	Recovered RCL FLT- Cannot Lock to track
44	4	06	05	RCL FLT- Cannot detect SAM during unparking
45	1	06	05	Recovered RCL FLT- Can't detect SAM during unpark
46	4	42	06	Marker for diskware vector table checksum
47	4	FF	00	Autowr cmd received while host channel disabled
48	4	15	06	Failure to enter Servo Oversampling mode
49	4	FF	02	Bad descriptor in format track descriptor list
4A	3	14	01	Bad block mark set for ID (AT)
4B	4	AC	00	Airlock stuck open
4C	4	03	00	WUS Write fault (bump)
4D	1	03	00	Recovered WUS Write fault (bump)
4E	3	82	00	Error during reading of diskware
4F	4	09	04	Unrecoverable Bad servo sync
50	1	09	04	Recovered bad servo sync
51	4	09	05	Unrecoverable Bad servo address mark (SAM)
52	1	09	05	Recovered bad servo address mark (SAM)
53	4	09	06	Unrecoverable Bad track number data
54	1	09	06	Recovered bad track number data
55	4	09	07	Unrecoverable Servo Defect
56	1	09	07	Recovered Servo Defect
57	4	09	08	Unrecoverable Bump
58	1	09	08	Recovered Bump
59	4	15	01	Unrecovrd Gray code != desired track while ontrk
5A	1	15	01	Recovered Gray code != desired track while ontrk
5B	4	15	03	Unrecovrd multi bad Sync/SAM while Settle/Ontrk
5C	1	15	03	Recovered multi bad Sync/SAM while Settle/Ontrk
5D	4	9E	01	Unrecoverable Speed out of range
5E	1	9E	01	Recovered speed out of range
5F	4	15	04	Seek timeout with no servo fault
60	1	15	04	Recovered seek timeout with no servo fault
61	3	11	01	Marker for CRC/Continue
62	1	17	08	Recovered marker for CRC/Continue
63	4	42	02	Marker for resident and overlay are incompatible
64	4	42	03	Marker for ROM and resident are incompatible
65	4	42	04	Marker for ROM and overlay are incompatible

Error Code	Sense Key	Sense Code	Qualifier	Description
66	4	06	06	RCL FLT - DAC offset calibration failure
67	1	06	06	Recovered RCL FLT - DAC offset calib failure
68	4	86	01	Unexpected SEQ Err during recovery from SEQ TMO
69	1	86	01	Recovrd unexpect SEQ err during SEQ TMO recovery
6A	4	86	02	Read, write ID miscompare
6B	1	86	02	Recovered read, write ID miscompare
6C	3	12	01	AM not found for ID field with internal continue
6D	1	12	01	Recovrd AM not found for ID w/ internal continue
6E	3	03	01	Write gate still asserted when wedge detected
6F	1	03	01	Recovrd WR Gate still asserted during servo wedge
70	4	15	07	Unrecovrd missing servo interrupts without mask
71	4	15	08	Unrecovrd missing servo interrupts with mask
72	4	06	10	RCL FLT - Cannot detect reliable SAM on one or more heads
73	1	06	10	Recovrd RCL FLT-Can't detect SAM on one or more heads
74	4	06	07	RCL FLT - Can't seek to OD to get near Sys Cyl
75	1	06	07	Recovrd RCL FLT - Can't seek to OD near Sys Cyl
76	4	06	08	RCL FLT - Can't seek to Fine Slope PES calib trk
77	1	06	08	Recovrd RCL FLT-Can't seek to Fine SLP calib trk
78	4	06	09	RCL FLT - Seek failure during Nulli calibration
79	1	06	09	Recovrd RCL FLT - Seek fail during Nulli calib
7A	4	06	0A	RCL FLT - Seek failure during V_SCALE adaptation
7B	1	06	0A	Recovered RCL FLT-Seek fail during V_SCALE adapt
7C	4	06	0B	RCL FLT - Seek failure during KLOOP calibration
7D	1	06	0B	Recovrd RCL FLT - Seek fail during KLOOP calib
7E	4	06	0C	RCL FLT - Seek failure during RRO calibration
7F	1	06	0C	Recovrd RCL FLT - Seek fail during RRO calib
80	4	06	0D	RCL FLT - Seek failure to track 0 during rezero
81	1	06	0D	Recovrd RCL FLT-Seek fail to trk 0 during rezero
82	4	06	0E	RCL FLT - Unable to complete KLOOP calibration
83	1	06	0E	Recovrd RCL FLT - Unable to complete KLOOP calib
84	4	06	0F	RCL FLT - Unable to complete RRO calibration
85	1	06	0F	Recovrd RCL FLT - Unable to complete RRO calib
86	4	01	00	No disk index found on current track
87	1	17	09	Data corrected via ECC on the fly algorithm
88	4	42	07	Resident and vector table diskware versions are incompatable.
89	4	42	08	ROM and vector table versions are incompatable.
8A	4	15	00	Unrecoverable seek error.
8B	1	15	00	Recoverable seek error.
8C	6	2A	00	Log parameters has been changed.
8D	6	5B	00	Threshold condition met.
8E	1	5B	00	Log counter is at maximum.
8F	5	20	00	Invalid revision in the failure prediction structure.
90	5	20	00	Invalid function in the features register.
91	5	20	00	Failure prediction operations are disabled.
92	5	20	00	Unable to read the failure prediction parameters from the media.
93	5	20	00	Unable to write the failure prediction parameters from the media.

Error Code	Sense Key	Sense Code	Qualifier	Description
94	5	20	00	Invalid password for executing drive failure prediction.
95	5	20	00	Invalid checksum in the warranty threshold data structure.
96	3	20	00	Medium error, all overlay copies was bad or due to uncorrectable.
97	4	09	00	Unrecoverable FLL_FAULT_ERR. Fll never got up to speed.
98	1	09	00	Recoverable FLL_FAULT_ERR. Fll never got up to speed.
99	1	5D	00	DPA variables have reached max.
9A	1	5D	80	The Spinup time threshold is exceeded.
9B	1	5D	81	The Media defects threshold is exceeded.
9C	1	5D	82	The Start/Stop threshold is exceeded.
9D	1	5D	84	The Compaq attribute threshold is exceeded.
9E	4	1B	00	Synchronous transfer error
9F	5	9B	00	Invalid period or offset in synchronous message
A0	5	9C	00	Active initiator selected us while disconnected
A1	5	25	00	Invalid LUN specified
A2	4	43	00	Message reject error
A3	B	45	00	Initiator did not reselect
A4	B	48	00	Initiator detected error
A5	4	85	00	Rejct of message that should never have been sent
A6	B	00	00	Response for an abort message
A7	5	8C	00	Intruding initiator selected drive a second time
A8	4	90	00	Synchronous REQ acknowledge error
A9	4	91	00	Synchronous acknowledge error
AA	4	94	00	Undocumented SIC error - SIC
AB	4	4A	00	Undocumented SIC error - Fifo load
AC	4	49	00	Undocumented SIC error - Fifo unload
AD	4	4B	00	Undocumented SIC error - Fifo pred full
AE	B	29	00	Undocumented SIC error Ram parity
AF	5	66	00	Undocumented SIC error - List length
B0	3	31	00	Undocumented SIC error - medium format corrupted
B1	5	C2	00	Undocumented SIC error - non applicable command
B2	2	C0	00	Undocumented SIC error - error in burn in test