MAX3147RC

MAX3073RC

MAX3036RC

HARD DISK DRIVES

PRODUCT/MAINTENANCE MANUAL

FUJITSU

FOR SAFE OPERATION

Handling of This Manual

This manual contains important information for using this product. Read thoroughly before using the product. Use this product only after thoroughly reading and understanding especially the section "Important Alert Items" in this manual. Keep this manual handy, and keep it carefully.

FUJITSU makes every effort to prevent users and bystanders from being injured or from suffering damage to their property. Use the product according to this manual.

IMPORTANT NOTE TO USERS

READ THE ENTIRE MANUAL CAREFULLY BEFORE USING THIS PRODUCT. INCORRECT USE OF THE PRODUCT MAY RESULT IN INJURY OR DAMAGE TO USERS, BYSTANDERS OR PROPERTY.

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C141-E237

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C141-E237

Related Standards

Product specifications and functions described in this manual comply with the following ANSI (*1) standards.

Document number	Title
T10/1236D Rev.20 [NCITS.351:2001]	SCSI Primary Commands-2 (SPC-2)
T10/996D Rev. 8c [NCITS.306:1998]	SCSI-3 Block Commands (SBC)
T10/1157D Rev. 24	SCSI Architecture Model-2 (SAM-2)
T10/1561D Rev. 14	SCSI Architecture Model-3 (SAM-3)
T10/1562D Rev. 05	Serial Attached SCSI (SAS)
T10/1601D Rev. 07	Serial Attached SCSI Model-1.1 (SAS 1.1)

*1 ANSI = American National Standard Institute

In case of conflict between this manual and any referenced document, this manual takes precedence.

C141-E237

Preface

This manual describes MAX3147RC, MAX3073RC, and MAX3036RC 3.5" type hard disk drives with an embedded Serial Attached SCSI (SAS).

This manual details the specifications and functions of the above disk drive, and gives the requirements and procedures for installing it into a host computer system.

This manual is written for users who have a basic understanding of hard disk drives and their use in computer systems. The MANUAL ORGANIZATION section describes organization and scope of this manual. The need arises, use the other manuals.

The organization of this manual, related reference manual and conventions for alert messages follow.

Overview of Manual

This manual consists of the following seven chapters:

Chapter 1 General Description

This chapter introduces the disk drives standard features, hardware, and system configuration.

Chapter 2 Specifications

This chapter gives detailed specifications of the disk drives and their installation environment.

Chapter 3 Data Format

This chapter describes the data structure of the disk, the address method, and what to do about media defects.

Chapter 4 Installation Requirements

This chapter describes the basic physical and electrical requirements for installing the disk drives.

Chapter 5 Installation

This chapter explains how to install the disk drives. It includes the notice and procedures for setting device number and operation modes, mounting the disk drive, and confirming drive operation.

Chapter 6 Diagnostics and Maintenance

This chapter describes the automatic diagnosis, and maintenance of the disk drive. This chapter also describes diagnostic methods for operation check and the basics of troubleshooting the disk drives.

Chapter 7 Error Analysis

This chapter describes in details how collect the information for error analysis and how analyze collected error information.

CONVENTIONS USED IN THIS MANUAL

MAX3147RC, MAX3073RC, and MAX3036RC disk drives are described as "the hard disk drives (HDD)", "the disk drive" or "the device" in this manual.

Decimal number is represented normally.

Hexadecimal number is represented as X'17B9', 17B9h or 17B9H.

Binary number is represented as "010".

Conventions for Alert Messages

This manual uses the following conventions to show the alert messages. An alert message consists of an alert signal and alert statements. The alert signal consists of an alert symbol and a signal word or just a signal word.

The following are the alert signals and their meanings:

⚠CAUTION

This indicates a hazardous situation *could* result in *minor* or *moderate personal injury* if the user does not perform the procedure correctly. This alert signal also indicates that damages to the product or other property, *may* occur if the user does not perform the product correctly.

IMPORTANT

This indicates information that could help the user use the product more efficiently.

In the text, the alert signal is centered, followed below by the indented message. A wider line space precedes and follows the alert message to show where the alert message begins and ends. The following is an example:

(Example)

⚠CAUTION

Damage
Never open the disk enclosure for any reason. Doing so will void any warranties.

The main alert messages in the text are also listed in the "Important Alert Items."

Attention

Please forward any comments you may have regarding this manual.

To make this manual easier for users to understand, opinions from readers are needed. Please write your opinions or requests on the Comment at the back of this manual and forward it to the address described in the sheet.

Important Alert Items

Important Alert Messages

The important alert messages in this manual are as follows:

⚠**CAUTION** A hazardous situation *could* result in *minor* or *moderate personal injury* if the user does not perform the procedure correctly. Also, damage to the product or other property, *may* occur if the user does not perform the procedure correctly.

Task	Alert message	Page
Installation	*Damage* *Never remove any labels from the drive or deface them in any way.*	4-3
	High temperature *To prevent injury, never touch the drive while it is hot. The DE and LSI become hot during operation and remain hot immediately after turning off the power.*	5-1, 5-10
	Damage 1. *When dismounting the drive which is mounted on the system while power is supplied to it.* • *The spindle motor can be stopped by a START/STOP command. It takes about 30 seconds for the spindle motor to stop completely.* • *Then, dismount the drive using the drive mounting/dismounting mechanism, etc. of the system. If the drive is dismounted while the spindle motor is running, special care is required to avoid excessive vibration or shock to the drive. Just in case, stop dismounting once when SAS connector breaks off contact and wait until the spindle motor stops (about 30 seconds.).* • *When storing or transporting the drive, put it in the antistatic bag (refer to Section 5.1).*	5-10

Task	Alert message	Page
Installation	*2. When dismounting the drive which is mounted on the system while power is not supplied to it.* • *Dismount the drive using the drive mounting/dismounting mechanism, etc. of the system.* • *When storing or transporting the drive, put it in the antistatic bag (refer to Section 5.1).*	5-10
Diagnostics and Maintenance	*Data loss* *Save data stored on the disk drive to other media before requesting repair. Fujitsu does not assume responsibility if data is destroyed during servicing or repair.*	6-5
	Electrical shock *Never touch the HDDs while power-feeding.*	6-5
	Damage *1. Always ground yourself with a wrist strap connected to ground before handling. ESD (Electrostatics Discharge) may cause the damage to the device.* *2. Never use a conductive cleaner to clean the HDDs.* *3. Never remove any labels from the drive or deface them in any way.* *4. Never remove the PCA.* *5. Never open the disk enclosure for any reason.*	6-5
	Damage *1. Never remove any labels from the drive.* *2. Never open the disk enclosure for any reason. Doing so will void any warranties.*	6-13

PRODUCT/ MAINTENANCE MANUAL (This manual)	1. General Description 2. Specifications 3. Data Format 4. Installation Requirements 5. Installation 6. Diagnostics and Maintenance 7. Error Analysis

INTERFACE SPECIFICATIONS	1. Interface 2. Command Processing 3. Data Buffer Management 4. Command Specifications 5. Sense Data and Error Recovery Methods 6. Disk Media Management

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CONTENTS

Illustrations

Figures

Tables

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CHAPTER 1   General Description

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┌─────────────────────────────────────────────────┐
│  ┌────────────────────────────────────────────┐ │
│  │                                            │ │
│  │   1.1    Standard Features                 │ │
│  │                                            │ │
│  │   1.2    Hardware Structure                │ │
│  │                                            │ │
│  │   1.3    System Configuration              │ │
│  │                                            │ │
│  └────────────────────────────────────────────┘ │
└─────────────────────────────────────────────────┘
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This chapter describes the feature and configuration of the hard disk drives (HDDs).

The HDDs are high performance large capacity 3.5" fixed disk drives with an embedded Serial Attached SCSI (SAS) controller.

The interface used to connect the HDDs to the host system complies with ANSI T10/1601-D Serial Attached SCSI-1.1 (SAS-1.1), which covers items ranging from SAS physical layers to SCSI command protocols.

The high-speed data transfer and long-distance transmission capabilities of SAS technology and the powerful command set the HDD facilitate creation of high-performance and highly reliable disk subsystems with large storage capacities.

1.1   Standard Features

(1)   Compactness

The HDDs are a compact enclosure which complies with the 3.5" disk drive form factor.

(2)   Restriction of Use of Hazardous Substances

The amounts of hazardous substances in use in these HDDs have been reduced in accordance with the Restriction of Use of Hazardous Substances (RoHS) Directive recently issued by European Union (EU).

Note:
> At present, the permissible limits on the use of certain materials specified by the RoHS directive have not been determined. In such cases, we are using the original criteria set by Fujitsu Limited while referring to the restrictions already established by End-of-Life (ELV) Directive or by the national environmental laws of the EU member nations.

(3)   SAS Standard

The HDDs are equipped with a serial attached SCSI (SAS) as a host interface.

- Transfer rate: 1.5Gbps, 3.0Gbps
- Number of SAS ports: Two
- Full-duplex (simultaneous bidirectional data transfer) is supported.

SCSI commands can manipulate data through logical block addressing, regardless of the physical characteristics of the disk drive. This enables software to accommodate expansion of system functionality.

(4)   Dual SAS port support

The HDDs have two pairs of driver and receiver set (PHY) for the SAS to support dual SAS port connection.

On MAX3147RC, MAX3073RC, and MAX3036RC, Primary and Secondary Ports on SAS plug connector (2 physical links plus power connections) are used for SAS port connection.

(5)   High-speed data transfer

The maximum data-transfer speed on the SAS is 300.0 MB/s. The large-capacity data buffer of the HDDs enable the effective use of such high-speed data transfers available on the SAS connection.

(6)   Continuous block processing

The addressing method of data blocks is logical block address. The initiator (INIT) can access data by specifying block number in a logically continuous data space without concerning the physical structure of the track or cylinder boundaries.

The continuous processing up to [64K-1] blocks in a command can be achieved, and the HDDs can perform continuous read/write operation when processing data blocks on several tracks or cylinder.

(7)   Multi-segment data buffer

The data buffer is 16M bytes. Data are transferred between SAS port and disk media through this data buffer. This feature provides the suitable usage environment for users.

(8)   Cache feature

After executing the READ command, the HDDs read automatically and store (prefetches) the subsequent data blocks into the data buffer (Read-ahead caching).

The high speed sequential data access can be achieved by transferring the data from the data buffer without reaccessing the disk in case the subsequent command requests the prefetched data blocks.

The Write Cache feature is supported. When this feature is enabled, the status report is issued without waiting for completion of write processing to disk media, thereby enabling high speed write processing.

IMPORTANT

When Write Cache is enabled, you should ensure that the cached data is surely flushed to the disk media before you turn off the drive's power.

To ensure it, you should issue either the SYNCHRONIZE CACHE command or the STOP UNIT command with specifying "0" to the Immediate bit, and then confirm that the command is surely terminated with the GOOD STATUS.

(9)   Command queuing feature

The HDDs can queue maximum 128 commands, and optimizes the issuing order of queued commands by the reordering function. This feature realizes the high speed processing.

(10)   Reserve and release functions

The HDDs can be accessed exclusively in the multi-host or multi-INIT environment by using the reserve and release functions.

(11)   Error recovery

The HDDs can try to recover from errors in the disk drive using its powerful retry processing. If a recoverable data check occurs, error-free data can be transferred to the INIT after being corrected in the data buffer. The INIT software is released from the complicated error recover processing by these error recovery functions of the HDDs.

(12)   Automatic alternate block reassignment
If a defective data block is detected during read or write the HDDs can automatically reassign their alternate data block.

(13)   Programmable data block length

Data can be accessed in fixed-block length units. The data block length is programmable, and can be specified at initializing with a multiple of four within the range of 512 to 528 bytes.

IMPORTANT

Error rate increase

1.   The drive format at factory shipment is generally 512 bytes.

2.   The recoverable Error of the drive might increase when the format would be modified from 512 bytes to the following values:
516 bytes, 520 bytes, 524 bytes, 528 bytes.

3.   The recoverable Error referred here is sense data (1-13-xx).

(14)   Defective block slipping

A logical data block can be reallocated in a physical sequence by slipping the defective data block at formatting. This results in high speed contiguous data block processing without a revolution delay due to defective data block.

(15)   High speed positioning

A rotary voice coil motor achieves fast positioning with high performance access control.

(16)   Large capacity

A large capacity can be obtained from the HDDs by dividing all cylinders into several partitions and changing the recording density on each partition (constant density recording). The disk subsystem with large capacity can be constructed in the good space efficiency.

(17)   Start/Stop of spindle motor

Using the SAS primitive or the SCSI command, the host system can start and stop the spindle motor.

(18)   Diagnosis

The HDDs have a diagnostic capability which checks internal controller functions and drive operations to facilitate testing and repair.

(19)   Low power consumption

By using highly integrated LSI components, the power consumption of the HDDs is very low, and this enables the units to be used in wide range of environmental conditions.

(20)   Low noise and low vibration

The noise level is low; approx. 3.5 Bels at Ready for the drive. This makes it ideal for office use.

(21)   Microcode downloading

The HDDs implement the microcode download feature. This feature easily achieves maintenance and function enhancement of the HDDs.

1.2 Hardware Structure

The HDDs have a disk enclosure (DE) and a printed circuit assembly (PCA). The DE includes heads on an actuator and disks on a spindle motor mounted on the DE. The PCA includes a read/write circuit and a controller circuit.

(1) Disks

The disks have an outer diameter of 70 mm (2.8 inch) and an inner diameter of 25 mm (0.98 inch). The disks are good for at least 50,000 contact starts and stops.

(2) Heads

The MR (Magnet – Resistive) of the CSS (contact start/stop) type heads are in contact with the disks when the disks are not rotating, and automatically float when the rotation is started.

(3) Spindle motor

The disks are rotated by a direct-drive hall-less DC motor. The motor speed is controlled by a feedback circuit using the counter electromotive current to precisely maintain the specified speed.

(4) Actuator

The actuator, which uses a rotary voice coil motor (VCM), consumes little power and generates little heat. The heads at the end of the actuator arm are controlled and positioned via feedback servo loop.

The heads are positioned on the CCS zone over the disks when the power is off or the spindle motor is stopped.

(5) Read/write circuit

The read/write circuit utilizes a read channel mounted with a head IC that supports high-speed transmission and an MEEPR4ML (Modified Enhanced Extended Partial Response Class 4 Maximum Likelihood) modulation/demodulation circuit in order to prevent errors being triggered by external noise and to improve data reliability.

(6) Controller circuit

The controller circuit uses LSIs to increase the reliability and uses a high speed microprocessing unit (MPU) to increase the performance of the SAS controller.

1.3   System Configuration

For the Serial Attached SCSI, the ANSI standard defines Point-to-Point technology. Figure 1.1 and Figure 1.2 give examples of the SAS system configuration.
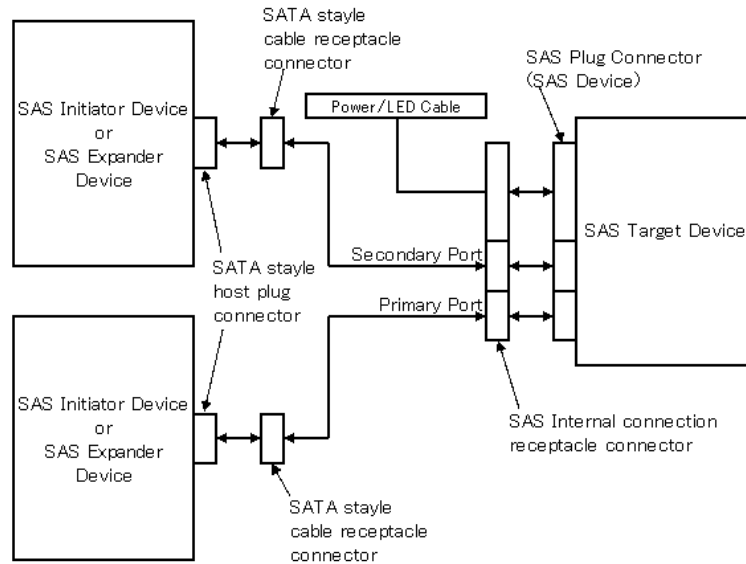
Figure 1.1   Example of SAS system configuration (Dual port internal cabled environment)
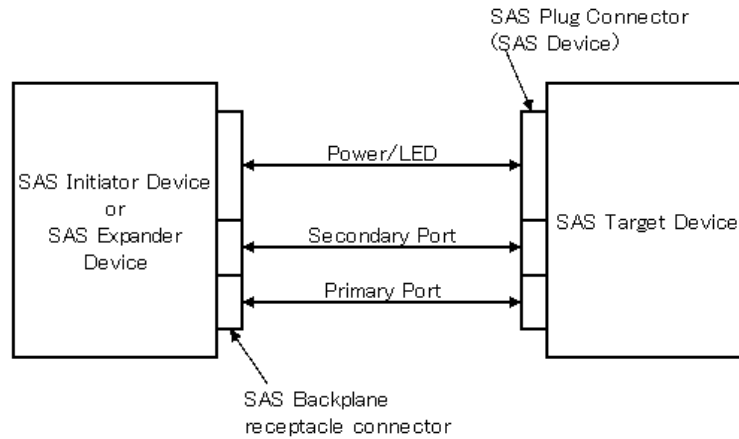
Figure 1.2   Example of SAS system configuration (Dual port internal backplane environment)

(1)   Port addressing

Every device connected with the SAS protocol has a unique address (SAS address). SAS addresses are in the Name Address Authority (NAA) IEEE Registered format defined by SCSI Primary Command-3 (SPC-3).

An SAS address consists of 8 bytes as a unique value set for each device.

The INIT can implement an I/O operation on a disk drive by using the corresponding SAS address stored by the HDDs.

CHAPTER 2   Specifications

2.1   Hardware Specifications

This chapter describes specifications of the HDDs.

2.1   Hardware Specifications

2.1.1   Model name and order number

Each model has different recording capacities when shipped.

Table 2.1 lists the model name and order number.

The data format can be changed by reinitializing with the user's system.

Table 2.1   Model names and order numbers

Model name	Order number	Interface type	Capacity (user area)
MAX3147RC	CA06697-B400	SAS	147 GB (*)
MAX3073RC	CA06697-B200	SAS	73.5 GB (*)
MAX3036RC	CA06697-B100	SAS	36.7 GB (*)

(*) 1 GB = 1,000,000,000 bytes

2.1.2 Function specifications

Table 2.2 shows the function specifications of the HDDs.

Table 2.2   Function specifications

Item		MAX3147RC	MAX3073RC	MAX3036RC
		Specification		
Formatted capacity/device (*1)		147 GB (*2)	73.5 GB (*2)	36.7 GB (*2)
Number of disks		4	2	1
Number of heads		8	4	2
Number of rotations min^{-1} (rpm)		15,000 ± 0.2 %		
Average latency time		2.0 ms		
Seek time (*3) (Read/Write)	Track to Track	0.2 ms / 0.4 ms		
	Average	3.3 ms / 3.8 ms		
	Full stroke	8.0 ms / 9.0 ms		
Start/stop time (*4)	Start time	30 s typ. (60 s max.)		
	Stop time	30 s typ.		
Recording mode		60/63 MEEPR4ML		
External dimensions	Height:	25.4 mm		
	Width:	101.6 mm		
	Depth:	146.0 mm		
Weight		0.8 kg max.		
Power consumption (*5)		11.5 W typ.		
Interface	SAS	Cable length: 8 m max		
Areal density		58 Gbit/inch^2		
Data transfer rate (*6)	Disk drive	147 MB/s		
	SAS	1.5 Gbps, 3 Gbps		
Logical data block length		512 to 528 byte (Fixed length) (*7)		
Command specification		SAS (T10/1562D Rev. 05), SAS1.1 (T10/1601D Rev. 07), SAM-3 (T10/1561D Rev. 14), SAM-2 (T10/1157D Rev. 24), SPC-2 (T10/1236D Rev. 20), SBC (T10/996D Rev. 8c)		
Data buffer		16 MB FIFO ring buffer (*8)		
Acoustic noise (Idle)		3.5 Bels typ.		

(*1)   The formatted capacity can be changed by changing the logical block length and using spare sector space. See Chapter 3 for the further information. The formatted capacity listed in the table is an estimate for 512 bytes per sector.

(*2)   1 GB = 1,000,000,000 bytes

(*3)   The seek time is as follows:

Seek Difference [4096 Cyl/div]
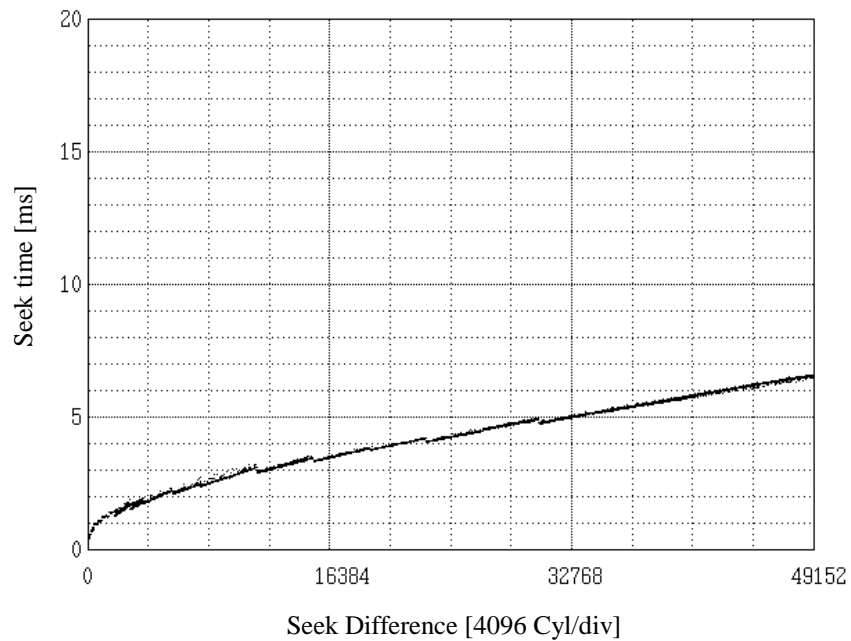
(*4)   The start time is the time from power on or start command to when the HDDs are ready, and the stop time is the time for disks to completely stop from power off or stop command.

(*5)   This value indicates in idle mode. Power supply at nominal voltage ±1%. 25°C ambient.

(*6)   The maximum data transfer rate may be restricted to the response speed of initiator and by transmission characteristics. 1 MB/s = 1,000,000 bytes/s.

(*7)   Refer to 1.1 (12).

(*8)   1 MB = 1,048,576 bytes.

2.1.3 Environmental specifications

Table 2.3 lists environmental and power requirements.

Table 2.3   Environmental/Power requirements

Item			Specification		
			MAX3147RC	MAX3073RC	MAX3036RC
Temperature (*1)	Operating		5 to 55 °C		
	Non-operating		–40 to 70 °C		
	Transport (within a week)		–40 to 70 °C		
	DE surface temperature at operating		5 to 60 °C		
	Gradient		15 °C/h or less		
Relative humidity	Operating		5 to 95 %RH		
	Non operating		5 to 95 %RH		
	Transport (within a week)		5 to 95 %RH		
	Maximum wet bulb temperature		29 °C (no condensation)		
Vibration (*2)	Operating (*3)		0.6 mm (5 to 20Hz) / 9.8 m/s^2 (1G) (20 to 300 Hz) or less		
	Non-operating (*4)		3.1 mm (5 to 20Hz) / 49 m/s^2 (5G) (20 to 300Hz) or less		
	Transport (packaged)		3.1 mm (5 to 20Hz) / 49 m/s^2 (5G) (20 to 300Hz) or less		
Shock (*2)	Operating		637.4 m/s^2 (65G) (2ms)		
	Non-operating		2451.7 m/s^2 (250G) (2ms)		
	Transport (packaged)		2451.7 m/s^2 (250G) (2ms)		
Altitude	Operating		–305 to +3,048 m (–1,000 to +10,000 feet)		
	Non-operating		–305 to +12,192 m (–1,000 to +40,000 feet)		
Power requirements (*5)	+12V DC ±5 %	Ready (Average)	0.75 A		
		Peak within 100 us at spin-up	3.0 A		
		Random W/R (about 80 IOPS)	1.0 A		
	+5V DC ±5 %	Ready (Average)	0.45 A		
		Random W/R (about 80 IOPS)	1.0 A		
	Ripple (+5V, +12V)		250mVp-p or less (*6)		

(*1)   For detail condition, see Section 4.1.

(*2)   Vibration applied to the drive is measured at near the mounting screw hole on the frame as much as possible.

(*3)   At random seek write/read and default on retry setting with log sweep vibration.

(*4)   At power-off state after installation
          Vibration displacement should be less than 2.5 mm.

(*5)   Input voltages are specified at the drive connector side, during drive ready state.

(*6)   High frequency noise (over 20MHz) is less than 100 mVp-p.

2.1.4   Error rate

Errors detected during initialization and replaced by alternate block assignments are not included in the error rate. Data blocks to be accessed should be distributed over the disk medium equally.

(1)   Unrecoverable error rate

Errors which cannot be recovered within 63 retries and ECC correction should not exceed 10 per 10^{16} bits read.

(2)   Positioning error rate

Positioning errors which can be recovered by one retry should be 10 or less per 10^8 seeks.

2.1.5   Reliability

(1)   Mean Time Between Failures (MTBF)

MTBF of the HDDs during their life time is 1,400,000 hours (operating: 24 hours/day, 7 days/week average DE surface temperature: 50°C or less).

Note:

The MTBF is defined as:

$$\mathrm{MTBF} \ = \ \frac{\text{Operating time (hours) at all field sites}}{\text{The number of equipment failures from all field sites}}$$

Failure of the equipment means failure that requires repair, adjustments, or replacement. Mishandling by the operator, failures due to bad environmental conditions, power trouble, host system trouble, cable failures, or other failures not caused by the equipment are not considered.

(2)   Mean Time To Repair (MTTR)

MTTR is the average time taken by a well-trained service mechanic to diagnose and repair a drive malfunction. The drive is designed for a MTTR of 30 minutes or less.

(3)   Service life

The service life under suitable conditions and treatment is as follows.

The service life is depending on the environment temperature. Therefore, the user must design the system cabinet so that the average DE surface temperature is as low as possible.

- DE surface temperature: 40°C or less   5 years
- DE surface temperature: 41°C to 45°C   4.5 years
- DE surface temperature: 46°C to 50°C   4 years
- DE surface temperature: 51°C to 55°C   3.5 years
- DE surface temperature: 56°C to 60°C   3 years
- DE surface temperature: Exceeding 60°C   Without warranty
                                                                      (Keep the DE surface temperature 60 °C or less.)

Even if the HDDs are used intermittently, the longest service life is 5 years.

Note:

The "average DE surface temperature" means the average temperature at the DE surface throughout the year when the HDDs are operating.
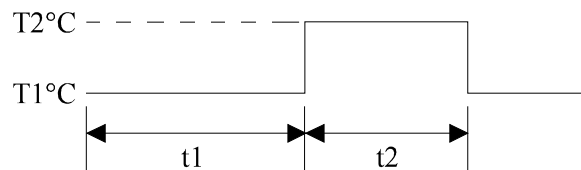
$$\text{Average DE surface temperature} = \frac{T1 \times t1 + T2 \times t2}{t1 + t2}$$

(4)   Data security at power failure
Integrity of the data on the disk is guaranteed against all forms of DC power failure except on blocks where a write operation is being performed. The above does not applied to formatting disks or assigning alternate blocks.

CHAPTER 3　　Data Format

> 3.1　Data Space
>
> 3.2　Logical Data Block Addressing
>
> 3.3　Defect Management

This chapter explains data space definition, logical data block addressing, and defect management on the HDDs.

3.1　Data Space

The HDDs manage the entire data storage area divided into the following three data spaces.

- User space: Storage area for user data

- Internal test space: Reserved area for diagnostic purposes

- System space: Area for exclusive use of HDDs themselves

The user space allows a user access by specifying data. These spaces can be accessed with the logical data block addressing method described in Section 3.2. The internal test space is used by Read/write test of self-diagnostics test, but user can't use direct access. The system space is accessed inside the HDDs at power-on or during the execution of a specific command, but the user cannot directly access the system space.

3.1.1　Cylinder configuration

The HDDs allocate cylinders to the user space, internal test space, and system space. Figure 3.1 is the cylinder configuration.

Spare areas (alternate areas) for defective sectors are provided in the user space. Several sectors in the last track of one cell and the last cylinder (alternate cylinders) in one zone are allocated as alternate areas according to the user's assignment (MODE SELECT command). See Subsection 3.1.2 for details.

Figure 3.1 Cylinder configuration
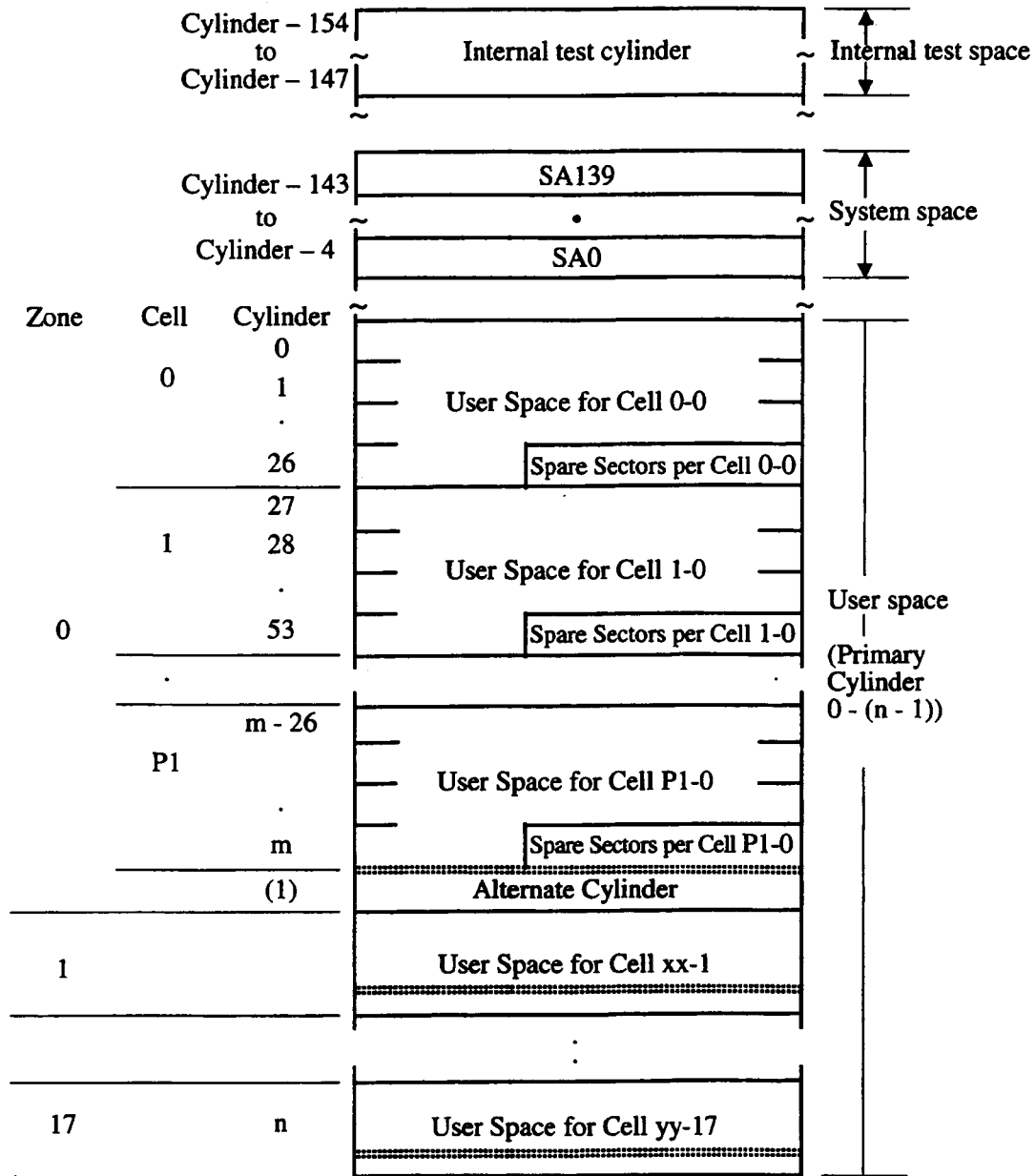
Note:

> Spare sectors on the last track in each cylinder are not necessarily placed at the end of the track because of a track skew or a cylinder skew. (Details are explained in Subsection 3.1.3)

Apart from the above logical configuration, the HDDs intend to increase the storage capacity by dividing all cylinders into several zones and changing a recording density of each zone.

(1)   User space

The user space is a storage area for user data. The data format on the user space (the length of data block and the number of data blocks) can be specified with the MODE SELECT or MODE SELECT EXTENDED command.

The user can also specify the number of logical data blocks to be placed in the user space with the MODE SELECT or MODE SELECT EXTENDED command. When the number of logical data blocks is specified, as many cylinders as required to place the specified data blocks are allocated in the user space.

A number starting with 0 is assigned to each cylinder required in the user space in ascending order. If the number of cylinders do not reach the maximum, the rest of the cylinders will not be used.

Always one cylinder is located at the end of each zone in the user space as an alternate cylinder. Alternate cylinders will be used for alternate blocks. See Subsections 3.1.2 and 3.3.2 for details.

(2)   Internal test space

The internal test space is an area for diagnostic purposes only and its data block length is always 512Byte. The internal test space consists of 8 cylinders and outer-most cylinder is always assigned (cylinder −147 to −154). The user cannot change the number of cylinders in the internal test space or their positions.

(3)   System space

The system space is an area for exclusive use of the HDDs themselves and the following information are recorded.

- Defect list (P list and G list)
- MODE SELECT parameter (saved value)
- Statistical information (log data)
- Controller control information

The above information is duplicated in several different locations for safety.

Note:

The system space is also called SA space.

3.1.2   Alternate spare area

The alternate spare area consists of the last track of each cell in the user space and an alternate cylinder allocated to the last cylinder of each zone.

The spare area in each cell is placed at the end of the last track as shown in Figure 3.2. These spare sectors are located in the end of the track logically, not necessarily located at the end physically because of track skew or cylinder skew. (Details are explained on Subsection 3.1.3.)

Size can be specified by the MODE SELECT command.

The number of spare sectors per cell can be specified from 0 to 200. The default for the spare sectors number is 200.
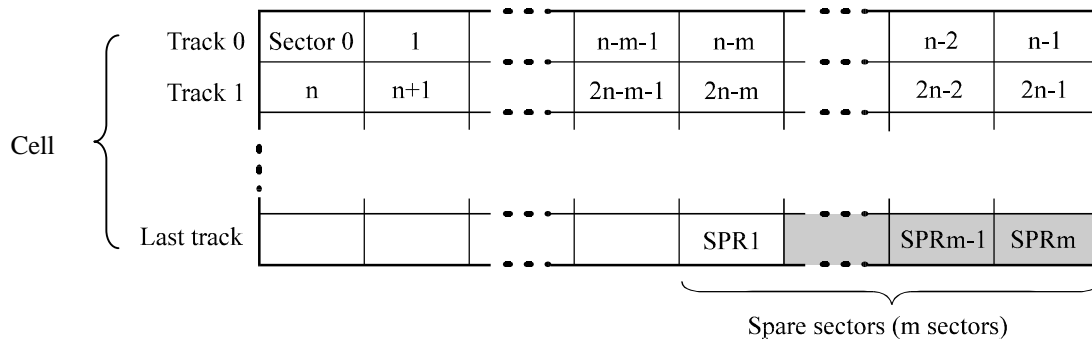
Note: This drive manages alternate spare areas for each cell, which is a set of cylinders. One cell consists of 27 cylinders.

Figure 3.2   Spare area in cell

An alternate cylinder is used when spare sectors in a cell are used up or 0 is specified as the number of spare sectors in a cell. 1 cylinder at the end of each zone of the user space is allocated as alternate cylinders as shown in Figure 3.3.

The user space and the CE space share the alternate cylinders.
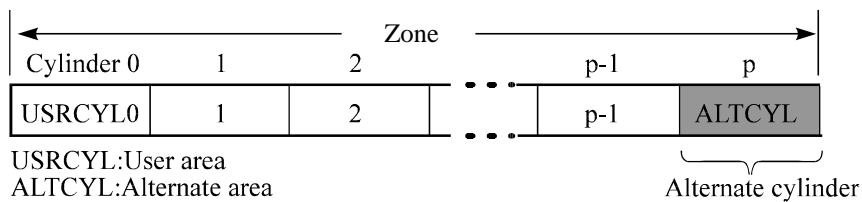
Note: The number of alternate cylinders cannot be changed.

Figure 3.3   Alternate cylinder

3.1.3 Track format

(1)   Physical sector allocation

Figure 3.4 shows the allocation of the physical sectors in a track. The length in bytes of each physical sector and the number of sectors per track vary depending on the logical data block length. The unused area (G4) exists at the end of the track in formats with most logical data block lengths.

The interval of the sector pulse (length of the physical sector) is decided by the HDDs internal free running clock frequency. This clock is not equal to the interval of the byte clock for each zone. Therefore, the physical sector length cannot be described with a byte length.
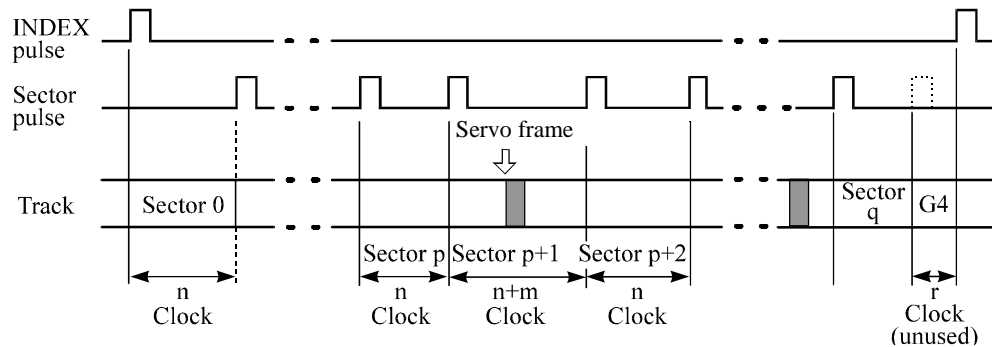
Figure 3.4   Track format

(2)   Track skew and head skew

To avoid waiting for one turn involved in head and cylinder switching, the first logical data block in each track is shifted by the number of sectors (track skew and head skew) corresponding to the switching time. Figure 3.5 shows how the data block is allocated in each track.

At the head switching location in a cylinder, the first logical data block in track t + 1 is allocated at the sector position which locates the track skew behind the sector position of the last logical data block sector in track t.

At the cylinder switching location, like the head switching location, the first logical data block in a cylinder is allocated at the sector position which locates the head skew behind the last logical sector position in the preceding cylinder. The last logical sector in the cylinder is allocated when formatting, and is an unused spare sector.
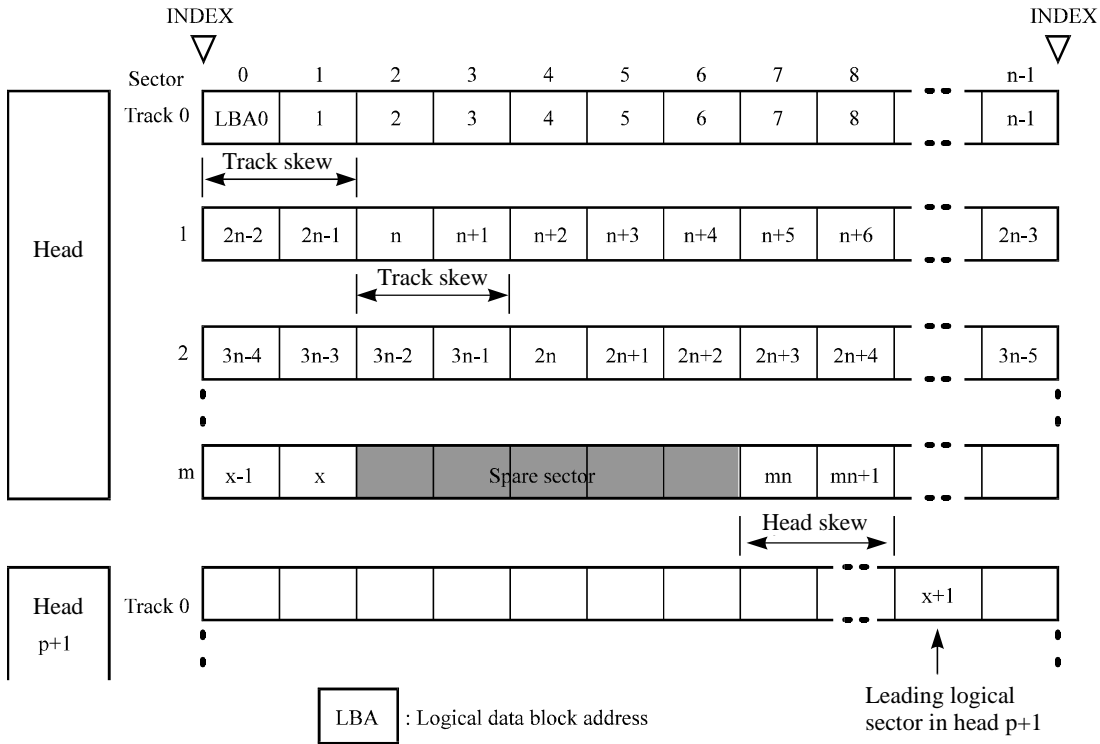
Figure 3.5   Track skew/head skew

The number of physical sectors (track skew factor and head skew factor) corresponding to the skew time varies depending on the logical data block length because the track skew and the head skew are managed for individual sectors. The HDDs automatically determine appropriate values for the track skew factor and the head skew factor according to the specified logical data block length. The value can be read out by the MODE SENSE or MODE SENSE EXTENDED command after the track has been formatted.

3.1.4   Sector format

Each sector on the track consists of an ID field, a data field, and a gap field which separates them. Figure 3.6 gives sector format examples.
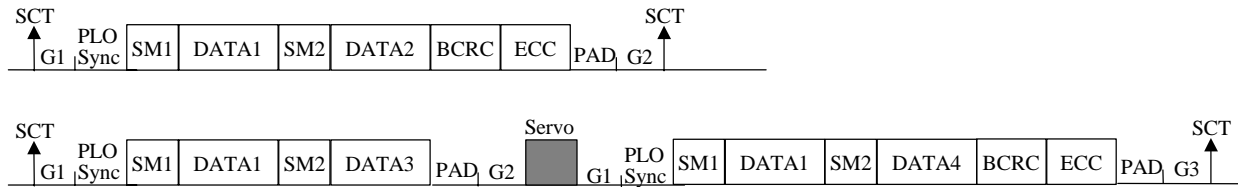
Figure 3.6   Sector format

Each sector on the track consists of the following fields:

(1)   Gaps (G1, G2, G3)

No pattern is written on the gap field.

(2)   PLO Sync

In this field, pattern X'00' is written.

(3)   Sync Mark (SM1, SM2)

In this field, special pattern is written. This special pattern indicates the beginning of the data field.

(4)   Data field (DATA1-DATA4)

User data is stored in the data field of the sector. The length of the data field is equal to that of the logical data block which is specified with a parameter in the MODE SELECT command. Any multiple of 4 between 512 and 528 bytes can be specified as the length.

(5)   BCRC

It is a 4-byte error detection code. Errors in the ID field. Single burst errors with lengths of up to 32 bits for each logical block can be detected.

(6)   ECC

This is the 400 bits code that allows detection and correction of errors in the data field, which is capable of correcting the single burst error up to 200 bits max. on the fly.

(7)   PAD

A specified length of x'00' pattern is written in this field. This field includes the variation by rotation and circuit delay till reading/writing.

3.1.5 Format capacity

The size of the usable area for storing user data on the HDDs (format capacity) varies according to the logical data block or the size of the spare sector area. Table 3.1 lists examples of the format capacity when the typical logical data block length and the default spare area are used. The following is the general formula to calculate the format capacity.

[Number of sectors of each zone] = [number of sectors per track × number of tracks per cell – number of alternate spare sectors per cell] × [number of cells in the zone]

[Formatted capacity] = [total of sectors of all zones] ÷ [number of physical sectors in logical block] × [logical data block length]

The following formula must be used when the number of logical data blocks are specified with the parameter in the MODE SELECT or MODE SELECT EXTENDED command.

[Format capacity] = [logical data block length] × [number of logical data blocks]

The logical data block length, the maximum logical block address, and the number of the logical data blocks can be read out by a READ CAPACITY, MODE SENSE, or MODE SENSE EXTENDED command after initializing the disk medium.

Table 3.1   Format capacity

Model	Data block length	User blocks	Format capacity (GB)
MAX3147RC		287,277,984	147.0 (*)
MAX3073RC	512	143,638,992	73.5 (*)
MAX3036RC		71,819,496	36.7 (*)

(*) 1 GB = 1,000,000,000 bytes

Note:

Total number of spare sectors is calculated by adding the number of spare sectors in each primary cylinder and the number of sectors in the alternate cylinders.

3.2   Logical Data Block Addressing

Independently of the physical structure of the disk drive, the HDDs adopt the logical data block addressing as a data access method on the disk medium. The HDDs relate a logical data block address to each physical sector at formatting. Data on the disk medium is accessed in logical data block units. The INIT specifies the data to be accessed using the logical data block address of that data.

The logical data block addressing is a function whereby individual data blocks are given addresses of serial hexadecimal numbers in each drive.

(1)   Block address of user space

The logical data block address number is consecutively assigned to all of the data blocks in the user space starting with 0 to the first data block.

The HDDs treat sector 0, track 0, cylinder 0 as the first logical data block. The data block is allocated in ascending order of addresses in the following sequence (refer to Figure 3.5):

1) Logical data blocks are assigned in ascending order of sector number in the same track.

2) Subsequent logical data blocks are assigned in ascending order of track number in the same head. Within the same track, logical data blocks are assigned in the same way as step 1).

3) Subsequent logical data blocks are assigned to sectors in every track except the last track in ascending order of track number in the same cell. Within the same track, logical data blocks are assigned in the same way as step 1) and 2).

4) For the last track in the same cell, subsequent logical data blocks are assigned to sectors other than spare sectors in ascending order of sector number.

5) After blocks have been assigned in the same cell according to steps 1) to 4), subsequent logical data blocks are assigned in ascending order of cell number in the same way as in steps 1) to 4). Logical data blocks are assigned starting from track 0 in the next cell until the last cylinder (immediately preceding the alternate cylinder n-1 shown in Figure 3.1) of the zone except alternate cylinders in cells in the user space.

When the logical data block is allocated, some sectors (track skew and head skew) shown in Figure 3.5 are provided to avoid waiting for one turn involving head and cylinder switching at the location where the track or the head is physically switched.

See Subsection 3.3.2 for defective/alternate block treatment and the logical data block allocation method in case of defective sectors exist on the disk.

(2)   Alternate area

Alternate areas in the user space (spare sectors in the cell and alternate cylinders) are not included in the above logical data block addresses. Access to sectors which are allocated as an alternate block in the alternate area is made automatically by means of the HDDs sector slip treatment or alternate block treatment (explained in Subsection 3.3.2), so the user does not have to worry about accessing the alternate area. The user cannot access with specifying the data block on the alternate area explicitly.

3.3   Defect Management

3.3.1   Defect list

Information of the defect location on the disk is managed by the defect list. The following are defect lists which the HDDs manage.

- P list (Primary defect list): This list consists of defect location information available at the disk drive shipment and is recorded in a system space. The defects in this list are permanent, so the INIT must execute the alternate block allocation using this list when initializing the disk.

- D list (Data defect list): This list consists of defect location information specified in a FORMAT UNIT command by the INIT at the initialization of the disk. This information is recorded in the system space of the disk drive as the G list. To execute the alternate block allocation, the FORMAT UNIT command must be specified.

- G list (Growth defect list): This list consists of defective logical data block location information specified in a REASSIGN BLOCKS command by the INIT, information on defective logical data blocks assigned alternate blocks by means of the HDD automatic alternate block allocation, information specified as the D list, and information generated as the C list. They are recorded in the system space on the disk drive.

The INIT can read out the contents of the P and G lists by the READ DEFECT DATA command.

3.3.2   Alternate block allocation

The alternate data block is allocated to a defective data block (= sectors) in defective sector units by means of the defect management method inside the HDDs.

The INIT can access all logical data blocks in the user space, as long as there is no error.

Spare sectors to which alternate blocks are allocated can be provided in "alternate cylinders". See Subsection 3.1.2 for details.

The INIT can specify the size and area for spare sectors by the MODE SELECT command at the time of the initialization of the disk.

Both of the following are applicable to the alternate block allocation.

- Sector slip treatment: Defective sectors are skipped and the logical data block corresponding to those sectors is allocated to the next physical sectors. This treatment is made on the same cell as the defective sector's and is effective until all spare sectors in that cell are used up.

- Alternate sector treatment: The logical data block corresponding to defective sectors is allocated to unused spare sectors in the alternate cylinder.

The alternate block allocation is executed by the FORMAT UNIT command, the REASSIGN BLOCKS command, or the automatic alternate block allocation. Refer to Chapter 4 "Command Specifications" and Subsection 5.3.2 "Auto alternate block allocation processing" of the Interface Specifications for details of specifications on these commands. The logical data block is allocated to the next physically continued sectors after the above sector slip treatment is made. On the other hand, the logical data block is allocated to spare sectors which are not physically consecutive to the adjacent logical data blocks. If a command which processes several logical data blocks is specified, the HDDs process those blocks in ascending order of logical data block.

(1) Alternate block allocation during FORMAT UNIT command execution

When the FORMAT UNIT command is specified, the allocation of the alternate block to those defective sectors included in the specified lists (P, G, or D) is continued until all spare sectors in the same cell are used up. When they are used up, unused spare sectors in the alternate cylinder are allocated to the subsequent sectors in the cylinder by means of alternate sector treatment. Figure 3.7 is examples of the alternate block allocation during the FORMAT UNIT command execution.

Example 1   Example 2

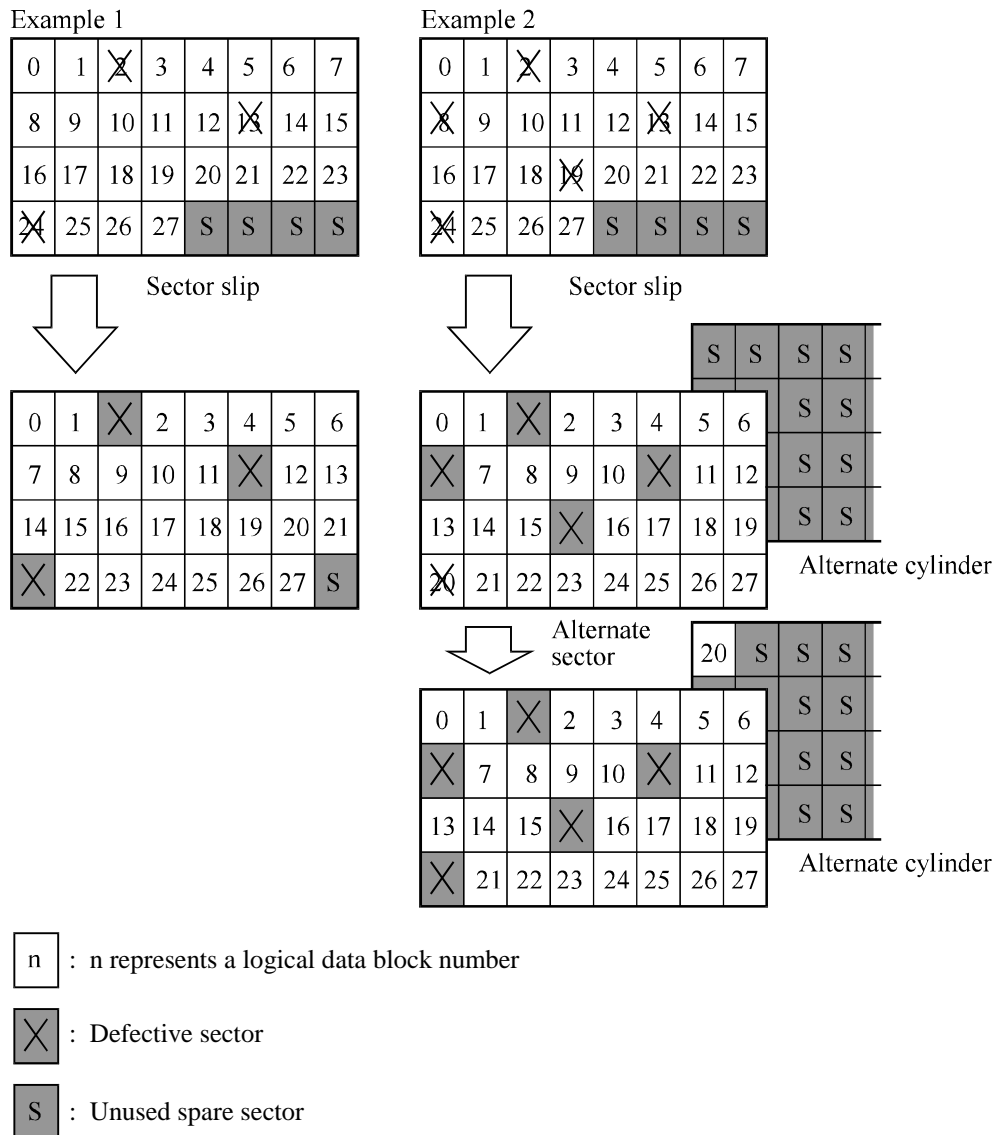| n | : n represents a logical data block number |
| X | : Defective sector |
| S | : Unused spare sector |

Figure 3.7   Alternate block allocation by FORMAT UNIT command

During FORMAT UNIT command, alternate block allocation is conducted in following cases:

1) Unrecovered write offtrack condition during a media write

2) Uncorrectable Data Error during a media read (certification) *1

If above errors are detected during FORMAT UNIT command, the HDDs allocate the alternate block(s) to the defective data blocks. Reassign procedure itself is the same as one in REASSIGN BLOCKS command.

*1   Certification is permitted when DCRT flag is cleared (DCRT flag=0) in FORMAT UNIT command.
The HDDs check all initialized logical data blocks by reading them out after the above alternate block allocation is made to initialize (format) the disk.

(2)   Alternate block allocation by REASSIGN BLOCKS command

When the REASSIGN BLOCKS command is specified, the alternate block is allocated to the defective logical data block specified by the initiator by means of alternate sector treatment. The alternate block is allocated to unused spare sectors in the alternate cylinder.

Figure 3.8 is examples of the alternate block allocation by the REASSIGN BLOCKS command.

Example Reassign: Block 16

0	1	✕	2	3	4	5	6
✕	7	8	9	10	✕	11	12
13	14	15	✕16	17	18	19	20
✕	21	22	23	24	25	26	27

Alternate sector
Alternate cylinder

				x	y	16	S
0	1	✕	2	3	4	5	6	S	S
✕	7	8	9	10	✕	11	12	S	S
13	14	15	✕	17	18	19	20	S	S
✕	21	22	23	24	25	26	27

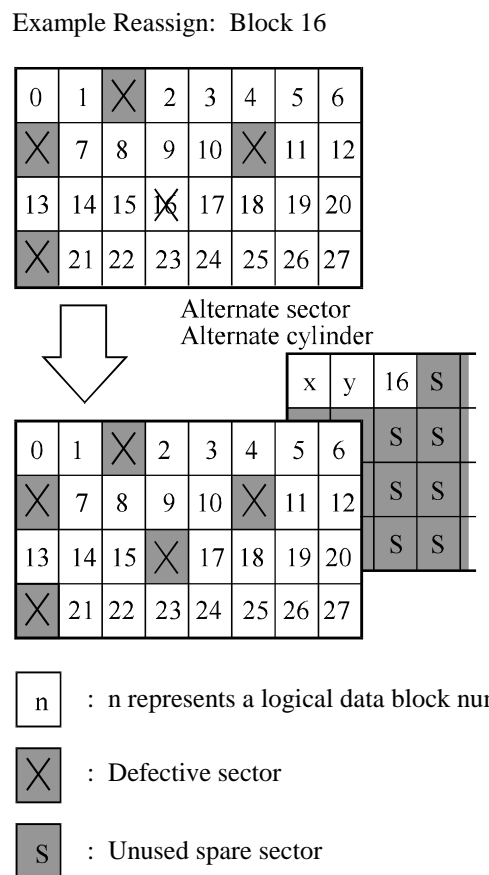| n	: n represents a logical data block number
✕	: Defective sector
S	: Unused spare sector

Figure 3.8   Alternate block allocation by REASSIGN BLOCKS command

(3)   Automatic alternate block allocation
   • Automatic alternate block allocation at read operation

If the ARRE flag in the MODE SELECT parameter permits the automatic alternate block allocation, the HDDs automatically execute the alternate block allocation and data duplication on the defective data block detected during the READ or READ EXTENDED command. This allocation method is the same as with the REASSIGN BLOCKS command (alternate sector treatment).

   • Automatic alternate block allocation at write operation

If AWRE flag in the MODE SELECT parameter permits the automatic alternate block allocation, the HDDs execute two kinds of automatic alternate processing during WRITE command processing as described below:

Type 1 (Reassignment of Uncorrectable Read Error)

1) Commands to be applied
    -    WRITE
    -    WRITE EXTEND
    -    WRITE at executing WRITE AND VERIFY
2) Application requirements
    When any of the above commands is issued to LBA registered in the uncorrectable error log of the READ command (LBA log of uncorrectable error while the READ command is executed), the AWRE processing is applied.
3) AWRE processing
    The following processings are performed when the LBA matches the one in the uncorrectable error log:
    a)   Primary media check
        -   Creates an uncorrectable error pattern (invalid LBA pattern) in the position of the error LBA, repeats the primary media check up to three times. If the error still occurs after the check repeated three times, it is judged to be defective. Then, it performs the alternate processing.
    b)   Alternate processing
        -   Alternate media check
            Writes the data that causes an unrecoverable error into the alternate block, and performs the media check.
            (If the alternate block is a defective sector, the block is registered to the G list, another alternate block is allocated.)
    c)   SA and defect map update processing (on alternate side)

When an error occurs in the alternate processing, this WRITE command terminates with error.

When the alternate processing normally terminates, the WRITE command is executed.

Type 2 (Reassignment of write fail sector)

1) Commands to be applied
   - WRITE
   - WRITE EXTENDED
   - FORMAT UNIT
   - WRITE at executing WRITE AND VERIFY

2) Application requirements / processing

   When WRITE/WRITE EXTENDED command detects any Servo error (e.g. Write offtrack error) and cannot be recovered within pre-determined retry number (specified in Mode Parameter). For the sectors around defective Servo, alternate blocks are allocated and the data of this WRITE commands are re-written.

   Sectors to be made AWRE shall be following:

   - the sector where the error occurs and the latter sectors and,
   - the sectors whose data are logically continual and stored in Cache,
   - the sectors which will be processed in this Write command and,
   - the sectors which locate between erroneous Servo -1 and +1 (including Split sector)

   This function is also applied for the sector that has already been re-assigned.

   Remark:

   When a write protection is prohibited through the setting terminal, the auto alternate block allocation processing specification is disabled.

IMPORTANT

Automatic alternate block allocation is made up to the following quantities during the execution of one command:

ARRE = Twice

AWRE (Type 1) = Eight times

AWRE (Type 2) = Maximum number which can be processed within the recovery time limit

If more than the above mentioned defective block is detected, the alternate block assignment processing for the first defective block is executed but the alternate block assignment processing for the second one is not executed and the command being executed terminates. However, the initiator can recover the twice error by issuing the same command again.

When an error is detected in a data block in the data area, recovery data is rewritten and verified in automatic alternate block allocation during the execution of the READ or READ EXTENDED command. Alternate block allocation will not be made for the data block if recovery is successful.

Example: Even if the data error which is recoverable by the WRITE LONG command is simulated, automatic alternate block allocation will not be made for the data block.

CHAPTER 4   Installation Requirements

> 4.1   Mounting Requirements
>
> 4.2   Power Supply Requirements
>
> 4.3   Connection Requirements

This chapter describes the environmental, mounting, power supply, and connection requirements.

4.1   Mounting Requirements

4.1.1   Dimensions

Figures 4.1 show the dimensions of the HDDs and the location of the mounting screw holes.

[Units: mm]

Figure 4.1   Dimensions

4.1.2 Mounting orientations

The permissible orientations of the HDDs are shown in Figure 4.2, and the tolerance of the angle is ±5° from the horizontal plane.

(a) Horizontal –1   (b) Horizontal –2

(c) Vertical –1   (d) Vertical –2

(e) Upright mounting –1   (f) Upright mounting –2
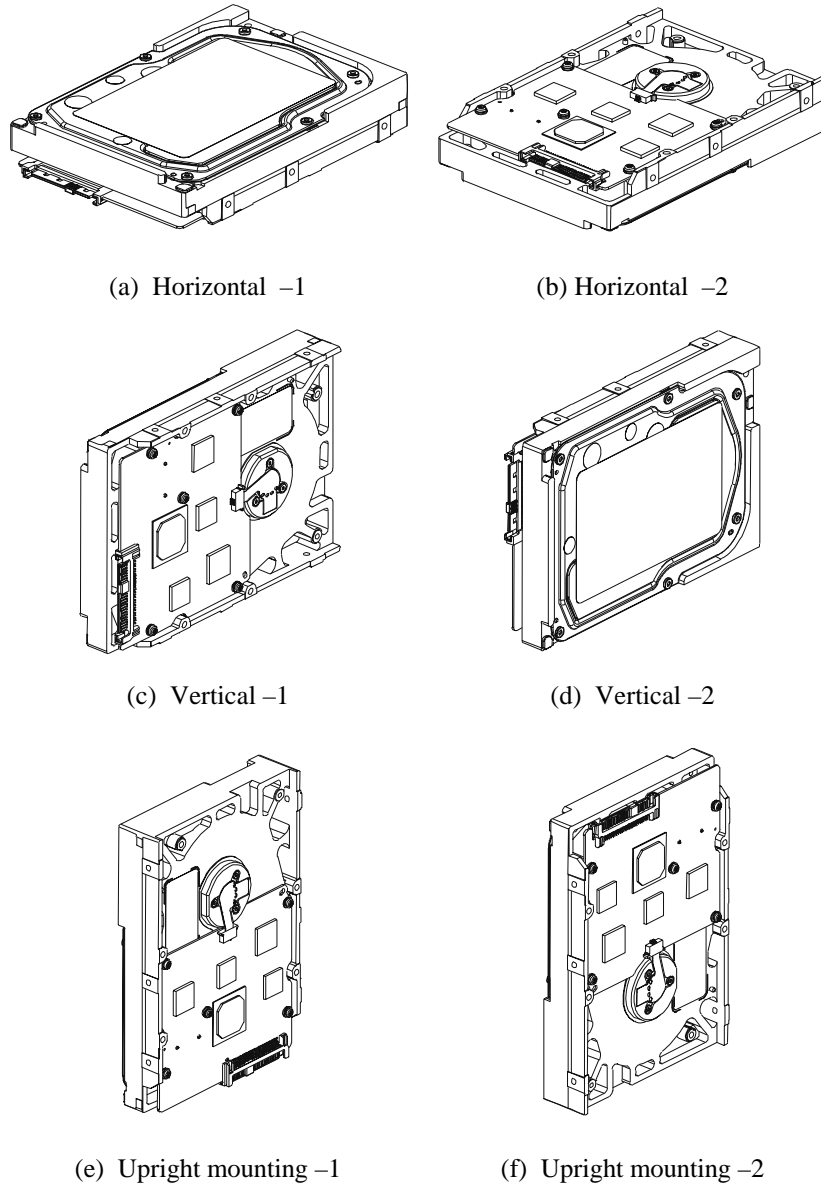
Direction of gravity
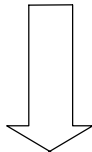
Figure 4.2   HDD orientations

4.1.3   Notes on mounting

<div align="center">

⚠**CAUTION**

</div>

Damage

Never remove any labels from the drive or deface them in any way.

(1)   Mounting screw

Use No.6-32UNC-2B metric

(2)   Mounting frame structure

Special attention must be given to mount the HDDs as follows.

a)   Use the frame with an embossed structure, or the like. Mount the HDDs with making a gap of 2.5 mm or more between the HDDs and the frame of the system.

b)   As shown in Figure 4.3, the inward projection of the screw from the HDD frame wall at the corner must be 5.0 mm or less.

c)   Tightening torque of screw must be secured with 0.59 N·m (6 kgf·cm) ±12%.

d)   Impact caused by the electric screwdriver must be within the drive specifications.

e)   Must be handled on an anti-static mat.
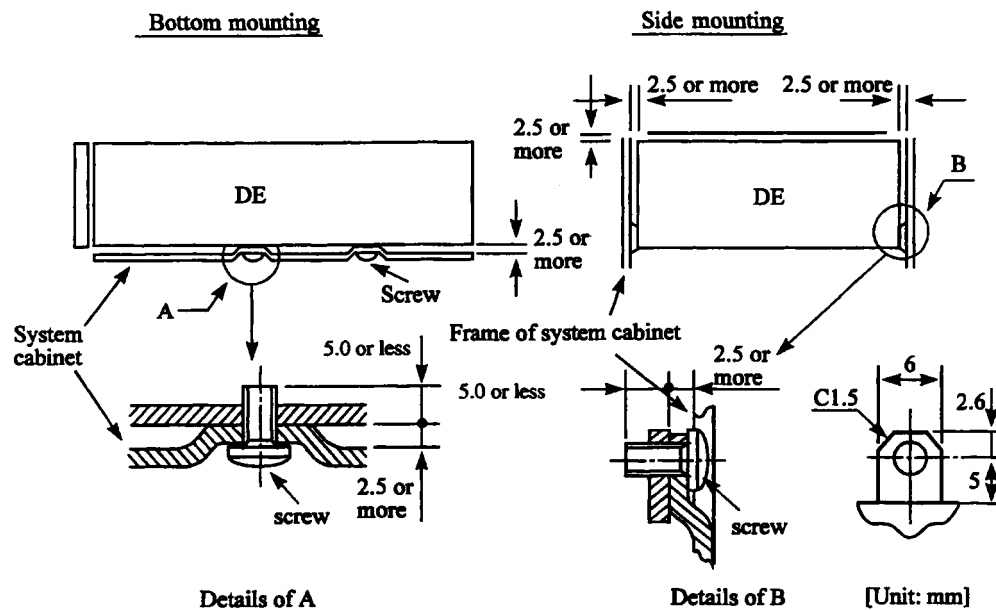
Figure 4.3   Mounting frame structure example

(3)   Limitation of side-mounting

Mount the HDDs using the 4 screw holes at the both ends on the both sides as shown in Figure 4.4. Do not use the center hole by itself.

In case of using the center hole, it must be used in combination with 2 holes on both ends. (Total 6 screws for 6 holes enclosed)
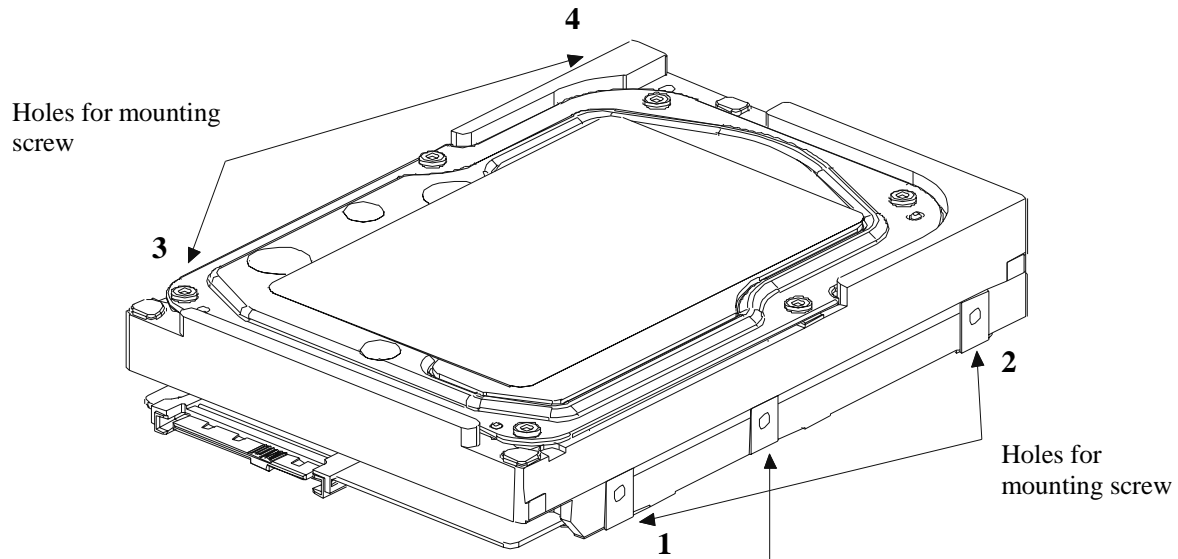
Use four holes (No.1 to No.4) to mount.

Figure 4.4   Limitation of side-mounting

(4)   Limitation of bottom-mounting

Use all 4 mounting holes on the bottom face.

(5)   Environmental temperature

Temperature condition at installed in a cabinet is indicated with ambient temperature measured 30 mm from the disk drive. At designing the system cabinet, consider following points.

- Make a suitable air flow so that the DE surface temperature never exceed 60°C.

- Cool the PCA side especially with air circulation inside the cabinet. Confirm the cooling effect by measuring the surface temperature of specific ICs and the DE. These measurement results must satisfy the temperature condition listed in Table 4.1.

- Keeping the DE surface temperature at 50°C or below at ambient temperature 30°C, which is a condition for assuring an MTBF of 1,400,000 hours, requires an air flow of 0.5 m/s or more.

Table 4.1   Surface temperature check point and maximum temperature

No.	Measurement point	Maximum temperature
1	DE Surface	60°C
2	Read channel LSI	80°C
3	VCM/SPM Driver	92°C
4	HDC	91°C
5	MPU	88°C
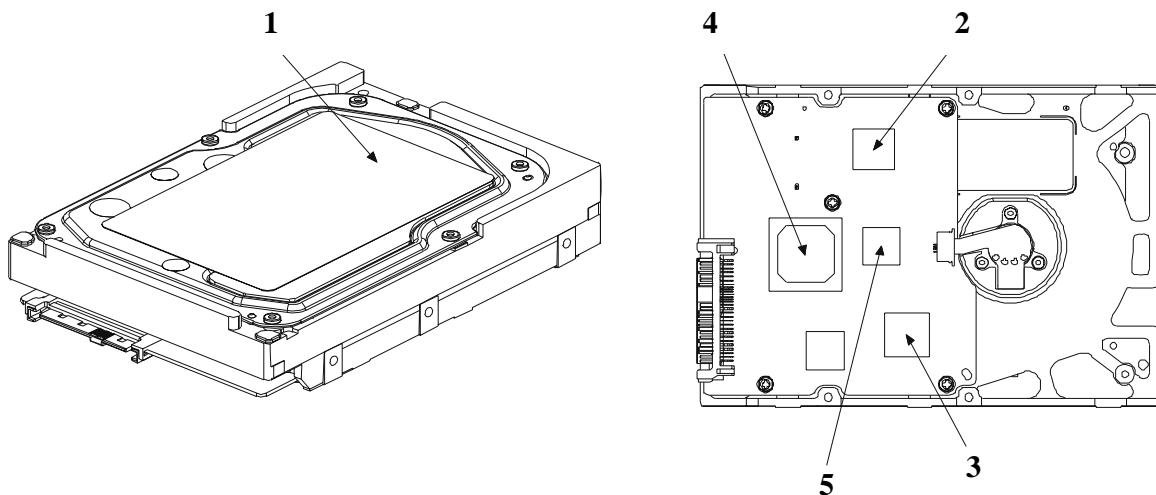
Figure 4.5   Surface temperature measurement points

(6)   Service clearance area

The service clearance area, or the sides which must allow access to the HDDs for installation or maintenance, is shown in Figure 4.6.

[Surface X]
• Holes for mounting screw
  (Both side)

[Surface Y]
• Interface connection

[Surface Z]
• Holes for mounting screw
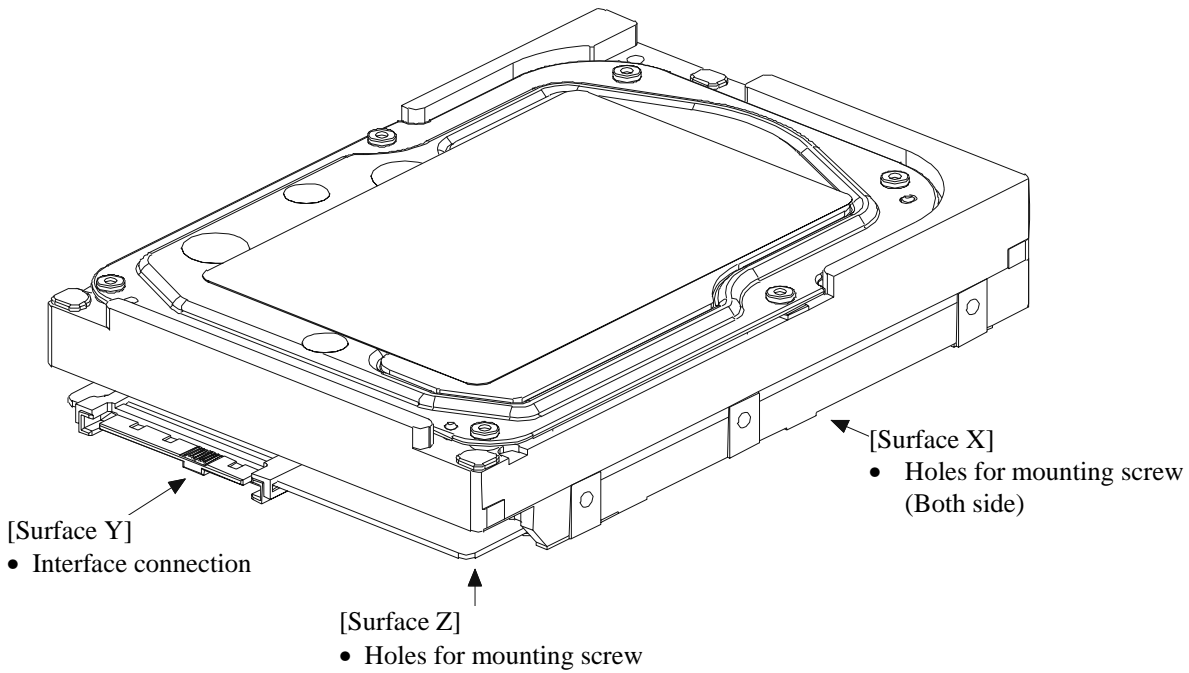
Figure 4.6   Service clearance area

(7)   External magnetic field

The drive should not be installed near the ferromagnetic body like a speaker to avoid the influence of the external magnetic field.

(8)   Leak magnetic flux

The HDDs use a high performance magnet to achieve a high speed seek. Therefore, a leak magnetic flux at surface of the HDDs are large. Mount the HDDs so that the leak magnetic flux does not affect to near equipment.

4.2   Power Supply Requirements

(1)   Allowable input voltage and current

The power supply input voltage measured at the power supply connector pin of the HDDs (receiving end) must satisfy the requirement given in Subsection 2.1.3. (For other requirements, see Items (4) and (5) below.)

(2)   Current waveform (reference)

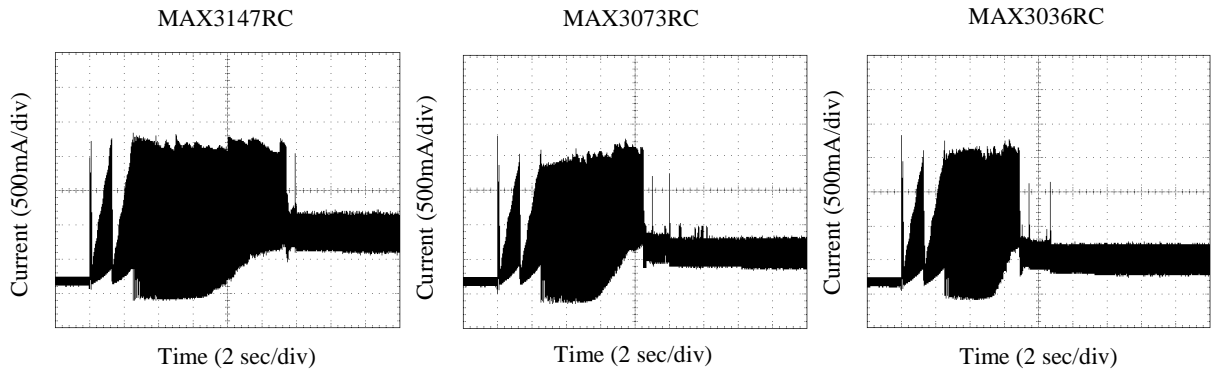Figure 4.7 shows the spin-up current waveform of +12V DC.

MAX3147RC   MAX3073RC   MAX3036RC

Figure 4.7   Current waveform (+12V DC)

(3)   Power on/off sequence

The order of the power on/off sequence of +5V DC and +12V DC, supplied to the HDDs, does not matter.

(4)   Sequential starting of spindle motors

After power is turned on to the HDDs, a large amount of current flows in the +12V DC line when the spindle motor rotation starts. Therefore, if more than one HDD is used, the spindle motors should be started sequentially using one of the following procedures to prevent overload of the power supply unit.

a)   Control the sending of the NOTIFY (ENABLE SPINUP) primitive so that the spindle motors of individual disk drives are started in intervals of 12 seconds or more.

b)   Turn on the +12V DC power in the power supply unit at intervals of 12 seconds or more to start the spindle motors sequentially.

(5)   Noise filter

To eliminate AC line noise, a noise filter should be installed at the AC input terminal on the HDD power supply unit. The specification of this noise filter is as follows:

- Attenuation: 40 dB or more at 10 MHz

- Circuit construction: T-configuration as shown in Figure 4.8 is recommended.
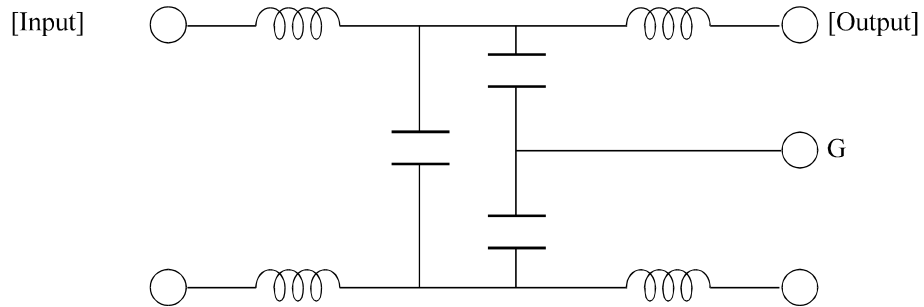
Figure 4.8   AC noise filter

4.3   Connection Requirements

4.3.1   Connector location

Figure 4.9 shows a location of the interface connector.

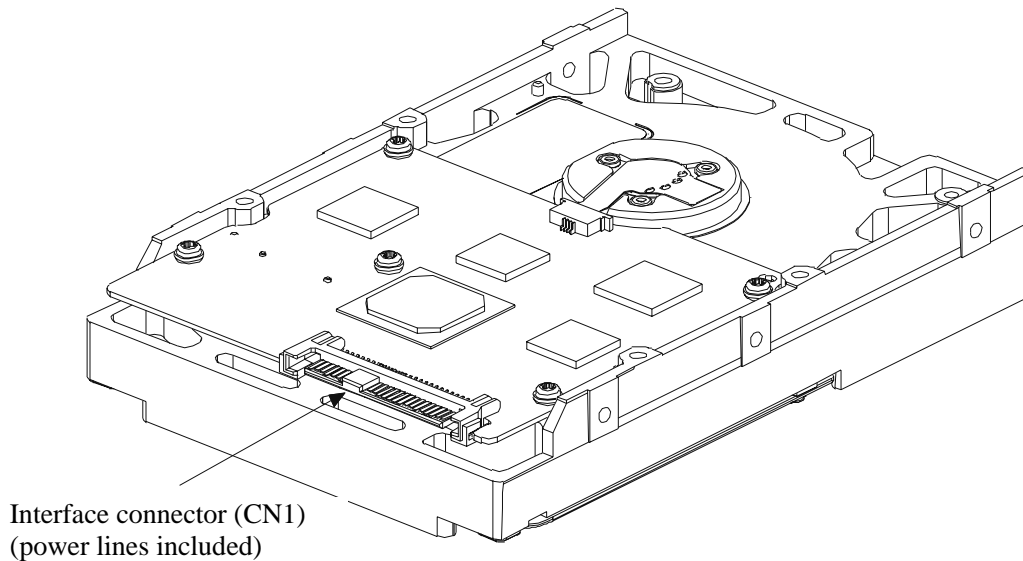Interface connector (CN1)
(power lines included)

Figure 4.9   Connector location

4.3.2   Interface connector

Figure 4.10 shows the SAS type interface connector (SAS plug) overview.

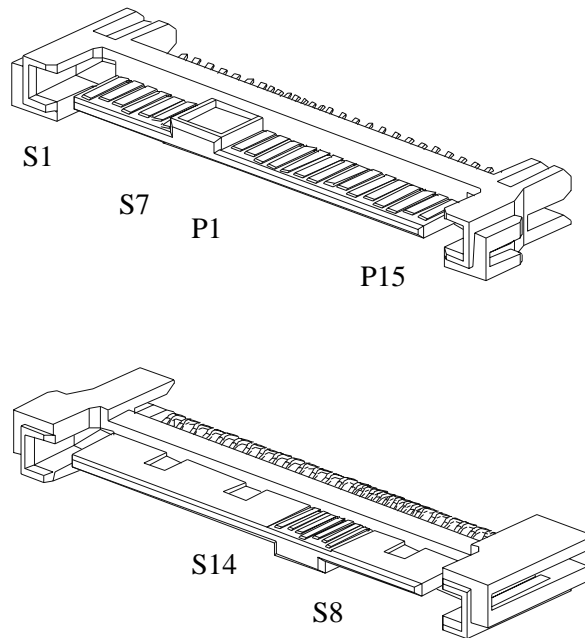Table 4.2 lists the signal allocation of the SAS plug on the HDDs.

Figure 4.10   SAS plug connector overview

Table 4.2   Interface connector (SAS plug) signal allocation:CN1

Pin No.	Signal	Description
S1	GND	GND for SAS Primary Port
S2	RP+	SAS Primary Port Receive (positive) signal
S3	RP-	SAS Primary Port Receive (negative) signal
S4	GND	GND for SAS Primary Port
S5	TP-	SAS Primary Port Transmit (negative) signal
S6	TP+	SAS Primary Port Transmit (positive) signal
S7	GND	GND for SAS Primary Port
S8	GND	GND for SAS Secondary Port
S9	RS+	SAS Secondary Port Receive (positive) signal
S10	RS-	SAS Secondary Port Receive (negative) signal
S11	GND	GND for SAS Secondary Port
S12	TS-	SAS Secondary Port Transmit (negative) signal
S13	TS+	SAS Secondary Port Transmit (positive) signal
S14	GND	GND for SAS Secondary Port
P1 [Note1]	Reserved (not used)	Not used
P2 [Note1]	Reserved (not used)	Not used
P3 [Note1]	Reserved (not used)	Not used
P4	GND	GROUND
P5	GND	GROUND
P6	GND	GROUND
P7	+5V-Charge	Pre-charge pin for +5V
P8	+5V	+5V power supply input
P9	+5V	+5V power supply input
P10	GND	GROUND
P11	READY LED	READY LED output
P12	GND	GROUND
P13	+12V-Charge	Pre-charge pin for +12V
P14	+12V	+12V power supply input
P15	+12V	+12V power supply input

Note 1)   P1 to P3 are 3.3V power supply input and pre-charge signals, and not used on MAXxxxxRC.

4.3.3   Ready LED output signal

Figure 4.11 shows a recommended circuit for external LED connection to Ready LED output signal.
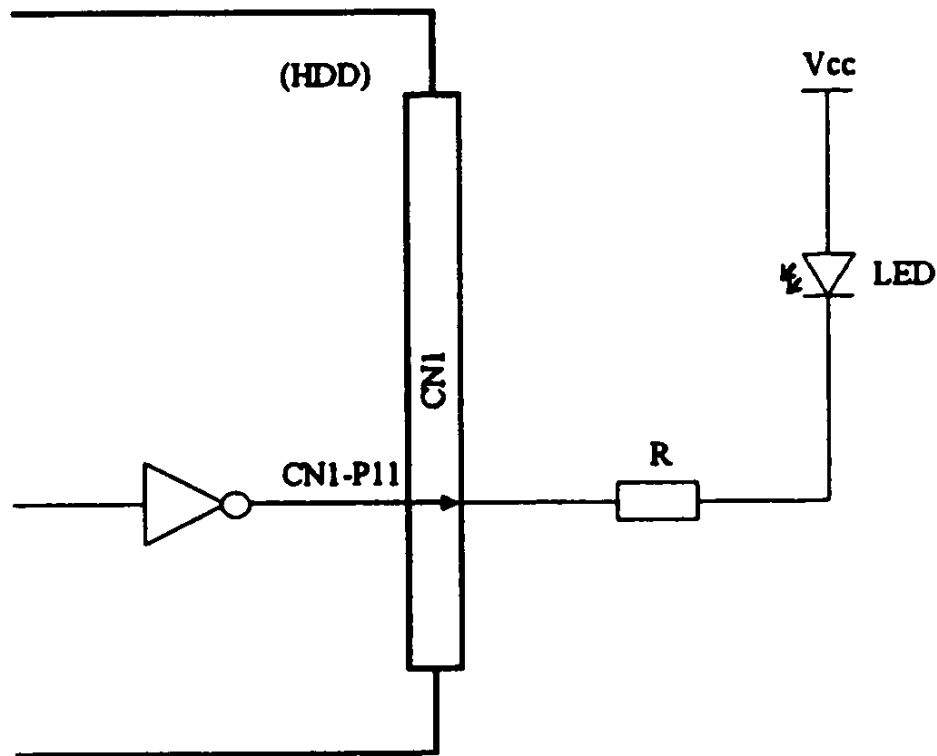

Figure 4.11   Recommended external circuit for Ready LED output

Either +3.3 V or +5 V can be used for external power supply for LED (Vcc). Current limiting resister (R) value need to be adjusted depend on the Vcc voltage. For +3.3 V Vcc voltage, recommended resistance is 220 Ω. For +5 V Vcc voltage, recommended resistance is 330 Ω.

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CHAPTER 5   Installation

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5.1   **Notes on Handling Drives**

5.2   **Setting**

5.3   **Mounting Drives**

5.4   **Checking Operation after Installation and Preparing the HDDs for Use**

5.5   **Dismounting Drives**

5.6   **Spare Disk Drive**

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This chapter describes the notes on handling drives, setting, mounting drives, confirming drive operations after installation and preparation for use, and dismounting drives.

5.1   Notes on Handling Drives

The items listed in the specifications in Table 2.3 must be strictly observed.

(1)   General notes

a)   Do not give the drive shocks or vibrations exceeding the value defined in the specifications because it may cause critical damage to the drive. Especially be careful when unpacking.

b)   Do not leave the drive in a dirty or contaminated environment.

c)   Since static discharge may destroy the CMOS semiconductors in the drive, note the following after unpacking:

- Use an antistatic mat and body grounding when handling the drive.
- Hold the DE when handling the drive. Do not touch PCAs except for setting.

⚠CAUTION

High temperature

To prevent injury, never touch the drive while it is hot. The DE and LSI become hot during operation and remain hot immediately after turning off the power.

C141-E237

(2)   Unpackaging

   a) Use a flat work area. Check that the "This Side Up" sign side is up. Handle the package on soft material such as a rubber mat, not on hard material such as a desk.

   b) Be careful not to give excess pressure to the internal unit when removing cushions.

   c) Be careful not to give excess pressure to the PCA and interface connector when removing the drive from the Fcell.

   d) Do not remove any labels from the drive. Never open the DE for any reason.

(3)   Installation/removal/replacement

   a) Do not move the drive when power is turned on or until the drive completely stops (for 30 seconds) after power is turned off.

   b) Place and keep removed screws and other parts where they will not get lost or damaged.

   c) Keep a record of all maintenance work for replacing.

(4)   Packaging

   a) Store the drive in the antistatic case (Fcell).

   b) It is recommended to use the same cushions and packages as those at delivery. If those at delivery cannot be used, use a package with shock absorption so that the drive is free from direct shocks. In this case, fully protect the PCA and interface connector so that they are not damaged.

(5)   Delivery

   a) When delivering the drive, provide packaging and do not turn it over.

   b) Minimize the delivery distance after unpacking and avoid shocks and vibrations with cushions. For the carrying direction at delivery, use one of the mount allowable directions in Subsection 4.1.2.

(6)   Storage

   a) Provide moistureproof packaging for storage.

   b) The storage environment must satisfy the requirements specified in Subsection 2.1.3 when the drive is not operating.

   c) To prevent condensation, avoid sudden changes in temperature.

5.2   Setting

5.2.1   Port Address

Every device that uses the SAS interface has a unique SAS address, and commands use an SAS address to identify each device for I/O operations. Every HDD is assigned a unique SAS address before shipment from the factory, so setting of an address is not required before the HDDs are used.

5.3   Mounting Drives

5.3.1   Mounting procedures

Since mounting the drive depends on the system cabinet structure, determine the work procedures considering the requirements specific to each system. The general mounting method and items to be checked are shown below.

See Subsection 4.1 for the details of requirements for installing the HDDs.

1)   With a system to which an external operator panel is mounted, if it is difficult to access the connector after the drive is mounted on the system cabinet, connect the external operator panel cable before mounting the drive.

2)   Fix the drive in the system cabinet with four mounting screws as follows:

- The drive has 10 mounting holes (both sides: 3×2, bottom: 4). Fix the drive by using four mounting holes of both sides of the drive or the bottom.

- Use mounting screws of which lengths inside the drive mounting frame are 2.5 mm ±0.5 mm when the screws are tightened (see Figure 4.3).

- When mounting the drive, be careful not to damage parts on the PCA.

3)   Confirm the DE is not touching the frame on the system side excluding the screw installing part after tightening the screws. At least 2.5mm of clearance is required between the DE and the frame. (Indicated in Figure 4.3)

4)   When using an electric screwdriver, use the screwdriver that does not apply a force on the drive that would exceed the drive specifications.

5.4   Checking Operation after Installation and Preparing the HDDs for Use

5.4.1   Checking initial operation

The procedure for verifying operation after power-on is explained below.

(1)   Initial diagnosis at the time of power-on:

a)   When the HDDs are turned on, the Active LED blinks and the HDDs perform the initial self-diagnosis (controller hardware diagnosis).

b)   When the SAS protocol controller diagnosis is completed normally, the HDDs start the LINK RESET sequence defined by the SAS protocol to establish synchronization with the connected SAS devices (e.g., the host system).

c)   When the initial diagnosis is completed normally, the HDDs can respond to commands from the host.

(2)   Verifying interface connection:

When verification of initial operation after power-on is completed normally, the host system checks whether the HDD connection to the interface is normal. The procedure for this check depends on the host system configuration. The following is a general check procedure:

a)   Confirm that the transfer rate and HDD SAS addresses can be recognized during the LINK RESET sequence.

b)   Issue the INQUIRY, WRITE BUFFER, and READ BUFFER commands to verify that data is received and transmitted normally in the interface.

(3)   Verifying disk drive operation :

When the LINK RESET sequence has completed, the host system can issue a spindle motor start instruction and check whether the disk drive is ready to operate.

a)   The host system instructs the spindle motor to start by sending the NOTIFY (ENABLE SPINUP) primitive to the disk drive.

b)   The HDDs do not start the motor until the NOTIFY (ENABLE SPINUP) primitive is issued.

c)   The disk drive enters the READY state within about 60 seconds after the NOTIFY (ENABLE SPINUP) primitive is issued.

d)   The HDD Active LED blinks (flashes on and off every 0.5 seconds) while the motor is running.

e)   The Active LED remains lit when the HDDs enter the READY state. The host system can use the TEST UNIT READY command to confirm that the HDDs are in the READY state.

(4)   Responses to operation errors :

a)   Confirm again that connectors are securely attached to cables.

b)   Check whether the supply voltage is supplied normally. (Measure the voltage at the power connectors of the HDDs.)

    c) Issue the REQUEST SENSE command to collect sense data. When sense data has been collected successfully, perform an analysis to check for recoverable errors, and retry operations for recovery from any such errors.

(5)   Checking at abnormal end

    a) When sense data can be obtained, analyze the sense data and retry recovery for a recoverable error. Refer to Chapter 5 "Sense Data and Error Recovery Method" of the Interface Specifications for further details.

5.4.2   Formatting

Since the disk drive is formatted with a specific (default) data format for each model (part number) when shipped from the factory, the disk need not be formatted (initialized) when it is installed in the system.

However, when the system needs data attributes different from the default format, all sides of the disk must be formatted (initialized) according to the procedures below.

The user can change the following data attributes at initialization:

- Logical data block length
- Number of logical data blocks in the user space
- Alternate spare area size

This section outlines the formatting at installation. Refer to Subsection 4.1.4 "MODE SELECT (15)", 4.1.5 "MODE SELECT EXTENDED (55)" of the Interface Specifications for further details.

(1)   MODE SELECT/MODE SELECT EXTENDED command

Specify the format attributes on the disk with the MODE SELECT or MODE SELECT EXTENDED command. The parameters are as follows.

    a.   Block descriptor

    Specify the size (byte length) of the logical data block in the "data block length" field. To explicitly specify the number of logical data blocks, specify the number in the "number of data blocks" field. Otherwise, specify 0 in "number of data blocks" field. In this case, the number of logical data blocks after initialization is determined by the value specified in the format parameter (page code = 3) and drive parameter (page code = 4).

    b.   Format parameter (page code = 3)

    Specify the number of spare sectors for each cell in the "alternate sectors/zone" field. It is recommended not to specify values smaller than the HDD default value in this field.

(2)   FORMAT UNIT command

Initialize entire recording surface of the disk with the FORMAT UNIT command. The FORMAT
UNIT command initializes entire surface of the disk using the P lists, verifies data blocks after
initialization, and allocates an alternate block for a defect block detected with verification. With
initialization, the value "00" is written into all bytes of all logical data blocks. Only the position
information of defect blocks detected with verification is registered in the G list. The specifications
are as follows:

a.   Specifying CDB

Specify 0 for the "FmtData" bit and the "CmpLst" bit on CDB, 000 for the "Defect List Format"
field, and data pattern written into the data block at initialization for the "initializing data pattern"
field.

b.   Format parameter

When the values in step a. are specified with CDB, the format parameter is not needed.

5.4.3   Setting parameters

The user can specify the optimal operation mode for the user system environments by setting the following parameters with the MODE SELECT or MODE SELECT EXTENDED command:

- Error recovery parameter
- Caching parameter
- Control mode parameter

With the MODE SELECT or MODE SELECT EXTENDED command, specify 1 for the "SP" bit on CDB to save the specified parameter value on the disk. This enables the HDDs to operate by using the parameter value set by the user when power is turned on again.

When the parameters are not set or saved with the MODE SELECT or MODE SELECT EXTENDED command, the HDDs set the default values for parameters and operates when power is turned on or after reset. Although the HDD operations are assured with the default values, the operations are not always optimal for the system. To obtain the best performance, set the parameters in consideration of the system requirements specific to the user.

This section outlines the parameter setting procedures. Refer to Subsection 4.1.4 "MODE SELECT (15)", 4.1.5 "MODE SELECT EXTENDED (55)" of the Interface Specifications for further details of the MODE SELECT and MODE SELECT EXTENDED commands and specifying the parameters.

IMPORTANT

1. *At factory shipment of the HDDs, the saving operation for the MODE SELECT parameter is not executed. So, if the user does not set parameters, the HDDs operates according to the default value of each parameter*

2. *The Mode select parameter is not saved for each INIT ID but as the common parameter for all INIT. In the multi-INIT System, parameter setting cannot be changed for each INIT.*

3. *Once parameters are saved, the saved value is effective as long as next saving operation is executed from the INIT. For example, even if the initialization of the disk is performed by the FORMAT UNIT command, the saved value of parameters described in this section is not affected.*

4. *When the HDDs, to which the saving operation has been executed on a system, are connected to another system, the user must pay attention to that the HDDs operate according to the saved parameter value if the saving operation is not executed at installation.*

5. *The saved value of the MODE SELECT parameter is assumed as the initial value of each parameter after the power-on, the RESET condition.. The INIT can change the parameter value temporary (actively) at any timing by issuing the MODE SELECT or MODE SELECT EXTENDED command with specifying "0" to the SP bit in the CDB.*

(1)   Error recovery parameters
The following parameters are used to control operations such as HDD internal error recovery:

a.   Read/write error recovery parameters (page code = 1)

Parameter		Default value
• AWRE:	Automatic alternate block allocation at Write operation	1 (enabled)
• ARRE:	Automatic alternate block allocation at read operation	1 (enabled)
• TB:	Uncorrectable data transfer to the INIT	0 (disabled)
• EER:	Immediate correction of correctable error	1 (enabled)
• PER:	Report of recovered error	0 (disabled)
• DCR:	Suppression of ECC error correction	0 (Correction is enabled.)
• Retry count at read operation		63
• Retry count at write operation		63
• Recovery time limit		30 sec

b.   Verify error recovery parameters (page code = 7)

Parameter		Default value
• ERR:	Immediate correction of recoverable error	1 (enabled)
• PER:	Report of recovered error	0 (disabled)
• DTE:	Stop of command processing at successful error recovery	0 (Processing is continued.)
• DCR:	Suppression of ECC error correction	0 (Correction is enabled.)
• Retry count at verification		63

c.   Additional error recovery parameters (page code = 21)

Parameter	Default value
• Retry count at seek error	15

Notes:

1.   The user can arbitrarily specify the following parameters according to the system requirements:

* ARRE
* AWRE
* TB
* PER

2.   The user also can arbitrarily specify parameters other than the above. However, it is recommended to use the default setting in normal operations.

(2)   Caching parameters

The following parameters are used to optimize HDD Read-Ahead caching operations under the system environments. Refer to Chapter 3 "Data Buffer Management" of the Interface Specifications for further details.

Parameter		Default value
• IC:	Initiator control	0 (Drive-specific control (page cache))
• RCD:	Disabling Read-Ahead caching operations	0 (enabled)
• WCE:	Write Cache Enable	1 (enabled)
• MS:	Specifying the multipliers of "minimum prefetch" and "maximum prefetch" parameters	0 (Specifying absolute value)
• DISC:	Prefetch operation after track switching during prefetching	1 (enabled)
• Number of blocks for which prefetch is suppressed		X'FFFF'
• Minimum prefetch		X'0000'
• Maximum prefetch		X' XXXX' (1 cache segment)
• Number of blocks with maximum prefetch restrictions		X'FFFF'
• Number of segments		X'08'

Notes:

1.   When Read-Ahead caching operations are disabled by the caching parameter, these parameter settings have no meaning except write cache feature.

2.   Determine the parameters in consideration of how the system accesses the disk. When the access form is not determined uniquely because of the processing method, the parameters can be re-set actively.

3.   For sequential access, the effective access rate can be increased by enabling Read-Ahead caching operations and Write Cache feature.

(3)   Control mode parameters

The following parameters are used to control the tagged queuing and error logging.

a.   Control mode parameters

Parameter		Default value
• Queue algorithm modifier		0 (Execution sequence of read/write commands is optimized.)
• QErr:	Resume or abort remaining suspended commands after sense pending state	0 (command is resumed)
• DQue:	Disabling tagged command queuing	0 (enabled)

5.5   Dismounting Drives

Since the method and procedure for dismounting the disk drive for replacement of the drive, etc. depends on the locker structure of the system, etc., the work procedure must be determined in consideration of the requirements specific to the system. This section describes the general procedure and notes on dismounting the drive.

<div align="center">

⚠**CAUTION**

</div>

Damage
1. *When dismounting the drive which is mounted on the system while power is supplied to it.*
   * *The spindle motor can be stopped by a START/STOP command. It takes about 30 seconds for the spindle motor to stop completely.*
   * *Then, dismount the drive using the drive mounting/dismounting mechanism, etc. of the system. If the drive is dismounted while the spindle motor is running, special care is required to avoid excessive vibration or shock to the drive. Just in case, stop dismounting once when SAS connector breaks off contact and wait until the spindle motor stops (about 30 seconds.).*
   * *When storing or transporting the drive, put it in the antistatic bag (refer to Section 5.1).*

2. *When dismounting the drive which is mounted on the system while power is not supplied to it.*
   * *Dismount the drive using the drive mounting/dismounting mechanism, etc. of the system.*
   * *When storing or transporting the drive, put it in the antistatic bag (refer to Section 5.1).*

5.6   Spare Disk Drive

See Subsection 2.1.1, "Model name and order number," to order a disk drive for replacement or as a spare

CHAPTER 6   Diagnostics and Maintenance

6.1   Diagnostics
6.2   Maintenance Information
6.3   Operation Check
6.4   Troubleshooting Procedures

This chapter describes diagnostics and maintenance information.

6.1   Diagnostics

6.1.1   Self-diagnostics

The HDDs have the following self-diagnostic function. This function checks the basic operations of the HDDs.

- Initial self-diagnostics
- Online self-diagnostics (SEND DIAGNOSTIC command)

Table 6.1 lists the contents of the tests performed with the self-diagnostics. For a general check of the HDDs including the operations of the host system and interface, use a test program that runs on the host system (see Subsection 6.1.2).

Table 6.1   Self-diagnostic functions

Test contents	Initial self-diagnostics	SEND DIAGNOSTIC command	
		Self Test=1 Unit Offline=0	Self Test=1 Unit Offline=1
Hardware function test	◯	◯	◯
Seek test			◯
Write/read test (Cylinder for internal test)			◯

Note:

◯ indicates the tests to be executed and arrows show the sequence of execution.

Brief test contents of self-diagnostics are as follows.

a. Hardware function test

This test checks the basic operation of the controller section, and contains following test.

- RAM (microcode is stored)
- Peripheral circuits of microprocessor (MPU)
- Memory (RAM)
- Data buffer

b. Seek test

This test checks the positioning operation of the disk drive using several seek modes (2 points seek, 1 position sequential seek, etc.). The positioning operation is regarded as success when the seek operation to the target cylinder is completed.

c. Write/read test

This test checks the write/read function by using the internal test space of the disk drive.

(1) Initial self-diagnostics

When the HDDs are turned on, they run the initial self-diagnostics. The initial self-diagnostics test the basic operations of hardware functions.

If the initial self-diagnostics detect an error, the LED on the drive blinks. The HDDs in this state post the CHECK CONDITION status to all I/O operation requests except the REQUEST SENSE command. The initiator can collect sense data when the CHECK CONDITION status is posted.

Sense data contains detailed information on the error detected by the initial self-diagnostics.

When sense data has been collected after the CHECK CONDITION status has been posted, the CHECK CONDITION status continues and the LED keeps blinking. This status can be cleared only when the HDDs are turned off and turned on again. When the status is cleared, the HDDs run the initial self-diagnostics again.

The HDDs do not reply to requests from the host system for a maximum of 2 seconds after the start of the initial self-diagnostics. Thereafter, the HDDs can accept I/O operation requests normally, but any received command, except commands that are executable even in the not ready state, is terminated with the CHECK CONDITION status until the spindle motor reaches the normal rotational speed and the HDDs become ready. The commands that are executable even in the not ready state are executed in parallel with the initial self-diagnostics, or they are queued by the command queuing feature and executed when the initial self-diagnostics is completed.

If the initial self-diagnostics detect an error, the CHECK CONDITION status is posted for all of the commands received and queued during the initial self-diagnostics.

(2)   Online self-diagnostics (SEND DIAGNOSTIC command)

The INIT can make the HDDs execute self-diagnostics by issuing the SEND DIAGNOSTIC command.

The INIT specifies the execution of self-diagnostics by setting 1 for the SelfTest bit on the CDB in the SEND DIAGNOSTIC command and specifies the test contents with the UnitOfl bit.

When the UnitOfl bit on the CDB is set to 0, the HDDs execute the hardware function test only once. When UnitOfl bit is set to 1, the HDDs execute the hardware function test, seek (positioning) test, and data write/read test for the internal test space only once.

a.   Error recovery during self-diagnostics

During the self-diagnostics specified by the SEND DIAGNOSTIC command, when the recoverable error is detected during the seek or the write/read test, the HDDs perform the error recovery according to the MODE SELECT parameter value (read/write error recovery parameter, additional error recovery parameter) which the INIT specifies at the time of issuing the SEND DIAGNOSTIC command.

PER	Operation of self-diagnostics
0	The self-diagnostics continues when the error is recovered. The self-diagnostics terminates normally so far as the unrecoverable error is not detected.
1	The self-diagnostics continues when the error is recovered. If the unrecoverable error is not detected, the consecutive tests are executed till last test but the self-diagnostics terminates with error. The error information indicates that of the last recovered error.

b.   Reporting result of self-diagnostics and error indication

When all specified self-diagnostics terminate normally, the HDDs post the GOOD status for the SEND DIAGNOSTIC command.

When an error is detected in the self-diagnostics, the HDDs terminate the SEND DIAGNOSTIC command with the CHECK CONDITION status.

When the CHECK CONDITION status is posted, sense data contains detailed information on the error detected by the initial self-diagnostics.

The HDD status after the CHECK CONDITION status is posted differs according to the type of the detected error.

a)   When an error is detected in the seek or write/read test, the subsequent command can be accepted correctly. When the command other than the REQUEST SENSE is issued from the same INIT, the error information (sense data) is cleared.

b) When an error is detected in the hardware function test, the HDDs post the CHECK CONDITION status for all I/O operation request except the REQUEST SENSE command. The error status is not cleared even if the error information (sense data) is read. Only when the power is turned off or re-turned on, the status can be cleared. When this status is cleared, the HDDs execute the initial self-diagnostics again (see item (1)).

Refer to Subsection 4.4.1 "SEND DIAGNOSTIC (1D)" of the Interface Specifications for further details of the command specifications.

6.1.2 Test programs

The basic operations of the HDDs themselves can be checked with the self-diagnostic function. However, to check general operations such as the host system and interface operations in a status similar to the normal operation status, a test program that runs on the host system must be used.

The structure and functions of the test program depend on the user system requirements. Generally, it is recommended to provide a general input/output test program that includes devices connected to the input/output devices on other I/O ports.

Including the following test items in the test program is recommended to test the HDD functions generally.

(1) Interface test

The operations of the data buffer on the HDDs are checked with the WRITE BUFFER and READ BUFFER commands.

(2) Basic operation test

The basic operations of the HDDs are checked by executing self-diagnosis with the SEND DIAGNOSTIC command (see Subsection 6.1.1).

(3) Random/sequential read test

The positioning (seek) operation and read operation are tested in random access and sequential access modes with the READ, READ EXTENDED, or VERIFY command.

6.2   **Maintenance Information**

See Section 5.1 for notes on packing and handling when returning the disk drive.

⚠**CAUTION**

Data loss

Save data stored on the disk drive to other media before requesting repair. Fujitsu does not assume responsibility if data is destroyed during servicing or repair.

6.2.1   **Precautions**

Take the following precautions to prevent injury during maintenance and troubleshooting:

⚠**CAUTION**

High temperature

To prevent injury, never touch the drive while it is hot. The DE and LSI become hot during operation and remain hot immediately after turning off the power.

⚠**CAUTION**

Electrical shock

Never touch the HDDs while power-feeding.

Take the following precautions to prevent disk drive damage during maintenance and troubleshooting:

⚠**CAUTION**

Damage

1.   *Always ground yourself with a wrist strap connected to ground before handling. ESD (Electrostatics Discharge) may cause the damage to the device.*

2.   *Never use a conductive cleaner to clean the HDDs.*

3.   *Never remove any labels from the drive or deface them in any way.*

4.   *Never remove the PCA.*

5.   *Never open the disk enclosure for any reason.*

6.2.2 Maintenance requirements

(1)   Preventive maintenance

Preventive maintenance is not required.

(2)   Service life

See "(3) Service life," in Section 2.1.5.

(3)   Parts that can be replaced in the field

The PCA cannot be replaced in the field. The DE cannot be replaced in the field.

(4)   Service system and repairs

Fujitsu has the service system and repair facility for the disk drive. Contact Fujitsu representative to submit information for replacing or repairing the disk drive. Generally, the following information must be included:

a)   Model part number (P/N), revision number, serial number (S/N), and date of manufacturing

b)   Error status

- Date when the error occurred
- System configuration
- Environmental conditions (temperature, humidity, and voltage)

c)   Error history

d)   Error contents

- Outline of inconvenience
- Issued commands and specified parameters
- Sense data
- Other error analysis information

6.2.3   Maintenance levels

If a disk drive is faulty, replace the whole disk drive since repair requires special tools and environment. This section explains the two maintenance levels.

(1)   Field maintenance (disk drive replacement)

- This replacement is done at the user's site.

- Replacement uses standard tools.

- Replacement is usually done by the user, retail dealer, distributor, or OEM engineer.

(2)   Factory maintenance (parts replacement)

- This replacement can only be done by Fujitsu.

- Replacement includes maintenance training and OEM engineer support. OEM engineers usually support retail dealers and distributors.

- Replacement uses factory tools and test equipment.

6.2.4   Revision numbers

The revision number of the disk drive is represented with a letter and a number indicated on the label attached on the HDDs. Figure 6.1 shows an example of the label.
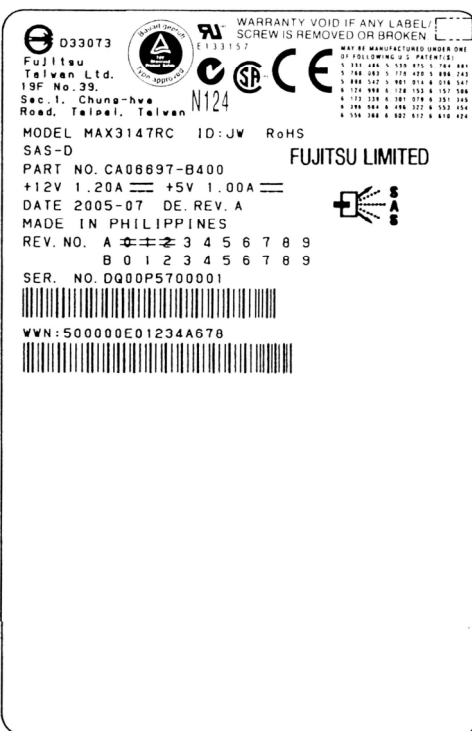
Figure 6.1   Revision label (example)

(1)   Indicating revision number at factory shipment

When the disk drive is shipped from the factory, the revision number is indicated by deleting numbers in the corresponding letter line up to the corresponding number with = (see Figure 6.2).

(2)   Changing revision number in the field

To change the revision number because parts are replaced or other modification is applied in the field, the new level is indicated by enclosing the corresponding number in the corresponding letter line with bold line (see Figure 6.2).

IMPORTANT

When the revision number is changed after the drive is shipped from the factory, Fujitsu issues "Engineering Change Request/Notice" in which the new revision number is indicated. When the user changes the revision number, the user should update the revision label as described in item (2) after applying the modification.

At shipment

```
+12V  1.20A ═══  +5V  1.00A ═══
DATE 2005-07  DE.REV.A
MADE  IN  PHILIPPINES
REV.NO.  A 0 1 2 ③ 4  5  6  7  8  9
              B 0  1  2  3  4  5  6  7  8  9
SER.  NO. DQ00P5700001
```
⟹ Rev. A2

Revising at field

```
+12V  1.20A ═══  +5V  1.00A ═══
DATE 2005-07  DE.REV.A
MADE  IN  PHILIPPINES
REV.NO.  A 0 1 2 3  4  5  6  7  8  9
              B 0  1  2  3  4  5  6  7  8  9
SER.  NO. DQ00P5700001
```
⟹ Rev. A3
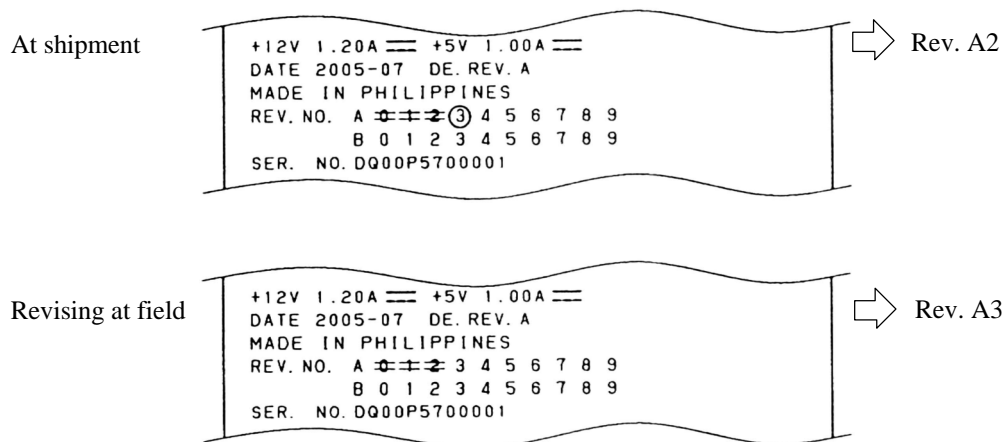
Figure 6.2   Indicating revision numbers

6.2.5   Tools and test equipment

Disk drive troubleshooting and repair in the field require only standard hand tools. No special tools or test equipment are required.

This manual does not describe the factory-level tools and test equipment.

6.2.6 Tests

This disk drive can be tested in the following ways:

- Initial seek operation check (See Subsection 6.3.1)
- Operation test (See Subsection 6.3.2)
- Diagnostic test (See Subsection 6.3.3)

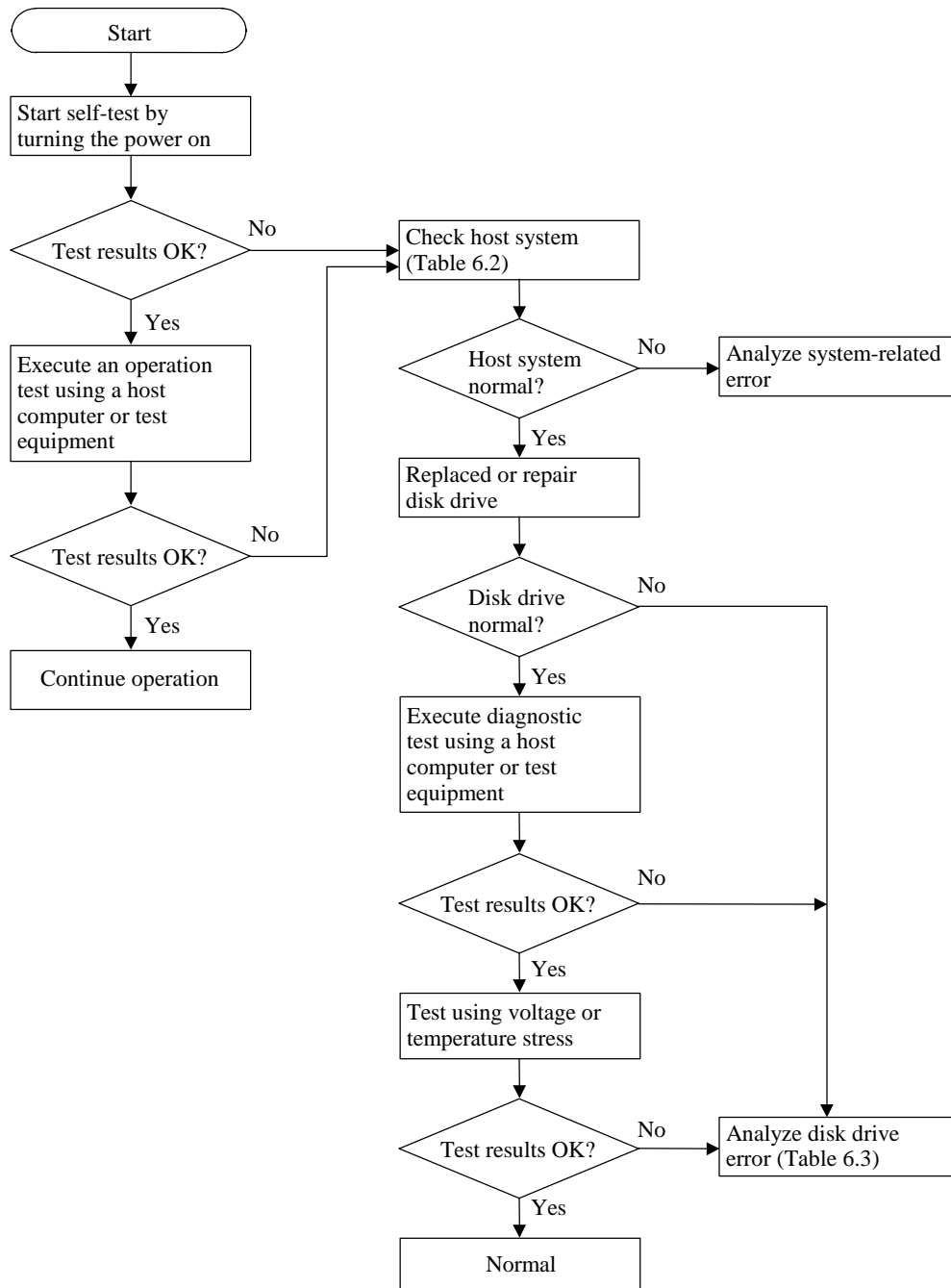Figure 6.3 shows the flow of these tests.

Figure 6.3   Test flowchart

6.3   Operation Check

6.3.1   Initial seek operation check

If an error is detected during initialization by the initial seek operation check routine at power-on, the spindle motor of the disk drive stops, and then the disk drive becomes unusable.

For an explanation of the operation check before the initial seek, refer to the Section 5.4.

6.3.2   Operation test

While the host computer is processing data, the HDDs monitor disk drive operation including data processing, command processing, and seek operations. If the HDDs detect an error, the HDDs post the error to the INIT. The INIT then posts the error to the user.

The user may detect an intermittent or nonfatal error such as abnormal noise, abnormal odor, or very slow operation.

An error posted in an operation test must be investigated. Replace the disk drive to see whether the error was caused by the disk drive.

Often, errors posted in an operation test may be caused by the host system. Possible causes include insufficient power capacity, loose cable connection, insufficient timing or insufficient mechanical play, and problems related to other systems.

If an operation error is detected by the error detection circuit of the disk drive, an interrupt occurs. The interrupt is posted to the MPU on the PCA. The MPU stops the currently processed command, and causes the CHECK CONDITION status to post the error to the INIT.

When receiving the CHECK CONDITION status, the INIT collects detailed information via SENSE data.

To analyze the error posted in the operation test, reconstruct the conditions in which the error occurred. Then, start troubleshooting the whole host system by replacing the disk drive.

6.3.3   Diagnostic test

The diagnostic test is executed to find a faulty subassembly in a faulty disk drive, or to check disk drive performance. This test is usually a combination of specific disk drive functions or group of functions. This test may be executed using a different host computers or test equipment and away from the environment where the error first occurred.

To analyze the error posted in the diagnostic test, reconstruct the conditions in which the error occurred. Then, look for a possibly faulty subassembly or part of the disk drive.

The procedures to be used in this test depend largely on the type of test equipment used, and are not covered by this manual.

6.4   Troubleshooting Procedures

6.4.1   Outline of troubleshooting procedures

This section explains the troubleshooting procedures for disk drive errors.

Depending on the maintenance level, analyze the error to detect a possibly faulty part (disk drive, or disk drive part).

Full-scale troubleshooting is usually required if the error cause is not known. If the error cause is clear (e.g., abnormal noise in disk enclosure or burning of the PCA), troubleshooting is straightforward.

6.4.2   Troubleshooting with disk drive replacement in the field

At this level of maintenance, we recommend replacing the disk drive as a unit. If replacing the disk drive rectifies the fault, return the removed disk drive to the factory, for test and repair. If the newly installed disk drive does not rectify the fault another part of the system is faulty.

Table 6.2 summarizes system-level field troubleshooting. Troubleshooting must be done in the field, to find faulty part (disk drive or system).

Table 6.2   System-level field troubleshooting

Item	Recommended work
DC power level	Check that the DC voltage is within the specified range (±5%). For +5V DC, measure the voltage between pin P8 (+5V) of the interface connector and the nearest PCA mounting screw (GND) from the interface connector, and confirm the value is from 4.75 to 5.25 VDC. For +12V DC, measure the voltage between pin P14 (+12V) of the interface connector and the nearest PCA mounting screw (GND) from the interface connector, and confirm the value is from 11.4 to 12.6 VDC.
Electrical noise	Make sure the maximum ripple peak-to-peak value of +5V DC is within 250 mV and +12V DC is within 250 mV. Make sure the high frequency noise (over 20 MHz) is less than 100 mVp-p.
System cables	Check that all system cables are connected correctly.
System diagnostic test	When possible, execute the system level diagnostic routine as explained in the host computer manual. This gives a detailed report of a possible fault.
Intermittent or nonfatal errors	Check the AC voltage from the power supply. Check the DC voltage level at the power connector for the disk drive. If the AC voltage level is abnormal or there is a lot of electrical noise, notify the user of the error. If the DC voltage level is unstable, replace the power supply unit. If possible, replace the disk drive. If replacing the disk drive does not eliminate the error, the removed disk drive is probably not faulty. To continue error analysis, refer to the hardware and software manuals supplied with the system.

6.4.3   Troubleshooting at the repair site

For maintenance at this level, we recommend additional testing of the disk drive and signal checking.

The sense data posted from the HDDs help with troubleshooting. This sense data makes the error type clear (functional, mechanical, or electrical error). Chapter 7 error analysis by sense data, and gives supplementary information on finding the error cause (faulty part).

Table 6.3 lists how to detect a faulty disk drive subassembly. This fault finding requires a working host computer or disk drive test equipment to recreate the error conditions.

If the detected error cannot be recreated in an ordinary test, disk drive conditions can be changed to force the error to recur. This is done by changing the DC voltage or the ambient temperature of the disk drive.

If the error does not recur with changed conditions, the disk drive is not faulty. If no error occurs in the disk drive test, notify the user of the test results, and find out from the user the environment conditions where the disk drive is used.

Table 6.3   Disk drive troubleshooting

Item	Recommended action
Frequent or repeated seek errors	Collect sense data, and see Chapter 7. Replace the disk drive, and check that the test method is correct. If the error recurs, it is likely that the disk drive is normal but the test method is incorrect.
Intermittent or nonfatal errors	Replace the disk drive, and check that the test method is correct. If the error recurs, it is likely that the disk drive is normal but the test method is incorrect. To check performance, change the disk drive conditions by changing the voltage or temperature.

If the disk drive error recurs or a possibly faulty part is found by troubleshooting, return the complete disk drive to the factory for repair. A media defect list must be included with the disk drive returned to the factory.

If the possibly faulty part is the disk enclosure, return the whole disk drive to the factory for repair. Also if a clear error (erroneous servo track information or noisy drive) is detected in the disk enclosure, return the whole disk drive to the factory. A media defect list must be included with the disk drive returned to the factory.

⚠CAUTION

Damage

1.   Never remove any labels from the drive.

2.   Never open the disk enclosure for any reason. Doing so will void any warranties.

6.4.4   Troubleshooting with parts replacement in the factory

This manual does not cover troubleshooting at the factory level.

6.4.5   Finding possibly faulty parts

Finding possibly faulty parts in the field was explained in Subsection 6.4.2. This manual does not cover finding possibly faulty parts at the factory level.

CHAPTER 7   Error Analysis

> **7.1   Error Analysis Information Collection**
>
> **7.2   Sense Data Analysis**

This chapter explains in detail how sense data collected from a disk drive is used for troubleshooting. Sense data reflects an error in the disk drive, and helps with troubleshooting.

A sense key, additional sense code, and additional sense code qualifier, taken from various sense data are repeated. Also in this chapter, troubleshooting is performed using these three codes. Unless otherwise specified, "sense data" means the above three codes. When sense data is represented as (x-xx-xx), the leftmost x is a sense key, the middle xx is an additional sense code, and the rightmost x is an additional sense code qualifier.

7.1   Error Analysis Information Collection

7.1.1   Sense data

When HDDs post a CHECK CONDITION status, the current command or queued command is cleared. In such a case, the HDDs generate sense data about the command-issuing INIT. The INIT can read the sense data by reading the sense data added to the response frame of the command where an error occurred (Auto Sense function).

7.1.2   Sense key, additional sense code, and additional sense code qualifier

If an error is detected in a disk drive, the error status is indicated in the sense data collected from the disk drive. Figure 7.1 shows the positions of a sense key, additional sense code, and additional sense code qualifier.

	Bit 7	6	5	4	3	2	1	0
Byte 0	Valid	X'70' or X'71' (error code)						
1	X'00'							
2	0	0	ILI	0	Sense key			
3	[MSB]							
4		Information						
5								
6								[LSB]
7	X'28' (additional sense data length)							
8	[MSB]							
9		Command-specific information						
10								
11								[LSB]
12	Additional sense code							
13	Additional sense code qualifier							
14	X'00'							
15	SKSV							
16		Sense key-specific information						
17								
18	0	0	0	Port	0	0	0	0
19	CDB operation code							
20		Detail information						
47								

Basic information: Byte 0 – 17
Additional information: Byte 18 – 47
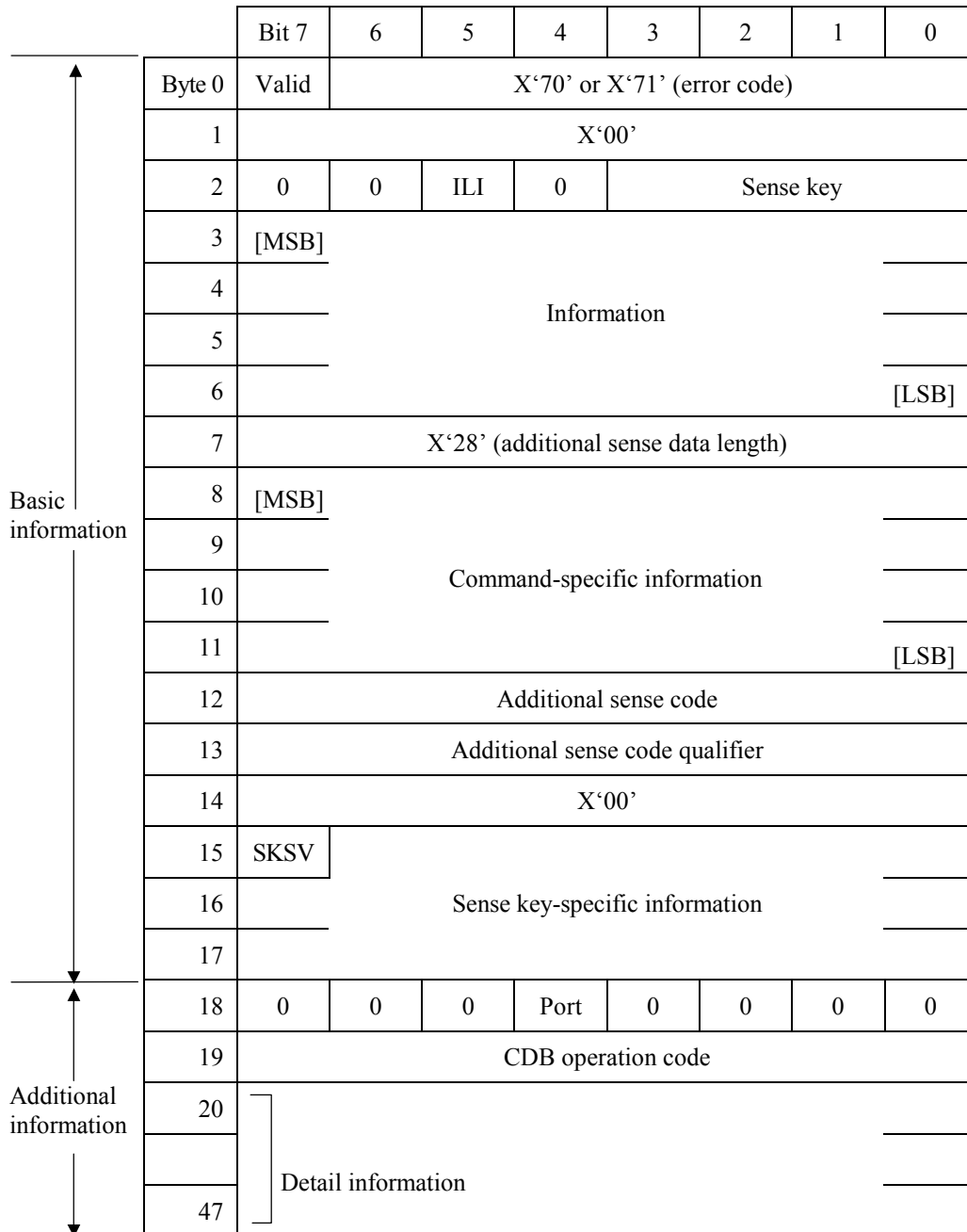
ILI: Incorrect Length Indicator
MSB: Most Significant Byte
LSB: Least Significant Byte
SKSV: Sense Key Specific Valid

Figure 7.1   Format of extended sense data

7.2   Sense Data Analysis

7.2.1   Error information indicated with sense data

Subsection 7.2.2 onwards explain troubleshooting using sense data. For details of the following sense data, refer to Chapter 5 "Sense Data Error Recovery Methods" of the Interface Specifications.

Table 7.1 lists the definition of sense data. For details of sense data, refer to the Interface Specifications.

Table 7.1   Definition of sense data

Sense data			Definition
Sense key	Additional sense code	Additional sense code qualifier	
3	0C	03	A write to a disk terminated abnormally.
4	32	01	Failed to update the defect list (due to unrecoverable error during write, verify error after write.).
	40	xx	An error occurred in power-on self-diagnosis.
	C4	xx	A drive error occurred.
1 3	1x 1x	xx xx	A disk read error occurred. A disk read error occurred.
E	1D	00	Data discrepancy found by VERIFY command byte check.
5	2x	xx	A SCSI error, such as an invalid operation code, occurred.
4 or B	44	xx	A hardware error occurred inside HDDs.
B	47	xx	An interface error occurred.
	4B	xx	An interface error occurred.
	4E	00	An overlap command was issued.

7.2.2   Sense data (3-0C-03), (4-32-01), (4-40-xx), (4-C4-xx), and (4-44-xx)

Sense data (3-0C-03), (4-32-01), (4-40-xx), (4-C4-xx), and (4-44-xx) indicate one of the following:

- A target sector could not be detected using the sector counter.

- A seek process overran the specified time.

- A write to a disk terminated abnormally.

- An error occurred in power-on self-diagnosis.

- A drive error occurred.

The symptoms above are generally caused by an error in a PCA or DE.

7.2.3   Sense data (1-1x-xx), (3-1x-xx) and (E-1D-00): Disk read error

If sense data (1-1x-xx), (3-1x-xx) or (E-1D-00) occurs frequently in a specific block of a disk, there is disk damage that was not recorded in the media defect list. In this case, assign an alternate block to the error-detected block using a REASSIGN BLOCKS command. For an explanation of the REASSIGN BLOCKS command, refer to Subsection 4.3.2 "REASSIGN BLOCKS (07)" of the Interface Specifications.

If this error occurs in different blocks, a PCA or DE is faulty.

7.2.4   Sense data (5-2x-xx), (B-44-xx), (B-47-xx), (B-4B-xx) and (B-4E-00): interface error

Sense data (5-2x-xx), (B-44-xx), (B-47-xx), (B-4B-xx) and (B-4E-00) indicates one of the following symptoms:

- An invalid or unsupported command was issued, or invalid or unsupported parameters were specified.

- An interface error occurred.

- A hardware error occurred inside HDDs.

If this error occurs, the PCA or the interface is faulty.

Glossary

Additional Sense Code

This is a 1-byte code displayed in the sense data and is information which specifies the type of error that was detected.

CCS

Common Command Set
This is the standard form of SCSI logical specifications stipulated by the operations subcommittee of the American National Standards Institute (ANSI) which stipulates functions which a direct access device (magnetic disk, etc.) should support.

CDB

Command Descriptor Block
A series of data which describes commands related to input/output operations, sent from the initiator to the target.

Command

This is a command to a target to perform an input/output operation, and it is described as the CDB.

Initiator (INIT)

This is an SAS device which initiates input and output operations on the SAS bus. In this manual, initiator has been abbreviated to "INIT."

SAS Device

The general name given to a device which is connected to the SAS bus (input/output device, I/O controller, host adapter, expander, etc.).

SCSI

Small Computer System Interface
The standardized input/output interface of the American National Standards Institute (ANSI). [Standard No.: ANSI X3. 131-1986]

Sense Data

When several items of error information are included in a command's completion status, this is information generated by the target for reporting detailed information on that status.

Sense Key

This is a 4-bit code displayed in the sense data. It contains information for classifying the type of error that was detected.

Status

This is 1 byte of information reported to the initiator by the target device when execution of each command is completed, which displays the command's completion state.

Target (TARG)

This is the SAS device that executes the input/output operations initiated by the initiator (INIT). In this manual, target is abbreviated "TARG."

Acronyms and Abbreviations

A

AC	Alternating Current
ACK	ACKnowledge primitive
AEN	Asynchoronous Event Notification
ALT	ALTernated (block)
ARRE	Automatic Read Reallocation Enabled
ASCII	American Standard Code for Information Interchange
ASG	ASiGned block
AWG	American Wire Gauge
AWRE	Automatic Write Reallocation Enabled

B

bpi	bits per inch
BytChk	Byte Check

C

C list	Target Certification list
CCS	Common command set
CDB	Command descriptor block
CE	Customer Engineer
CmpLst	Complete List
CRC	Cyclic Redundancy Check
CYL	CYLinder

D

D	Depth
D list	Data Defect List
DBD	Disable Block Descriptor
DC	Direct Current
DCR	Disable Correction
DCRT	Disable CeRtificaTion
DE	Disk Enclosure
DEF	DEFective block
DevOfl	Device Offline
DPO	Disable Page Out
DPRY	Disable PRimarY
DSP	Disable Saving Parameters
DTDC	Data Transfer Disconnect Control
DTE	Disable Transfer on Error

E

ECC	Error Correction Code
EER	Enable Early Recovery
EVPD	Enable Vital Product Data

F

FG	Frame Ground
FIFO	First In First Out
FmtData	Format Data
FOV	Format Options Valid
FUA	Force Unit Access

G

G	Gap
G list	Grown defect list

H

H	Height
HDC	Hard Disk Controller
HDD	Hard Disk Drive
HSEC	Hard SECtor

I

ID	IDentifier
ILBN	Ideal Logical Block Number
Immed	Immediate
INDX/SCT	INDeX/SeCTor
IP	Initialization Pattern
ISG	InterSector Gap

L

LBdata	Logical Block data
LBN	Logical Block Number
LED	Light Emitting Diode
LUN	Logical Unit Number
LSI	Large-Scale Integration Circuit

M

MPU	MicroProcessor Unit
MR	Magnetro Resistive
MS	Multiple Select

N

NACK	Negative ACKnowledge primitive

O

OEM	Original Equipment Manufacturer

P

P list	Primary defect list
P/N	Parts/Number
PBdata	Physical Block data
PC board	Printed Circuit board
PCA	Printed Circuit Assembly
PER	Post ERror
PF	Page Format
PLO Sync	Phase Lock Oscillator Syncronous
PMI	Partial Medium Indicator
PR4ML	Partial Response class 4 Maximum Likelihood

R

RC	Read Continuous
RCD	Read Cache Disable
RH	Relative Humidity
RMB	ReMovaBle
RSV	ReSerVed

S

S/N	Serial/Number
SAS	Serial Attached SCSI
SBd	Synchronized Byte data area
SBi	Synchronized Byte identifier area
SCSI	Small Computer System Interface
SCT	SeCTor
SelfTest	Self Test
SG	Signal Ground
SP	Save Page
SPR	SPaRe block
SR	Servo
SSEC	Soft SECtor
STPF	SToP Format
SURF	SURFace

T

TB	Transfer Block
TPI	Tracks Per Inch
TRM	TeRMinator

U

UnitOfl	Unit Offline

V

VCM	Voice Coil Motor
VPD	Vital Product Data
VU	Vendor Unique

W

W	Width
WCE	Write Cache Enable
WP	Write Protect
WWN	World Wide Name

Index

T

U

V

W

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