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OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS

CATEGORY: HARDWARE STANDARD
SUBCATEGORY: INTERFACE

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Foreword

Federal Information Processing Standards Publications of the National Bureau of Standards are adopted and promulgated under the provisions of Public Law 89-306, and Part 6 of Title 15 Code of Federal Regulations. The standards are required for implementation by Federal agencies in the acquisition, development and use of automated information systems and in the interchange of data between and among agencies and with the public. The use of such standards which are adopted after extensive review by Federal agencies, industry and the public is intended to reduce Government costs and improve the effectiveness of Government services.

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Ernest Ambler, *Director*

Abstract

This Federal Information Processing Standard specifies the command, status and sense codes associated with three classes of rotating mass storage subsystems designed to be employed with the I/O channel interface prescribed by FIPS 60-1. The three classes of rotating mass storage subsystems provided for are: Class A with 100 to 200 megabytes per logical device address; Class B with 317.5 megabytes per logical device address; Class C with 35 or 70 megabytes per logical device address. The provisions of this standard are effective on June 23, 1980.

KEY words: Command codes; disk drives; Federal Information Processing Standard; format track; operational specification; rotating mass storage subsystems; sense information; status byte.

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ANNOUNCING THE STANDARD FOR

OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS

Federal Information Processing Standards Publications are issued by the National Bureau of Standards pursuant to the Federal Property and Administrative Services Act of 1949, as amended, Public Law 89-306 (79 Stat. 1127), Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 Code of Federal Regulations (CFR).

Name of Standard. Operational Specifications for Rotating Mass Storage Subsystems (FIPS PUB 63).

Category of Standard. Hardware Standard, Interface.

Explanation. This standard defines the peripheral device dependent operational interface specifications for connecting rotating mass storage equipment as a part of automatic data processing (ADP) systems. It is to be used together with FIPS PUB 60, I/O Channel Interface and FIPS PUB 61, Channel Level Power Control Interface. This standard, together with these two referenced standards provides for full plug-to-plug interchangeability of rotating mass storage equipment as a part of ADP systems.

The Government's intent in employing this standard for Operational Specifications for Rotating Mass Storage Subsystems is to reduce the cost of satisfying its data processing requirements through increasing its available alternative sources of supply for computer systems components at the time of initial system acquisition, as well as in system replacement augmentation and in system component replacement. This standard is also expected to lead to improved reutilization of system components.

When acquiring ADP systems and system components, Federal agencies shall cite this standard in specifying the interface for connecting rotating mass storage peripheral equipment as a part of ADP systems.

Approving Authority. Secretary of Commerce.

Maintenance Agency. Department of Commerce, National Bureau of Standards (Institute for Computer Sciences and Technology).

Cross Index. American National Standards Institute document X3T9/848 Rev. 2, Draft Proposed Operational Specifications for Rotating Mass Storage Subsystems. This operational specification is in turn supplemented by three draft proposed American National Standards, each of which provides supplemental track format definition and specifies the sense information format and content for a particular class of rotating mass storage devices: (1) American National Standards Institute document X3T9/904 Rev. 1, Draft Proposed American National Standard Class A Rotating Mass Storage Device Specification, (2) American National Standards Institute document X3T9/905 Rev. 1, Draft Proposed American National Standard Class B Rotating Mass Storage Device Specification, and (3) American National Standards Institute document X3T9/906 Rev. 1, Draft Proposed American National Standard Class C Rotating Mass Storage Specification.

Applicability. This standard is applicable to the acquisition of all rotating mass storage equipment whenever the use of Federal Information Processing Standard I/O Channel Interface (NBS-FIPS-PUB 60) is required.

Verification of the correct operation of all interfaces that are required to conform to this standard shall, through demonstration or other means acceptable to the Government, be provided prior to the acceptance of all applicable ADP equipment.

Specifications. This standard incorporates by reference the technical specifications of the following ANSI documents: X3T9/904 Rev. 1, X3T9/905 Rev. 1, and X3T9/906 Rev. 1, and X3T9/848 Rev. 2.

Copies of the technical specifications section of the standard will be available from the National Technical Information Service as described in the **Where To Obtain Copies** section below.

Implementation. The provisions of this standard are effective June 23, 1980.

All applicable equipment ordered on or after the effective date, or procurement actions for which solicitation documents have not been issued by that date, must conform to the provisions of this standard unless a waiver has been granted in accordance with the procedure described elsewhere in this publication.

Regulations concerning the specific use of this standard in Federal procurement will be issued by the General Services Administration to be a part of the Federal Property Management Regulations.

This standard shall be reviewed by NBS within three years after its effective date, taking into account technological trends and other factors, to determine whether the standard should be affirmed, revised, or withdrawn.

Waivers. Heads of agencies desiring a waiver from the requirements stated in this publication, so as to acquire ADP equipment that does not conform to this standard, shall submit a request for such a waiver to the Secretary of Commerce for review and approval. Approval will be granted if, in the judgment of the Secretary based on all available information, including that provided in the waiver request, a major adverse economic or operational impact would occur through conformance with this standard.

A request for waiver shall include: (1) a description of the existing or planned ADP system for which the waiver is being requested, (2) a description of the system configuration, identifying those items for which the waiver is being requested, and including a description of planned expansion of the system configuration at any time during its life cycle, and (3) a justification for the waiver, including a description and discussion of the major adverse economic or operational impact that would result through conformance to this standard as compared to the alternative for which the waiver is requested.

The request for waiver shall be submitted to the Secretary of Commerce, Washington, D.C. 20230, and labeled as a Request for Waiver to a Federal Information Processing Standard. Waiver requests will normally be processed within 45 days of receipt by the Secretary. No action shall be taken to issue solicitation documents or to order equipment for which this standard is applicable and which does not conform to this standard prior to receipt of a waiver approval response from the Secretary.

Where To Obtain Copies. Either paper or microfiche copies of this Federal Information Processing Standard, including the technical specifications, may be purchased from the National Technical Information Service (NTIS) by ordering Federal Information Processing Standard Publication 63 (NBS–FIPS–PUB–63), Operational Specifications for Rotating Mass Storage Subsystems. Ordering information, including prices and delivery alternatives, may be obtained by contacting the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Virginia 22161, Telephone: (703) 557-4650.

TECHNICAL SPECIFICATIONS

FOR

OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS

X3T9/848 Rev. 2
1978 July 25
X3 Project 52

Draft Proposed

American National Standard

OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS

Prepared by
Technical Committee X3T9—I/O Interface

American National Standards Committee
X3—Computers and Information Processing

Secretariat: Computer and Business
Equipment Manufacturers Association

Abstract

The operational specifications are defined for rotating mass storage subsystems that attach to the proposed ANS I/O Channel Interface, BSR X3.67. This will facilitate the interconnection of rotating mass storage subsystems to general purpose computer systems.

To complete the specification of rotating mass storage subsystems, subsequent standard specifications of track format and sense information are needed for each device class.

Full "plug-to-plug" interchangeability is possible if no changes in hardware or software components in the system are required when interchanging rotating mass storage subsystems. This standard provides operational specifications that define the command codes, data formats, program considerations, etc., for rotating mass storage subsystems. The I/O Channel Interface standard provides functional, electrical, and mechanical specifications for attaching I/O subsystems to the I/O channel of a general purpose computing system.

Foreword

(This Foreword is not part of the standard for Operational Specifications for Rotating Mass Storage Subsystems).

This Standard provides the specifications for the operational characteristics of rotating mass storage subsystems that attach to the proposed ANS I/O Channel Interface, BSR X3.67. The I/O Channel Interface is the communication link between a general purpose computer system I/O channel and various I/O control units. Rotating mass storage subsystem refers to the combined rotating mass storage control unit and device subsystem.

The I/O Channel Interface standard provides specifications for the functional, electrical, and mechanical characteristics of the I/O Channel Interface. This includes the general

specification of address, command, status and data information flow over the I/O Channel Interface.

The Rotating Mass Storage Subsystem standard specifies the logical interface between one class of peripheral subsystem (rotating mass storage) and the Standard I/O Channel, including:

(1) Addressing formats for rotating mass storage control units and devices.
(2) Command formats for the control of rotating mass storage control units and devices.
(3) Data formats for transfer of data to and from rotating mass storage subsystems.
(4) Record formats for the rotating mass storage media.
(5) Programming consideration for rotating mass storage subsystems.

To complete the specification of rotating mass storage subsystems, subsequent standard specifications of track format and sense information are needed for each device class.

Contents

OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS

1. INTRODUCTION. This Standard is one of several standards that, as a set, specify I/O subsystem interconnections to general purpose computer systems.

1.1 Scope. This Standard specifies the operational characteristics of rotating mass storage subsystems that attach to I/O channel interfaces utilizing the proposed ANS I/O Channel Interface, BSR X3.67, to facilitate plug-to-plug compatibility and ensure interchangeability of rotating mass storage subsystems used on I/O channels of general purpose computer systems. It is distinct from a specification in that it delineates a minimum set of restrictions consistent with compatibility and interchange.

To complete the specification of rotating mass storage subsystems, subsequent standard specifications of track format and sense information are needed for each device class.

1.2 I/O Channel Interface. The proposed ANS I/O Channel Interface, BSR X3.67, specifies the functional, electrical, and mechanical characteristics of the interface which serves as the communications link between the general purpose computer system's I/O channel and the rotating mass storage subsystem.

1.3 Power Control Interface. The proposed ANS Power Control Interface, BSR X3.68, specifies the functional and mechanical characteristics which provide a sequential and interlocked means of controlling the power supplied by the general purpose computer system to the rotating mass storage subsystem.

1.4 Subsystem Organization.

See figure 1 and descriptions below.

1.4.1 Control Units. A basic RMS (Rotating Mass Storage) subsystem consists of a single control unit and one attached RMS device. Multiple control units and devices can be inter-connected, limited only by the addressable range limits of each.

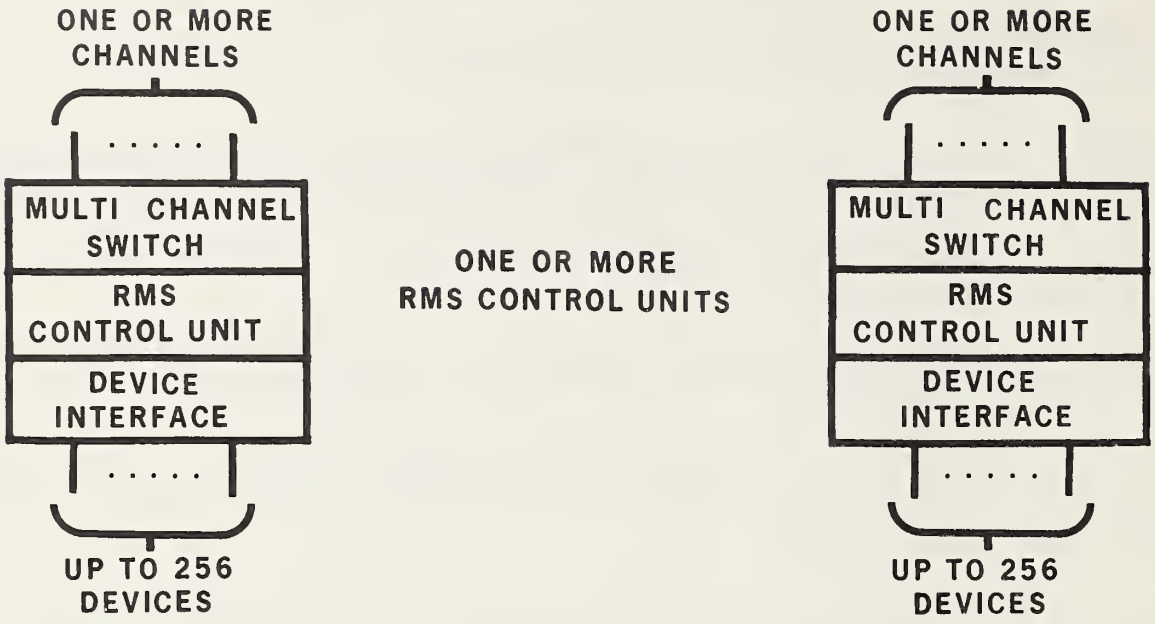
1.4.2 Multi-Channel Switch. Each control unit may be optionally accessed via more than one I/O Channel Interface. This permits programming control (within the computing system) over the sharing of RMS control units. The control-unit-busy sequence, specified in the ANS I/O Channel Interface standard, is used to inform one channel's requested use of the control unit that the control unit is busy on another channel.

The additional channel interface(s) may be for the first computer system or for other computer systems.

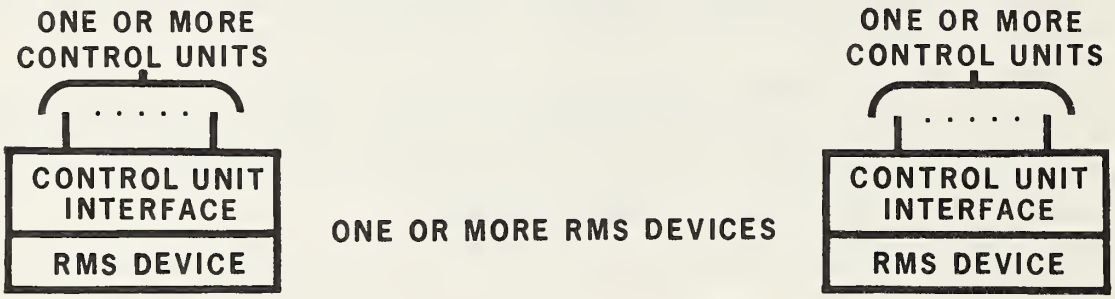
1.4.3 Device Sharing. A multiple rotating mass storage control unit subsystem provides for shared access of multiple rotating mass storage devices by any of several shared access techniques. This allows for fully shared access of attached rotating mass storage devices by two or more control units.

The device sharing may be accomplished by a dynamic switch, multiple sub-control-units each supporting one or more devices, multiple control unit access at the device level, any combination of the above or any other technique affecting device sharing.

It is not the intention of this standard to specify the architecture of the technique used to accomplish device sharing, only its externally observable (outside of the rotating mass storage subsystem) characteristics. In all configurations, device sharing is logically invisible except for busy responses due to a device or sharing path being used by another control unit.



ACCESS TO MULTIPLE DEVICES, AND DEVICE SHARING, BY MULTIPLE CONTROL UNITS MAY BE DONE VIA SEVERAL TECHNIQUES NOT SPECIFIED BY THIS STANDARD



RMS SUBSYSTEM CONFIGURATION

FIG. 1

1.5 Device Characteristics. The RMS subsystem includes rotating mass storage devices, drives or units that record (write) and read back digital information for storage purposes on a media not specified in this standard beyond the specification of the information records being stored. It is possible, and entirely within the scope of this standard, for the digital information records to be stored on a medium other than rotating magnetic disks, such as charge coupled devices, magnetic bubble memory, etc.

1.5.1 Information Structure. The basic information structure of the rotating mass storage device refers to the structure of information within a track, defined by a cylinder/head address, and consists of:

1.5.1.1 Basic Information Unit. The basic information unit is a byte consisting of eight (8) binary digits (bits).

1.5.1.2 Information Area. Areas are a group of bytes. Areas are separated by gaps and may include error detection/correction information.

Gaps are not defined by this standard and may not even exist explicitly as the actual storage media may offer an alternative way to delimit areas.

Error detection/correction information is not defined by this standard. Many different techniques exist and no attempt to preclude or specify them is included in this standard.

1.5.1.3 Information Record. An information record consists of one or more areas. Records are separated by gaps, just as areas are, and these gaps are not specified by this standard.

1.5.2 Record Address. A record has a location which is defined by the cylinder and head address (used by the Seek commands) and a 40 bit identifier (used by the Search commands).

1.5.3 Track Format. The logical track defined by a cylinder/head address consists of:

(1) an index point, marking the start of the track;

(2) a home address, when present, optionally supplies basic track information, immediately following the index point (and associated gap);

(3) Record Zero, an optional descriptor record, immediately following the home address (and associated gap);

(4) data records, one or more of them, immediately following record zero (and associated gap).

See figure 2 for pictorial representation of a track.

1.5.4 Index Point. The Index points indicate the start and end of a logical track; refer to figure 2. The indication of the end of a track by an index point is explicit.

1.5.5 Home Address. Each track optionally contains a home address area (HA) immediately following the index point (and associated gap); refer to figure 2. The home address contains the track identifier. The home address has the following format:

FHAID

F = Flag, 1 byte — defines track condition

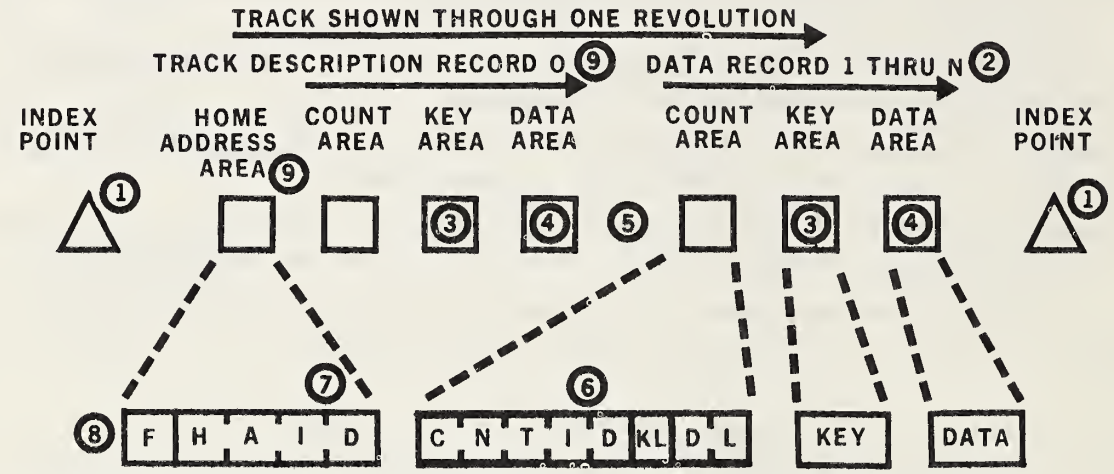
Bits, high order first

0–5 unspecified by this standard—further details on the specification of these bits are prescribed in separate standards, each pertaining to a particular device class

6–7 Track status
- 00 = primary track
- 01 = alternate track
- 1X = defective track (X = 0 or 1)

HAID = Home Address ID — a 32 bit identifier

Home addresses may have an error detection/correction code which is device specific, and is not specified here, either in length, type or use.



① THE TWO INDEX POINTS OCCURING AT THE BEGINNING AND END OF THE REVOLUTION MAY BE THE SAME ONE

② THE NUMBER OF DATA RECORDS DEPENDS ON THE DEVICE CHARACTERISTICS AND FORMATTING USED, UP TO 255

③ IF COUNT AREA KEY LENGTH (KL) ZERO, KEY AREA LOGICALLY NOT PRESENT

④ IF COUNT AREA DATA LENGTH (DL) ZERO, DATA AREA LOGICALLY NOT PRESENT

⑤ RECORD FORMAT IS IDENTICAL FOR RECORD 0 AND DATA RECORDS

⑥ CNTID IS A 40 BIT IDENTIFIER USED IN SEARCH ID COMMANDS

⑦ HAID IS A 32 BIT IDENTIFIER USED IN SEARCH HA COMMANDS

⑧ OPTIONAL UNSPECIFIED PRE HOME ADDRESS FIELD

⑨ OPTIONAL, MAY NOT BE PHYSICALLY PRESENT

RMS TRACK FORMAT

FIG. 2

1.5.6 Record Zero. Each track contains a first record, record zero (RO), immediately following the home address (and associated gap); refer to figure 2. Record zero may be used to contain track descriptor information, such as the alternate or defective track address.

The format for record zero is the same as for data records except that the count area of record zero may be used to contain the alternate or defective track address.

Special commands, Write RO and Read RO, are used to write and read record zero.

The use and length of the key and data areas is undefined, in this standard, for record zero.

1.5.7 Data Records. Each track contains one or more, up to 255, data records beginning after record zero (and associated gap); refer to figure 2. Data records contain key and data information.

Data records (and record zero) contain three areas—count, key, and data—that are defined when first written by a format write command (e.g., Write Count, Key, and Data).

Each area in a data record (and record zero) is followed by an error detection/correction code which is device specific, and is not specified here, either in length, type or use.

1.5.8 Count Area. All records include a count area before the key and data areas. The count area follows the inter record gap preceding the record and is separated by a gap from the key area (or data area if no key present); refer to figure 2.

The count area contains the record identifier and defines the size of key and data areas. The count area is written when the record is formatted with a format write command (e.g., Write Count, Key, and Data).

The count area format is:

CNTIDKDL

CNTID = Count Area ID — a 40 bit identifier

K = Key length, 1 byte — gives the length, in bytes, of the key area. If no key area is used its value is 0.

DL = Data length, 2 bytes — gives the length, in bytes, of the data area.

The count area is followed by an error detection/correction code which is device specific, and is not specified here, either in length, type or use.

1.5.9 Key Area. All records may optionally include a key area between the count and data areas. The key area, if present (indicated by a non-zero key length field in the count area), follows the post count area gap and precedes the pre data area gap; see figure 2.

The key area, if present, contains a logical key that may be used to identify the data in the data area. The key area is fixed in length during writing when the record is formatted with a format write command (e.g., Write Count, Key, and Data). The contents of the key area may be changed as required with a Write Key and Data command.

The key area format is a key field of the length specified in the key length field in the count area.

The key area, if present, is followed by an error detection/correction code which is device specific, and is not specified here, either in length, type or use.

15.10 Data Area. All records may have a data area after the key area, or count area if there is no key area. The data area follows the post key area (or count area) gap and is the third and final part of any record; see figure 2.

A logical End-of-File is indicated by detection of a zero data length in the count area.

The data area contains data that is the primary information being stored on the rotating mass storage subsystem. The data area is fixed in length during writing when the record is formatted with a format write command (e.g., Write Count, Key, and Data). The contents of the data area may be changed as required with a Write Data or Write Key and Data command.

The data area format is a data field of the length specified in the data length field in the count area.

The data area is followed by an error detection/correction code which is device dependent, and is not specified here, either in length, type or use.

1.6 Addressing. Every RMS device has a unique address consisting of an RMS control unit and an RMS device address. The method for assigning these addresses is not defined as part of this standard.

1.7 Control Unit Features.

1.7.1 Multitrack Operation (M/T). Optional multitrack operation is the ability to automatically select the next sequentially numbered head on the addressed device's cylinder during certain specific read and search commands. Multitrack operation is selectable on certain specific read and search commands (see command descriptions) by setting the high order bit of the command code to a one.

If M/T is selected on a given command, and the data transfer has not started, the next sequential head is selected at index. This eliminates the need for Seek Head commands in a chain of read or search commands.

The M/T operation must have a starting point indicated before it is used. If a multitrack search is started without a Read HA or Read R0, the required record may have passed the read head before the search is started. Thus the head sequencing would continue on to the next track, and ultimately to the end of the cylinder, without finding a comparison.

If a Set Sector command with a value of zero preceded the multitrack command, head switching before the record is reached may again occur.

A correct use of M/T would be:

Set File Mask	(to allow Write and Seek commands)
Seek	(to the beginning cylinder and track)
Read HA	(to guarantee a start at Index Point)
Search Key Equal	(M/T on)
(loop on Search Key Equal until desired record found)	
Write Data	(to update desired record in cylinder)

Note that if head switching operations cross a file-protected boundary or exceed a cylinder limit, channel end, device end and unit check will be presented to the channel.

Multitrack operation can not be selected on Read IPL and Read Sector commands.

1.7.2 Record Overflow. The optional record overflow feature allows records that exceed

the capacity of a track to be continued on the next logical track within the cylinder. Each part of an overflow record is called a segment. Each segment contains count, optional key and data area, as do all records.

The key and data lengths specified by KL and DL in each segment count area apply only to the record segment, not the entire multi-segment record. Since the only significant key area is in the first segment, the remaining segments do not need a key area for normal search key purposes.

1.7.2.1 Overflow Record Formatting. All overflow records, except the last segment, are formatted by the Write Special CKD command. The last segment uses a normal Write CKD command.

All head switching must be done by the formatting program. A correct example of this is:

Seek Head for starting track (track 1 in this case)
Set Sector
Search ID for record 1
(loop on Search ID until record 1 is found)
Write Special CKD to format segment 1 following record 1
Seek Head for next track (track 2 in this case)
Search ID for record 0
(loop on Search ID until record 0 found)
Write Special CKD to format segment 2 following R0
Seek Head for next track (track 3 in this case)
Search ID for record 0
(loop on Search ID until record 0 is found)
Write CKD to format last segment (3) following R0

Except for the first, all record segments must be written immediately following R0, and all segments but the last must be the last actual physical record on a track.

1.7.2.2 Overflow Record Processing. Overflow records can be read or updated (written) with Read Data, Read KD, Read CKD, Write Data, and Write KD commands. A data length of zero in any segment before the last will terminate the record overflow process on read.

The logical track address is incremented by one at the Index Point and the operation continues on the next track. When a segment is found that is not flagged (as an overflow record), the operation terminates at the end of the data area. The net effect of this overflow record process is that the data areas of all segments (for the given record) appear as a single logical record data area.

If a data overrun occurs, unit check should be signaled immediately, or as soon as practically possible, to allow the controlling channel to attempt error recovery at whatever level appropriate.

If a data check or bus out parity error occurs, unit check should be signaled as soon as practically possible.

If the transfer count is less than the number of bytes in the total logical record, the operation continues to the end of the logical record before presenting status.

Spacing over overflow records does not occur automatically. For example, in the sequence:

Set Sector

Search ID for segment 1
(loop on Search ID until segment 1 found)
Read CKD M/T

the Read CKD does not read the next logical record on the cylinder. It commences reading the overflow record at the count field of segment 2.

The sequence:

Set Sector
Search ID for segment 1
(loop on Search ID until segment 1 found)
Read KD
Read CKD M/T

will read the count, key and data of the next logical record.

Multitrack operations should not be confused with overflow record operations. Head switching, when processing overflow records, occurs automatically regardless of whether M/T is on or off.

An example of a correct read or write sequence is:

Set Sector
Search ID for segment 1 of logical record
(loop on Search ID until segment 1 is found)
Read Data or Write Data.

Note that in this example all data areas of the logical record will be read or written, not just the data area of segment 1.

1.7.3 End-Of-File. The end-of-file feature uses a special end-of-file record format to define the end of a logical group of records, and is written by executing a Write CKD command with the DL bytes in the count area set to zero. The KL byte in the count area can be either zero or non-zero as the recognition of an end-of-file record does not rely on the presence or absence of a key area.

Unit exception status is generated if a zero data length is found and no data from the data area is sent to the channel. A Read R0, Read CKD, or Read KD transfers the key area, if any, to the channel. The unit exception is generated during execution of Read IPL, Read R0, Read CKD, Read KD, Read Data, Write KD, and Write Data commands.

1.7.4 Rotational Position Sensing. The rotational position sensing (RPS) feature aids in reducing the time required for the channel to search for a record. This feature allows a Search command to be started just before the required record comes to the point where it may be read or written (read/write head for a rotating mass type device).

RPS is accomplished by dividing the storage tracks into sectors. Each track in the cylinder is divided into equally spaced sectors, thus each record on a track has an approximate angular position sector location as well as its record address. The sector location is not physically indicated within the record.

A Set Sector command is used to inform the storage control unit what the sector number is for a given Search and Read/Write command chain that follows. The storage control unit will signal channel end immediately after receiving the sector number from the channel. Device end is not sent to the channel until the storage control unit has arrived at the angular position specified, thus allowing the channel to be utilized for other operations

until the device is actually capable of efficiently proceeding with the Search and Read/Write chain.

A correct example of the use of RPS is:

Seek	(channel available while heads are accessed)
Set Sector	(channel available while rotating mass rotating to sector)
Search ID Equal	(busy only a short time to find next record)
(loop till Search ID Equal	satisfied, normally next record)
Read/Write Data	(transfer data)

The method for determining the sector location of a record is device dependent and no attempt is made by this standard to specify the required formulae.

1.8 Abbreviations.

CKD	Count, Key and Data
DL	Data Length
HA	Home Address
ID	Identification
I/O	Input/Output
IPL	Initial Program Load
KD	Key and Data
KL	Key Length
M/T	Multitrack; also Multiple Track
R0	Record Zero
RMS	Rotating Mass Storage
RPS	Rotational Position Sensing

1.9 Definitions.

CONTROL UNIT — Provides control over the devices of the RMS subsystem.

COUNT AREA — The part of a record defining the record status, cylinder/head/record number and the key and data length of the record.

CYLINDER — All the tracks at a given accessor position.

DATA AREA — The part of a record containing data.

DEVICE — A rotating mass storage access mechanism.

DRIVE — Typically used alternative name for device.

HEAD — Defines the unique track at an accessor position.

HOME ADDRESS — An optional area at the beginning of a track, following the index point, which may define the track status, cylinder number and head number.

INDEX POINT — Marks indicating the start and end of a track.

KEY AREA — The optional part of a record defining a key for searching purposes.

RECORD, OR INFORMATION RECORD — All the information at a given cylinder/head/record address.

RECORD ZERO — A record immediately following the home address at the beginning of a track, optionally defining track defect and other descriptive information.

ROTATING MASS STORAGE — The physical file storage medium wherein data is cyclically available. For example, magnetic disk, charge-coupled (shift register) storage, magnetic bubble storage, etc.

TRACK — All the information at a given cylinder/head address.

2. COMMAND DESCRIPTIONS.

2.1 Commands. Commands executed by rotating mass storage subsystems fall into one of the following categories:

(1) Control Commands
(2) Search Commands
(3) Read Commands
(4) Sense Commands
(5) Write Commands

Figure 3 lists the commands that must be recognized and executed by a RMS subsystem to provide interchangeability. Also included in figure 3, for reference purposes, are certain optional commands which may be implemented in rotating mass storage subsystems, but which are not a requirement for interchange ability. RMS subsystems may have additional commands implemented to aid in fault recognition, diagnosis, logging, etc. at the discretion of the individual vendor. Attempts to execute commands that are not implemented in a given rotating mass storage control unit shall result in a unit check status response with a command reject indicated in the sense information.

2.2 Optional Command Extensions. Certain command codes are in extensive, but not unanimous, usage and are defined as being optional command extensions to provide specific design/device dependent functions.

2.3 Control Commands.

2.3.1 No-Op.

COMMAND CODE 0000 0011 binary, 03 hexadecimal.

NO-OP an immediate command; causes no action at addressed device; no data is transferred except for indiscriminate usage situations, see example below.

CHANNEL END AND DEVICE END presented in initial status unless No-op follows a format write command. Then initial status is zero and channel end and device end are presented during ending status.

INDISCRIMINATE USAGE must be avoided; a No-op resets orientation information and causes all or parts of records to be skipped.

> EXAMPLE a No-op between Read Count and Read Data results in the following record's data being read.
>
> EXAMPLE a No-op between a command that reads the data field of record n–1 and a command that must process the count area of record n, may skip record n and process the count area of record n+1.

2.3.2 Recalibrate.

COMMAND CODE 0001 0011 binary, 13 hexadecimal.

COMMAND	COMMAND CODE			
	Multitrack Off		Multitrack On	
	Hex	Binary	Hex	Binary
CONTROL				
No Operation	03	0000 0011		
Recalibrate	13	0001 0011		
Seek	07	0000 0111		
Seek Cylinder	0B	0000 1011		
Seek Head	1B	0001 1011		
Space Count	0F	0000 1111		
Set File Mask	1F	0001 1111		
Set Sector	23	0010 0011		
Restore	17	0001 0111		
SEARCH				
Home Address Equal	39	0011 1001	B9	1011 1001
Identifier ID Equal	31	0011 0001	B1	1011 0001
Identifier ID High	51	0101 0001	D1	1101 0001
Identifier ID Equal or High	71	0111 0001	F1	1111 0001
Key Equal	29	0010 1001	A9	1010 1001
Key High	49	0100 1001	C9	1100 1001
Key Equal or High	69	0110 1001	E9	1110 1001
READ				
Home Address	1A	0001 1010	9A	1001 1010
Count	12	0001 0010	92	1001 0010
Record Zero (R0)	16	0001 0110	96	1001 0110
Data	06	0000 0110	86	1000 0110
Key and Data	0E	0000 1110	8E	1000 1110
Count, Key, and Data	1E	0001 1110	9E	1001 1110
IPL	02	0000 0010		
Sector	22	0010 0010		
SENSE				
Input/Output (I/O)	04	0000 0100		
Read and Reset Buffered Log	A4	1010 0100		
Device Reserve	B4	1011 0100		
Device Release	94	1001 0100		
WRITE				
Home Address	19	0001 1001		
Record Zero (R0)	15	0001 0101		
Erase	11	0001 0001		
Count, Key, and Data	1D	0001 1101		
Special Count, Key, and Data	01	0000 0001		
Data	05	0000 0101		
Key and Data	0D	0000 1101		

Figure 3 Rotating Mass Storage Subsystem Commands

COMMAND	COMMAND CODE			
	Multitrack Off		Multitrack On	
	Hex	Binary	Hex	Binary
CONTROL OPTIONAL EXTENSIONS				
Seek and Set Sector	27	0010 0111		
Vary Sensing	27	0010 0111		
Orient	2B	0010 1011		
Set RPS	2F	0010 1111		
SEARCH OPTIONAL EXTENSIONS				
Key and Data Equal	2D	0010 1101	AD	1010 1101
Key and Data High	4D	0100 1101	CD	1100 1101
Key and Data Equal and High	6D	0110 1101	ED	1110 1101
CONTINUE SCAN OPTIONAL EXTENSIONS				
Search Equal	25	0010 0101	A5	1010 0101
Search High	45	0100 0101	C5	1100 0101
Search High and Equal	65	0110 0101	E5	1110 0101
Set Compare 1	35	0011 0101	B5	1011 0101
Set Compare 2	75	0111 0101	F5	1111 0101
No Compare	55	0101 0101	D5	1101 0101
READ OPTIONAL EXTENSIONS				
Multiple Count, Key, and Data 1	5E	0101 1110		
Multiple Count, Key, and Data 2	DE	1101 1110		
SENSE OPTIONAL EXTENSIONS				
Input/Output Type	E4	1110 0100		
Unconditional Reserve	14	0001 0100		
DIAGNOSTIC OPTIONAL EXTENSIONS				
Diagnostic Load	53	0101 0011		
Diagnostic Write	73	0111 0011		
Read Diagnostic Status 1	44	0100 0100		
Read Diagnostic Trace Data	82	1000 0010		

Figure 3 Rotating Mass Storage Subsystem Commands (cont.)

RECALIBRATE causes addressed drive to seek to cylinder zero, head zero; no data is transferred.

INITIAL STATUS byte normally zero; not processed as an immediate command; ending status follows immediately.

CHANNEL END presented in ending status.

DEVICE END presented when drive positions the access mechanism to cylinder zero, head zero.

FILE MASK must be set to allow Seek commands.

2.3.3 Seek

COMMAND CODE 0000 0111 binary, 07 hexadecimal.

SEEK transfers the six-byte seek address from channel to storage control unit.

INITIAL STATUS normally zero.

STORAGE CONTROL selects drive, moves access mechanism to proper cylinder, and selects proper head.

ACCESS MOTION if any, initiated after seek address transfer.

TRANSFER COUNT >SIX control unit transfers only six bytes of address information.

TRANSFER COUNT <SIX Seek is not executed. Unit check, channel end, and device end are presented in ending status. A subsequent Sense command indicates command reject.

SEEK ADDRESS FORMAT *XXCCHH* where *XX* is 16 undefined bits, *CC* is a 16 bit cylinder number, and *HH* is a 16 bit head number.

INVALID SEEK ADDRESS for the selected drive. Seek not executed. Unit check, channel end, and device end are presented. A subsequent Sense command indicates command reject.

PARITY ERROR detected in seek address transfer: command not executed; unit check, channel end, and device end presented in ending status. A subsequent Sense command indicates bus out parity error.

FILE MASK must allow Seeks or unit check is presented in initial status.

CHANNEL END presented after seek address transfer.

DEVICE END presented with channel end if no movement; with movement, presented after access mechanism is positioned.

2.3.4 Seek Cylinder.

COMMAND CODE 0000 1011 binary, 0B hexadecimal.

SEEK CYLINDER transfers the six-byte seek address from channel to storage control unit.

INITIAL STATUS normally zero.

STORAGE CONTROL selects drive, moves access mechanism to proper cylinder, and selects proper head.

ACCESS MOTION if any, initiated after seek address transfer.

TRANSFER COUNT >SIX control unit transfers only six bytes of address information.

TRANSFER COUNT <SIX Seek Cylinder not executed. Unit check, channel end, and device end presented. A subsequent Sense command indicates command reject.

SEEK ADDRESS FORMAT *XXCCHH* where *XX* is 16 undefined bits, *CC* is a 16 bit cylinder number, and *HH* is a 16 bit head number.

INVALID SEEK ADDRESS Seek not executed. Unit check, channel end, and device end are presented. A subsequent Sense command indicates command reject.

PARITY ERROR detected in seek address transfer: command not executed; unit check, channel end, and device end presented. A subsequent Sense command indicates bus out parity error.

FILE MASK must allow Seeks or unit check is presented in initial status.

CHANNEL END presented after Seek address transfer.

DEVICE END presented with channel end if no movement; with movement, presented after access mechanism is positioned.

2.3.5 Seek Head.

COMMAND CODE 0001 1011 binary, 1B hexadecimal.

SEEK HEAD transfers the six-byte seek address from channel to storage control unit.

INITIAL STATUS normally zero.

STORAGE CONTROL selects drive and proper head.

TRANSFER COUNT >SIX control unit transfers only six bytes of address information.

TRANSFER COUNT <SIX Seek Head not executed. Unit check, channel end, and device end are presented. A subsequent Sense command indicates command reject.

VALID SEEK ADDRESS REQUIRED however, only the head address specified in the sixth byte is significant.

SEEK ADDRESS FORMAT *XXCCHH* where *XX* is 16 undefined bits, *CC* is a 16 bit cylinder number, and *HH* is a 16 bit head number.

INVALID SEEK ADDRESS Seek Head not executed. Unit check, channel end, and device end are presented. A subsequent Sense command indicates command reject.

PARITY ERROR detected in seek address transfer: command not executed; unit check, channel end, and device end presented. A subsequent Sense command indicates bus out parity error.

FILE MASK must allow Seeks or unit check is presented in initial status.

CHANNEL END/DEVICE END presented after seek address transfer.

2.3.6 Space Count.

COMMAND CODE 0000 1111 binary, 0F hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS cannot be chained from a format Write or Erase command. Cannot be followed by a Write, Erase, Read IPL, or Set File Mask command in the same chain.

SPACE COUNT bypasses a defective count area to allow data recovery in key and/or data areas following the defective area.

INITIAL STATUS normally zero.

STORAGE CONTROL performs the following steps:

Chained from Read, Write, Search or Space Count Command

1. Orients at start of next count area.
2. Spaces over the count area.
3. Key and data length are transferred as data from channel.
4. Presents channel end and device end to channel.

NOTE: If the track is flagged defective, the Space Count should always follow a Search ID Equal to provide consistent results.

Using the above:

Command chain (a) may be used to recover key and data areas of record (n). Command chain (b) used to recover n+1.

(a) Set Sector
Search ID (loop until equal)
(record n–1)
Space Count*
Read KD

(b) Set Sector
Search ID (loop until equal)
(record n–1)
Space Count*
Read CKD

* Must specify correct key and data lengths.

If the Space Count is not chained from Read, Write, Search, or Space Count Command, the Storage Control:

1. Searches for index.
2. Clocks through gap 1, home address and gap 2.
3. Spaces over R0 count area.
4. Receives key and data length transfer from channel.
5. The control unit sets end-of-count-area internal orientation state indicator.
6. Presents channel end and device end to channel.

Using the above:

a. Space Count followed by Read Key and Data bypasses bad R0 Count area and allows recovery of R0 Key and Data.
b. Space Count followed by Read CKD reads R1.

DATA TRANSFERRED FROM CHANNEL used by storage control unit as key length (first byte) and data length (last two bytes) of record to be recovered.

TRANSFER COUNT >THREE three bytes are transferred.

TRANSFER COUNT <THREE the specified number of bytes are transferred.

NO BYTES TRANSFERRED storage control unit uses zero. Read Data and Read KD commands will receive unit exception status, Read CKD commands may find data checks if the key and data areas spaced over have data errors.

INVALID TRACK FORMAT if index found before command execution an invalid track format will be indicated in the sense data next read.

2.3.7 Set File Mask.

COMMAND CODE 0001 1111 binary, 1F hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Only one Set File Mask is permitted in a command chain. Should not be used in the same command chain with a Space Count command.

SET FILE MASK sets the write and seek masks which protect the data.

FILE MASK, 1 byte—defines file protection

Bits, high order first

0–1 write protection
- 00 = inhibit Write Home Address and Write R0
- 01 = inhibit all Write commands
- 10 = inhibit all format Write commands
- 11 = permit all Write commands

2 not specified

3–4 Seek protection
- 00 = permit all Seek commands
- 01 = permit Seek Cylinder and Seek Head
- 10 = permit Seek Head
- 11 = inhibit all Seek commands and head switching

5 reserved—diagnostic protection

6 must be zero or unit check, channel end, and device end are presented in initial status

7 reserved—PCI fetch mode

COMMAND EXECUTION allowed only once in command chain; more than one Set File Mask in a chain causes unit check in status:

COMMAND REJECT is indicated by subsequent Sense command if a second Set File is issued.

FILE MASK IS RESET to zeros at end of command chain.

WRITE COMMANDS violating file mask are not executed:

UNIT CHECK is presented in initial status.

COMMAND REJECT is indicated by subsequent Sense command.

SEEK COMMANDS violating file mask are not executed:

UNIT CHECK presented in initial status.

FILE PROTECTED indicated by subsequent Sense command (end-of-cylinder not set).

MULTITRACK/OVERFLOW operations violating file mask present unit check and file protect.

CHANNEL END/DEVICE END presented to channel after transfer of mask byte.

SYSTEM OR SELECTIVE RESET resets file mask to zeros.

ANY COMMAND following a reset without Set File Mask in command permits Seek and Write commands (except Write HA and Write R0).

DIAGNOSTIC WRITE violating file mask not executed and unit check is presented.

2.3.8. Set Sector.

COMMAND CODE 0010 0011 binary, 23 hexadecimal.

SET SECTOR allows the storage control unit to disconnect from the channel during rotational delay. This is done by Set Sector specifying an angular position section number to define when to continue the command chain.

COMMAND EXECUTION transfers a sector number from the channel to the storage control unit.

ANGULAR POSITIONS checked for validity by the storage control unit.

VALID ARGUMENT (device dependent, not specified by this standard):

At the end of the command, the storage control unit presents channel end and disconnects.

Device end signaled when angular position reached and channel reconnects; if interrupt stacked, request in is lowered and raised when angular position repeats.

If no reconnection, storage control unit attempts reconnection on following revolutions.

ZERO ARGUMENT Storage control unit attempts reconnection just before index.

ARGUMENT = 255

1. Command treated as a No-op.
2. Channel end/device end presented in ending status.
3. Track orientation is destroyed.

INVALID ARGUMENT Channel end, device end, and unit check presented in ending status. Command reject indicated in a subsequent Sense command.

PROGRAMMING NOTE

1. The Set Sector command does not guarantee record orientation. The Search commands must still be used for this function.
2. Indiscriminate use of Set Sector with multitrack search may result in missing the desired record. A Set Sector 0, Read HA, and Search Multitrack sequence will avoid this problem.
3. If a device without RPS is addressed, channel end and device end are returned. No operation is performed; track orientation is not maintained.

2.3.9 Restore.

COMMAND CODE 0001 0111 binary, 17 hexadecimal.

RESTORE an immediate command; resets orientation; no data is transferred.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END immediately follows initial status.

2.4 Search Commands.

2.4.1 Search Home Address Equal.

COMMAND CODE 0011 1001 binary, 39 hexadecimal Multitrack off
1011 1001 binary, B9 hexadecimal Multitrack on.

SEARCH HOME ADDRESS EQUAL transfers the four-byte address from the channel to the storage control unit, searches for the index point and compares the track home address ID with the Search HA ID from the channel.

SEARCH HA FORMAT *HAID* where *HAID* is a 32 bit identifier.

INITIAL STATUS normally zero.

COMPARISON EQUAL channel end, device end, and status modified presented to channel.

COMPARISON NOT EQUAL channel end and device end presented to channel at the end of the Home Address area.

TRANSFER COUNT >FOUR control unit transfers only first four bytes used.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was equal.

TRANSFER COUNT <FOUR comparison is attempted with number of bytes transferred.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was equal using short address.

MULTITRACK OFF search confined to one track; continues (as long as channel repeats command) until search condition satisfied or end-of-track detected.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-track is reached or parity error detected.

MULTITRACK ON causes search to continue (as long as channel repeats command); head number automatically increments at index until search is satisfied or end-of-cylinder is reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-cylinder is reached or parity error detected.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.4.2 Search ID Equal.

COMMAND CODE 0011 0001 binary, 31 hexadecimal Multitrack off
1011 0001 binary, B1 hexadecimal Multitrack on.

SEARCH ID EQUAL transfers the five-byte record ID from the channel to the storage control unit and compares the next count area ID for equality with the Search ID from the channel.

SEARCH ID FORMAT *CNTID* where *CNTID* is a 40 bit identifier.

INITIAL STATUS normally zero.

COMPARISON EQUAL channel end, device end, and status modifier presented to channel.

COMPARISON NOT EQUAL channel end and device end presented to the channel at the end of the Count Area.

TRANSFER COUNT >FIVE control unit transfers only first five bytes used.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was equal.

TRANSFER COUNT <FIVE comparison is attempted with number of bytes transferred.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was equal using short ID.

MULTITRACK OFF search confined to one track; continues (as long as channel repeats command) until search condition satisfied or end-of-track is reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-track is reached or a parity error is detected.

MULTITRACK ON search continues (as long as channel repeats command); head number automatically increments at index until search condition satisfied or end-of-cylinder reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel at end-of-cylinder.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.4.3 Search ID High.

COMMAND CODE 0101 0001 binary, 51 hexadecimal Multitrack off
1101 0001 binary, D1 hexadecimal Multitrack on.

SEARCH ID HIGH transfers the five-byte record ID from the channel to the storage control unit, and compares the next count area ID to be higher than the Search ID from the channel.

SEARCH ID FORMAT *CNTID* where *CNTID* is a 40 bit identifier.

INITIAL STATUS normally zero.

COMPARISON HIGH channel end, device end, and status modifier presented to channel. Record ID higher than ID from channel.

COMPARISON NOT HIGH channel end and device end presented to channel at the end of the Count Area.

TRANSFER COUNT >FIVE control unit transfers only first five bytes used.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was completed successfully.

TRANSFER COUNT <FIVE comparison is attempted with number of bytes transferred.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was successful using short ID.

MULTITRACK OFF search confined to single track, continues (as long as channel repeats command) until search condition satisfied or end-of-track is reached.

CHANNEL END/DEVICE END/UNIT CHECK presented when end-of-track is reached or parity error is detected.

MULTITRACK ON search continues (as long as channel repeats command); head number automatically increments at index until search condition is satisfied or end-of-cylinder reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel at end-of-cylinder or if parity error found.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.4.4 Search ID Equal or High.

COMMAND CODE 0111 0001 binary, 71 hexadecimal Multitrack off
1111 0001 binary, F1 hexadecimal Multitrack on.

SEARCH ID EQUAL OR HIGH transfers the five-byte record ID from the channel to the storage control unit and compares the next count area ID to be higher than or equal to the Search ID from the channel.

SEARCH ID FORMAT *CNTID* where *CNTID* is a 40 bit identifier.

INITIAL STATUS normally zero.

COMPARISON EQUAL OR HIGH channel end, device end, and status modifier presented to the channel. Record ID equal to or higher than ID from channel.

COMPARISON NOT EQUAL OR HIGH channel end and device end presented to the channel at the end of the Count Area.

TRANSFER COUNT >FIVE control unit transfers only first five bytes used.

CHANNEL END/DEVICE END when comparison complete.

STATUS MODIFIER presented if comparison completed successfully.

TRANSFER COUNT <FIVE comparison is attempted with number of bytes transferred.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if search was successful using the short ID.

MULTITRACK OFF search confined to one track; continues (as long as channel repeats command) until search condition satisfied or end-of-track detected.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-track is reached or a parity error is detected.

MULTITRACK ON search continues (as long as channel repeats command); head number automatically increments at index until search condition satisfied or end-of-cyclinder reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel at end-of-cylinder.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.4.5 Search Key Equal.

COMMAND CODE 0010 1001 binary, 29 hexadecimal Multitrack off
1010 1001 binary, A9 hexadecimal Multitrack on.

CHAINING AND SPECIAL REQUIREMENTS When command chained from Search ID or Read Count, key is in same record as ID or count. Search Key Equal bypasses R0 unless chained from Search ID command which searched R0 ID. If followed by a chained Read Data, the data area read is from current record if KL not zero, or from next record if KL is zero.

SEARCH KEY EQUAL transfers the one or more byte long key field from the channel to the storage control unit and compares the key area for equality with the key field from the channel.

KEY FIELD is optimal in length and in the format of the record key field.

INITIAL STATUS normally zero.

COMPARISON EQUAL channel end, device end, and status modifier presented to channel.

COMPARISON NOT EQUAL OR NO KEY channel end and device end presented to channel at the end of the Key Area.

TRANSFER COUNT >KEY LENGTH comparison is attempted with number of bytes transferred from the RMS device Key Area.

CHANNEL END/DEVICE END when comparison complete.

STATUS MODIFIER presented if comparison was equal.

TRANSFER COUNT <KEY LENGTH comparison is attempted with number of bytes transferred from the channel.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was equal using short key field.

MULTITRACK OFF search confined to one track; continues (as long as channel repeats command) until search condition satisfied or end-of-track detected.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-track is reached or a parity error is detected.

MULTITRACK ON search continues (as long as channel repeats command); head number automatically increments at index until search condition or end-of-cylinder reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel at end-of-cylinder.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.4.6 Search Key High.

COMMAND CODE 0100 1001 binary, 49 hexadecimal Multitrack off
1100 1001 binary, C9 hexadecimal Multitrack on.

CHAINING AND SPECIAL REQUIREMENTS When command chained from Search ID or Read Count, key is in same record as ID or count. Search Key High bypasses R0 unless chained from Search ID command which searched R0 ID. If followed by a chained Read Data, the data area read is from current record if KL not zero, or from next record if KL is zero.

SEARCH KEY HIGH transfers the one or more byte long key field from the channel to the storage control unit and compares the key area to be higher than the key field from the channel.

KEY FIELD is optional in length and in the format of the record key field.

INITIAL STATUS normally zero.

COMPARISON HIGH channel end, device end, and status modifier presented to channel. Record key field higher than the key field from channel.

COMPARISON NOT HIGH OR NO KEY channel end/device end presented to channel at the end of the Key Area.

TRANSFER COUNT >KEY LENGTH comparison attempted with number of bytes transferred from RMS device Key Area.

CHANNEL END/DEVICE END when comparison complete.

STATUS MODIFIER presented if comparison was completed successfully.

TRANSFER COUNT <KEY LENGTH comparison is attempted with number of bytes transferred from the channel.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was successful using the short key.

MULTITRACK OFF search confined to one track; continues (as long as channel repeats command) until search condition satisfied or end-of-track detected.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-track is reached or a parity error is detected.

MULTITRACK ON search continues (as long as channel repeats command); head number automatically increments at index until search condition or end-of-cylinder reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel at end-of-cylinder.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.4.7 Search Key Equal or High.

COMMAND CODE 0110 1001 binary, 69 hexadecimal Multitrack off
1110 1001 binary, E9 hexadecimal Multitrack on.

CHAINING AND SPECIAL REQUIREMENTS When command chained from Search ID or Read Count, key is in same record as ID or count. Search Key Equal or High bypasses R0 unless chained from Search ID command which searched R0 ID. If followed by a chained Read Data, the data area read is from next record.

SEARCH KEY EQUAL OR HIGH transfers the one or more byte long key field from the channel to the storage control and compares the next key area (excluding R0) key field to be equal or higher than the key field from the channel.

KEY FIELD is optional in length and in the format of the searched for record key field.

INITIAL STATUS normally zero.

COMPARISON EQUAL OR HIGH channel end, device end, and status modifier presented to channel. Record key field equal or higher than the key field from channel.

COMPARISON NOT EQUAL OR HIGH OR NO KEY channel end/device end presented to channel.

TRANSFER COUNT >KEY LENGTH comparison attempted with number of bytes transferred.

CHANNEL END/DEVICE END when comparison complete.

STATUS MODIFIER presented if comparison was completed successfully.

TRANSFER COUNT <KEY LENGTH comparison is attempted with number of bytes transferred.

CHANNEL END/DEVICE END presented when comparison complete.

STATUS MODIFIER presented if comparison was successful using the short key.

MULTITRACK OFF search confined to one track; continues (as long as channel repeats command) until search condition satisfied or end-of-track detected.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel when end-of-track is reached or a parity error is detected.

MULTITRACK ON search continues (as long as channel repeats command); head number automatically increments at index until search condition or end-of-cylinder reached.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel at end-of-cylinder.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5 Read Commands.

2.5.1 Read Home Address (HA).

COMMAND CODE 0001 1010 binary, 1A hexadecimal Multitrack off
1001 1010 binary, 9A hexadecimal Multitrack on.

READ HA transfers the five-byte track home address from the storage control unit to the channel.

HOME ADDRESS FORMAT *FHAID* where *F* is an 8 bit track condition flag, *HAID* is a 32 bit identifier.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after home address is transferred and the validity of the home address is checked. If HA not physically existent, channel end and device end presented after orientation on index.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.2 Read Count.

COMMAND CODE 0001 0010 binary, 12 hexadecimal Multitrack off
1001 0010 binary, 92 hexadecimal Multitrack on.

READ COUNT transfers the eight bytes of count information following the flag byte from the storage control unit/device to the channel.

COUNT INFORMATION FORMAT *CNTIDKDL* where *CNTID* is a 40 bit identifier, *K* is an 8 bit key length, and *DL* is a 16 bit data length.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after count information is transferred and the validity of the count information is checked.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.3 Read Record 0 (R0).

COMMAND CODE 0001 0110 binary, 16 hexadecimal Multitrack off
1001 0110 binary, 96 hexadecimal Multitrack on.

READ R0 transfers the count, key and data areas of R0 from the storage control unit/device to the channel. The storage control will search for index, to find R0, unless command chained from a Search HA or Read HA command. In the chained case the storage control unit does not search for index.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after R0 is transferred and the validity of the entire record has been checked.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.4 Read Data.

COMMAND CODE 0000 0110 binary, 06 hexadecimal Multitrack off
1000 0110 binary, 86 hexadecimal Multitrack on.

READ DATA transfers the data area of a record from the storage control unit/device to the channel. The data area read is:

1. Data area of record processed by Search ID or Search Key preceding Read Data.
2. Data area of record whose ID was read by Read Count preceding the Read Data.
3. Data area of record following next count area on the track (excluding R0).

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after data area is transferred and the validity of the count and data area is checked (key area not checked).

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.5 Read Key and Data (KD).

COMMAND CODE 0000 1110 binary, 0E hexadecimal Multitrack off
1000 1110 binary, 8E hexadecimal Multitrack on.

READ KD transfers the key and data areas of a record from the storage control/device to the channel. The key and data areas read are:

1. Key and data areas of record processed by Search ID preceding Read KD.
2. Key and data areas of record whose ID was read by Read Count preceding the Read KD.
3. Key and data areas of record following next count area on track (excluding R0).

KEY LENGTH ON RMS DEVICE = ZERO command same as Read Data command.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after key and data areas are transferred and the validity of each record area is checked.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.6 Read Count, Key and Data (CKD).

COMMAND CODE 0001 1110 binary, 1E hexadecimal Multitrack off
1001 1110 binary, 9E hexadecimal Multitrack on.

READ CKD transfers the next record on the track (count, key and data areas) from the storage control unit/device to the channel (excluding R0).

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after count, key and data areas are transferred and the validity of each record area is checked.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check), either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.7 Read Initial Program Load (IPL).

COMMAND CODE 0000 0010 binary, 02 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must not be preceded by Set File Mask or Space Count in the same chain.

READ IPL causes storage control unit to position the addressed device to cylinder zero/head zero, to search for index and to transfer the data area of the first record after R0 from the storage control unit/device to the channel. This command is intended primarily for initial loading of a computer systems program at initial start-up of the computer system.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after data area is transferred and the validity of the count and data areas is checked (key area not checked).

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. data overrun or data check) either after original transfer or after optional command retry transfer.

OVERRUN/DATA CHECK if detected, control unit optionally attempts command retry.

COMMAND RETRY if unsuccessful, channel end, device end, and unit check presented.

2.5.8 Read Sector.

COMMAND CODE 0010 0010 binary, 22 hexadecimal.

READ SECTOR transfers the addressed device's one byte sector number from the storage control unit to the channel. The storage control unit's orientation information is reset by execution of this command. In some circumstances (e.g. after power up or with a device not supporting RPS) a zero byte will be transferred. The use of this command is very device specific and this standard makes no attempt to define the actions, relative to this command, beyond what is specified here.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after sector number transferred.

2.6 Sense Commands.

2.6.1 Sense I/O.

COMMAND CODE 0000 0100 binary, 04 hexadecimal.

SENSE I/O transfers up to twenty-four bytes of sense I/O information from the storage control unit to the channel, then resets the sense information contained in the control unit to zero.

SENSE I/O FORMAT is defined in the section on Status and Sense Information.

CONTINGENT CONNECTION is a condition established in the storage control unit after the channel accepts a status byte containing unit check. In the contingent connection state, the storage control unit is busy to all device addresses and any other channel interfaces other than the one establishing the connection. The contingent connection lasts until a command, other than Test I/O and No-op, receives an initial status byte of zero for the device address which generated the unit check.

CHANNEL END/DEVICE END presented to channel after Sense I/O information is transferred.

2.6.2 Read and Reset Buffered Log.

COMMAND CODE 1010 0100 binary, A4 hexadecimal.

READ AND RESET BUFFERED LOG transfers up to twenty-four bytes of usage or error information from the storage control unit to the channel, then resets the usage information, internal to the storage control unit, to zero.

USAGE OR ERROR INFORMATION FORMAT is defined in the section on Status and Sense Information.

STATISTICAL USAGE AND ERROR RECORDING information is kept, by the storage control unit, for each physical device in the rotating mass subsystem. When accumulated information, either usage or error, reaches a preset level a unit check is presented to the channel when the next command is addressed to the storage control unit.

The resulting contingent connection and required reading of Sense I/O information will retrieve the usage and error information to the channel, and cause the internal storage of these values to be reset to zero.

The Read and Reset Buffered Log command is used to read, and reset, the usage and error information before the present levels are reached causing a forced Sense I/O read.

INITIAL STATUS normally zero.

CHANNEL END/DEVICE END presented to channel after usage and error information is transferred.

2.6.3 Device Reserve.

COMMAND CODE 1011 0100 binary, B4 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Valid only for multi-channel and/or multi-storage control unit rotating mass subsystems. Must be first command in chain.

DEVICE RESERVE transfers up to twenty-four bytes of Sense I/O information from the storage control to the channel and reserves the address rotating mass device for the channel issuing the command (if multiple access paths to the device exist).

RESERVATION MAINTAINED until a Device Release or system reset is performed by the issuing channel, or an Unconditional Reserve is issued from another channel.

INITIAL STATUS normally zero.

UNIT CHECK is presented when the command is rejected because a command precedes the Device Reserve command in the chain or the device is busy for some reason (e.g. reserved to another channel). Abnormal file conditions (e.g. unsafe, offline, etc.) do not halt command execution. Unit Check is also presented if the storage control cannot support the Device Reserve for any reason.

CHANNEL END/DEVICE END presented to channel after Sense I/O information is transferred and reservation is complete.

2.6.4 Device Release.

COMMAND CODE 1001 0100 binary, 94 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Valid only for multi-channel and/or multi-storage control rotating mass subsystems. Must be first command in chain.

DEVICE RELEASE transfers up to twenty-four bytes of Sense I/O information from the storage control unit to the channel and releases reservation of the addressed rotating mass device from the channel issuing the command (if multiple access paths to the device exist). Must be issued on the same channel that has reservation of the addressed device.

INITIAL STATUS normally zero.

UNIT CHECK is presented when the command is rejected because a command preceded the Device Release in the chain or the storage control cannot support Device Release for any reason. Abnormal file conditions (e.g. unsafe, offline, etc.) do not halt command execution.

CHANNEL END/DEVICE END presented to channel after Sense I/O information is transferred and the device reservation is released.

2.7 Write Commands.

2.7.1 Write Home Address (HA).

COMMAND CODE 0001 1001 binary, 19 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be preceded by a Set File Mask permitting Write Home Address commands. May be required to be chained from a satisfied Search Home Address Equal (unless the command is to flag the track as defective), on devices where improper use could destroy media defect information in an extended home address field.

HOME ADDRESS FORMAT *FHAID* where *F* is an 8 bit track condition flag, *HAID* is a 32 bit identifier.

EXTENDED HOME ADDRESS FORMAT includes the basic home address format (above) and an unspecified number of 8 bit bytes before and/or after it to describe extended information about the track such as to define the length, format or content of these device specific optional extended home address formats.

WRITE HA transfers the five-byte (more on devices supporting extended home address formats) home address from the channel to the storage control/device. The storage control unit orients on the index point and appropriately records the home address on the device. If the Write Home Address command is the last command in the chain, the storage control unit writes a fixed pattern on the balance of the track. The value of this pattern is unspecified by this standard; however, all useful user information is certainly destroyed by it.

INITIAL STATUS normally zero.

TRANSFER COUNT >HOME ADDRESS FORMAT LENGTH only the first byte (5 or more, depending on the extended address format used) will be written.

TRANSFER COUNT <HOME ADDRESS FORMAT LENGTH results are optional. The storage control unit may record zeros as a home address or present command reject.

CHANNEL END/DEVICE END presented to channel after home address area successfully recorded.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel if transfer failed (e.g. parity error, data overrun or command reject), or if otherwise cannot be completed.

DATA OVERFLOW will cause zeros to be written as a home address.

WARNING Home address areas are normally prewritten by the rotating mass, or other media supplier. The use of this command should be limited to identifying defective tracks and assigning alternate tracks. For devices supporting extended home address formats, improper use of the Write Home Address command could destroy media defect, or other, important information recorded at the time of manufacture.

2.7.2 Write Record 0 (R0).

COMMAND CODE 0001 0101 binary, 15 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be chained from a successful Write HA or Search HA Equal command.

WRITE R0 transfers the count, key and data areas of R0 from the channel to the storage control unit/device. Typically used for track formatting.

R0 FORMAT for the purposes of the Write R0 command contains count, key and data areas. The flag byte, if included in the format, is not sent from the channel. This is to allow the storage control unit to generate its own flag byte. The remainder of the R0 format is as specified in the format section. The key and data area lengths are as specified by the KL and DL bytes in the count area.

INITIAL STATUS normally zero.

TRANSFER COUNT >COUNT LENGTH+KL+DL only the first COUNT LENGTH+KL+DL bytes are written.

TRANSFER COUNT <COUNT LENGTH+KL+DL zeros are written in the remainder of the record. Thus if the transfer count was so small that even some KL and DL bytes are not present, then the number of zeros written will be based on the KL and DL lengths with zero bytes substituted for nontransferred bytes.

CHANNEL END/DEVICE END presented to channel after Record 0 is successfully recorded.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel in initial status if chaining requirements not met, otherwise presented in normal ending status (e.g. parity error or data overrun).

WARNING R0 records are normally prewritten by the rotating mass, or other media supplier. The use of this command should be limited to identifying defective tracks and assigning alternate tracks. Alternate and defective tracks may be identified in the R0 count area instead of the normal CCHH bytes. Improper use of the Write R0 command could destroy media alternate track, or other important information recorded at the time of manufacture.

2.7.3 Erase.

COMMAND CODE 0001 0001 binary, 11 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be chained from Write R0, Write CKD, Search ID Equal, or Search Key Equal commands. Search commands must compare equal on all bytes transferred from the channel. A Read Data or Read KD command may be inserted between the Search and Erase command.

ERASE writes zeros over the remainder of the track, after the record identified by the previous command in the chain.

Synchronization of bytes transferred by the channel is maintained with the bytes erased, so that the difference count may aid in identifying the remaining track balance (bytes remaining within track).

INITIAL STATUS normally zero.

TRANSFER COUNT is the number of count, key and data area bytes in the record.

CHANNEL END/DEVICE END presented to channel following the successful erasure of the data area of the record.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel in initial status if chaining requirements not met, otherwise presented for normal reasons in ending status (e.g. parity error or data overrun).

2.7.4 Write Count, Key and Data (CKD).

COMMAND CODE 0001 1101 binary, 1D hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be chained from Write R0, Write CKD, Search ID Equal, or Search Key Equal commands. Search commands must compare equal on all bytes transferred from the channel. A Read Data or Read KD commands may be inserted between the Search and Write CKD commands.

WRITE CKD transfers the count, key and data areas of a data record from the channel to the storage control/device. Typically used for record formatting.

DATA RECORD FORMAT for the purposes of the Write CKD command contains count, key and data areas. The flag byte, if included in the format, is not sent from the channel. This is to allow the storage control unit to generate its own flag byte. The remainder of the data record format is as specified in the Data Record section. The key and data area lengths are as specified by the KL and DL bytes in the count area.

ZERO LENGTH DATA AREA specifying DL to zero will cause the storage control to record a single 8 bit byte of zeros to indicate that the record is a special end-of-file record. Subsequent reading (or writing) of the end-of-file record will cause a unit exception status to uniquely identify the end-of-file condition. See the end-of-file standard feature description for further information.

INITIAL STATUS normally zero.

TRANSFER COUNT >COUNT LENGTH+KL+DL only the first COUNT LENGTH+KL+DL bytes are written.

TRANSFER COUNT <COUNT LENGTH+KL+DL zeros are written in the remainder of the record. See discussion under Write R0.

CHANNEL END/DEVICE END presented to channel after data record is successfully written.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel in initial status if chaining requirements not met, otherwise presented in normal ending status (e.g. parity error or data overrun). Presented in initial status if Write CKD attempted after Write R0 on a defective track.

2.7.5 Write Special Count, Key and Data (CKD).

COMMAND CODE 0000 0001 binary, 01 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be chained from Write R0, Write CKD, Search ID Equal, or Search Key Equal commands. Search commands must compare equal on all bytes transferred from the channel. A Read Data or Read KD command may be inserted between the Search and Write Special CKD commands.

WRITE SPECIAL CKD transfers the count, kkey and data areas of a data record from the channel to the storage control unit/device, with a flag byte containing a one in bit 4 indicating that another part of the record is located on the next track. Typically used for record formatting extended records.

DATA RECORD FORMAT for the purposes of the Write CKD command contains count, key and data areas. This is to allow the storage control unit to generate its own flag byte. The remainder of the data record format is as specified in the Data Record section. The key and data area lengths are as specified by the KL and DL bytes in the count area.

INITIAL STATUS normally zero.

TRANSFER COUNT >COUNT LENGTH+KL+DL only the first COUNT LENGTH+KL+DL bytes are written.

TRANSFER COUNT <COUNT LENGTH+KL+DL zeros are written in the remainder of the record. See discussion under Write R0.

CHANNEL END/DEVICE END presented to channel after data record is successfully written.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel in initial status if chaining requirements not met, otherwise presented in normal end status (e.g. parity error or data overrun).

2.7.6 Write Data.

COMMAND CODE 0000 0101 binary, 05 hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be chained from a Search ID Equal or Search Key Equal command. Search commands must compare equal on all bytes transferred from the channel.

WRITE DATA transfers the data area of a record from the channel to the storage control unit/device.

INITIAL STATUS normally zero.

TRANSFER COUNT >COUNT AREA DL only the first DL bytes are written.

TRANSFER COUNT <COUNT AREA DL zeros are written in the remainder of the data area.

CHANNEL END/DEVICE END presented to channel after data area successfully written.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel in initial status if chaining requirements not met, otherwise presented in normal end status (e.g. parity error or data overrun).

2.7.7 Write Key and Data (KD).

COMMAND CODE 0000 1101 binary, 0D hexadecimal.

CHAINING AND SPECIAL REQUIREMENTS Must be chained from a Search ID Equal command which compared equal on all bytes transferred from the channel.

WRITE KD transfers the key and data areas of a data record from the channel to the storage control unit/device. Typically used for record updating after track formatting.

INITIAL STATUS normally zero.

TRANSFER COUNT >COUNT AREA KL+DL only the first KL+DL bytes written.

TRANSFER COUNT <COUNT AREA KL+DL zeros are written in the remainder of the areas.

CHANNEL END/DEVICE END presented to the channel after the key and data areas successfully written.

CHANNEL END/DEVICE END/UNIT CHECK presented to channel in initial status if chaining requirements not met, otherwise presented in normal end status (e.g. parity error or data overrun).

2.8 Diagnostic Commands.

These are commands used only for design/device dependent diagnostic maintenance (or other) type purposes. All of these commands are currently unspecified and thus only designated as optional command extensions.

3. STATUS AND SENSE INFORMATION

3.1 Status Byte. As defined in the ANS I/O Channel Interface specification.

3.1.1 Contingent Connection. Under certain circumstances, a temporary connection is maintained between the storage control unit and the rotating mass storage device on behalf of the channel until the computer system can provide certain required actions.

This connection is called a contingent connection and is initiated when a status byte with unit check is presented to, and accepted by, the channel. The contingent connection is maintained until:

(a) a command, other than Test I/O and No-Op, generates an initial status byte of zero for the storage control unit and device that generated the unit check.

(b) a selective reset occurs for the storage control unit and device that generated the unit check.

(c) a system reset occurs.

The purpose of the contingent connection is to maintain the integrity of the sense bytes that supply further information as to the cause of the unit check status. Thus, if a command received for a device other than the contingently connected one, the storage control unit responds with a busy status to indicate control unit busy. This also applies to any command received on the other channel accesses (i.e. four channel switch feature) to the storage control unit.

3.2 Sense Information. As described in BSR X3.67, ANS I/O Channel Interface Specification, sense bytes are used to supplement information contained in the status byte (see Section 2.7 of BSR X3.67). In general, sense information is fundamentally related to the design, operating features and performance characteristics associated with a particular class of I/O device. Since this standard is applicable to a variety of rotating mass storage subsystem designs, covering a wide range of storage capacities and data rates, it addresses only those items of sense information common to all applicable equipment. Further details on the interpretation of information contained in the sense bytes are prescribed in separate standards, each pertaining to a particular device performance grouping or classification.

3.2.1 Sense Information Length. All of the rotating mass storage subsystems for which this standard is applicable provide for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the subsystem and is transmitted to the channel in response to any of the sense commands (see Section 2.6). The sense information is cleared from the subsystem upon acceptance of any command other than Test I/O or No-Op or by a systems reset of the control unit.

3.2.2 Sense Information Formats. The first eight bytes (0–7) of sense information provide high level information concerning general subsystem status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0–6, by which the remaining bytes 8–23 are to be interpreted. Three of these formats, numbered 0, 2 and 3, are employed for reporting manufacturer-related maintenance and diagnostic information. The remaining four formats, numbered 1, 4, 5 and 6, are employed for reporting specific subsystem and device-dependent conditions or states. Further details regarding the definition of these seven formats as well as the specifications for their contents are provided in separate standards for each of the established rotating mass storage device performance classifications.

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CLASS A ROTATING MASS STORAGE DEVICE SPECIFICATION

Abstract

This standard is one of a series that supplement the draft proposed American National Standard entitled OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series provides supplemental track format definition and specifies the sense information format and content for a particular class of rotating mass storage devices.

This standard defines the track format and specifies the 24 bytes of sense information generated by Class A rotating mass storage devices—namely, those devices that attach to the proposed American National Standard I/O Channel Interface, BSR X3.67, and meet the requirements specified in section 1.2. The first 8 sense bytes are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte (byte 7) identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

Foreword

(This Foreword is not part of the Standard for Class A Rotating Mass Storage Device Specification.)

This standard is one of a series defining the track format and specifying the sense information generated by various designated classes of RMS (Rotating Mass Storage) devices that attach to the proposed American National Standard I/O Channel Interface, BSR X3.67. Class A devices, for which this standard is applicable, are those meeting the requirements specified in section 1.2.

The proposed standard I/O Channel Interface, BSR X3.67, provides specifications for the functional, electrical, and mechanical characteristics of the I/O Channel Interface. This includes the general specification of address, command, status and data information flow over the I/O Channel Interface.

The draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, specifies the logical interface between peripheral subsystems of the rotating mass storage generic category and the Standard I/O Channel, including:

(1) Addressing formats for rotating mass storage control units and devices.
(2) Command formats for the control of rotating mass storage control units and devices.
(3) Data formats for transfer of data to and from rotating mass storage subsystems.
(4) Record formats for the rotating mass storage media.
(5) Programming considerations for rotating mass storage subsystems.

This series of standards supplements the proposed standard Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series provides supplemental track format definition and specifies the format and content of the 24 bytes of sense information generated by a particular class of rotating mass storage device.

Contents

CLASS A ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This standard is one of a series that supplement the draft proposed American National Standard entitled OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS, X3T9/348 Rev. 2, dated July 25, 1978. Each standard in this series specifies the track format and sense information content for a particular class of rotating mass storage device. This standard is distinct from a specification in that it delineates a minimum set of restrictions consistent with compatibility and interchange.

1.1 Scope. This standard specifies the format and content of the 24 bytes of sense information generated by Class A rotating mass storage devices. The first eight sense bytes (bytes 0–7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Class A rotating mass storage devices for which this standard is applicable are those that attach to the proposed American National Standard I/O Channel Interface (BSR X3.67) and meet the following requirements:

Storage Capacity	=	100 or 200 megabytes per logical device address.
Cylinders/Address	=	404 (808 for 200 megabyte devices) logical user cylinders plus 7 alternate cylinders per logical device address.
Tracks/Cylinder	=	19 logical tracks per logical cylinder.
Bytes/Track	=	13,030 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in the draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, with the exception that the optional extended home address information defined in figure 2 is not present for Class A RMS devices.

3. SENSE INFORMATION. As described in BSR X3.67, ANS I/O Channel Interface Specification, sense bytes are used to supplement information contained in the status byte (see Section 2.7 of BSR X3.67). In general, sense information is fundamentally related to the design, operating features and performance characteristics associated with a particular class of I/O device. Since BSR X3.67 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to all applicable equipment. The draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, provides operational specifications for rotating mass storage subsystems but again (as with BSR X3.67) the sense byte information content is specified only at the general level, common for all such subsystems. Further details on the interpretation of information contained in the sense bytes are prescribed in separate standards, such as this one, pertaining to a particular device class.

3.1 Generation and Processing. The rotating mass storage devices for which this standard is applicable provides for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense information is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set

to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 **Summary of Formats.** The first eight bytes (0–7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0–6, by which the remaining bytes 8–23 are to be interpreted. Three of these formats, numbered 1, 2 and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Format 7 may be used to report command retry information in those environments that do not support channel-level retry. Further details regarding the definition of these eight formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class A rotating mass storage devices.

4. **HIGH-LEVEL SENSE BYTES 0-7.** The first eight sense bytes contain high level information for Class A devices, as defined in section 1.2.

4.1 **Byte 0: Common.**

Bit	*Designation*	*Interpretation*
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Diagnostic Write or Load command issued and diagnostic is resident in control storage. (4) Addressed device in maintenance mode and unavailable for use.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.
3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.

4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 22. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation.
6–7	Not Used	Set to zero for Class A devices.

4.2 Byte 1: Control Unit/Device State.

Bit	*Designation*	*Interpretation*
0	Permanent Error	Indicates an error not able to be recovered: (1) Control unit retry has been attempted and was unsuccessful. (2) A drive in unsafe condition has been detected and retry should not be attempted.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation.
2	End of Cylinder	Indicates: (1) A multitrack read or search attempted to go beyond the cylinder boundary. (2) An overflow operation attempted to go past the cylinder boundary. Byte 1, bit 7 will be set to indicate this condition.
3	Not Used	Set to zero for Class A devices.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without a Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. (3) Overflow operation. Byte 1, bit 7 will also be set.
6	Write Inhibited	Indicates a Write command issued when write protection mechanism enabled. Byte 0, bit 0 will also be set.

7	Operation Incomplete	Indicates one of the following conditions occurred when processing an overflow record. For any of these conditions, byte 3 contains restart command information: (1) Overflow to a file protected boundary. Byte 1, bit 5 also set. (2) Overflow beyond cylinder boundary. Byte 1, bit 2 also set. (3) Correctable data error found in data area —not last segment. Byte 2, bit 1 and byte 0, bit 4 also set. (4) Correctable data error found in home address or count area—not first segment. (5) Uncorrectable data error found in any area —not first segment. (6) Defective or alternate track found after start of data transfer. (7) Seek error found in second or later segment.

4.3 Byte 2: Device/Media State.

Bit	*Designation*	*Interpretation*
0	Not Used	Set to zero for Class A devices.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 22 contain error recovery information.
2	Redundant Path	Indicates that the connection between control unit and device is via a redundant path. Redundant paths are used to achieve higher availability.
3	Environmental Data Present	Indicates that bytes 8 through 23 contain either usage/error statistics (format 6) or error logging information.
4	Emulation Mode	When on, indicates that Class A RMS device characteristics are being emulated by a device that does not have class A characteristics in its native mode.
5–7	Not Used	Set to zero for Class A devices.

4.4 Byte 3: Restart Command.

Bit	*Designation*	*Interpretation*
0–7	Restart Command	When bit 7, byte 1 is set, byte 3 indicates the command in process at the time of the interruption of the incomplete operation. 06 hexadecimal for the Read command and 05 hexadecimal for the Write command.

4.5 Byte 4: Physical Device Identification.

If not operating in emulation mode, byte 2 bit 4 off, byte 4 has the following definition:

Bit	*Designation*	*Interpretation*
0–4	Unspecified	
5–7	Physical Device	Indicates indentification of physical device as follows: 000 = 0 (physical device 0) 001 = 1 010 = 2 011 = 3 100 = 4 101 = 5 110 = 6 111 = 7

If operating in emulation mode, byte 2 bit 4 on, byte 4 has the following definition:

Bit	*Designation*	*Interpretation*
0–7	Physical Device	Indicates identification of physical device as follows: 1000 0000 = 0 (physical device 0) 0100 0000 = 1 0010 0000 = 2 0001 0000 = 3 0000 1000 = 4 0000 0100 = 5 0000 0010 = 6 0000 0001 = 7

4.6 Byte 5: Cylinder Address.

Bit	*Designation*	*Interpretation*
0–7	Cylinder Low Address	Identifies the low-order cylinder address of the latest seek argument from channel.

4.7 Byte 6: Head Address.

4.7.1 For 100 megabyte devices the format of byte 6 is as follows:

Bit	*Designation*	*Interpretation*
0	Diagnostic Cylinder	Indicates that a diagnostic cylinder is selected.
1	Cylinder High Address	Indicates the high-order cylinder address bit for the low-order cylinder address in byte 5.
2	Not Used	Set to zero for Class A devices.
3–7	Head Address	Indicates head address of the last seek, except retries. If an alternate track condition is detected and operation incomplete is posted during an overflow operation, byte 6 is set to the

		head address of the defective track plus 1. This information is used by the error recovery procedures to construct the seek argument to continue the operation. The remainder of the seek argument must be obtained from the user program.

4.7.2 For 200 megabyte devices the format of byte 6 is as follows:

Bit	*Designation*	*Interpretation*
0	Diagnostic Cylinder	Indicates that a diagnostic cylinder is selected.
1–2	Cylinder High Address	Indicates the high-order cylinder address bits for the low-order cylinder address in byte 5. Bit 1 has the highest binary weight.
3–7	Head Address	Indicates head address of the last seek, except retries. If an alternate track condition is detected and operation incomplete is posted during an overflow operation, byte 6 is set to the head address of the defective track plus 1. This information is used by the error recovery procedures to construct the seek argument to continue the operation. The remainder of the seek argument must be obtained from the user program.

4.8 Byte 7: Format/Message Designation.

Bit	*Designation*	*Interpretation*
0–3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check 6 usage/error statistics 7–F Not used for Class A devices.
4–7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class A devices are shown below under the description for each of those formats.

5. FORMAT 0: Control Unit Program/System Check.

If format bits 0–3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	*Meaning*
0	No message.
1–F	Unspecified for Class A devices.

5.2 Format 0, Bytes 8 Through 23. Sense bytes 8 through 23, for format 0, are not used and are set to zero for Class A devices.

6. FORMAT 1: Device Equipment Check. If format bits 0–3 in byte 7 contain a hexidecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the device equipment check. When message numbers are labeled unspecified, no attempt is made by this standard to define the message number meaning.

Hexadecimal Number	*Meaning*
0	No message.
1–F	Unspecified for Class A devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified by this standard.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0–3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class A devices are:

Hexadecimal Number	*Meaning*
0	No message.
1–F	Unspecified for Class A devices.

7.2 Format 2, Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. No attempt is made by this standard to specify this information for Class A devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0–3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	*Meaning*
0	No message.
1–F	Unspecified for Class A devices.

8.2 **Format 3, Bytes 8 Through 23.** Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. No attempt is made by this standard to specify this information for Class A devices.

9. **FORMAT 4: Data Check.** If format bits 0–3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 **Format 4 Message Numbers.** The message bits 4–7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	*Meaning*
0	Home Address (HA) area. Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	No sync byte in HA area.
5	No sync byte in count area.
6	No sync byte in key area.
7	No sync byte in data area.
8	Unspecified.
9	No address mark detection on retry.
A–F	Unspecified.

9.2 **Format 4, Bytes 8 Through 23.** Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class A devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4 (error occurred in HA), 1 or 5 (error occurred in count area), or 9 (no Address Mark (AM) detection on retry).

Byte 13	Sector number of the record in error.
Byte 14	Amount of offset used to recover from the error.
Byte 15	Number of retries required to recover from the error.
Byte 16	Identification of physical device that wrote record in error. Format is identical to the format of sense byte 4.
Bytes 17–21	Unspecified.
Bytes 22–23	Fault symptom code.

10. **FORMAT 5: Correctable Data Check.** If format bits 0–3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 **Format 5 Message Numbers.** The message bits 4–7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class A devices follow:

Hexadecimal Number	*Meaning*
0	Correctable HA area.
1	Correctable count area.
2	Correctable key area.
3	Correctable data area.
4–F	Unspecified.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class A devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 (error occurred in HA), or 1 (error occurred in count area).

Byte 13	Sector number of the record in error.
Byte 14	Amount of offset used to recover from the error.
Bytes 15–17	Specifies the number of bytes processed by the control unit to the end of the data area in error.
Bytes 18–19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20–22	Error pattern used for error correction function.
Byte 23	Bits 0–6 Not used. Bit 7 Channel truncation.

11. FORMAT 6: Usage/Error Statistics. If format bits 0–3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the usage/error statistics. Message number meanings are unspecified for Class A devices.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class A devices.

Byte Number	*Usage*
8–11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12–13	Count of the number of correctable data errors processed by the control unit.
14–15	Count of the number of uncorrectable data errors retried and successfully processed by the control unit.
16–17	Count of the number of Seek commands processed by the control unit.

18	If bit 0 set to zero, bytes 20 through 23 are for control unit channel interfaces A and B (first and second). If bit 0 set to one, bytes 20 through 23 are for control unit channel interfaces C and D (third and fourth).
19	Count of the number of seek errors retried by the control unit. Seek errors during retry are not included.
20	Count of the number of command overruns for channel interface A or C.
21	Count of the number of data overruns for channel interface A or C.
22	Count of the number of command overruns for channel interface B or D.
23	Count of the number of data overruns for channel interface B or D.

12. **FORMAT 7: Command Retry Information.** If format bits 0–3 in byte 7 contain a 7, then the sense format indicates command retry information for those environments that do not support channel-level retry.

12.1 **Format 7 Message Numbers.** The message bits 4–7 in byte 7 contain numbers further identifying the command retry situation. This information is manufacturer dependent and is not specified by this standard.

13. **FORMATS 8 Through F.** If formats bits 0–3 in byte 7 contain hexadecimal 8 through F, the sense format is unspecified for Class A devices.

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CLASS B ROTATING MASS STORAGE DEVICE SPECIFICATION

Abstract

This standard is one of a series that supplement the draft proposed American National Standard entitled OPERATIONAL SPECIFIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series provides supplemental track format definition and specifies the sense information format and content for a particular class of rotating mass storage devices.

This standard defines the track format and specifies the 24 bytes of sense information generated by Class B rotating mass storage devices—namely, those devices that attach to the proposed American National Standard I/O Channel Interface, BSR X3.67, and meet the requirements specified in section 1.2. The first 8 sense bytes are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte (byte 7) identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

Foreword

(This Foreword is not part of the Standard for Class B Rotating Mass Storage Device Specification.)

This standard is one of a series defining the track format and specifying the sense information generated by various designated classes of RMS (Rotating Mass Storage) devices that attach to the proposed American National Standard I/O Channel Interface, BSR X3.67. Class B devices, for which this standard is applicable, are those meeting the requirements specified in section 1.2.

The proposed standard I/O Channel Interface, BSR X3.67, provides specifications for the functional, electrical, and mechanical characteristics of the I/O Channel Interface. This includes the general specification of address, command, status and data information flow over the I/O Channel Interface.

The draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, specifies the logical interface between peripheral subsystems of the rotating mass storage generic category and the Standard I/O Channel, including:

(1) Addressing formats for rotating mass storage control units and devices.

(2) Command formats for the control of rotating mass storage control units and devices.

(3) Data formats for transfer of data to and from rotating mass storage subsystems.

(4) Record formats for the rotating mass storage media.

(5) Programming considerations for rotating mass storage subsystems.

This series of standards supplements the proposed standard Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series provides supplemental track format definition and specifies the format and content of the 24 bytes of sense information generated by a particular class of rotating mass storage device.

Contents

CLASS B ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This standard is one of a series that supplement the draft proposed American National Standard entitled OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series specifies the track format and sense information content for a particular class of rotating mass storage device. This standard is distinct from a specification in that it delineates a minimum set of restrictions consistent with compatibility and interchange.

1.1 Scope. This standard specifies the format and content of the 24 bytes of sense information generated by Class B rotating mass storage devices. The first eight sense bytes (bytes 0–7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Class B rotating mass storage devices for which this standard is applicable are those that attach to the proposed American National Standard I/O Channel Interface (BSR X3.67) and meet the following requirements:

Storage Capacity	=	317.5 megabytes per logical device address.
Cylinders/Address	=	555 logical user cylinders plus 5 alternate cylinders per logical device address.
Tracks/Cylinder	=	30 logical tracks per logical cylinder.
Bytes/Track	=	19,069 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in the draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, figure 2. For Class B devices there are 6 bytes of optional extended home address information defining the presence and location of media defects. From zero to three defects may be defined.

3. SENSE INFORMATION. As described in BSR X3.67, ANS I/O Channel Interface Specification, sense bytes are used to supplement information contained in the status byte (see section 2.7 of BSR X3.67). In general, sense information is fundamentally related to the design, operating features and performance characteristics associated with a particular class of I/O device. Since BSR X3.67 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to all applicable equipment. The draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, provides operational specifications for rotating mass storage subsystems but again (as with BSR X3.67) the sense byte information content is specified only at the general level, common for all such subsystems. Further details on the interpretation of information contained in the sense bytes are prescribed in separate standards, such as this one, pertaining to a particular device class.

3.1 Generation and Processing. The rotating mass storage devices for which this standard is applicable provides for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense informa-

tion is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 Summary of Formats. The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2 and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Format 7 may be used to report command retry information in those environments that do not support channel-level retry. Further details regarding the definition of these eight formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class B rotating mass storage devices.

4. HIGH-LEVEL SENSE BYTES 0-7. The first eight sense bytes contain high level information for Class B devices, as defined in section 1.2.

4.1 Byte 0: Common.

Bit	*Designation*	*Interpretation*
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Diagnostic Write or Load command issued and diagnostic is resident in control storage. (4) Addressed device in maintenance mode and unavailable for use.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.
3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.

4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 22. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation.
6–7	Not Used	Set to zero for Class B devices.

4.2 Byte 1: Control Unit/Device State.

Bit	*Designation*	*Interpretation*
0	Permanent Error	Indicates an error not able to be recovered: (1) Control unit retry has been attempted and was unsuccessful. (2) No system error recovery procedure required.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation.
2	End of Cylinder	Indicates: (1) A multitrack read or search attempted to go beyond the cylinder boundary. (2) An overflow operation attempted to go past the cylinder boundary. Byte 1, bit 7 will be set to indicate this condition.
3	Not Used	Set to zero for Class B devices.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without a Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. (3) Overflow operation. Byte 1, bit 7 will also be set.
6	Write Inhibited	Indicates a write command issued when write protection mechanism enabled. Byte 0, bit 0 will also be set.

7	Operation Incomplete	Indicates one of the following conditions occurred when processing an overflow record. For any of these conditions, byte 3 contains restart command information: (1) Overflow to a file protected boundary. Byte 1, bit 5 also set. (2) Overflow beyond cylinder boundary. Byte 1, bit 2 also set. (3) Correctable data error found in data area —not last segment. Byte 2, bit 1 and byte 0, bit 4 also set. (4) Uncorrectable data error found in any area —not first segment. (5) Defective or alternate track found after start of date transfer. (6) Seek error found in second or later segment.

4.3 Byte 2: Device/Media State.

Bit	*Designation*	*Interpretation*
0	Not Used	Set to zero for Class B devices.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 22 contain error recovery information.
2	Redundant Path	Indicates that the connection between control unit and device is via a redundant path. Redundant paths are used to achieve higher availability.
3	Environmental Data Present	Indicates that bytes 8 through 23 contain either usage/error statistics (format 6) or error logging information.
4–7	Not Used	Set to zero for Class B devices.

4.4 Byte 3: Restart command.

Bit	*Designation*	*Interpretation*
0–7	Restart Command	When bit 7, byte 1 is set, byte 3 indicates the command in process at the time of the interruption of the incomplete operation. 06 hexadecimal for the Read command and 05 hexadecimal for the Write command.

4.5 Byte 4: Physical Device Identification.

Bit	*Designation*	*Interpretation*
0–7	Physical Device	Indicates identification of physical device as follows: 1000 0000 = 0 (physical device 0)

0100 0000 = 1
0010 0000 = 2
0001 0000 = 3
0000 1000 = 4
0000 0100 = 5
0000 0010 = 6
0000 0001 = 7

4.6 Byte 5: Cylinder Address.

Bit	*Designation*	*Interpretation*
0–7	Cylinder Low Address	Identifies the low-order cylinder address of the latest seek argument from channel.

4.7 Byte 6: Head Address

Bit	*Designation*	*Interpretation*
0	Diagnostic Cylinder	Indicates that a diagnostic cylinder is selected.
1–2	Cylinder High Address	Indicates the high-order cylinder address bits for the low-order cylinder address in byte 5. Bit 1 has the highest binary weight.
3–7	Head Address	Indicates head address of the last seek, except retries. If an alternate track condition is detected and operation incomplete is posted during an overflow operation, byte 6 is set to the head address of the defective track plus 1. This information is used by the error recovery procedures to construct the seek argument to continue the operation. The remainder of the seek argument must be obtained from the user program.

4.8 Byte 7: Format/Message Designation.

Bit	*Designation*	*Interpretation*
0–3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check 6 usage/error statistics 7-F Not used for Class B devices.
4–7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class B devices are shown below under the description for each of those formats.

5. FORMAT 0: Control Unit Program/SystemCheck.
If format bits 0–3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class B devices.

5.2 Format 0, Bytes 8 Through 23. Sense bytes 8 through 23, for format 0, are not used and are set to zero for Class B devices.

6. FORMAT 1: Device Equipment Check. If format bits 0–3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the device equipment check. When message numbers are labeled unspecified, no attempt is made by this standard to define the message number meaning.

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class B devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified by this standard.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0–3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class B devices are:

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class B devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. No attempt is made by this standard to specify this information for Class B devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0–3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class B devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. No attempt is made by this standard to specify this information for Class B devices.

9. FORMAT 4: Data Check. If format bits 0–3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	*Meaning*
0	Home Address (HA) area Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	No sync byte in HA area.
5	No sync byte in count area.
6	No sync byte in key area.
7	No sync byte in data area.
8	Unspecified.
9	No address mark detection on retry.
A–F	Unspecified.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class B devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4

(error occurred in HA), 1 or 5 (error occurred in count area), or 9 (no Address Mark (AM) detection on retry).

Byte 13	Sector number of the record in error.
Bytes 14–21	Unspecified.
Bytes 22–23	Fault symptom code.

10. FORMAT 5: Correctable Data Check. If format bits 0–3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class B devices follow:

Hexadecimal Number	*Meaning*
0–2	Unspecified.
3	Correctable data area.
4–F	Unspecified.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class B devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 (error occurred in HA), or 1 (error occurred in count area).

Byte 13	Sector number of the record in error.
Byte 14	Unspecified.
Bytes 15–17	Specifies the number of bytes processed by the control unit to the end of the data area in error.
Bytes 18–19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20–22	Error pattern used for error correction function.
Byte 23	Not used. Set to zero for Class B devices.

11. FORMAT 6: Usage/Error Statistics. If format bits 0–3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the usage/error statistics. Message number meanings are unspecified for Class B devices.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class B devices.

Byte Number	*Usage*
8–11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12–13	Not used. Set to zero for Class B devices.
14–15	Count of the number of initially uncorrectable data errors retried by the control unit.
16–17	Count of the number of Seek commands processed by the control unit.
18	If bit 0 set to zero, bytes 20 through 23 are for control unit channel interfaces A and B (first and second). If bit 0 set to one, bytes 20 through 23 are for control unit channel interfaces C and D (third and fourth).
19	Count the number of seek errors retried by the control unit. Seek errors during retry are not included.
20	Count of the number of command overruns for channel interface A or C.
21	Count of the number of data overruns for channel interface A or C.
22	Count of the number of command overruns for channel interface B or D.
23	Count of the number of data overruns for channel interface B or D.

12. FORMAT 7: Command Retry Information. If format bits 0–3 in byte 7 contain a 7, then the sense format indicates command retry information for those environments that do not support channel-level retry.

12.1 Format 7 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the command retry situation. This information is manufacturer dependent and is not specified by this standard.

13. FORMATS 8 Through F. If format bits 0–3 in byte 7 contain hexadecimal 8 through F, the sense format is unspecified for Class B devices.

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CLASS C ROTATING MASS STORAGE DEVICE SPECIFICATION

Abstract

This standard is one of a series that supplement the draft proposed American National Standard entitled OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series provides supplemental track format definition and specifies the sense information format and content for a particular class of rotating mass storage devices.

This standard defines the track format and specifies the 24 bytes of sense information generated by Class C rotating mass storage devices—namely, those devices that attach to the proposed American National Standard I/O Channel Interface, BSR X3.67, and meet the requirements specified in section 1.2. The first 8 sense bytes are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte (byte 7) identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

Foreword

(This Foreword is not part of the Standard for Class C Rotating Mass Storage Device Specification.)

This standard is one of a series defining the track format and specifying the sense information generated by various designated classes of RMS (Rotating Mass Storage) devices that attach to the proposed American National Standard I/O Channel Interface, BSR X3.67. Class C devices, for which this standard is applicable, are those meeting the requirements specified in section 1.2.

The proposed standard I/O Channel Interface, BSR X3.67, provides specifications for the functional, electrical, and mechanical characteristics of the I/O Channel Interface. This includes the general specification of address, command, status and data information flow over the I/O Channel Interface.

The draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, specifies the logical interface between peripheral subsystems of the rotating mass storage generic category and the Standard I/O Channel, including:

(1) Addressing formats for rotating mass storage control units and devices.
(2) Command formats for the control of rotating mass storage control units and devices.

(3) Data formats for transfer of data to and from rotating mass storage subsystems.
(4) Record formats for the rotating mass storage media.
(5) Programming considerations for rotating mass storage subsystems.

This series of standards supplements the proposed standard Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series provides supplemental track format definition and specifies the format and content of the 24 bytes of sense information generated by a particular class of rotating mass storage device.

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CLASS C ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This standard is one of a series that supplement the draft proposed American National Standard entitled OPERATIONAL SPECIFICATIONS FOR ROTATING MASS STORAGE SUBSYSTEMS, X3T9/848 Rev. 2, dated July 25, 1978. Each standard in this series specifies the track format and sense information content for a particular class of rotating mass storage device. This standard is distinct from a specification in that it delineates a minimum set of restrictions consistent with compatibility and interchange.

1.1 Scope. This standard specifies the format and content of the 24 bytes of sense information generated by Class C rotating mass storage devices. The first eight sense bytes (bytes 0-7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Class C rotating mass storage devices for which this standard is applicable are those that attach to the proposed American National Standard I/O Channel Interface (BSR X3.67) and meet the following requirements:

Storage Capacity =	35 or 70 megabytes per logical device address.
Cylinders/Address =	348 (696 for 70 megabyte devices) logical user cylinders plus 1 (2 for 70 megabyte devices) alternate cylinders per logical device address.
Tracks/Cylinder =	12 logical tracks per logical cylinder.
Bytes/Track =	8,368 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in the draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848, Rev. 2, dated July 2, 1978, figure 2. For Class C devices there are 2 bytes of optional extended home address information defining the presence and location of media defects. For Class C devices one defect per track is allowed.

3. SENSE INFORMATION. As described in BSR X3.67, ANS I/O Channel Interface Specification, sense bytes are used to supplement information contained in the status bytes (see section 2.7 of BSR X3.67). In general, sense information is fundamentally related to the design, operating features and performance characteristics associated with a particular class of I/O device. Since BSR X3.67 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to all applicable equipment. The draft proposed American National Standard entitled Operational Specifications for Rotating Mass Storage Subsystems, X3T9/848 Rev. 2, dated July 25, 1978, provides operational specifications for rotating mass storage subsystems but again (as with BSR X3.67) the sense byte information content is specified only at the general level common for all such subsystems. Further details on the interpretation of information contained in the sense bytes are prescribed in separate standards, such as this one, pertaining to a particular device class.

3.1 Generation and Processing. The rotating mass storage devices for which this standard is applicable provides for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense informa-

tion is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 **Summary of Formats.** The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2 and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Format 7 may be used to report command retry information in those environments that do not support channel-level retry. Further details regarding the definition of these eight formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class C rotating mass storage devices.

4. **HIGH-LEVEL SENSE BYTES 0-7.** The first eight sense bytes contain high level information for Class C devices, as defined in section 1.2.

4.1 Byte 0: **Common.**

Bit	*Designation*	*Interpretation*
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Diagnostic Write or Load command issued and diagnostic is resident in control storage. (4) Addressed device in maintenance mode and unavailable for use.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.
3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.

4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 22. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation.
6	Track Condition Check	(1) A read or search command, other than Search HA, Read HA, or Read RO, was attempted on a defective track. (2) A multi-track command caused head switching from a defective or alternate track.
7	Seek Check	Indicates a seek error on selected device.

4.2 Byte 1: Control Unit/Device State.

Bit	*Designation*	*Interpretation*
0	Permanent Error	This bit set by error recovery procedure (ERP) software for Class C devices.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity.
2	End of Cylinder	Indicates: (1) A multitrack read or search attempted to go beyond the cylinder boundary. (2) An overflow operation attempted to go past the cylinder boundary. Byte 1, bit 7 will be set to indicate this condition.
3	Not used	Set to zero for Class C devices.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without a Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. (3) Overflow operation. Byte 1, bit 7 will also be set.
6	Write Inhibited	Indicates a Write command issued when write protection mechanism enabled. Byte 0, bit 0 will also be set.
7	Operation Incomplete	Indicates one of the following conditions occurred when processing an overflow record. For any of

these conditions, byte 3 contains restart command information:

(1) Overflow to a file protected boundary. Byte 1, bit 5 also set.

(2) Overflow beyond cylinder boundary. Byte 1, bit 2 also set.

(3) Correctable data error found in data area —not last segment. Byte 2, bit 1 and byte 0, bit 4 also set.

(4) Uncorrectable data error found in any area —not first segment.

(5) Defective or alternate track found after start of data transfer.

(6) Seek error found in second or later segment.

4.3 Byte 2: Device/Media State.

Bit	*Designation*	*Interpretation*
0	RPS Feature Present	Rotational position sensing (RPS) installed on selected device.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 22 contain error recovery information.
2	Not used	Set to zero for Class C devices.
3	Environmental Data Present	Indicates that bytes 8 through 23 contain either usage/error statistics (format 6) or error logging information.
4	Emulation Mode	When on, indicates that Class C RMS device characteristics are being emulated by a device that does not have Class C characteristics in its native mode.
5–7	Capacity	Indicates capacity per logical device address as follows: 001 = 35 megabyte capacity 010 = 70 megabyte capacity 110 = 70 megabyte capacity with some part of the capacity implemented in zero seek time storage.

4.4 Byte 3: Restart Command.

Bit	*Designation*	*Interpretation*
0–7	Restart Command	When bit 7, byte 1 is set, byte 3 indicates the command in process at the time of the interruption of the incomplete operation. 06 hexadecimal for the Read command and 05 hexadecimal for the Write command.

4.5 Byte 4: Physical Device Identification.

If not operating in emulation mode, byte 2 bit 4 off, byte 4 has the following format:

Bit	*Designation*	*Interpretation*
0–7	Physical Device	Indicates identification of physical device as follows: 1000 0000 = 0 (physical device 0) 0100 0000 = 1 0010 0000 = 2 0001 0000 = 3 0000 1000 = 4 0000 0100 = 5 0000 0010 = 6 0000 0001 = 7

If operating in emulation mode, byte 2 bit 4 on, byte 4 has the following format:

Bit	*Designation*	*Interpretation*
0–4	Unspecified	
5–7	Physical Device	Indicates identification of physical device as follows: 000 = 0 (physical device 0) 001 = 1 010 = 2 011 = 3 100 = 4 101 = 5 110 = 6 111 = 7

4.6 Byte 5: Cylinder Address.

Bit	*Designation*	*Interpretation*
0–7	Cylinder Low Address	Identifies the low-order cylinder address of the latest seek argument from channel.

4.7 Byte 6: Head Address.

Bit	*Designation*	*Interpretation*
0	Not used	Set to zero for Class C devices.
1–2	Cylinder High Address	Indicates the high-order cylinder address bits for the low-order cylinder address in byte 5. Bit 1 has the binary weight 512. Bit 2 has the binary weight 256.
3	Cylinder High Address, Continuation	Set to zero if emulation mode bit off (byte 2 bit 4). Has cylinder address binary weight 2048 if emulation mode bit on. When emulation mode is used (byte 2 bit 4 on) cylinders 2800 through 2804 are diagnostic cylinders.

4–7	Head Address	Indicates head address of the last seek, except retries. If an alternate track condition is detected and operation incomplete is posted during an overflow operation, byte 6 is set to the head address of the defective track plus 1. This information is used by the error recovery procedures to construct the seek argument to continue the operation. The remainder of the seek argument must be obtained from the user program.

4.8 Byte 7: **Format/Message Designation.**

Bit	*Designation*	*Interpretation*
0–3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check 6 usage/error statistics 7–F Not used for Class C devices.
4–7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class C devices are shown below under the description for each of those formats.

5. FORMAT 0: Control Unit Program/System Check.
If format bits 0–3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class C devices.

5.2 Format 0, Bytes 8 Through 23. Sense bytes 8 though 23, for format 0, are not used and are set to zero for Class C devices.

6. FORMAT 1: Device Equipment Check. If format bits 0–3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the device equipment check. When message numbers are labeled unspecified, no attempt is made by this standard to define themessage number meaning.

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class C devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacture-dependent and is not specified by this standard.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0–3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class C devices are:

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class C devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. No attempt is made by this standard to specify this information for Class C devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0–3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	*Meaning*
0	No message
1–F	Unspecified for Class C devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. No attempt is made by this standard to specify this information for Class C devices.

9. FORMAT 4: Data Check. If format bits 0–3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	*Meaning*
0	Home Address (HA) area. Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	No sync byte in HA area.
5	No sync byte in count area.
6	No sync byte in key area.
7	No sync byte in data area.
8	Unspecified.
9	No address mark detection on retry.
A–F	Unspecified.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class C devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4 (error occurred in HA), 1 or 5 (error occurred in count area), or 9 (no Address Mark (AM) detection on retry).

Byte 13	Sector number of the record in error.
Bytes 14–21	Unspecified.
Bytes 22–23	Fault symptom code.

10. FORMAT 5: Correctable Data Check. If format bits 0–3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class C devices follow:

Hexadecimal Number	*Meaning*
0–2	Unspecified.
3	Correctable data area.
4–F	Unspecified.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class C devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 (error occurred in HA), or 1 (error occurred in count area).

Byte 13	Sector number of the record in error.
Byte 14	Unspecified.
Bytes 15–17	Specifies the number of bytes processed by the control unit to the end of the data area in error.
Bytes 18–19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20–22	Error pattern used for error correction function.
Byte 23	Not used. Set to zero for Class C devices.

11. FORMAT 6: Usage/Error Statistics. If format bits 0–3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the usage/error statistics. Message number meanings are unspecified for Class C devices.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class C devices.

Byte Number	*Usage*
8–11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12–15	Not used. Set to zero for Class C devices.
16–17	Count of the number of Seek commands processed by the control unit.
18	If bit 0 set to zero, bytes 20 through 23 are for control unit channel interfaces A and B (first and second). If bit 0 set to one, bytes 20 through 23 are for control unit channel interfaces C and D (third and fourth).
19	Not used. Set to zero for Class C devices.
20	Count of the number of command overruns for channel interface A or C.
21	Count of the number of data overruns for channel interface A or C.
22	Count of the number of command overruns for channel interface B or D.
23	Count of the number of data overruns for channel interface B or D.

12. FORMAT 7: Command Retry Information. If format bits 0–3 in byte 7 contain a 7, then the sense format indicates command retry information for those environments that do not support channel-level retry.

12.1 Format 7 Message Numbers. The message bits 4–7 in byte 7 contain numbers further identifying the command retry situation. This information is manufacturer dependent and is not specified by this standard.

13. FORMATS 8 Through F. If format bits 0–3 in byte 7 contain hexadecimal 8 through F, the sense format is unspecified for Class C devices.

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