Universal Serial Bus

Mass Storage Specification

For

Bootability

Change History

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1 Introduction

When personal computers and similar devices are powered up, they typically load and begin executing the main operating system from a mass storage device such as a disk drive. This specification defines a set of commands and associated data sufficient to allow the loading of an operating system stored on a USB Mass Storage Class device.

1.1   Scope

This specification fully defines the minimum required set of CDBs and Data a USB Mass Storage device must implement in order for a host to boot from it. The commands defined herein are taken from other industry command set specifications. Some of these specifications conflict with each other in minor details. The command definitions in this specification resolve the applicable conflicts.

1.2   Related Documents

1.2.1   Command Sets

1545-D *Multi-Media Commands - 4 (MMC-4)*, www.t10.org/scsi-3.htm

BSR NCITS 330 *Reduced Block Commands* (RBC), www.t10.org/scsi-3.htm

NCITS 306-1998 *SCSI Block Commands* (SBC), www.t10.org/scsi-3.htm

NCITS 351-2001 *SCSI Primary Commands – 2* (SPC-2), www.t10.org/scsi-3.htm

ATAPI Removable Rewritable Media (INF-8070i), ftp.seagate.com/sff/INF-8070.PDF

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1.2.2   Other

ANSI INCITS 361-2nnn AT *Attachment with Packet Interface (ATA/ATAPI-6)*, www.t13.org/#Projects

ANSI INCITS 363-2nnn *BIOS Enhanced Disk Drive Services* (EDD-2), www.t13.org/#Projects

BIOS Boot Specification (Compaq, Phoenix and Intel), www.phoenix.com/techs/specs.html

El Torito CD-ROM Boot Specification, www.phoenix.com/techs/specs.html

ATAPI Removable Media BIOS Specification, www.phoenix.com/techs/specs.html

other USB Mass Storage Class specifications

1.3   Terms and Abbreviations

1.3.1   Reserved

In the case of Data sent In to the host from the device, reserved fields shall not be used by the host. The device may set reserved fields to values other than zero.

In the case of a CDB or Data sent Out from the host to the device, reserved fields shall be set to 0.

Reserved fields may be defined in other standards or specifications, but for the purposes of bootability are unused.

1.3.2 Out of scope

A value that is out of the scope of this specification. The host may attempt to boot from a device that returns an out-of-scope value, or the host may instead attempt to boot from other devices.

1.3.3 Pad

Some CDBs are defined to have conflicting lengths. PAD bytes are added to make the CDBs have a fixed length of 12 (0Ch). Pad bytes shall be set to zero by the host.

1.3.4 CDB

Command Descriptor Block – the structure used to communicate commands from a host to a logical unit.

1.3.5 BOT

Bulk-Only Transport (specification).

2 General Device Requirements

For devices implementing the BOT specification:
1. If the device is a multiple LUN device, then the bCBWLUN shall be used to determine the logical unit addressed by the command block.
2. The device shall accept a BOT bCBWCBLength of 12 (0Ch) for all the commands documented in this specification.

3 Device Required Command Support

The following sections document the commands that are used to support the firmware abstraction layer for devices. These commands are fully documented in the SFF-8070i and SBC documents. The host shall support all values defined herein. The host may, but is not required to, support values that are out of scope. The host may attempt to boot from a device that returns an out-of-scope value, or the host may instead attempt to boot from other devices.

For optical devices, such as CD, DVD, and MO, when the sector size is 2k the El Torito CD-ROM boot specification is used for booting.

All devices shall support the commands in this section in order to boot.

3.1 INQUIRY Command

The INQUIRY command requests that information regarding parameters of the Device be sent to the Host Computer.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (12h)							
1	Logical Unit Number			Reserved				
2	Reserved							
3	Reserved							
4	Allocation Length (24h)							
5	Reserved							
6 11	PAD							

Table 1 INQUIRY command format

Allocation Lengths other than 24h (36) are *reserved*.

The INQUIRY command returns CHECK CONDITION status only when the Device cannot return the requested INQUIRY data. The INQUIRY data should be returned even though the Device may not be ready for other commands.

If an INQUIRY command is received with a pending unit attention condition (i.e. before the Device reports CHECK CONDITION status), the Device shall perform the INQUIRY command and shall not clear the unit attention condition.

Standard INQUIRY Data

The standard INQUIRY data contains 36 required bytes.

Bit Byte	7	6	5	4	3	2	1	0
0	Reserved			Peripheral Device Type				
1	RMB	Reserved						
2	Reserved							
3	Reserved			Reserved				
4	Additional Length							
5 7	Reserved							
8 15	Vendor Identification							
16 31	Product Identification							
32 35	Product Revision Level							

Table 2 Standard INQUIRY Data

The PDT (Peripheral Device Type) field identifies the device currently connected. The host shall support PDT codes 00h, 05h, 07h, and 0Eh; all others are out of scope.

Code	Description
00h	SBC Direct-access device (e.g., UHD Floppy disk)
01-04h	*Out of scope*
05h	CD-ROM device
06h	*Out of scope*
07h	Optical memory device (e.g., Non-CD optical disks)
08h-0Dh	*Out of scope*
0Eh	RBC Direct-access device (e.g., UHD Floppy disk)
0F-1Fh	*Out of scope*

Table 3 Peripheral Device Type (PDT) codes

A Removable Medium Bit (RMB) of zero indicates that the medium is not removable. An RMB bit of one indicates that the medium is removable. The host shall support both values.

The host shall support Additional Length values 1F-FAh. All others (i.e. 00-1Eh and FB-FFh) are out of scope.

In the Vendor Identification, Product Identification, and Product Revision fields, the host shall support ASCII graphic codes (i.e. code values 20-7Eh). All other byte values (i.e. code values 00-1Fh and 7F-FFh) are out of scope.

3.2   READ(10) Command

The READ(10) command requests that the Device transfer data to the host computer. The most recent data value written in the addressed logical block is returned.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (28h)							
1	Logical Unit Number			Reserved				
2	(MSB)							
3	Logical Block Address							
4								
5	(LSB)							
6	Reserved							
7	(MSB) Transfer Length							
8	(LSB)							
9	Reserved							
10	PAD							
11								

Table 4 READ(10) command

The Logical Block Address field specifies the logical block at which the read operation begins.

The Transfer Length field specifies the number of contiguous logical blocks of data that are transferred. A Transfer Length of zero indicates that no logical blocks are transferred. This condition is not considered an error. Any other value indicates the number of logical blocks that are transferred.

3.3   REQUEST SENSE Command

The REQUEST SENSE command instructs the Device to transfer sense data to the host computer.

Whenever an error is reported, the Host Computer should issue a REQUEST SENSE command to receive the sense data describing what caused the error condition. If the Host Computer issues some other command, the sense data is lost.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (03h)							
1	Logical Unit Number			Reserved				
2	Reserved							
3	Reserved							
4	Allocation Length							
5	Reserved							
6 11	PAD							

Table 5 REQUEST SENSE command

The sense data is available if:
1. an error condition (CHECK CONDITION) had previously been reported to the Host Computer;
2. other information (e.g. medium position) is available in any field.

If the Device has no other sense data available to return, it returns a sense key of NO SENSE and an additional sense code of NO ADDITIONAL SENSE INFORMATION.

The sense data is preserved by the Device until retrieved by a REQUEST SENSE command or until the receipt of any other I/O Command.

The Device returns CHECK CONDITION status for a REQUEST SENSE command only to report exception conditions specific to the command itself. For example:
1. A non-zero reserved bit is detected in the Command Packet;
2. A Device malfunction prevents return of the sense data.

If a recovered error occurs during the execution of the REQUEST SENSE command, the Device returns the sense data with GOOD status. If a Device returns CHECK CONDITION status for a REQUEST SENSE command, the sense data may be invalid.

Devices shall be capable of returning at least 18 bytes of data in response to a REQUEST SENSE command. If the Allocation Length is 18 or greater, and a Device returns less than 18 bytes of data, the Host Computer should assume that the bytes not transferred are zeros. Host Computers can determine how much sense data has been returned by examining the Allocation Length parameter in the Command Packet and the Additional Sense Length in the sense data. Devices do not adjust the Additional Sense Length to reflect truncation if the Allocation Length is less than the sense data available.

Bit Byte	7	6	5	4	3	2	1	0
0	Valid	Error Code (70h or 71h)						
1	Segment Number (Reserved)							
2	Reserved		ILI	Reserved	Sense Key			
3 6	Information							
7	Additional Sense Length (n - 7)							
8 11	Command Specific Information							
12	Additional Sense Code							
13	Additional Sense Code Qualifier (Optional)							
14 17	Reserved							
18 n	Reserved							

Table 6 Standard REQUEST SENSE data

The Sense Key, Additional Sense Code and Additional Sense Code Qualifier provide a hierarchy of information. The intention of the hierarchy is to provide a top-down approach for a Host Computer to determine information relating to the error and exception conditions. The Sense Key provides generic categories in which error and exception conditions can be reported. Host Computers would typically use sense keys for high-level error recovery procedures. Additional Sense Codes provide further detail describing the sense key. Additional Sense Code Qualifiers add further detail to the additional sense code. The Additional Sense Code and Additional Sense Code Qualifier can be used by Host Computers where sophisticated error recovery procedures require detailed information describing the error and exception conditions.

3.4 TEST UNIT READY Command

The TEST UNIT READY command provides a means to check if the Device is ready. This is not a request for a self-test. If the Device would accept an appropriate medium-access command without returning CHECK CONDITION status, this command returns a GOOD status. If the Device cannot become operational or is in a state such that a Host Computer action is required to make the Device ready, the Device returns CHECK CONDITION status with a sense key of NOT READY.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (00h)							
1	Logical Unit Number			Reserved				
2	Reserved							
3	Reserved							
4	Reserved							
5	Reserved							
6 11	PAD							

Table 7 TEST UNIT READY command

The TEST UNIT READY command is useful in that it allows a Host Computer to poll a Device until it is ready without the need to allocate space for returned data. It is especially useful to check media status. Devices are expected to respond promptly to indicate the current status of the Device.

4 Read/Write Media Device Required Commands

The commands in this section are required for all devices which report a Peripheral Device Type (PDT) of 0x00, 0x07, or 0x0E.

4.1 MODE SENSE(10) Command

The MODE SENSE command provides a means for a Device to report parameters to the Host Computer. It is a complementary command to the MODE SELECT command.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (5Ah)							
1	Logical Unit Number			Reserved	DBD(0)	Reserved		
2	Reserved		Page Code					
3	Reserved							
4	Reserved							
5	Reserved							
6	Reserved							
7	Parameter List Length (MSB)							
8	Parameter List Length (LSB)							
9	Reserved							
10	PAD							
11								

Table 8 MODE SENSE(10) command

4.1.1 Flexible Disk Mode Page (FDMP)

Support for the Flexible Disk Mode Page is required for all devices with a Peripheral Device Type other than 05h. The FDMP provides the geometry that is necessary for translating a CHS address to a SCSI standard logical block address.

The 28h bytes of Flexible Disk Mode Page data returned by the Device shall begin with an 8-byte MODE PARAMETER HEADER. Byte 0 shall be 00 and byte 1 shall be 26h.

Bit Byte	7	6	5	4	3	2	1	0
0	(MSB)							
1	Mode Data Length							(LSB)
2	Reserved							
3								
4								
5								
6	(MSB) Block Descriptor Length (0 or 8)							
7								(LSB)

Table 9 Mode Parameter Header(10)

Bit Byte	7	6	5	4	3	2	1	0
0-7	Mode parameter header							
0-7	Block descriptor (if Block Descriptor Length is 8)							
0-n	Page(s)							

Table 10 Mode Parameter List

Note:
The device may return zero or more Block Descriptors regardless of the value of DBD. The host shall accept any Block Descriptors returned by the device in consideration of conflicts between existing industry specifications.

Bit Byte	7	6	5	4	3	2	1	0
0	Unused		Page Code (05)					
1	Page length in bytes (1Eh)							
2	Unused							
3								
4	Number of Heads							
5	Sectors per Track							
6	Bytes per Sector							
7								
8	Number of Cylinders							
9								
10-31	Unused							

Table 11 Mode Page (05)

The number of heads field specifies the number of heads used for reading and writing data on the medium. Heads used exclusively for servo information are excluded.

The sectors per track field specifies the number of sectors per revolution per head.

The data bytes per sector field specifies the number of bytes of data per sector that an application client can read or write.

The number of cylinders field specifies the number of cylinders used for data storage.

4.2 READ CAPACITY

The READ CAPACITY command provides a means for the host computer to request information regarding the capacity of the installed medium of the device.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (25h)							
1	Logical Unit Number			Reserved				
2	Reserved							
3	Reserved							
4	Reserved							
5	Reserved							
6	Reserved							
7	Reserved							
8	Reserved							
9	Reserved							
10	PAD							
11								

Table 12 READ CAPACITY command

Eight bytes of READ CAPACITY data shall be returned to the host computer.

Bit Byte	7	6	5	4	3	2	1	0
0	(MSB)							
1	Last Logical Block Address							
2								
3								(LSB)
4	(MSB)							
5	Block Length in Bytes							
6								
7								(LSB)

Table 13 READ CAPACITY data

The Last Logical Block Address field holds the last valid LBA for use with media access commands.

5 CD/DVD Device Required Commands

CD-ROM and DVD devices shall report device type 5 in the response data returned by the Inquiry command. CD-ROM and DVD devices differ from devices described previously in that they have a 2k-logical block size and are read only. Although these devices support many of the same commands, their file system requires additional commands such as read table of contents.

5.1 READ TOC

The READ TOC command is used by the Host Computer to identify a multi-session CD.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (43h)							
1	Reserved						MSF	Reserved
2	Reserved				Format-A			
3	Reserved							
4	Reserved							
5	Reserved							
6	Reserved							
7	MSB	Allocation Length						
8								LSB
9	Format-B		Reserved					
10	PAD							
11								

Table 14 READ TOC command

To identify the multi-session CD TOC, the Host Computer shall issue the following READ TOC command.

The Format-A field in byte 2 of the CBD shall be set to zero and the Format-B field, bits 7-6 of byte 9, shall be set to 01b. These values indicate "Multi-session mode". All other values are reserved for definition in MMC.

The MSF bit shall be set to 0 to indicate that the return CD address values are specified in LBA format, not minute second frame.

The Allocation Length shall be set to 0Ch (12); all other values are reserved.

The device shall return the following data.

Bit Byte	7	6	5	4	3	2	1	0
0	MSB		TOC Data Length (0Ah)					
1								LSB
2	First Complete Session Number							
3	Last Complete Session Number							
	TOC Track Descriptor							
0	Reserved							
1	Reserved							
2	First Track Number in Last Complete Session							
3	Reserved							
4	MSB							
5	Logical Block Address of First Track in Last Session							
6								
7								LSB

Table 15 READ TOC data

The TOC Data Length specifies the length in bytes of the following TOC data that is available to be transferred to the Host. The TOC Data Length Value does not include the TOC Data Length field itself. The data length shall be set to 10 (0Ah). All other values are out of scope.

The First Complete Session Number shall be set to one. All other values are out of scope.

The Last Complete Session Number indicates the number of the last complete session on the disc. The Last Complete Session Number shall be set to one for a single session disc or if the Logical Unit does not support multi-session discs.

First Track Number In Last Complete Session returns the first track number in the last complete session.

The Logical Block Address contains the address of the first block with user information for the first track of the last session, as read from the Table of Contents. If the MSF bit is zero, the Logical Block Address field shall contain a logical block address. Any other values for the MSF bit and this Logical Block Address are out of scope.

6 SCSI Commands To Support Optional INT 13 Functions

The following commands are required to support optional INT 13 commands such as Verify and Format

6.1 FORMAT UNIT Command

The host sends the FORMAT UNIT command to physically format a diskette according to selected options.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (04h)							
1	Logical Unit Number			FmtData (1)	CmpList (0)	Defect List Format (7)		
2	Vendor Specific							
3	(MSB)	Interleave						
4								(LSB)
5	Reserved							
6	PAD							
11								

Table 16 FORMAT UNIT command

The FmtData bit is set to 1, the CmpList bit is set to 0, and the Defect List Format is set to 7. All other values in these fields return a Check Condition with the Sense Key set to ILLEGAL REQUEST and the Sense Code set to INVALID FIELD IN COMMAND PACKET.

Interleave: This specifies the interleave to be used when formatting. A value of 0 specifies that the Block Device uses the default value. The default is 1:1 for all formattable media. A 1:1 interleave specifies that consecutive logical blocks are placed in contiguous ascending order.

6.2 VERIFY Command

The VERIFY command requests that the Device verify the data written on the medium.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (2Fh)							
1	Logical Unit Number			Reserved			ByteChk	Reserve
2	(MSB)							
3	Logical Block Address							
4								
5								(LSB)
6	Reserved							
7	Verification Length (MSB)							
8	Verification Length (LSB)							
9	Reserved							
10	PAD							
11								

Table 17 VERIFY command

The Byte Check (ByteChk) bit is optional. A ByteChk bit of zero causes a medium verification to be performed with no data comparison. A ByteChk bit of one causes a byte-by-byte compare of data written on the medium and the data transferred from the Host Computer. If the comparison is unsuccessful for any reason, the Device returns a CHECK CONDITION status with the sense key set to MISCOMPARE. The Verification Length field specifies the number of contiguous logical blocks of data to be verified. A Verification Length of zero indicates that no logical blocks are to be verified. This condition is considered an error-free null operation.

6.3   WRITE(10) Command

The WRITE(10) command requests that the Device write the data transferred by the Host Computer to the medium.

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (2Ah)							
1	Logical Unit Number			Reserved				
2	(MSB)							
3	Logical Block Address							
4								
5								(LSB)
6	Reserved							
7	Transfer Length (MSB)							
8	Transfer Length (LSB)							
9	Reserved							
10	PAD							
11								

Table 18 WRITE(10) command

The Logical Block Address field specifies the logical block at which the write operation begins.

The Transfer Length field specifies the number of contiguous logical blocks of data that are transferred. A Transfer Length of zero indicates that no logical blocks are transferred. This condition is not considered an error and no data is written. Any other value indicates the number of logical blocks that are transferred.