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Information technology – AT Attachment – Part 102: ATA/ATAPI Command Set - 2 (ACS-2)



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INFORMATION TECHNOLOGY – AT Attachment –

Part 102: ATA/ATAPI Command Set - 2 (ACS-2)

FOREWORD

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International Standard ISO/IEC 17760-102 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

The list of all currently available parts of the ISO/IEC 17760 series, under the general title *Information technology – AT Attachment*, can be found on the IEC web site.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2, except as indicated in 3.3.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This International Standard standard encompasses the following:

Clause 1 describes the scope.

Clause 2 provides normative references for the entire standard.

Clause 3 provides definitions, abbreviations, and conventions used within the entire standard.

Clause 4 describes the general operating requirements of the command layer.

Clause 5 describes the ATA protocols used by the commands in this standard.

Clause 6 describes Normal and Error Output fields.

Clause 7 describes commands.

Clause 8 describes the SCT Command Transport.

Clause 9 describes command normal and error outputs.

Normative Annex A describes logs.

Informative Annex B provides command summaries.

Informative Annex C describes considerations for using devices with non-512-byte sectors.

Informative Annex D provides a tutorial on how to use SCT.

Informative Annex E provides implementation guidelines for 1 024/4 096 byte sectors.

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ATA document relationships

The set of AT Attachment standards consists of this standard and the ATA implementation standards described in AT Attachment - 8 ATA/ATAPI Architecture Model (ATA8-AAM). Figure 1 shows the relationship of this standard to the other standards and related projects in the ATA and SCSI families of standards and specifications.

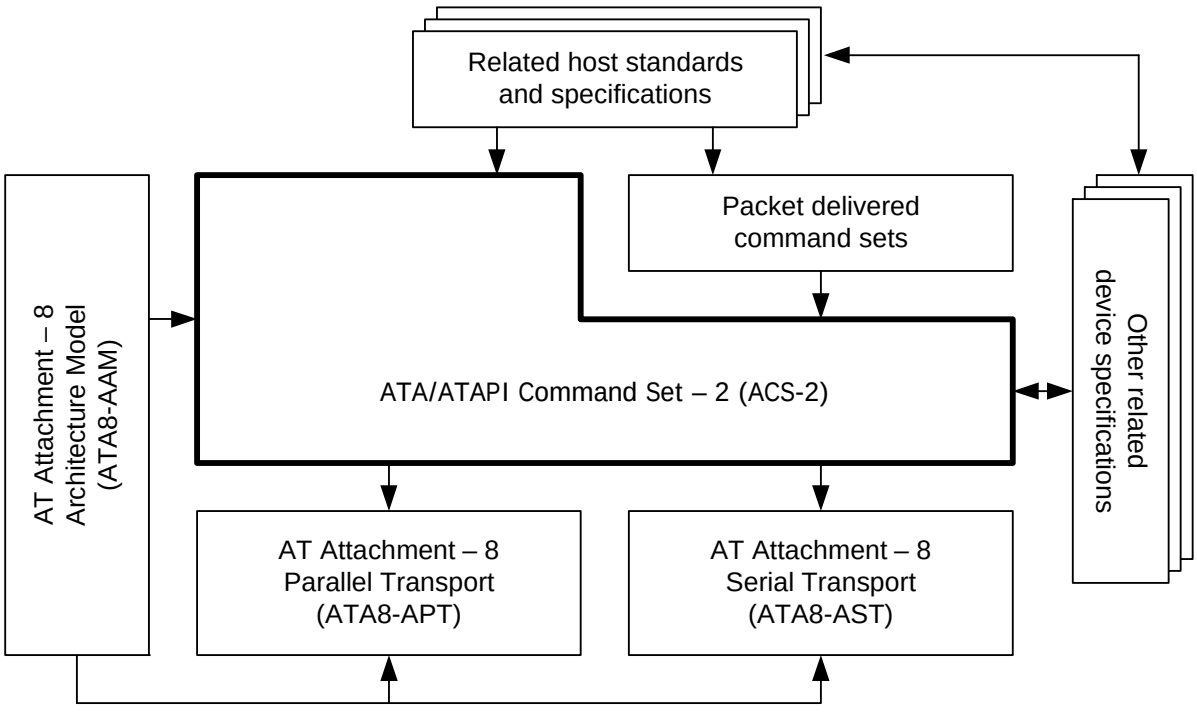


Figure 1 — ATA document relationships

The International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) draw attention to the fact that it is claimed that compliance with this document may involve the use of a patent.

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INFORMATION TECHNOLOGY – AT Attachment –

Part 102: ATA/ATAPI Command Set - 2 (ACS-2)

1 Scope

This part of ISO/IEC 17760-102 specifies the command set host systems use to access storage devices. It provides a common command set for systems manufacturers, system integrators, software suppliers, and suppliers of intelligent storage devices.

This standard maintains compatibility with the ATA8-ACS standard, INCITS 452-2008, while providing additional functions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 646, *Information technology – ISO 7-bit coded character set for information interchange*[1]

ISO/IEC 14776-323, *SCSI Block Commands - 3 (SBC-3)*

ISO 7779:1999, *Acoustics – Measurement of airborne noise emitted by information technology and telecommunications equipment*

ANSI INCITS 451-2008[R2013], *AT Attachment-8 – ATA/ATAPI Architecture Model (ATA8-AAM)*

ANSI INCITS 493-2012, *AT Attachment-8 – Serial Transport (ATA8-AST)*

ANSI INCITS 524-2016, *AT Attachment-8 – Parallel Transport (ATA8-APT)*

ANSI INCITS BSR 513, *SCSI Primary Commands - 4 (SPC-4)* (planned as ISO/IEC 14776-454)

Serial ATA revision 2.6 (SATA 2.6) (see http://www.sata-io.org)

CompactFlash Association Specification, *Revision 5.0* (see http://www.compactflash.org)

CFast™, a CompactFlash™ Association Specification, *Rev 1.0* (see http://www.compactflash.org)[2]

IETF RFC 3280, *Internet X.509 Public Key Infrastructure: Certificate and Certificate Revocation List (CRL) Profile* (see http://www.ietf.org)

IETF RFC 3281, *An Internet Attribute Certificate: Profile for Authorization* (see http://www.ietf.org)

1. ANSI INCITS 4-1986 (R2002), *Information Systems – Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)*

2. CFast and CompactFlash are trademarks of the Compact Flash Association.

3 Terms, definitions, abbreviations, and conventions

3.1 Terms and definitions

For the purposes of this document the following terms and definitions apply.

3.1.1
28-bit command
command that uses Feature (7:0), Count (7:0), LBA (27:0), Device (15:8) and Command (7:0) to specify its arguments

3.1.2
48-bit command
command that uses Feature (15:0), Count (15:0), LBA (47:0), Device (15:8) and Command (7:0) to specify its arguments

3.1.3
acoustics
measurement of airborne noise emitted by information technology and telecommunications equipment

Note 1 to entry: See ISO 7779:1999(E).

3.1.4
Active mode
power condition specified by the PM0: Active state

3.1.5
application
software that is dependent on the services of an operating system

3.1.6
application client
object in the host that is the source of commands and device management functions

Note 1 to entry: See ATA8-AAM.

3.1.7
ASCII character
byte containing a 7-bit ASCII pattern in bits (6:0) with bit 7 cleared to zero

Note 1 to entry: See ISO/IEC 646.

3.1.8
ATA device
AT Attachment device
device implementing the General feature set

Note 1 to entry: See 4.2.

3.1.9
ATA string
set of ASCII characters (see 3.1.7) in the format specified in 3.3.10

3.1.10
ATAPI device
AT Attachment Packet Interface device
device implementing the PACKET feature set

Note 1 to entry: See 4.3.

3.1.11
Audio-Video
AV
Audio-Video application data that is related to video images and/or audio

Note 1 to entry: See 4.24.

3.1.12
Background Activities
activities initiated by a command that occur after command completion has been reported

3.1.13
basic input/output system
BIOS
initial application client that is run when power is applied

Note 1 to entry: The primary function of BIOS is to initialize various components (e.g. storage devices).

3.1.14
block erase
internal media operation supported by some devices that sets a block of data to a vendor specific value (i.e., replacing previous data) and may precondition the media for write operations

3.1.15
byte
sequence of eight contiguous bits considered as a unit

Note 1 to entry: See 3.3.9.

3.1.16
cache
data storage area outside the area accessible by application clients that may contain a subset of the data stored in the non-volatile data storage area

3.1.17
CFA device
device implementing the CFA feature set

Note 1 to entry: CFA devices may implement the ATA8-APT transport or the ATA8-AST transport (see 3.1.19).

Note 2 to entry: See 4.6.

3.1.18
CFA-APT device
CFA device that implements the ATA8-APT transport and not the ATA8-AST transport

3.1.19
CFast™ Device
CF form factor device that conforms to the SATA device requirements in this standard, implements the ATA8-AST transport and does not implement the ATA8-APT transport

Note 1 to entry: CFast™ devices may support the CompactFlash™ feature set.

3.1.20
check condition
indicates an error or exception condition has occurred for an ATAPI device

3.1.21
circular buffer
buffer that is filled starting at the first byte continuing to the last byte and then wraps to store data in the first byte of the buffer again

3.1.22
command aborted
command completion with the Error bit set to one in the Status field and the Abort bit set to one in the Error field

3.1.23
command acceptance
positive acknowledgement of a command being received by a device

Note 1 to entry: See the appropriate transport standard for a definition of positive acknowledgement.

3.1.24
command completion
completion by the device of the action requested by the command or the termination of the command with an error, the setting of the appropriate bits in the Error field, and the setting of the appropriate bits in the Status field

3.1.25
command packet
data structure transmitted to the device during the processing of a PACKET command

Note 1 to entry: A command packet includes the command and command parameters.

3.1.26
COMRESET
commanded hardware reset in the Serial ATA transport

Note 1 to entry: See SATA 2.6.

3.1.27
Data Set
set of LBA Ranges used by the device as a single group

3.1.28
DCO Set
command which changes the device configuration

Note 1 to entry: The following commands are DCO Set commands: DEVICE CONFIGURATION SET command (see 7.10.6) and DEVICE CONFIGURATION SET DMA command (see 7.10.7).

Note 2 to entry: See 4.7.

3.1.29
device
data storage peripheral

EXAMPLE a disk drive.

Note 1 to entry: See 3.1.8 and 3.1.10.

3.1.30
DMA data transfer
direct memory access data transfer
means of data transfer between device and host memory without application client intervention

3.1.31
DRQ data block
Data Request data block
number of logical sectors with available status when using either the PIO Data-In command protocol or the PIO Data-Out command protocol

3.1.32
DWord
sequence of four contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.33
FIS
Frame Information Structure for the serial ATA interface

Note 1 to entry: See ATA8-AST.

3.1.34
free fall
vendor specific condition of acceleration

3.1.35
hardware reset
routine performed by a device after a hardware reset event as defined in ATA8-AAM

3.1.36
HPA Locked
condition of a device in the H2, HL1-HL6 or HEL1-HEL6 state

Note 1 to entry: See 4.11.6.

3.1.37
HPA Unlocked
condition of a device in the H0, H1, H3, HS1-HS6, or HES1-HES6 state

Note 1 to entry: HPA Unlocked states are those in which the password may or may not be set.

Note 2 to entry: See 4.11.6.

3.1.38
host
object that originates commands and device management functions

Note 1 to entry: See ATA8-AAM.

3.1.39
host adapter
implementation of the host transport, link, and physical layers

3.1.40
host interface
service delivery subsystem

Note 1 to entry: See ATA8-AAM.

3.1.41
Idle mode
power condition specified by the PM1: Idle state

3.1.42
Invalid LBA
LBA that is greater than or equal to the largest value reported in IDENTIFY DEVICE data words 60..61 (see 7.17.7.22), IDENTIFY DEVICE data words 100..103 (see 7.17.7.53), or IDENTIFY DEVICE data words 230..233 (see 7.17.7.89)

3.1.43
Invalid LBA Range
range of LBAs that contains one or more invalid LBAs

3.1.44
least significant bit
LSB
<binary code> bit or bit position with the smallest numerical weighting in a group of bits that, when taken as a whole, represent a numerical value

EXAMPLE - In the number 0001b, the bit that is set to one.

3.1.45
logical block address
LBA
value used to reference a logical sector

3.1.46
logical sector
logical block
sector
set of logical words accessed and referenced as a unit

Note 1 to entry: Logical sectors are referenced by LBA (see 3.1.45).

Note 2 to entry: See IDENTIFY DEVICE data words 118:117 (see 7.17.7.61).

3.1.47
log
named sequence of one or more log pages

Note 1 to entry: See Annex A.

3.1.48
log address
numeric value that a log command uses to identify a specific log

3.1.49
log command
SMART READ LOG command (see 7.54.7), SMART WRITE LOG command (see 7.54.9), or GPL feature set (see 4.10) command

3.1.50
log page
512-byte block of data associated with a log

Note 1 to entry: See Annex A.

3.1.51
Master Password Capability
Security Level
indication of whether the Master password may be used to unlock the device

3.1.52
Media
material on which user data is stored

3.1.53
Media Access Command
command that causes the device to access non-volatile media

3.1.54
most significant bit
MSB
<binary code> bit or bit position with the largest numerical weighting in a group of bits that, when taken as a whole, represent a numerical value

EXAMPLE - In the number 1000b, the bit that is set to one.

3.1.55
native max address
highest LBA that a device accepts as reported by DEVICE CONFIGURATION IDENTIFY data as reduced by the DEVICE CONFIGURATION SET command

Note 1 to entry: The native max address is the highest LBA that is accepted by a device using the SET MAX ADDRESS command (see 7.50.2). If the 48-bit Address feature set is supported, the native max address is the highest value accepted by a device using the SET MAX ADDRESS EXT command (see 7.51).

3.1.56
Non-Volatile cache
cache that retains data through all reset events (e.g. power-on reset)

Note 1 to entry: Non-volatile cache is a subset of the non-volatile media.

3.1.57
Non-Volatile Media
physical storage media that retains data written to it through all reset events (e.g., power-on reset)

3.1.58
NV Cache Pinned Set
set of logical blocks specified by the application client for which all user data accesses associated with those logical blocks are written to or read from the non-volatile cache

3.1.59
NV Cache Set
set of logical blocks represented in the device's entire NV Cache

3.1.60
NV Cache Set Data
data structure representing the standard format of transmitting logical blocks in the form of a list of LBA Range Entries

3.1.61
NV Cache Unpinned Set
set of logical blocks that are represented in the NV Cache Set but not represented in the NV Cache Pinned Set

Note 1 to entry: See 4.15.1.

3.1.62
organizationally unique identifier
OUI
numeric identifier that is assigned by the IEEE such that no assigned identifiers are identical

Note 1 to entry: OUI is equivalent to company_id or IEEE company_id.

Note 2 to entry: The numeric identifier is called an OUI when it is assigned by the IEEE.

Note 3 to entry: The IEEE maintains a tutorial describing the OUI at http://standards.ieee.org/regauth/oui/.

3.1.63
partition
range of LBAs specified by an application client

3.1.64
Password Attempt Counter Exceeded
contents of IDENTIFY DEVICE, word 128, bit 4 (see 7.17.7.66)

3.1.65
PATA device
Parallel ATA device
device implementing the parallel ATA transport

Note 1 to entry: See ATA8-APT.

3.1.66
physical sector
one or more contiguous logical sectors that are read from or written to the device media in a single operation

3.1.67
PIO data transfer
programmed input/output data transfer
data transfers performed using PIO commands and protocol

3.1.68
power condition
one of the following power management substates: Idle_a, Idle_b, Idle_c, Standby_y or Standby_z

Note 1 to entry: See 4.8.

3.1.69
power cycle
interval from when power is removed from a host or device until the subsequent power-on event

Note 1 to entry: See ATA8-AAM.

3.1.70
power-on reset
host specific routine performed by the host or the routine performed by a device after detecting a power-on event

Note 1 to entry: See ATA8-AAM.

3.1.71
Queued Command
NCQ command that has reported command acceptance but not command completion

3.1.72
QWord
sequence of eight contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.73
read command
command that causes the device to transfer data from the device to the host

Note 1 to entry: The following commands are read commands: READ DMA, READ DMA EXT, READ DMA QUEUED, READ FPDMA QUEUED, READ MULTIPLE, READ MULTIPLE EXT, READ SECTOR(S), READ SECTOR(S) EXT, READ STREAM EXT, READ STREAM DMA EXT, READ VERIFY SECTOR(S), or READ VERIFY SECTOR(S).

3.1.74
read stream command
command that causes the device to transfer data from the device to the host

Note 1 to entry: The following commands are read stream commands: READ STREAM EXT and READ STREAM DMA EXT.

3.1.75
SATA device
Serial ATA device
device implementing the serial ATA transport

Note 1 to entry: See ATA8-AST.

3.1.76
SCT Command
command that writes to the SCT command/status log

Note 1 to entry: See clause 8.

3.1.77
SCT Status
command that reads from the SCT command/status log

Note 1 to entry: See clause 8.

3.1.78
Serial ATAPI device
device implementing the serial ATA transport (see ATA8-AST) and the PACKET feature set

3.1.79
signature
unique set of values placed in the return parameters used to distinguish device types (e.g., General, ATAPI device, Port Multiplier)

Note 1 to entry: See table 217.

3.1.80
signed
value that is encoded using two's compliment

3.1.81
Sleep mode
power condition specified by the PM3: Sleep state

3.1.82
software reset
routine performed by a device after a software reset event as defined in ATA8-AAM

Note 1 to entry: The software reset routine includes the actions defined in ATA8-AAM, this standard, and the applicable transport standards.

3.1.83
spin-down
process of bringing a rotating media device's media to a stop

3.1.84
spin-up
process of bringing a rotating media device's media to operational speed

3.1.85
Standby mode
power condition specified by the PM2: Standby state

3.1.86
Stream
set of operating parameters specified by a host using the CONFIGURE STREAM command (see 7.8) to be used for subsequent READ STREAM commands and WRITE STREAM commands

3.1.87
transport
mechanism used to communicate with a device

Note 1 to entry: See ATA8-APT and ATA8-AST.

3.1.88
unaligned write
write command that does not start at the first logical sector of a physical sector or does not end at the last logical sector of a physical sector

3.1.89
unrecoverable error
when the device sets either the Error bit or the Device Fault bit to one in the Status field at command completion

3.1.90
user data
data that is transferred between the application client and the device using read commands and write commands

3.1.91
user data area
area of the device's media that stores user data and is addressable by the host from LBA 0 to DEVICE CONFIGURATION IDENTIFY data words 3..6

3.1.92
Volatile Cache
cache that does not retain data through power cycles

3.1.93
vendor specific
bits, bytes, fields, and code values that are reserved for vendor specific purposes, also levels of functionality whose definition is left to the vendor

Note 1 to entry: Vendor specific bits, bytes, fields, and code values are not described in this standard, and implementations may vary among vendors.

3.1.94
word
sequence of two contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.95
write command
command that causes the device to transfer data from the host to the device

Note 1 to entry: The following commands are write commands: SCT Write Same, WRITE DMA, WRITE DMA EXT, WRITE DMA FUA EXT, WRITE FPDMA QUEUED, WRITE MULTIPLE, WRITE MULTIPLE EXT, WRITE MULTIPLE FUA EXT, WRITE SECTOR(S), WRITE SECTOR(S) EXT, WRITE STREAM DMA EXT, or WRITE STREAM EXT.

3.1.96
write stream command
command that causes the device to transfer data from the host to the device

Note 1 to entry: The following commands are write stream commands: WRITE STREAM DMA EXT and WRITE STREAM EXT.

3.1.97
world wide name
WWN
64-bit worldwide unique name based upon a company's IEEE OUI

Note 1 to entry: The WWN is reported in IDENTIFY DEVICE data words 108..111 (see 7.17.7.58) and IDENTIFY PACKET DEVICE data words 108..111 (see 7.18.6.44).

3.2 Symbols and abbreviations

3.2.1 Abbreviations

Abbreviations used in this standard:

Abbreviation	Meaning
ACS	ATA/ATAPI Command Set
APM	Advanced Power Management
ASC	Additional Sense Code
ASCII	American Standard Code for Information Interchange
ASCQ	Additional Sense Code Qualifier
ASR	Asynchronous Signal Recovery
ATA	AT Attachment
ATAPI	AT Attachment with Packet Interface
ATA/ATAPI-5	AT Attachment with Packet Interface Extension - 5 (see Bibliography)
ATA/ATAPI-6	AT Attachment with Packet Interface Extension - 6 (see Bibliography)
ATA/ATAPI-7	AT Attachment with Packet Interface Extension - 7 (see Bibliography)
ATA8-AAM	AT Attachment-8 - ATA/ATAPI Architecture Model (see clause 2)
ATA8-ACS	AT Attachment – 8 ATA/ATAPI Command Set (see Bibliography)
ATA8-APT	AT Attachment-8 - Parallel Transport (see clause 2)
ATA8-AST	AT Attachment-8 - Serial Transport (see clause 2)

Abbreviation	Meaning
AV	Audio/Visual
BIOS	Basic I/O System
CDB	Command Descriptor Block (see SPC-4)
CFA	Compact Flash Association
CFast	Compact Flash ATA Serial Transport
CRC	Cyclic Redundancy Check
DCO	Device Configuration Overlay
DDT	Method to Disable Data Transfer after Error Technical Report (see Bibliography)
DMA	Direct Memory Access
DRQ	Data ReQuest
EPC	Extended Power Conditions
EXT	Command used the extended (48-bit LBA) format parameters
FIS	Frame Information Structure
FUA	Forced Unit Access
GPL	General Purpose Logging
HBA	Host Bus Adapter
HBA-2	Host Bus Adapter - 2 (see Bibliography)
HPA	Host Protected Area
INCITS	InterNational Committee for Information Technology Standards (see www.incits.org)
ISO	Organization for International Standards
LBA	Logical Block Address
LLS	Long Logical Sector
LPS	Long Physical Sector
LSB	Least Significant Bit
MSB	Most Significant Bit
NCQ	Native Command Queueing
NV	Non-volatile
OUI	Organizationally Unique Identifier
PARTIES	Protected Area Run Time Interface Extensions (see Bibliography)
PATA	Parallel ATA
PIO	Programmed Input/Output
PUIS	Power-Up In Standby
RMW	Read-Modify-Write
SATA	Serial ATA
SATA-IO	Serial ATA International Organization (see www.sata-io.org)
SCT	SMART Command Transport
SMART	Self-Monitoring Analysis and Reporting Technology
SPC-4	SCSI Primary Commands - 4 (see clause 2)
SSP	Software Settings Preservation
T10	INCTIS Technical Committee T10
T13	INCTIS Technical Committee T13
TCG	Trusted Computing Group (see www.trustedcomputinggroup.org)
TLC	Time Limited Commands (see Bibliography)

Abbreviation	Meaning
VS	Vendor Specific
WWN	World Wide Name

3.2.2 Units

Units used in this standard:

Unit	Meaning
h	hour (unit of time)
min	minute (unit of time)
ma	milliampere
ms	millisecond (i.e., 10^{-3} seconds)
ns	nanosecond (i.e., 10^{-9} seconds)
s	second (unit of time)
µs	microsecond (i.e., 10^{-6} seconds)
V	volt

3.2.3 Symbols

Symbols used in this standard:

Symbol	Meaning
®	registered trademark
™	registered trademark

3.2.4 Mathematical operators

Mathematical operators used in this standard:

Mathematical Operator	Meaning
+	added to
–	subtracted from
×	multiplied by
/	divided by
<	less than
≤	less than or equal to
>	greater than
≥	greater than or equal to

3.3 Conventions

3.3.1 Overview

Lowercase is used for words having the normal English language meaning. Certain words and terms used in this standard have a specific meaning beyond the normal English language meaning. These words and terms are defined either in clause 3 or in the text where they first appear.

The names of abbreviations, commands, fields, and acronyms used as signal names are in all uppercase (e.g., IDENTIFY DEVICE). Fields containing only one bit are usually referred to as the “name” bit instead of the “name” field. (See 3.3.6 for the naming convention used for naming bits.)

Names of device fields begin with a capital letter (e.g., Count).

The expression “word n” or “bit n” shall be interpreted as indicating the content of word n or the content of bit n.

3.3.2 Precedence

If there is a conflict between text, figures, and tables, the precedence shall be tables, figures, then text.

3.3.3 Lists

3.3.3.1 Lists overview

Lists are associated with an introductory paragraph or phrase, and are numbered relative to that paragraph or phrase (i.e., all lists begin with an a) or 1) entry).

Each item in a list shall be preceded by an identification with the style of the identification being determined by whether the list is intended to be an ordered list or an unordered list.

If the item in a list is not a complete sentence, then the first word in the item shall not be capitalized. If the item in a list is a complete sentence, then the first word in the item shall be capitalized,

Each item in a list shall end with a semicolon, except the last item, which shall end in a period. The next to the last entry in the list shall end with a semicolon followed by an “and” or an “or” (i.e., “…; and”, or “…; or”). The “and” is used if all the items in the list are required. The “or” is used if only one or more items in the list are required.

3.3.3.2 Unordered lists

An unordered list is one in which the order of the listed items is unimportant (i.e., it does not matter where in the list an item occurs as all items have equal importance). Each list item shall start with a lower case letter followed by a close parenthesis. If it is necessary to subdivide a list item further with an additional unordered list (i.e., have a nested unordered list), then the nested unordered list shall be indented and each item in the nested unordered list shall start with an upper case letter followed by a close parenthesis.

The following is an example of an unordered list with a nested unordered list:

EXAMPLE - The following are the items for the assembly:

a) a box containing:
   A) a bolt;
   B) a nut; and
   C) a washer;
b) a screwdriver; and
c) a wrench.

3.3.3.3 Ordered lists

An ordered list is one in which the order of the listed items is important (i.e., item n is required before item n+1). Each listed item starts with an Western-Arabic numeral followed by a close parenthesis. If it is necessary to subdivide a list item further with an additional unordered list (i.e., have a nested unordered list), then the nested unordered list shall be indented and each item in the nested unordered list shall start with an upper case letter followed by a close parenthesis.

The following is an example of an ordered list with a nested unordered list:

EXAMPLE - The following are the instructions for the assembly:

1) remove the contents from the box;
2) assemble the item;
   A) use a screwdriver to tighten the screws; and
   B) use a wrench to tighten the bolts;
   and
3) take a break.

3.3.4 Keywords

3.3.4.1
expected
keyword used to describe the behavior of the hardware or software in the design models assumed by this standard

Note 1 to entry: Other hardware and software design models may also be implemented.

3.3.4.2
mandatory
keyword indicating items to be implemented as defined by this standard

3.3.4.3
may
keyword that indicates flexibility of choice with no implied preference

3.3.4.4
N/A
keyword that indicates a field is not applicable and has no defined value and should not be checked by the host or device

3.3.4.5
obsolete
keyword indicating that the designated bits, bytes, words, fields, and code values that may have been defined in previous standards are not defined in this standard and shall not be reclaimed for other uses in future standards

Note 1 to entry: Some degree of functionality may be required for items designated as “obsolete” to provide for backward compatibility.

Note 2 to entry: Obsolete commands should not be used by the host.

Note 3 to entry: Commands defined as obsolete may return command aborted by devices conforming to this standard. However, if a device does not return command aborted for an obsolete command, the device shall return command completion for the command.

3.3.4.6
optional
keyword that describes features that are not required by this standard

Note 1 to entry: If any optional feature defined by the standard is implemented, the feature shall be implemented in the way defined by the standard.

3.3.4.7
prohibited
keyword indicating that an item shall not be implemented by an implementation

3.3.4.8
reserved
keyword indicating reserved bits, bytes, words, fields, and code values that are set aside for future standardization

Note 1 to entry: The use and interpretation of reserved bits, bytes, words, fields, and code values may be specified by future extensions to this or other standards.

Note 2 to entry: A reserved bit, byte, word, or field shall be cleared to zero, or in accordance with a future extension to this standard. The recipient shall not check reserved bits, bytes, words, or fields.

Note 3 to entry: Receipt of reserved code values in defined fields shall be considered a command parameter error and reported by returning command aborted.

3.3.4.9
retired
keyword indicating that the designated bits, bytes, words, fields, and code values that had been defined in previous standards are not defined in this standard and may be reclaimed for other uses in future standards

Note 1 to entry: If retired bits, bytes, words, fields, or code values are used before they are reclaimed, they shall have the meaning or functionality as described in previous standards.

3.3.4.10
shall
keyword indicating a mandatory requirement

Note 1 to entry: Designers are required to implement all such mandatory requirements to ensure interoperability with other products that conform to this standard.

3.3.4.11
should
keyword indicating flexibility of choice with a strongly preferred alternative

Note 1 to entry: The keyword “should” is equivalent to the phrase “it is recommended”.

3.3.5 Numbering

A binary number is represented in this standard by any sequence of digits consisting of only the Western-Arabic numerals 0 and 1 immediately followed by a lower-case b (e.g., 0101b). Underscores or spaces may be included between characters in binary number representations to increase readability or delineate field boundaries (e.g., 0 0101 1010b or 0_0101_1010b).

A hexadecimal number is represented in this standard by any sequence of digits consisting of only the Western-Arabic numerals 0 through 9 and/or the upper-case English letters A through F immediately followed by a lower-case h (e.g., FA23h). Underscores or spaces may be included between characters in hexadecimal number representations to increase readability or delineate field boundaries (e.g., B FD8C FA23h or B_FD8C_FA23h).

A decimal number is represented in this standard by any sequence of digits consisting of only the Arabic numerals 0 through 9 not immediately followed by a lower-case b or lower-case h (e.g., 25). This standard uses the following conventions for representing decimal numbers:

a) the decimal separator (i.e., separating the integer and fractional portions of the number) is a period;
b) the thousands separator (i.e., separating groups of three digits in a portion of the number) is a space; and
c) the thousands separator is used in both the integer portion and the fraction portion of a number.

Table 1 shows some examples of decimal numbers using various numbering conventions.

Table 1 — Numbering conventions

ISO/IEC	US	This standard
0,6	0.6	0.6
3,141 592 65	3.14159265	3.141 592 65
1 000	1,000	1 000
1 323 462,95	1,323,462.95	1 323 462.95

A decimal number represented in this standard with an overline over one or more digits following the decimal point is a number where the overlined digits are infinitely repeating (e.g., $666.\overline{6}$ means 666.666 666… or 666 2/3, and $12.\overline{142\ 857}$ means 12.142 857 142 857… or 12 1/7).

3.3.6 Bit conventions

Name (n:m), where n shall be greater than m, denotes a set of bits (e.g., Feature (7:0)). n:m where n shall be greater than m denotes a bit range in a table.

3.3.7 Number range convention

p..q, where p is less than q, represents a range of numbers (e.g., words 100..103 represents words 100, 101, 102, and 103).

3.3.8 State diagram conventions

All state diagrams use the notation shown in Figure 2.

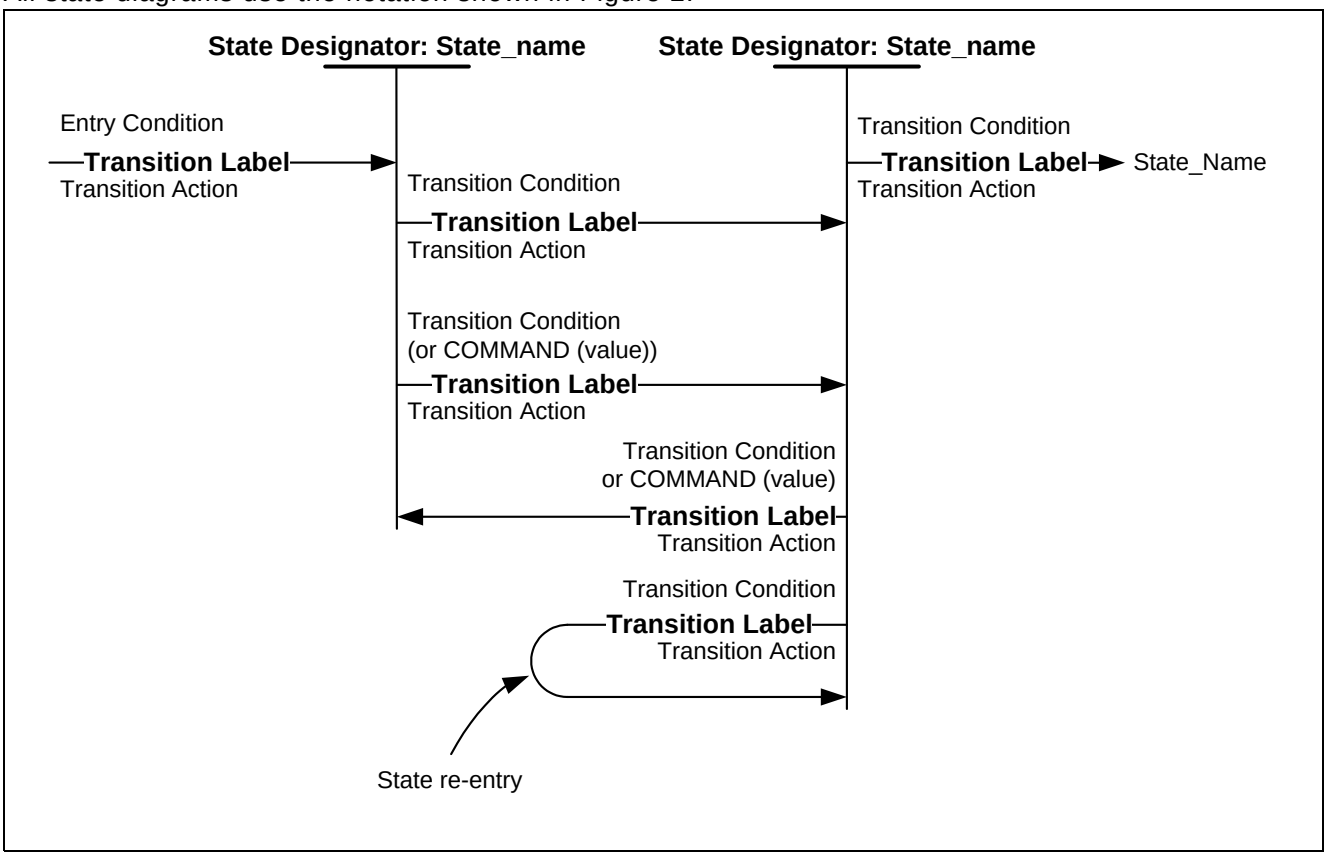


Figure 2 — State diagram convention

Each state is identified by a state designator and a state name. The state designator is unique among all states in all state diagrams in this standard. The state designator consists of a set of letters that are capitalized in the title of the figure containing the state diagram followed by a unique number. The state name is a brief description of the primary action taken during the state, and the same state name may appear in other state diagrams. If the same primary function occurs in other states in the same state diagram, then the primary functions are designated with a unique letter at the end of the name. Additional actions may be taken while in a state and these actions are described in the state description text.

Each transition is identified by a transition label, a transition condition, and optionally by a transition action. The transition label consists of the state designator of the state from which the transition is being made followed by the state designator of the state to which the transition is being made. The transition to enter or exit a state diagram may come from or go to a number of state diagrams, depending on the command being processed. In this case, the state designator is labeled State_name. The transition condition is a brief description of the event or condition that causes the transition to occur. A transition action may be included, indicated in italics, that is taken when the transition occurs. This action is described in the transition description text.

Upon entry to a state, all actions to be processed in that state are processed. If a state is re-entered from itself, all actions to be processed in the state are processed again.

Each state machine is instantiated based on the Entry Conditions. An Entry Condition is a transition based on an action occurring outside of the state machine.

All transitions shall be instantaneous.

The notation COMMAND (value), as a transition condition, refers to the device receiving the command with a specific value or values.

EXAMPLE 1 - SET MAX ADDRESS (volatile) means the device successfully processes a volatile SET MAX ADDRESS command (i.e., a SET MAX ADDRESS with the V_V field set to zero).

EXAMPLE 2 - SET MAX ADDRESS (non-volatile) means the device successfully processes a non-volatile SET MAX ADDRESS command (i.e., a SET MAX ADDRESS with the V_V field set to one).

If a state has a transition condition that specifies native max, then any other set max conditions imply a value less than the native max value. If a state has a transition condition that specifies neither volatile nor non-volatile, then both are implied.

If the (value) notation is not present on a transition, then the transition occurs for any parameter combination of the command.

3.3.9 Byte, word, DWord, and QWord Relationships

Figure 3 illustrates the relationship between bytes, words, DWords, and QWords.

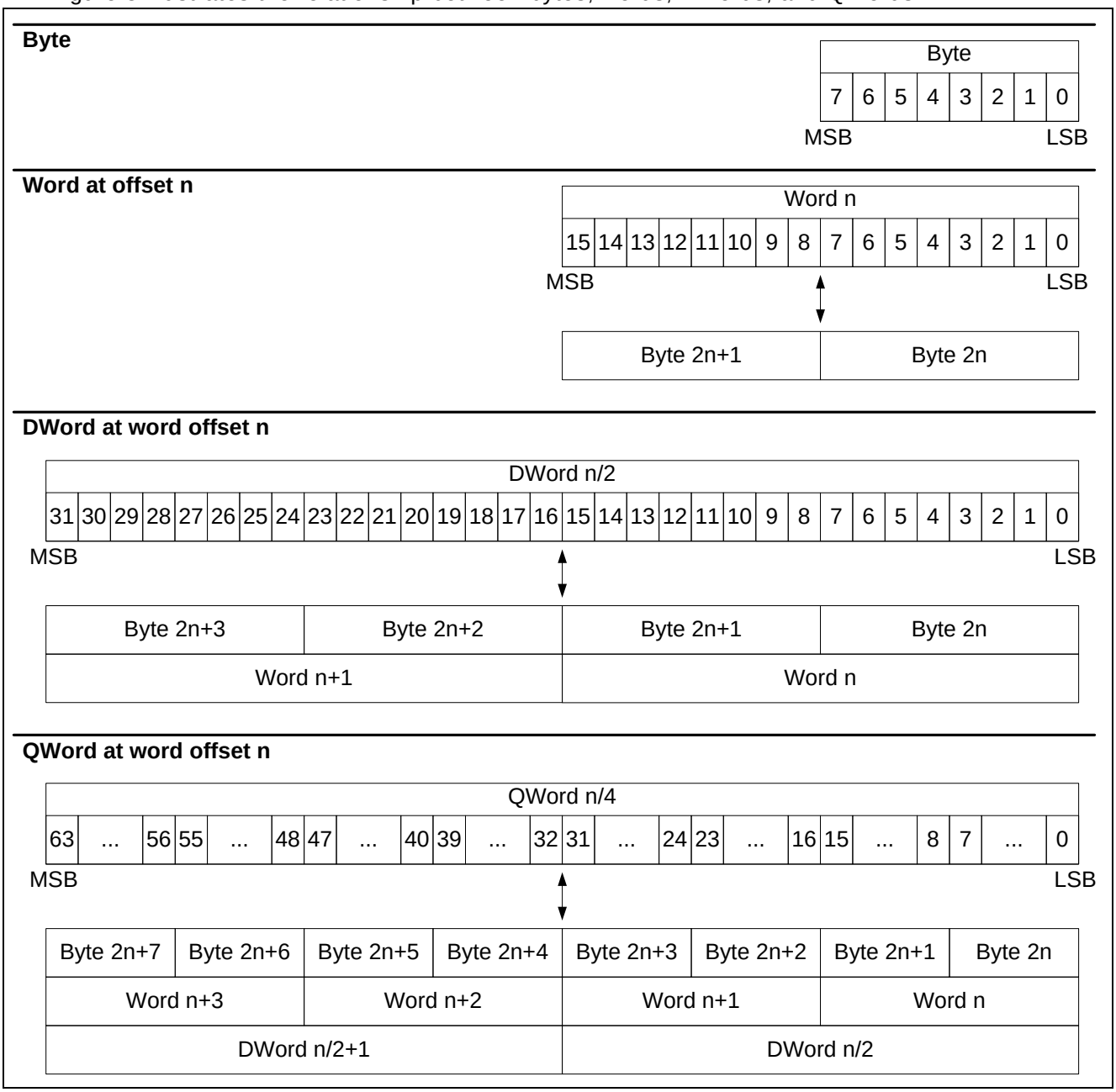


Figure 3 — Byte, word, DWord and QWord relationships

Unless stated or defined otherwise, in a field containing a multi-byte value (e.g., a word, DWord, or QWord), the byte containing the LSB is stored at the lowest offset and the byte containing the MSB is stored at the highest offset.

EXAMPLE 1 - if the two-byte field (i.e., word) in SCT command (see table 197) word 0 contains 0007h, then:

a) byte 0 contains 07h; and
b) byte 1 contains 00h.

EXAMPLE 2 - if the four-byte field (i.e., DWord) at IDENTIFY DEVICE data words 60..61 (see table 50) contains 8001_0203h (i.e., 2 147 549 699), then:

a) byte 120 contains 03h;
b) byte 121 contains 02h;
c) byte 122 contains 01h; and
d) byte 123 contains 80h.

EXAMPLE 3 - if an eight-byte field (i.e., QWord) in the WRITE SAME command words 2..5 (see table 199) contains 0000_0504_0302_0100h), then:

a) byte 4 contains 00h;
b) byte 5 contains 01h;
c) byte 6 contains 02h;
d) byte 7 contains 03h;
e) byte 8 contains 04h;
f) byte 9 contains 05h;
g) byte 10 contains 00h; and
h) byte 11 contains 00h.

Exceptions to this convention include:

a) each field containing an ATA string (e.g., the IDENTIFY DEVICE data and IDENTIFY PACKET DEVICE data Serial number, Firmware revision, and Model number fields) is considered to be an array of bytes, not a multi-byte value, and is handled as described in 3.3.10;
b) the IDENTIFY DEVICE data and IDENTIFY PACKET DEVICE data World Wide Name field consists of four word fields rather than one QWord field and is handled as described in 7.17.7.58;
c) the CFA TRANSLATE SECTOR data LBA and logical sector write cycles count fields (see table 25);
d) the command packet in the PACKET command (see 7.23) is formatted as defined by the applicable command standard); and
e) parameter data in the TRUSTED RECEIVE command (see 7.58), TRUSTED RECEIVE DMA command (see 7.59), TRUSTED SEND command (see 7.60), and TRUSTED SEND DMA command (see 7.61) is formatted as defined in those sections or in the standard defining the security protocol.

3.3.10 ATA string convention

ATA strings are sequences of bytes containing ASCII graphic characters in the range of 20h-7Eh. ATA strings shall not contain values in the range of 00h-1Fh or 7Fh-FFh.

The following fields in IDENTIFY DEVICE data (see 7.17.7) and IDENTIFY PACKET DEVICE data (see 7.18.6) contain ATA strings:

a) Serial number (words 10..19) (see 7.17.7.10);
b) Firmware revision (words 23..26) (see 7.17.7.13);
c) Model number (words 27..46) (see 7.17.7.14); and
d) Current media serial number (words 176..205) (see 7.17.7.74).

Each pair of bytes in an ATA string is swapped as shown in table 2.

Table 2 — ATA string byte swapping

Word	Offset	Character in string
0	0	Second character
	1	First character
1	2	Fourth character
	3	Third character
…	…	…
n	2n	Last character
	2n+1	Second-to-last character

If the Firmware revision field (i.e., words 23..26) contains the string “abcdefg ”, including one padding space character at the end, then the word and byte representations for the field are shown in table 3.

Table 3 — ATA firmware revision example

Word	Value	Offset	Value
23	6162h (i.e., “ba”)	46	62h (i.e., “b”)
		47	61h (i.e., “a”)
24	6364h (i.e., “dc”)	48	64h (i.e., “d”)
		49	63h (i.e., “c”)
25	6566h (i.e., “fe”)	50	66h (i.e., “f”)
		51	65h (i.e., “e”)
26	6720h (i.e., “ g”)	52	20h (i.e., “ “, the space character)
		53	67h (i.e., “g”)

3.3.11 Offset Convention

An offset is a byte value used as an index into a larger data structure.