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Standard

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**Information technology — Small
computer system interface (SCSI) —**

**Part 346:
Zoned Block Commands - 2 (ZBC-2)**

*Technologies de l'information — Interface de petit système
d'ordinateur (SCSI) —*

Partie 346: Commandes de blocs de zones - 2 (ZBC-2)

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Foreword (This foreword is not part of American National Standard INCITS 550-2023.)

This purpose of this standard is to define the model and command set extensions to be used in conjunction with the SCSI Primary Command Set standard – 6 (SPC-6) and the SCSI Block Commands standard – 5 (SBC-5) to facilitate operation of zoned block devices.

Requests for interpretation, suggestions for improvement and addenda, or defect reports are welcome. They should be sent to the INCITS Secretariat, InterNational Committee for Information Technology Standards, Information Technology Industry Council, 700 K Street NW, Suite 600, Washington, DC 20001.

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Information technology — Small computer system interface (SCSI) —

Part 346: Zoned Block Commands - 2 (ZBC-2)

1 Scope

This standard defines the model and command set extensions to facilitate operation of zoned block devices. The clauses in this standard, implemented in conjunction with the applicable clauses of SPC-6 and SBC-5, specify the standard command set for zoned block devices.

2 Normative references

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

T10/BSR INCITS 546, *SCSI Architecture Model - 6 (SAM-6)* (planned as ISO/IEC 14776-416)

T10/BSR INCITS 557, *SCSI / ATA Translation - 5 (SAT-5)* (under national consideration)

T10/BSR INCITS 566, *SCSI Primary Commands - 6 (SPC-6)* (planned as ISO/IEC 14776-456)

T10/BSR INCITS 571, *SCSI Block Commands - 5 (SBC-5)* (planned as ISO/IEC 14776-325)

3 Definitions, symbols, abbreviations, and conventions

3.1 Definitions

3.1.1 access pattern requirements

requirements, in addition to requirements in SBC-5, that apply to read operations, verify operations, and write operations performed by the device server in a zoned block device

3.1.2 activate

cause a write pointer zone to become an active zone

3.1.3 active zone

write pointer zone that has a Zone Condition other than INACTIVE

3.1.4 additional sense code

combination of the ADDITIONAL SENSE CODE field and the ADDITIONAL SENSE CODE QUALIFIER field in sense data

Note 1 to entry: See SPC-6.

3.1.5 application client

object that is the source of SCSI commands

Note 1 to entry: See SAM-6.

3.1.6 byte

8-bit construct

3.1.7 cache

temporary data storage area that is capable of containing a subset of the logical block data stored by the logical unit and is either volatile or non-volatile

Note 1 to entry: See 4.13.

3.1.8 close zone operation

device server process that makes zone resources non-volatile, releases open zone resources, and results in the Zone Condition becoming CLOSED or EMPTY

Note 1 to entry: See 4.5.3.2.3.

3.1.9 command

request describing a unit of work to be performed by a device server

Note 1 to entry: See SAM-6.

3.1.10 command descriptor block (CDB)

structure used to communicate commands from an application client to a device server

Note 1 to entry: See SPC-6.

3.1.11 conventional zone

zone that is not associated with a write pointer

Note 1 to entry: See 4.5.2.

3.1.12 deactivate

cause a write pointer zone to become an inactive zone

3.1.13 device server

object within a logical unit (see 3.1.28) that processes SCSI commands according to the rules of command management

Note 1 to entry: See SAM-6.

3.1.14 ending LBA

highest numbered LBA of a command

3.1.15 field

group of one or more contiguous bits, a part of a larger structure

Note 1 to entry: Examples of larger structures are a CDB (see 3.1.10) and sense data (see SPC-6).

3.1.16 finish zone operation

device server process that results in the Zone Condition becoming FULL

Note 1 to entry: See 4.5.3.2.4.

3.1.17 format operation

process by which a device server initializes the medium in a logical unit

Note 1 to entry: See 4.10.

3.1.18 gap zone

zone in which all of the LBAs are incapable of storing user data

Note 1 to entry: Gap zones enable the alignment of the starting LBAs of zones that are capable of storing user data (e.g., as described in 4.2.4.1 and 4.9).

Note 2 to entry: See 4.5.4.

3.1.19 hard reset

condition resulting from the events defined by SAM-6 during which the SCSI device performs the hard reset operations described in SAM-6, this standard, and other applicable command standards

3.1.20 host aware zoned block device

logical unit that implements the host aware zoned block device model

Note 1 to entry: See 4.2.2.

3.1.21 host managed zoned block device

logical unit that implements the host managed zoned block device model

Note 1 to entry: See 4.2.3.

3.1.22 inactive zone

write pointer zone that has a Zone Condition of INACTIVE

3.1.23 I_T nexus

relationship between a SCSI initiator port and a SCSI target port

Note 1 to entry: See SAM-6.

3.1.24 logical block

set of data bytes accessed and referenced as a unit

Note 1 to entry: See SBC-5.

3.1.25 logical block access command

command that requests access to one or more logical blocks that may require access to the medium

Note 1 to entry: See SBC-5.

3.1.26 logical block address (LBA)

value used to reference a logical block

Note 1 to entry: See SBC-5.

3.1.27 logical block data

user data and protection information, if any

3.1.28 logical unit

externally addressable entity within a SCSI target device (see 3.1.48) that implements a SCSI device model

Note 1 to entry: See SAM-6.

3.1.29 manage open zone resources operation

device server process that determines the availability of open zone resources

Note 1 to entry: See 4.5.3.2.8.

3.1.30 media

plural of medium

3.1.31 medium

material that is not cache on which data is stored (e.g., a magnetic disk)

3.1.32 non-sequential write operation

write operation performed on a write pointer zone for which the lowest LBA for that operation is not equal to the write pointer for that write pointer zone

Note 1 to entry: See 4.5.3.3.2.

3.1.33 non-volatile cache

cache that retains logical block data through any power cycle

3.1.34 open zone

zone with a Zone Condition of EXPLICITLY OPENED or IMPLICITLY OPENED

3.1.35 open zone operation

device server process that results in the Zone Condition becoming EXPLICITLY OPENED

3.1.36 open zone resources

zone resources that are available only to an open zone

Note 1 to entry: See 4.5.3.1.3.

3.1.37 persistent zone resources

zone resources that persist across all condition changes or SCSI events (see SAM-6) including a power on

Note 1 to entry: For a zone in any Zone Condition other than IMPLICITLY OPENED or EXPLICITLY OPENED, all zone resources are persistent zone resources.

3.1.38 physical block

set of data bytes accessed as a unit by the device server (see SBC-5)

3.1.39 power cycle

sequence of power being removed followed by power being applied to a SCSI device

3.1.40 power on

condition resulting from the events defined by SAM-6 during which a SCSI device performs the power on operations described in SAM-6, this standard, and other applicable command standards

3.1.41 protection information

group of fields at the end of each logical block or at specified intervals within each logical block that contain a logical block guard, an application tag, and a reference tag

Note 1 to entry: See SBC-5.

3.1.42 read command

command that requests read operations

3.1.43 read operation

read operation as described in SBC-5 with the additional requirements described in this standard

3.1.44 realm

set of zone ranges, each in a different zone domain, and an indicated relationship among those zone ranges

Note 1 to entry: See 4.2.4.6.

3.1.45 realm attribute

named property associated with a realm

Note 1 to entry: In the absence of other conditions or actions (e.g., actions by the application client), realm attributes do not affect the operation of the zone condition state machine.

Note 2 to entry: See 4.4.

3.1.46 reset write pointer operation

device server process that results in the write pointer being set to the lowest LBA of the write pointer zone

Note 1 to entry: See 4.5.3.2.5.

3.1.47 sanitize operation

process by which a device server alters information on a logical unit such that recovery of previous logical block data from the cache and the medium is not possible

Note 1 to entry: See 4.11.

3.1.48 SCSI target device

SCSI device containing logical units and SCSI target ports that receives device service requests and task management requests for processing and sends device service responses and task management responses to SCSI initiator devices

Note 1 to entry: See SAM-6.

3.1.49 sense key

contents of the SENSE KEY field in the sense data

Note 1 to entry: See SPC-6.

3.1.50 sequential or before required zone

write pointer zone in which the device server allows write commands that specify a starting LBA that is less than or equal to that zone's write pointer

Note 1 to entry: See 4.5.3.5.

3.1.51 sequential write preferred zone

write pointer zone in which the device server allows write operations that specify a lowest LBA that is within the zone but is not equal to the zone's write pointer

Note 1 to entry: See 4.5.3.3.

3.1.52 sequential write required zone

write pointer zone in which the device server requires that the lowest LBA for a write operation be the LBA indicated by the zone's write pointer

Note 1 to entry: See 4.5.3.4.

3.1.53 starting LBA

lowest numbered LBA of a command

3.1.54 state machine variable

variable that exists within the context of a state machine

Note 1 to entry: A state machine variable may contain status from one state that is used in another state of the same state machine.

Note 2 to entry: The value contained in a state machine variable may affect subsequent state transitions or state machine outputs.

3.1.55 status

one byte of response information that contains a coded value defined in SAM-6, transferred from a device server to an application client upon completion of each command

Note 1 to entry: See SAM-6.

3.1.56 Trusted Computing Group

organization that develops and promotes open standards for hardware-enabled trusted computing and security technologies

Note 1 to entry: See <https://www.trustedcomputinggroup.org>.

3.1.57 unit attention condition

state that a logical unit (see 3.1.28) maintains while the logical unit has asynchronous status information to report to the SCSI initiator ports associated with one or more I_T nexuses (see 3.1.23)

Note 1 to entry: See SAM-6.

3.1.58 unmet prerequisite

requirement that, as a result of its not being met, prevents the successful performing of a zone activation operation (see 4.5.3.2.7)

Note 1 to entry: Unmet prerequisites are indicated by bits in the parameter data (see 5.11.3.1) returned by a command (e.g., the NOT EMPTY bit) as described in 4.5.3.2.7.2.

3.1.59 user data

data contained in logical blocks that is accessible by an application client and is neither protection information nor other information that may not be accessible to the application client

3.1.60 verify command

command that requests verify operations

3.1.61 verify operation

verify operation as described in SBC-5 with the additional requirements described in this standard

3.1.62 volatile cache

cache that does not retain logical block data between power cycles

3.1.63 write command

command that requests write operations

3.1.64 write operation

write operation as described in SBC-5 with the additional requirements described in this standard

3.1.65 write pointer

pointer to a logical block in a write pointer zone where the next write operation in that zone should start

Note 1 to entry: See 4.5.3.1.

3.1.66 write pointer zone

zone that has an associated write pointer

Note 1 to entry: See 4.5.3.

3.1.67 zone

one of a set of disjoint contiguous ranges of LBAs that comprise a logical unit

Note 1 to entry: See 4.5.

3.1.68 zone activation operation

operation that manages active zones and inactive zones

Note 1 to entry: See 4.5.3.2.7.

3.1.69 zone attribute

named property associated with a zone

Note 1 to entry: This standard assumes that all zone attributes (see 4.3) are zone resources regardless of how the device server maintains the defined information.

Note 2 to entry: In the absence of other conditions or actions (e.g., actions by the application client), zone attributes do not affect the operation of the zone condition state machine.

Note 3 to entry: See 4.3.

3.1.70 zone domain

zone range in which all of the zones are able to be active zones at the same time

Note 1 to entry: See 4.2.4.2.

3.1.71 zone ID

lowest LBA of a zone

3.1.72 zone range

contiguous set of zones specified by a zone ID and a non-zero integer number of zones

3.1.73 zone resources

device server resources that are used by a zone

Note 1 to entry: This standard defines open zone resources and persistent zone resources.

3.1.74 zoned block device

host aware zoned block device, host managed zoned block device, or domains and realms zoned block device

Note 1 to entry: See 4.2.

3.1.75 zoned maximum address

maximum LBA as indicated by the MAXIMUM LBA field (see 5.8.2) returned by the REPORT ZONES command

Note 1 to entry: See 4.8.

3.2 Symbols and abbreviations

3.2.1 Abbreviations

Abbreviations used in this standard:

Abbreviation	Meaning
CDB	command descriptor block
LBA	logical block address
LSB	least significant bit
MSB	most significant bit
n/a	not applicable
SAM-6	SCSI Architecture Model - 6 (see clause 2)
SAT-5	SCSI / ATA Translation - 5 (see clause 2)
SBC-5	SCSI Block Commands - 5 (see clause 2)
SCSI	Small Computer System Interface family of standards
SPC-6	SCSI Primary Commands - 6 (see clause 2)
TCG	Trusted Computing Group (see 3.1.56)
VPD	Vital product data

3.2.2 Mathematical operators

Mathematical operators used in this standard:

Mathematical Operators	Meaning
$\wedge$ or XOR	exclusive logical OR
$\times$	multiplication
$/$	division
$\pm$	plus or minus
$+$	add
$-$	subtract
AND	logical AND
$<$ or LT	less than
$\leq$ or LE	less than or equal to
$=$ or EQ	equal
$\neq$ or NE	not equal
$>$ or GT	greater than
$\geq$ or GE	greater than or equal to

3.3 Keywords

3.3.1 invalid

keyword used to describe an illegal or unsupported bit, byte, word, field, or code value

Note 1 to entry: Receipt by a device server of an invalid bit, byte, word, field, or code value shall be reported as error.

3.3.2 mandatory

keyword indicating an item that is required to be implemented as defined in this standard

3.3.3 may

keyword that indicates flexibility of choice with no implied preference

3.3.4 may or may not

keyword that indicates flexibility of choice with no implied preference

Note 1 to entry: Significant uses of "may or may not" occur in descriptions where attention is being drawn to the "may not" case.

3.3.5 obsolete

keyword indicating that an item was defined in prior SCSI standards but has been removed from this standard

3.3.6 option, optional

keywords that describe features that are not required to be implemented by this standard

Note 1 to entry: If any optional feature defined by this standard is implemented, then it shall be implemented as defined in this standard.

3.3.7 prohibited

keyword used to describe a feature, function, or coded value that is defined in a non-SCSI standard (i.e., a standard that is not a member of the SCSI family of standards) to which this standard makes a normative reference where the use of said feature, function, or coded value is not allowed for implementations of this standard

3.3.8 reserved

keyword referring to bits, bytes, words, fields, and code values that are set aside for future standardization

Note 1 to entry: A reserved bit, byte, word, or field shall be set to zero, or in accordance with a future extension to this standard.

Note 2 to entry: Recipients are not required to check reserved bits, bytes, words, or fields for zero values.

Note 3 to entry: Receipt of reserved code values in defined fields shall be reported as an error.

3.3.9 restricted

keyword referring to bits, bytes, words, and fields that are set aside for other identified standardization purposes

Note 1 to entry: A restricted bit, byte, word, or field shall be treated as a reserved bit, byte, word, or field in the context where the restricted designation appears.

3.3.10 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.

3.3.11 should

keyword indicating flexibility of choice with a strongly preferred alternative

3.3.12 vendor specific

something (e.g., a bit, field, code value) that is not defined by this standard

Note 1 to entry: Specification of the referenced item is determined by the SCSI device vendor and may be used differently in various implementations.

3.4 Editorial conventions

Certain words and terms used in this standard have a specific meaning beyond the normal English meaning. These words and terms are defined either in the glossary or in the text where they first appear.

Upper case is used when referring to the name of a numeric value defined in this specification or a formal attribute possessed by an entity. When necessary for clarity, names of objects, procedure calls, arguments or discrete states are capitalized or set in bold type. Names of fields are identified using small capital letters (e.g., OPERATION CODE field).

Quantities having a defined numeric value are identified by large capital letters (e.g., CHECK CONDITION). Quantities having a discrete but unspecified value are identified using small capital letters (e.g., OFFLINE is a value of the Zone Condition zone attribute). Such quantities are associated with an event or indication whose observable behavior or value is specific to a given implementation standard.

Lists sequenced by lowercase or uppercase letters show no ordering relationship between the listed items.

EXAMPLE 1 - The following list shows no relationship between the named items:

- a) red (i.e., one of the following colors):
 - A) crimson; or
 - B) amber;
- b) blue; or
- c) green.

Lists sequenced by numbers show an ordering relationship between the listed items.

EXAMPLE 2 -The following list shows an ordered relationship between the named items:

- 1) top;
- 2) middle; and
- 3) bottom.

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).

If a conflict arises between text, tables, or figures, the order of precedence to resolve the conflicts is:

- 1) text;
- 2) tables; and
- 3) figures.

Not all tables or figures are fully described in the text.

Notes and examples do not constitute any requirements.

Notes are numbered consecutively throughout this standard.

3.5 Numeric and character conventions

3.5.1 Numeric conventions

A binary number is represented in this standard by any sequence of digits comprised of only the Arabic numerals 0 and 1 immediately followed by a lower-case b (e.g., 0101b). Underscores or spaces may be included 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 comprised of only the Arabic numerals 0 to 9 and/or the upper-case English letters A to F immediately followed by a lower-case h (e.g., FA23h). Underscores or spaces may be included in hexadecimal number representations to increase readability

or delineate field boundaries (e.g., 3456FDCA 84BD5E7Ah, 3456FDCA_84BD5E7Ah, B FD8C FA23h, or B_FD8C_FA23h).

A decimal number is represented in this standard by any sequence of digits comprised of only the Arabic numerals 0 to 9 not immediately followed by a lower-case b or lower-case h (e.g., 25).

Variables (i.e., alphanumeric names that represent values in computations and other statements) are represented in the same San-serif font as other information in this standard.

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;
- c) the thousands separator is used in both the integer portion and the fraction portion of a number; and
- d) the decimal representation for a year is 1999 not 1 999.

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

Table 1 – Numbering conventions

French	English	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 $666 \frac{2}{3}$, and 12.142 857 means 12.142 857 142 857... or $12 \frac{1}{7}$).

A range of numeric values is represented in this standard in the form “a to z”, where a is the first value included in the range, all values between a and z are included in the range, and z is the last value included in the range (e.g., the representation “0h to 3h” includes the values 0h, 1h, 2h, and 3h).

3.5.2 Units of measure

This standard represents values using both decimal units of measure and binary units of measure. Values are represented by the following formats:

- a) for values based on decimal units of measure:
 - 1) numerical value (e.g., 100);
 - 2) space; and
 - 3) prefix symbol and unit:
 - 1) decimal prefix symbol (e.g., M) (see table 2); and
 - 2) unit abbreviation (e.g., B);

and
- b) for values based on binary units of measure:
 - 1) numerical value (e.g., 1 024);
 - 2) space; and
 - 3) prefix symbol and unit:
 - 1) binary prefix symbol (e.g., Gi) (see table 2); and
 - 2) unit abbreviation (e.g., b).

Table 2 compares the prefix, symbols, and power of the binary and decimal units.

Table 2 – Comparison of decimal prefixes and binary prefixes

Decimal			Binary		
Prefix name	Prefix symbol	Power (base-10)	Prefix name	Prefix symbol	Power (base-2)
kilo	k	10^3	kibi	Ki	2^{10}
mega	M	10^6	mebi	Mi	2^{20}
giga	G	10^9	gibi	Gi	2^{30}
tera	T	10^{12}	tebi	Ti	2^{40}
peta	P	10^{15}	pebi	Pi	2^{50}
exa	E	10^{18}	exbi	Ei	2^{60}
zetta	Z	10^{21}	zebi	Zi	2^{70}
yotta	Y	10^{24}	yobi	Yi	2^{80}

3.6 Bit and byte ordering

In this standard, data structures may be defined by a table. A table defines a complete ordering of elements (i.e., bits, bytes, fields, and dwords) within the structure. The ordering of elements within a table does not in itself constrain the order of storage or transmission of the data structure, but in combination with other normative text in this standard, may constrain the order of storage or transmission of the structure.

In a table, any element that is presented in a row above another element in a lower row is more significant than the lower element, and any element presented to the left of another element in the same row is more significant than the element to the right.

If a table shows bit numbering (see table 3), the least significant bit (LSB) is numbered 0 and each more significant bit has the next greater number than the immediately less significant bit. If a table shows numbering of bytes or characters (see table 4), the most significant byte or character is represented at the lowest number and each less significant byte or character has the next greater number than the immediately more significant byte.

In a field in a table consisting of more than one bit that contains a single value (e.g., a number), the least significant bit (LSB) is shown on the right and the most significant bit (MSB) is shown on the left (e.g., in a byte, bit 7 is the MSB and is shown on the left, bit 0 is the LSB and is shown on the right). The MSB and LSB are not labeled if the field consists of eight or fewer bits. The MSB and LSB are labeled if the field consists of more than eight bits and has no internal structure defined.

In a field in a table consisting of more than one byte that contains multiple fields each with their own values (e.g., a descriptor), there is no MSB and LSB of the field itself and thus there are no MSB and LSB labels. Each individual field has an MSB and LSB, but they are not labeled.

In a field containing a text string (e.g., ASCII or UTF-8), only the MSB of the first character and the LSB of the last character are labeled.

Multiple byte fields are represented with only two rows, with the non-sequentially increasing byte number denoting the presence of additional bytes.

A data dword consists of 32 bits. Table 3 shows a data dword containing a single value, where the MSB is on the upper left in bit 31 and the LSB is on the lower right in bit 0.

Table 3 – Example of ordering of bits and bytes within a data dword

Bit Byte	7	6	5	4	3	2	1	0
0	(MSB) Bit 31	Bit 30	Bit 29	Bit 28	Bit 27	Bit 26	Bit 25	Bit 24
1	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16
2	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
Note - The Bit x labels in the individual table cells are for reference only and should not appear within tables that use this element format.								

Table 4 shows a data dword containing four one-byte fields, where byte 0 (the first byte) is on the left and byte 3 (the fourth byte) is on the right. Each byte has an MSB on the left and an LSB on the right.

Table 4 – Example of ordering of bits and bytes within an element dword

Bit Byte	7	6	5	4	3	2	1	0
0	First byte							
	Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
1	Second byte							
	Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
2	Third byte							
	Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
3	Fourth byte							
	Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
Note - The Bit x labels in the individual table cells and the xx byte labels in the individual bytes are for reference only and should not appear within tables that use these element formats. In this example the MSB and LSB labels are for reference only, however, they may appear in multi-byte fields as described in this subclause (i.e., 3.6).								

3.7 Notation for state diagrams

All state diagrams use the notation shown in figure 1.

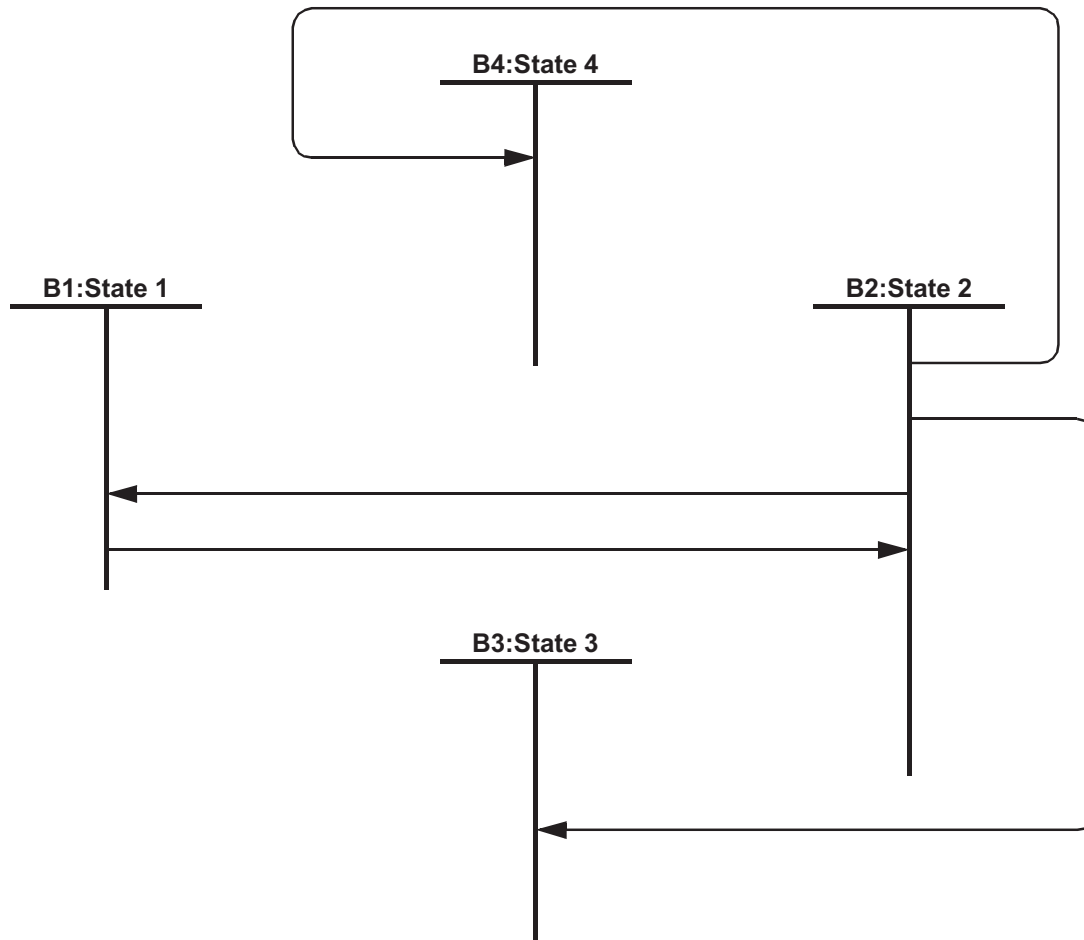


Figure 1 – Example state diagram

Each state is identified by a state designator and a state name. The state designator (e.g., B1) is unique among all state machines in this standard. The state name (e.g., State 1) is a brief description of the primary action taken during the state, and the same state name may be used by other state machines. Actions taken while in each state are described in the state description text.

Transitions between states are shown with solid lines, with an arrow pointing to the destination state.

The conditions and actions are described fully in the transition description text.

Transitions between states are instantaneous.

Upon entry into 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. A state may be entered and exited in zero time if the conditions for exiting the state are valid upon entry into the state.

4 Zoned Block Device Model

4.1 Zoned Block Device model overview

4.1.1 Established SCSI concepts

Table 5 lists established SCSI concepts that apply to zoned block devices.

Table 5 – Zoned block device model concepts (part 1 of 2)

Concept ^a	Reference
Zoned block device models	4.2
Zone attributes	4.3
Realm attributes	4.4
Zone type models	4.5
Error reporting	4.5.3 and SBC-5
Zoned block device extensions to block device model	4.6
Capacity reporting and LBAs out of range	4.8
Constant zone starting LBA values	4.9
Format operations	4.10 and SBC-5
Sanitize operations	4.11 and SBC-5
Reservations	4.12, SPC-6, and SBC-5
Caches	4.13
Pseudo unrecovered errors	4.14 and SBC-5
Storage element depopulation and restoration operations that modify data	4.15.1 and SBC-5
Storage element depopulation with zone modifications	4.15.2 and SBC-5
Background scan operations	SBC-5
Deferred microcode activation	SBC-5
Grouping function	SBC-5
Implicit head of queue command processing	SBC-5
Initialization	SBC-5
Media examples	SBC-5
Medium defects	SBC-5
^a Except for host managed zoned block devices, zoned block devices may support any concept or model defined in SBC-5. Host managed zoned block devices should not support SBC-5 model subclauses not listed in this table.	

Table 5 – Zoned block device model concepts (part 2 of 2)

Concept ^a	Reference
Logical blocks	SBC-5
Physical blocks	SBC-5
Protection information model	SBC-5
Ready state	SBC-5
START STOP UNIT and power conditions	SBC-5
Write and unmap failures	SBC-5
Write protection	SBC-5
^a Except for host managed zoned block devices, zoned block devices may support any concept or model defined in SBC-5. Host managed zoned block devices should not support SBC-5 model subclauses not listed in this table.	

4.1.2 Peripheral device type and supported commands

Zoned block devices indicate their primary model using the PERIPHERAL DEVICE TYPE field in the standard INQUIRY data (see SPC-6). Peripheral device type of:

- a) 14h indicates a host managed zoned block device (see 4.2.3); and
- b) 00h (i.e., direct access block device) indicates:
 - A) a host aware zoned block device (see 4.2.2); or
 - B) a domains and realms zoned block device (see 4.2.4).

Application clients may use the contents of the PERIPHERAL DEVICE TYPE field as an indication of what commands may be supported by the device server, as follows:

- a) 00h indicates that command support requirements are defined in SBC-5 and this standard (see table 6); and
- b) 14h indicates that command support requirements are defined in this standard (see table 7).

Additional information may be available in the ZONED BLOCK DEVICE EXTENSION field in the Zoned Block Device Characteristics VPD page (see 6.5.2).

For commands that are unique to zoned block devices (see table 19), support requirements are shown in table 6.

4.2 Zoned Block Device models

4.2.1 Zoned Block Device models introduction

Zoned block device models described in this standard are as follows:

- a) host aware zoned block device (see 4.2.2);
- b) host managed zoned block device (see 4.2.3); and
- c) domains and realms zoned block device (see 4.2.4).

Zoned block devices are accessed using LBAs. The LBAs are divided into ranges called zones (see 4.5). The entire capacity of a zoned block device is organized into a set of logically contiguous, non-overlapping zones. Figure 2 shows a zoned block device with n zones and m LBAs where LBA 0 is the lowest LBA of zone 0 and LBA m-1 is the highest LBA of zone n-1.

Zone	0		1	...	n-1	
LBA	0	1	...			m-1

Figure 2 – Zones in a zoned block device

Each zone of a zoned block device has an associated zone type (see 4.5). Zoned block devices support the REPORT ZONES command (see 5.8) for reporting the zone type and other information for each zone.

Table 6 defines the characteristics of zoned block devices defined in this standard.

Table 6 – Requirements of zoned block devices

Characteristic	Reference	Host aware zoned block device	Host managed zoned block device	Domains and realms zoned block device
Command support	4.1.2	See SPC-6 and SBC-5	See table 7	See SPC-6 and SBC-5
PERIPHERAL DEVICE TYPE field value	4.1.2	00h	14h	00h
ZONED BLOCK DEVICE EXTENSION field value in the Zoned Block Device Characteristics VPD page	6.5.2	1h	0h	2h
Conventional zone	4.5.2	Optional	Optional	Not supported
Sequential write preferred zone	4.5.3.3	Mandatory	Not supported	Optional ^a
Sequential write required zone	4.5.3.4	Not supported	Mandatory	Optional ^a
Sequential or before required zone	4.5.3.5	Not supported	Not supported	Mandatory
Gap zone	4.5.4	Not supported	see 4.2.3	Optional
CLOSE ZONE command	5.2	Mandatory	Mandatory	Mandatory
FINISH ZONE command	5.3	Mandatory	Mandatory	Mandatory
OPEN ZONE command	5.4	Mandatory	Mandatory	Mandatory
REMOVE ELEMENT AND MODIFY ZONES command	5.5	Optional	Optional	Optional
REPORT REALMS command	5.6	Not supported	Not supported	Optional
REPORT ZONE DOMAINS command	5.7	Not supported	Not supported	Mandatory
REPORT ZONES command	5.8	Mandatory	Mandatory	Mandatory
RESET WRITE POINTER command	5.9	Mandatory	Mandatory	Mandatory
SEQUENTIALIZE ZONE command	5.10	Mandatory	Not supported	Optional ^b
ZONE ACTIVATE command	5.11	Not supported	Not supported	Mandatory
ZONE QUERY command	5.12	Not supported	Not supported	Mandatory
^a The device server shall support one or more of the following types of zones: a) sequential write preferred zones; or b) sequential write required zones. ^b If the device server supports sequential write preferred zones (see 4.5.3.3), then the SEQUENTIALIZE ZONE command (see 5.10) is mandatory.				

4.2.2 Host aware zoned block device model

A host aware zoned block device reports:

- a) the PERIPHERAL DEVICE TYPE field set to 00h (i.e., direct access block device) (see SPC-6); and
- b) the ZONED BLOCK DEVICE EXTENSION field set to 1h in the Zoned Block Device Characteristics VPD page (see 6.5.2).

Host aware zoned block devices:

- a) may support conventional zones (see 4.5.2);
- b) shall support one or more sequential write preferred zones (see 4.5.3.3);
- c) shall not support sequential write required zones (see 4.5.3.4);
- d) shall not support sequential or before required zones (see 4.5.3.5); and
- e) shall not support gap zones (see 4.5.4).

Capacity reporting requirements are defined in 4.8.

In addition to primary commands (see SPC-6) and commands for direct access block devices (see SBC-5), host aware zoned block devices shall support the commands specified in table 6.

4.2.3 Host managed zoned block device model

A host managed zoned block device reports:

- a) the PERIPHERAL DEVICE TYPE field set to 14h (i.e., host managed zoned block device) (see SPC-6); and
- b) the ZONED BLOCK DEVICE EXTENSION field set to 0h in the Zoned Block Device Characteristics VPD page (see 6.5.2).

Host managed zoned block devices:

- a) may support conventional zones (see 4.5.2);
- b) shall not support sequential write preferred zones (see 4.5.3.3);
- c) shall support one or more sequential write required zones (see 4.5.3.4); and
- d) shall not support sequential or before required zones (see 4.5.3.5).

If the ZONE ALIGNMENT METHOD field (see 6.5.2) is:

- a) set to 8h, then the host managed zone block device may support gap zones (see 4.5.4) as described in 4.9; and
- b) not set to 8h, then the host managed zone block device shall not support gap zones.

Capacity reporting requirements are defined in 4.8.

Table 7 lists the commands for host managed zoned block devices.

Table 7 – Commands for host managed zoned block devices (part 1 of 2)

Command	Operation code	Type	LBACT	Reference
ATA PASS-THROUGH (12)	A1h	O	n/a	SAT-5
ATA PASS-THROUGH (16)	85h	O	n/a	SAT-5
CLOSE ZONE	94h/01h	M	Z	5.2
FINISH ZONE	94h/02h	M	Z	5.3
FORMAT UNIT	04h	O	Z	SBC-5 and 4.10
FORMAT WITH PRESET	38h	O	Z	SBC-5 and 4.10
INQUIRY	12h	M	n/a	SPC-6
LOG SELECT	4Ch	O	n/a	SPC-6
LOG SENSE	4Dh	M	n/a	SPC-6
MODE SELECT (10)	55h	M	n/a	SPC-6
MODE SENSE (10)	5Ah	M	n/a	SPC-6
OPEN ZONE	94h/03h	M	Z	5.4
PERSISTENT RESERVE IN	5Eh	O	n/a	SPC-6
PERSISTENT RESERVE OUT	5Fh	O	n/a	SPC-6
READ (16)	88h	M	R	SBC-5
READ BUFFER (10)	3C	O	n/a	SPC-6
READ BUFFER (16)	9Bh	O	n/a	SPC-6
READ CAPACITY (16)	9Eh/10h	M	n/a	SBC-5 and 4.8
READ DEFECT DATA (12)	B7h	O	n/a	SBC-5
REMOVE ELEMENT AND MODIFY ZONES	9Eh/1Ah	O	Z	5.5
REMOVE ELEMENT AND TRUNCATE	9Eh/18h	O	Z	SBC-5
REPORT LUNS	A0h	M	n/a	SPC-6
REPORT SUPPORTED OPERATION CODES	A3h/0Ch	M	n/a	SPC-6
Key: O = optional M = mandatory R = read command U = unmap command V = verify command W = write command Z = other command LBACT = logical block access command type (see SBC-5)				

Table 7 – Commands for host managed zoned block devices (part 2 of 2)

Command	Operation code	Type	LBACT	Reference
REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS	A3h/0Dh	M	n/a	SPC-6
REPORT TIMESTAMP	A3/0Fh	O	n/a	SPC-6
REPORT ZONES	95h/00h	M	Z	5.8
REQUEST SENSE	03h	M	n/a	SPC-6
RESET WRITE POINTER	94h/04h	M	Z	5.9
RESTORE ELEMENT AND REBUILD	9Eh/19h	O	Z	SBC-5
SANITIZE	48h	O	Z	SBC-5 and 4.11
SECURITY PROTOCOL IN	A2h	O	n/a	SPC-6
SECURITY PROTOCOL OUT	B5h	O	n/a	SPC-6
SEND DIAGNOSTIC	1Dh	O	n/a	SPC-6
SET TIMESTAMP	A4h/0Fh	O	n/a	SPC-6
START STOP UNIT	1Bh	M	n/a	SBC-5
SYNCHRONIZE CACHE (16)	91h	M	W	SBC-5
TEST UNIT READY	00h	M	n/a	SPC-6
VERIFY (16)	8Fh	O	V, W	SBC-5
WRITE (16)	8Ah	M	W	SBC-5
WRITE BUFFER	3Bh	O	n/a	SPC-6
WRITE LONG (16)	9Fh/11h	O	Z	SBC-5 and 4.14
WRITE SAME (16)	93h	M	U, W	SBC-5
Key: O = optional M = mandatory R = read command U = unmap command V = verify command W = write command Z = other command LBACT = logical block access command type (see SBC-5)				

4.2.4 Domains and realms zoned block device model

4.2.4.1 Domains and realms zoned block device model overview

A domains and realms zoned block device reports:

- the PERIPHERAL DEVICE TYPE field set to 00h (i.e., direct access block device) (see SPC-6); and
- the ZONED BLOCK DEVICE EXTENSION field set to 2h in the Zoned Block Device Characteristics VPD page (see 6.5.2).

Domains and realms zoned block devices:

- a) shall not support conventional zones (see 4.5.2);
- b) shall support one or more of the following types of zones:
 - A) sequential write preferred zones (see 4.5.3.3); or
 - B) sequential write required zones (see 4.5.3.4);
- c) shall support one or more sequential or before required zones (see 4.5.3.5); and
- d) may support gap zones (see 4.5.4).

Capacity reporting requirements are defined in 4.8.

In addition to primary commands (see SPC-6) and commands for direct access block devices (see SBC-5), domains and realms zoned block devices shall support the commands specified in table 6.

Zone domains and realms enhance the basic zoned block device model (see 4.2.1) to define a mechanism that allows an application client to manage contention for certain SCSI device resources in a way that is independent of many details about those SCSI device resources. Two or more zone domains (see 4.2.4.2) represent the SCSI device resources for which an application client is able to manage contention.

The SCSI device resources for which contention management is provided include, but are not limited to, the ability to store logical block data. The contention for SCSI device resources is managed by having:

- a) some zones be active zones (i.e., able to use the SCSI device resource in contention); and
- b) the remaining zones be inactive zones (i.e. unable to use the SCSI device resource in contention).

The REPORT ZONES command (see 5.8), REPORT REALMS command (see 5.6), REPORT ZONE DOMAINS command (see 5.7), and the ZONE QUERY command (see 5.12) provides current indications of what zone domains and zone types are available for the application client to choose to make active zones.

The ZONE ACTIVATE command (see 5.11) may activate a zone range in one zone domain and may deactivate a corresponding zone range in one or more different zone domains.

Commands that specify LBAs (e.g., read commands and write commands) in inactive zones are processed as described in 4.5.3.1.5 and 4.5.3.1.6.

4.2.4.2 Zone domains

A zone domain (see figure 3) is a zone range that is identified by a zone domain ID (see table 8). A zone domain ID is assigned by the device server starting at zero and incrementing by one. The zone range that constitutes the Zone domain shown in figure 3:

- 1) starts with Zone t, followed by Zone t+1, Zone t+2, and Zone t+3;
- 2) continues for zero or more zones; and
- 3) ends with Zone x-3, followed by Zone x-2, Zone x-1 and Zone x.

Zone t is the first zone in the Zone domain shown in figure 3 and the lowest LBA in Zone t is the lowest LBA of the Zone domain. Zone x is the last zone in the Zone domain shown in figure 3 and the highest LBA in Zone x is the highest LBA of the Zone domain.

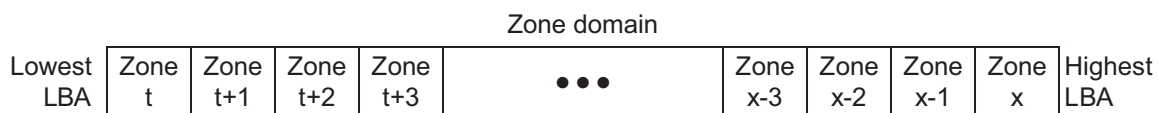


Figure 3 – Zone domain

Table 8 – Zone domain ID values

Code	Description
00h to F7h	Zone domain ID values
F8h to FEh	Reserved
FFh	No zone domain ID specified

All the zones in a single zone domain shall be capable of being active zones at the same time.

Each zone that is capable of being activated shall be included in one and only one zone domain.

Two different zone domains may have:

- a) different numbers of zones; and
- b) different numbers of LBAs.

Figure 4 shows an example of a device server that supports two zone domains with:

- 1) Zone domain 0:
 - A) starting with Zone a and ending with Zone b; and
 - B) containing:
 - a) LBA 0 as the lowest LBA in Zone domain 0; and
 - b) LBA m as the highest LBA in Zone domain 0;
- 2) zero or more gap zones (see 4.5.4) that separate Zone domain 0 from Zone domain 1, with
 - A) LBA m+1 as the lowest LBA of the lowest gap zone, if any; and
 - B) LBA p-1 as the highest LBA of the highest gap zone, if any;
 and
- 3) Zone domain 1:
 - A) starting with Zone y and ending with Zone z; and
 - B) containing:
 - a) LBA p as the lowest LBA in Zone domain 1; and
 - b) LBA r as the highest LBA in Zone domain 1.

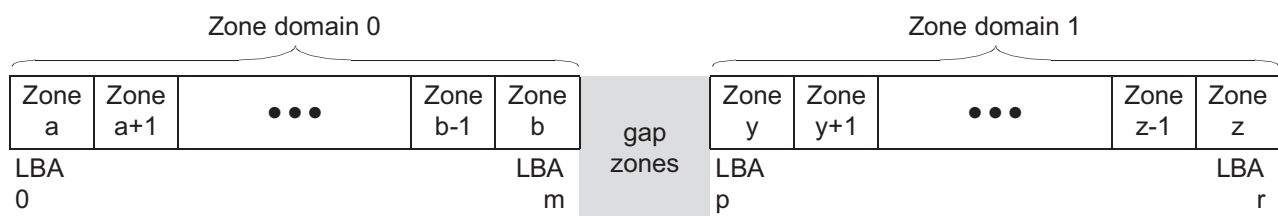


Figure 4 – Example of two zone domains

4.2.4.3 Zone domain 0

A domains and realms zoned block device shall have one zone domain with LBA 0 as its lowest numbered LBA. That zone domain is identified as zone domain 0.

As described in 4.8, the highest LBA in zone domain 0 establishes the value returned in the RETURNED LOGICAL BLOCK ADDRESS field in the READ CAPACITY (16) parameter data.

At the time of manufacture, a domains and realms zoned block device shall have a zone domain 0 that contains only sequential or before required zones (see 4.5.3.5) that have a Zone Condition of FULL.

4.2.4.4 Zone domains other than zone domain 0

For zone domains other than zone domain 0, the device server shall support accesses (e.g., reads and writes) that specify LBAs that are greater than the contents of the RETURNED LOGICAL BLOCK ADDRESS field in the READ CAPACITY (16) parameter data (see SBC-5 and 4.8).

The LBAs in the zones in zone domains other than zone domain 0 are:

- a) greater than the value in the RETURNED LOGICAL BLOCK ADDRESS field; and
- b) less than or equal to the zoned maximum address.

4.2.4.5 Zone activation

A successful ZONE ACTIVATE command (see 5.11) that specifies a zone range to be activated activates one or more zones and deactivates zero or more zones. A successful ZONE ACTIVATE command that specifies a zone range to be deactivated activates zero or more zones and deactivates one or more zones.

The smallest zone range processed by a ZONE ACTIVATE command or a ZONE QUERY command (see 5.12) is:

- a) one zone, if the AAORB bit (see 6.5.2) is set to zero (see example in figure 5); and
- b) all the zones in one zone realm, if the AAORB bit is set to one (see example in figure 8).

Figure 5 shows an example of the before and after conditions for a ZONE ACTIVATE command that is processed with the AAORB bit set to zero.

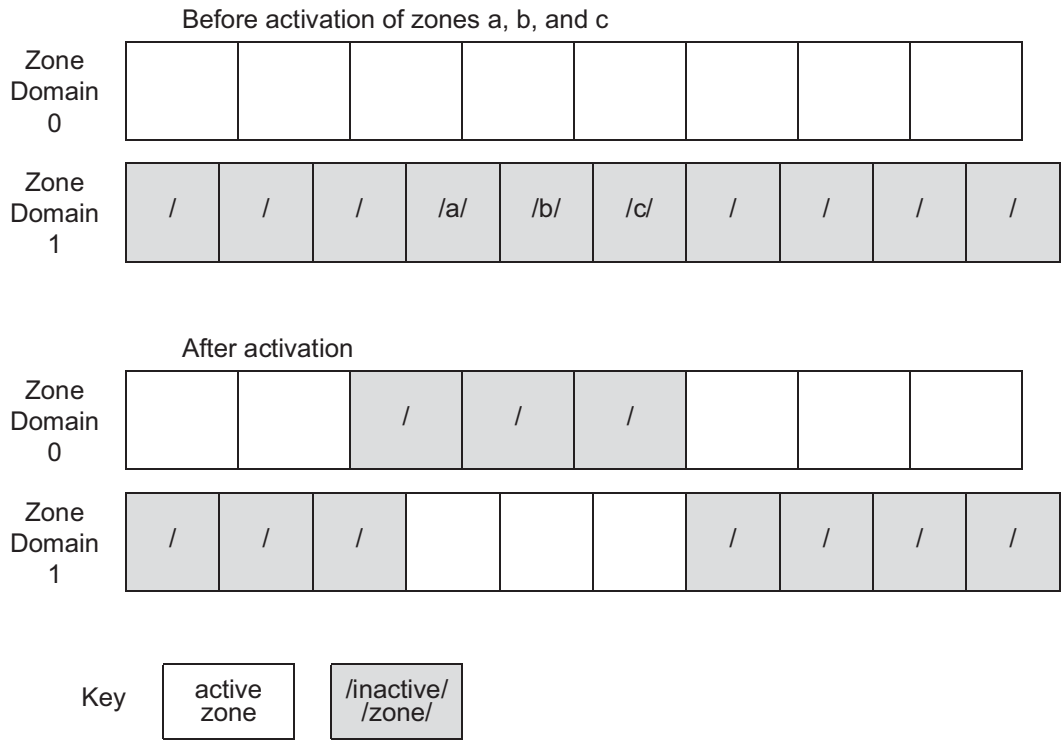


Figure 5 – Example of zone activation with the AAORB bit set to zero

4.2.4.6 Realms

Combined with zone domains (see 4.2.4.2), realms form a matrix (see figure 6) that provides applications clients with a set of choices for which zones are active. In figure 6, zone domain 0 contains LBA 0 (see 4.2.4.3) and each realm contains more than one zone. Figure 3 describes how zones are contained within zone domains.

Realm 0	Realm 1	Realm 2	...	Realm r
	Zone Domain 0			
			...	
	Zone Domain 1			
		...	...	
	Zone Domain z			

Figure 6 – Realms model

Each realm shall contain at least one zone.

Realms associate characteristics with:

- a) zone domains (e.g., zone type, recording technology, data transfer performance); and
- b) realms (e.g., location on the media, data storage density, storage density performance).

EXAMPLE - Figure 7 shows a configuration in which one zone domain uses conventional recording in sequential or before required zones (see 4.5.3.5) and one zone domain uses shingled magnetic recording in sequential write required zones (see 4.5.3.4). In this configuration, the domains and realms zoned block device allows a host to modify which realms store logical block data without the full effects of shingled magnetic recording and which realms store logical block data using shingled magnetic recording.

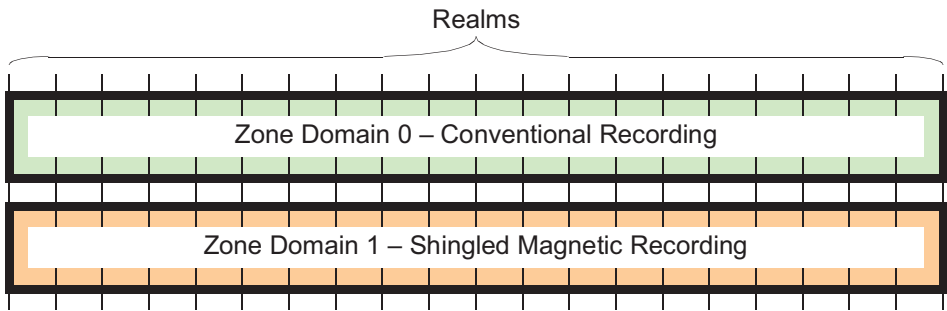


Figure 7 – Example of conventional and shingled recording technologies using two zone domains

The ZONE ACTIVATE command (see 5.11) modifies which zones are active zones within a contiguous set of realms.

The result of processing a ZONE ACTIVATE command is that zones in one zone domain within a realm become active zones at the same time as zones in a different zone domain within the same realm become inactive zones.

At any point in time, all the zones in one realm are active zones in only one of the zone domains associated with that realm.

Figure 8 shows an example of the before and after conditions for a ZONE ACTIVATE command that is processed with the AAORB bit set to one (i.e., in the case where realm boundaries affect the processing of a ZONE ACTIVATE command).

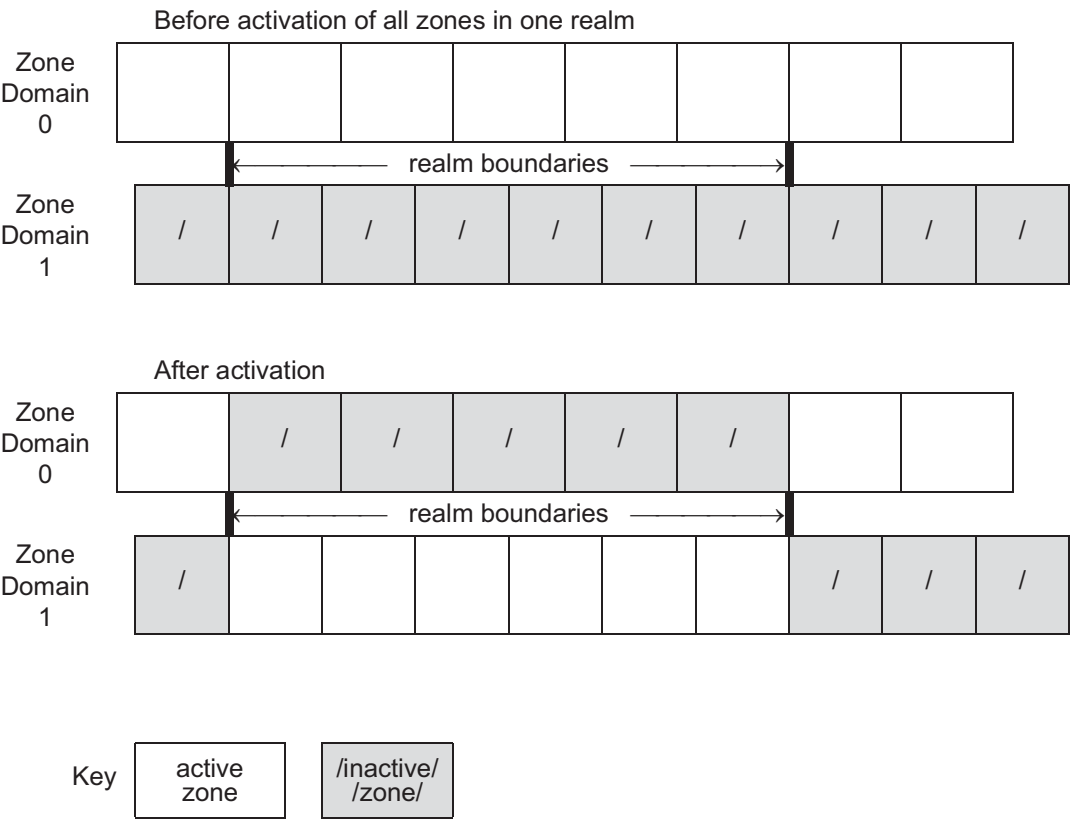


Figure 8 – Example of zone activation with the AAORB bit set to one

4.2.4.7 Realm boundary considerations

If the SRB bit (see 5.7.2) is set to zero for a processed zone domain, then the processing of a ZONE ACTIVATE command (see 5.11) shall not result in any realm boundaries changing in that zone domain. If the SRB bit is set to one for a processed zone domain, then updated realm boundary information is available from the REPORT REALMS command (see 5.6) after a ZONE ACTIVATE command is processed to successful completion.

Changes in realm boundary information may result in the RLM ALIGN bit (see 5.11.3) being set to one as an unmet prerequisite for a subsequent ZONE ACTIVATE command, unless the updated information provided by a REPORT REALMS command is used to prepare that ZONE ACTIVATE command.

The realm starting LBAs and ending LBAs returned by a REPORT REALMS command shall not change unless the device server processes a ZONE ACTIVATE command, a FORMAT UNIT command (see SBC-5), or a FORMAT WITH PRESET command (see SBC-5).

4.3 Zone attributes

4.3.1 Zone attributes summary

The zoned block device zone attributes are summarized in table 9.

Table 9 – Summary of zone attributes

Zone attribute	Description	Reference
Zone Type	Type of zone (e.g., CONVENTIONAL)	4.3.2
Zone Condition	Zone's operational characteristics	4.3.3
WPointer	Combination of the write pointer (see 4.5.3.1) and whether the write pointer is valid	4.3.4
RWP Recommended	Indication of whether the processing of a RESET WRITE POINTER command (see 5.9) for this zone is recommended	4.3.5
Non-Sequential Write Resources Active	Indication of whether zone resources are allocated for non-sequential write operations	4.3.6
Predicted Unrecovered Errors Present	Indication of whether predicted unrecovered errors (see SBC-5) are associated with logical blocks in the zone	4.3.7

4.3.2 Zone Type zone attribute

The Zone Type zone attribute (see table 10) indicates the type of zone.

Table 10 – Zone Type zone attribute

Zone Type	Reference
CONVENTIONAL	4.5.2
SEQUENTIAL WRITE PREFERRED	4.5.3.3
SEQUENTIAL WRITE REQUIRED	4.5.3.4
SEQUENTIAL OR BEFORE REQUIRED	4.5.3.5
GAP	4.5.4

The relationships between Zone Type and other zone attributes are shown in table 11.

Table 11 – Relationships between zone attributes

Zone Type	Other zone attributes			
	Non-Sequential Write Resources Active	RWP Recommended	WPointer	Zone Condition
Write pointer zones (see 4.5.3)				
SEQUENTIAL WRITE PREFERRED	see 4.3.6	see 4.3.5	see 4.5.3.1 and table 15	see 4.3.3
SEQUENTIAL WRITE REQUIRED	false ^a			
SEQUENTIAL OR BEFORE REQUIRED	false ^b			
Other zone types				
CONVENTIONAL	false ^c	false ^c	invalid ^c	NOT WRITE POINTER
GAP	false	false	invalid	
^a Zone resources for non-sequential write operations are not allocated for a zone in which all non-sequential write commands are terminated with an error. ^b For a sequential or before required zone (see 4.5.3.5), the values of zone attributes are required to be compatible with the direct access block device type defined in SBC-5. ^c For a conventional zone (see 4.5.2), the values of zone attributes are required to be compatible with the direct access block device type defined in SBC-5.				

4.3.3 Zone Condition zone attribute

The Zone Condition zone attribute (see table 12) is determined by Zone Type (see 4.3.2) and the zone condition state machine state (see 4.5.3.6).

Table 12 – Zone Condition zone attribute

Zone Type	Zone condition state machine	Reference	Zone Condition
Write pointer zones (see 4.5.3)			
SEQUENTIAL WRITE PREFERRED or SEQUENTIAL WRITE REQUIRED	ZC1:Empty state	4.5.3.6.2	EMPTY
	ZC2:Implicit_Open state	4.5.3.6.3	IMPLICITLY OPENED
	ZC3:Explicit_Open state	4.5.3.6.4	EXPLICITLY OPENED
	ZC4:Closed state	4.5.3.6.5	CLOSED
	ZC5:Full state	4.5.3.6.6	FULL
	ZC6:Read_Only state	4.5.3.6.7	READ ONLY
	ZC7:Offline state	4.5.3.6.8	OFFLINE
	ZC8:Inactive	4.5.3.6.9	INACTIVE
SEQUENTIAL OR BEFORE REQUIRED	ZC1:Empty state	4.5.3.6.2	EMPTY
	ZC2:Implicit_Open state	4.5.3.6.3	IMPLICITLY OPENED
	ZC5:Full state	4.5.3.6.6	FULL
	ZC6:Read_Only state	4.5.3.6.7	READ ONLY
	ZC7:Offline state	4.5.3.6.8	OFFLINE
	ZC8:Inactive	4.5.3.6.9	INACTIVE
Other zone types			
CONVENTIONAL	outside the scope of this standard	4.5.2	NOT WRITE POINTER
GAP	outside the scope of this standard	4.5.4	

4.3.4 WPointer zone attribute

For write pointer zones (see 4.5.3), the WPointer zone attribute is the combination of the write pointer (see 4.5.3.1) and whether the write pointer is valid (see table 15).

If Zone Type is CONVENTIONAL or GAP, then WPointer shall be invalid.

4.3.5 RWP Recommended zone attribute

For write pointer zones (see 4.5.3), if RWP Recommended is:

- true, then the device server has determined (e.g., through the detection by the device server that the zone is using too many resources) that the processing of a RESET WRITE POINTER command (see 5.9) specifying this zone is recommended; or

- b) false, then the device server has no recommendation for or against the processing of a RESET WRITE POINTER command specifying this zone.

RWP Recommended shall be set to false if:

- a) the Zone Type is CONVENTIONAL or GAP; or
- b) the Zone Condition is EMPTY, READ ONLY, OFFLINE, or INACTIVE.

If RWP Recommended changes from false to true then the device server should establish a unit attention condition for the SCSI initiator port (see SAM-6) associated with each I_T nexus with additional sense code set to ZONE RESET WRITE POINTER RECOMMENDED (see SPC-6) and the INFORMATION field (see SPC-6) set to the zone ID of the zone for which RWP Recommended was set to true.

4.3.6 Non-Sequential Write Resources Active zone attribute

For sequential write preferred zones (see 4.5.3.3), if Non-Sequential Write Resources Active is:

- a) true, then the device server has zone resources allocated for the processing of non-sequential write operations (see 4.5.3.3.2) in this zone; or
- b) false, then the device server does not have zone resources allocated for the processing of non-sequential write operations in this zone.

If a non-sequential write operation is performed in a zone, then the device server may set Non-Sequential Write Resources Active to true. The device server may set Non-Sequential Resources Active to false at any time if:

- a) the write pointer does not indicate the lowest LBA in the zone; and
- b) zone resources are no longer allocated for the processing of non-sequential write operations in this zone.

If the write pointer indicates the lowest LBA in the zone and the device server has performed any non-sequential write operations in a zone since the last time the Zone Condition was EMPTY, then Non-Sequential Resources Active shall not be set to false until the write pointer does not indicate the lowest LBA in the zone.

Non-Sequential Write Resources Active shall be set to false if:

- a) the Zone Type is CONVENTIONAL, GAP, SEQUENTIAL WRITE REQUIRED, or SEQUENTIAL OR BEFORE REQUIRED;
- b) the Zone Condition is EMPTY, READ ONLY, OFFLINE, or INACTIVE; or
- c) the device server has not performed a non-sequential write operation in a zone since the last time the Zone Condition was EMPTY.

4.3.7 Predicted Unrecovered Errors Present zone attribute

For conventional zones (see 4.5.2), if Predicted Unrecovered Errors Present is:

- a) true, then the zone contains one or more logical blocks for which:
 - A) read command accesses result in predicted unrecovered read errors (see 4.15.2.3.2); and
 - B) write command accesses result in predicted unrecovered write errors (see 4.15.2.3.3);
 or
- b) false, then none of the logical blocks in the zone are affected by predicted unrecovered errors.

Predicted Unrecovered Errors Present may be changed to:

- a) true by the processing of a REMOVE ELEMENT AND MODIFY ZONES command (see 5.5); and
- b) false by the processing of a RESTORE ELEMENTS AND REBUILD command (see SBC-5).

If Predicted Unrecovered Errors Present is true, then read commands and write commands may report predicted unrecovered errors in ranges of logical blocks as described in SBC-5.

Predicted Unrecovered Errors Present shall be set to false if the Zone Type is SEQUENTIAL WRITE REQUIRED, SEQUENTIAL WRITE PREFERRED, SEQUENTIAL OR BEFORE REQUIRED, or GAP.

4.4 Realm attributes

4.4.1 Realm attributes overview

The realm attributes are summarized in table 13.

Table 13 – Summary of realm attributes

Realm attribute	Description	Reference
Restrict Write Pointer Reset	Indication of whether the processing of a RESET WRITE POINTER command (see 5.9) is restricted for all zones in this realm	4.4.2
Restrict Zone Activate	Indication of whether the processing of a ZONE ACTIVATE command (see 5.11) is restricted for all zones in this realm	4.4.3

4.4.2 Restrict Write Pointer Reset realm attribute

If the Restrict Write Pointer Reset realm attribute is:

- a) true, then a RESET WRITE POINTER command (see 5.9) with the ALL bit set to:
 - A) zero and a zone range that includes any zones in this realm is terminated with CHECK CONDITION status, the sense code set to ILLEGAL REQUEST, and the additional sense code set to RESET WRITE POINTER NOT ALLOWED; or
 - B) one does not perform a Reset Write Pointer operation (see 4.5.3.2.5) for any zone in this realm; or
- b) false, then the processing of a RESET WRITER POINTER command is not affected by the Restrict Write Pointer Reset realm attribute.

A command that initializes the media and performs a Reset Write Pointer operation (e.g., a FORMAT UNIT command, or SANITIZE command) shall not perform a Reset Write Pointer operation for any zone in a realm for which the Restrict Write Pointer Reset realm attribute is true.

4.4.3 Restrict Zone Activate realm attribute

If the Restrict Zone Activate realm attribute is:

- a) true, then a ZONE ACTIVATE command (see 5.11) does not activate or deactivate any zones in this realm; or
- b) false, then the processing of a ZONE ACTIVATE command is not affected by the Restrict Zone Activate realm attribute.

4.5 Zone type models

4.5.1 Zone type models overview

In a zoned block device, each zone:

- a) has the zone attributes defined in 4.3; and
- b) is one of the following zone types:
 - A) a conventional zone (see 4.5.2);
 - B) a gap zone (see 4.5.4); or
 - C) a write pointer zone (see 4.5.3) that is either:
 - a) a sequential write preferred zone (see 4.5.3.3);
 - b) a sequential write required zone (see 4.5.3.4); or
 - c) a sequential or before required zone (see 4.5.3.5).

The coded values that indicate the zone type are shown in table 43.

4.5.2 Conventional zone model

4.5.2.1 Conventional zone model overview

A conventional zone is a type of zone that is not associated with a write pointer and for which the device server performs operations as described in 4.5.2.2, 4.5.2.3, and SBC-5.

4.5.2.2 Write access pattern requirements for conventional zones

For conventional zones, if the device server processes a write command for that zone, then the device server shall process that command as described in SBC-5.

The device server shall terminate the command with CHECK CONDITION status, with the sense key set to ILLEGAL REQUEST, and the additional sense code set to WRITE BOUNDARY VIOLATION, if a write command specifies:

- a) a starting LBA that is in a conventional zone; and
- b) access to a logical block that is in a different type of zone.

4.5.2.3 Read access pattern requirements for conventional zones

For conventional zones, the device server shall terminate the command with CHECK CONDITION status, with the sense key set to ILLEGAL REQUEST, and the additional sense code set to ATTEMPT TO READ INVALID DATA, if a read command or a verify command specifies:

- a) a starting LBA that is in a conventional zone; and
- b) access to a logical block that is in a different type of zone.

4.5.3 Write pointer zone models

4.5.3.1 Features common to all write pointer zones

4.5.3.1.1 Write pointer features

A write pointer zone is a type of zone that maintains a write pointer that indicates a location within that zone. The write pointer may be modified as a result of processing of a write command. Depending on the state of a zone (see 4.5.3.6), the write pointer for that zone may or may not be valid.

Each write pointer zone has one write pointer. That write pointer indicates the LBA that the application client should specify in the LOGICAL BLOCK ADDRESS field of the next write command to that zone. The write pointer may be set to the lowest LBA of a zone by a reset write pointer operation (see 4.5.3.2.5) for that zone.