

ISO/IEC 17760-302:2025-10 (E)

Information technology - AT Attachment - Part 302: Zoned Device ATA Command Set-2-(ZAC-2)

| Contents | Page |
|--|------|
| Contents..... | iv |
| Tables | xiii |
| Figures | xv |
| 1 Scope | 1 |
| 2 Normative references..... | 2 |
| 3 Definitions, abbreviations, and conventions..... | 3 |
| 3.1 Definitions..... | 3 |
| 3.2 Symbols and abbreviations..... | 8 |
| 3.2.1 Abbreviations | 8 |
| 3.2.2 Units | 9 |
| 3.2.3 Symbols | 9 |
| 3.2.4 Mathematical operators..... | 9 |
| 3.3 Keywords..... | 9 |
| 3.4 Conventions..... | 10 |
| 3.4.1 Overview | 10 |
| 3.4.2 Precedence | 11 |
| 3.4.3 Lists..... | 11 |
| 3.4.3.1 Lists overview | 11 |
| 3.4.3.2 Unordered lists..... | 11 |
| 3.4.3.3 Ordered lists | 11 |
| 3.4.4 Numbering..... | 12 |
| 3.4.5 Bit conventions..... | 12 |
| 3.4.6 Number range convention..... | 12 |
| 3.4.7 State diagram convention | 13 |
| 3.4.8 Offset convention | 13 |
| 4 Features..... | 14 |
| 4.1 Feature set introduction..... | 14 |
| 4.2 Basic zoned device model..... | 15 |
| 4.3 Host Aware Zones feature set..... | 16 |
| 4.4 Host Managed Zones feature set | 17 |
| 4.5 Zone Domains feature set | 18 |
| 4.5.1 Overview | 18 |
| 4.5.2 Zone Domains..... | 19 |
| 4.5.3 Zone domain 0 | 20 |
| 4.5.4 Zone domains other than zone domain 0..... | 20 |
| 4.5.5 Zone activation in the Zone Domains feature set..... | 21 |
| 4.6 Zone Realms feature set | 22 |
| 4.6.1 Overview | 22 |
| 4.6.2 Realm boundary considerations..... | 24 |
| 4.6.3 Zone activation in the Zone Realms feature set..... | 25 |
| 4.6.4 Realm attributes | 25 |
| 4.6.4.1 Introduction..... | 25 |
| 4.6.4.2 Restrict Write Pointer Reset | 25 |
| 4.6.4.3 Restrict Zone Activate..... | 26 |

| | |
|---|----|
| 4.7 Zone attributes..... | 27 |
| 4.7.1 Summary..... | 27 |
| 4.7.2 Zone Type zone attribute..... | 27 |
| 4.7.3 Zone Condition zone attribute..... | 29 |
| 4.7.4 WPointer zone attribute..... | 29 |
| 4.7.5 RWP Recommended zone attribute..... | 29 |
| 4.7.6 Non-Sequential Write Resources Active zone attribute..... | 30 |
| 4.7.7 Predicted Unrecovered Errors Present zone attribute..... | 30 |
| 4.8 Zone types..... | 31 |
| 4.8.1 Overview..... | 31 |
| 4.8.2 Conventional zones..... | 31 |
| 4.8.2.1 Overview..... | 31 |
| 4.8.2.2 Access Pattern Requirements..... | 31 |
| 4.8.2.3 Conventional Zone state machine..... | 32 |
| 4.8.2.3.1 Overview..... | 32 |
| 4.8.2.3.2 CMR1: Not Write Pointer state..... | 33 |
| 4.8.2.3.3 CMR2: Read Only state..... | 33 |
| 4.8.2.3.4 CMR3: Offline state..... | 34 |
| 4.8.3 Write pointer zones..... | 34 |
| 4.8.3.1 Features common to all write pointer zones..... | 34 |
| 4.8.3.1.1 General..... | 34 |
| 4.8.3.1.2 Resetting the write pointer..... | 35 |
| 4.8.3.1.3 Open zone resources..... | 36 |
| 4.8.3.1.4 Errors common to access pattern requirements for all write pointer zones..... | 36 |
| 4.8.3.2 Sequential Write Preferred zones..... | 37 |
| 4.8.3.2.1 Overview..... | 37 |
| 4.8.3.2.2 Access Pattern Requirements..... | 37 |
| 4.8.3.2.2.1 Writing in Sequential Write Preferred zones..... | 37 |
| 4.8.3.2.2.2 Reading in Sequential Write Preferred zones..... | 39 |
| 4.8.3.2.2.3 Substitute data pattern for Sequential Write Preferred zones..... | 39 |
| 4.8.3.3 Sequential Write Required zones..... | 39 |
| 4.8.3.3.1 Overview..... | 39 |
| 4.8.3.3.2 Access Pattern Requirements..... | 39 |
| 4.8.3.3.2.1 Writing in Sequential Write Required zones..... | 39 |
| 4.8.3.3.2.2 Reading in Sequential Write Required zones..... | 40 |
| 4.8.3.3.2.3 Substitute data pattern for Sequential Write Required zones..... | 41 |
| 4.8.3.3.2.4 Opening Sequential Write Required zones..... | 41 |
| 4.8.3.4 Sequential Or Before Required zones..... | 41 |
| 4.8.3.4.1 Overview..... | 41 |
| 4.8.3.4.2 Access pattern requirements..... | 41 |
| 4.8.3.4.2.1 Writing in Sequential Or Before Required zones..... | 41 |
| 4.8.3.4.2.2 Reading in Sequential Or Before Required zones..... | 42 |
| 4.8.3.4.2.3 Substitute data pattern for Sequential Or Before Required zones..... | 42 |
| 4.8.3.5 Zone Condition state machine..... | 42 |
| 4.8.3.5.1 Overview..... | 42 |
| 4.8.3.5.2 ZC1: Empty state..... | 45 |
| 4.8.3.5.3 ZC2: Implicit_Open state..... | 46 |
| 4.8.3.5.4 ZC3: Explicit_Open state..... | 47 |
| 4.8.3.5.5 ZC4: Closed state..... | 48 |
| 4.8.3.5.6 ZC5: Full state..... | 49 |
| 4.8.3.5.7 ZC6: Read_Only state..... | 50 |
| 4.8.3.5.8 ZC7: Offline state..... | 51 |
| 4.8.3.5.9 ZC8: Inactive state..... | 51 |
| 4.8.3.5.10 Manage Open Zone Resources function..... | 51 |
| 4.8.3.5.10.1 Overview..... | 51 |
| 4.8.3.5.10.2 Processing a sequential write preferred zone..... | 52 |
| 4.8.3.5.10.3 Processing a sequential write required zone..... | 52 |
| 4.8.3.5.11 Explicitly Open Zone function..... | 53 |
| 4.8.3.5.12 Close Zone function..... | 53 |
| 4.8.3.5.13 Finish Zone function..... | 53 |
| 4.8.3.5.14 Reset Write Pointer function..... | 54 |

| | |
|---|----|
| 4.8.3.5.15 Sequentialize function | 54 |
| 4.8.4 Gap zones | 54 |
| 4.9 Additional feature set interactions..... | 56 |
| 4.9.1 Introduction | 56 |
| 4.9.2 Capacity reporting | 56 |
| 4.9.3 Zoned device internal resource management..... | 56 |
| 4.9.4 Unexpected power removal | 56 |
| 4.9.5 Media failure..... | 57 |
| 4.9.6 Interactions with volatile caches..... | 57 |
| 4.9.7 Interactions with the Sanitize Device feature set | 58 |
| 4.9.8 Interactions with the Power Management feature set | 59 |
| 4.9.9 Interactions with the Security feature set | 59 |
| 4.9.9.1 Interactions with the SECURITY ERASE UNIT command | 59 |
| 4.9.9.2 Interactions with the SEC4: Security Enabled/Locked/Not Frozen state | 60 |
| 4.9.10 Interactions with the SCT Write Same command | 60 |
| 4.9.10.1 Overview..... | 60 |
| 4.9.10.2 WRITE AND SET SUBSTITUTE DATA PATTERN bit..... | 61 |
| 4.9.10.3 ZONE POST PROCESSING field | 61 |
| 4.9.11 Interactions with the WRITE UNCORRECTABLE EXT command..... | 61 |
| 4.9.12 Interactions with the SET SECTOR CONFIGURATION EXT command and MUTATE EXT command | 62 |
| 4.9.13 Interactions with the Storage Element Depopulation feature set | 62 |
| 4.9.13.1 Depopulation operations and depopulation restoration operations | 62 |
| 4.9.13.2 Depopulation with zone modifications | 63 |
| 4.9.13.2.1 Depopulation with zone modifications overview..... | 63 |
| 4.9.13.2.2 Depopulation with zone modifications processing | 63 |
| 4.9.13.2.2.1 Processing overview..... | 63 |
| 4.9.13.2.2.2 Predicted unrecovered errors processing..... | 64 |
| 4.9.13.2.3 Allowed commands during depopulation with zone modifications processing | 64 |
| 4.9.13.2.4 Power-on reset handling | 64 |
| 4.9.13.2.5 Progress checking during depopulation with zone modifications | 65 |
| 4.9.13.2.6 Depopulation with zone modifications interactions with logs..... | 65 |
| 4.9.13.2.7 Depopulation with zone modifications interactions with caches..... | 65 |
| 5 Command descriptions | 66 |
| 5.1 Command description introduction | 66 |
| 5.2 Zone management commands..... | 69 |
| 5.2.1 Overview | 69 |
| 5.2.2 ZAC Management In command template, 4Ah, DMA | 70 |
| 5.2.2.1 Feature Set | 70 |
| 5.2.2.2 Description..... | 70 |
| 5.2.2.3 Inputs | 70 |
| 5.2.2.3.1 Overview | 70 |
| 5.2.2.3.2 Action specific fields..... | 70 |
| 5.2.2.3.3 ZM_ACTION field..... | 71 |
| 5.2.2.3.4 RETURN PAGE COUNT field | 71 |
| 5.2.2.4 Normal Outputs and Error Outputs | 71 |
| 5.2.2.5 NCQ encapsulation for a DMA ZAC Management In command | 71 |
| 5.2.3 ZAC Management Out command template, 9Fh, DMA | 72 |
| 5.2.3.1 Feature Set | 72 |
| 5.2.3.2 Description..... | 72 |
| 5.2.3.3 Inputs | 72 |
| 5.2.3.3.1 Overview | 72 |
| 5.2.3.3.2 PAGES TO SEND field..... | 72 |
| 5.2.3.4 Normal Outputs and Error Outputs | 72 |
| 5.2.3.5 NCQ encapsulation for a DMA ZAC Management Out command..... | 73 |
| 5.2.4 ZAC Management Out command template, 9Fh, Non-Data | 74 |

| | |
|--|----|
| 5.2.4.1 Feature Set..... | 74 |
| 5.2.4.2 Description..... | 74 |
| 5.2.4.3 Inputs..... | 74 |
| 5.2.4.3.1 Overview..... | 74 |
| 5.2.4.3.2 ALL bit..... | 74 |
| 5.2.4.3.3 Zone range specification fields..... | 75 |
| 5.2.4.3.3.1 Overview..... | 75 |
| 5.2.4.3.3.2 ZONE COUNT field..... | 75 |
| 5.2.4.3.3.3 ZONE ID field..... | 75 |
| 5.2.4.3.3.4 Zone range specification errors..... | 75 |
| 5.2.4.4 Normal Outputs..... | 75 |
| 5.2.4.5 Error Outputs..... | 76 |
| 5.2.4.6 Non-Data NCQ encapsulation..... | 76 |
| 5.2.5 CLOSE ZONE EXT command – 9Fh/01h, Non-Data..... | 77 |
| 5.2.5.1 Feature Set..... | 77 |
| 5.2.5.2 Description..... | 77 |
| 5.2.5.3 Inputs..... | 77 |
| 5.2.5.3.1 Overview..... | 77 |
| 5.2.5.3.2 Zone range specification fields for the CLOSE ZONE EXT command..... | 77 |
| 5.2.5.3.3 CLOSE ZONE EXT command processing..... | 77 |
| 5.2.5.4 Normal Outputs..... | 78 |
| 5.2.5.5 Error Outputs..... | 78 |
| 5.2.6 FINISH ZONE EXT command – 9Fh/02h, Non-Data..... | 79 |
| 5.2.6.1 Feature Set..... | 79 |
| 5.2.6.2 Description..... | 79 |
| 5.2.6.3 Inputs..... | 79 |
| 5.2.6.3.1 Overview..... | 79 |
| 5.2.6.3.2 Zone range specification fields for the FINISH ZONE EXT command..... | 79 |
| 5.2.6.3.3 FINISH ZONE EXT command processing..... | 80 |
| 5.2.6.4 Normal Outputs..... | 80 |
| 5.2.6.5 Error Outputs..... | 80 |
| 5.2.7 OPEN ZONE EXT command – 9Fh/03h, Non-Data..... | 81 |
| 5.2.7.1 Feature Set..... | 81 |
| 5.2.7.2 Description..... | 81 |
| 5.2.7.3 Inputs..... | 81 |
| 5.2.7.3.1 Overview..... | 81 |
| 5.2.7.3.2 Zone range specification fields for the OPEN ZONE EXT command..... | 81 |
| 5.2.7.3.3 OPEN ZONE EXT command processing..... | 82 |
| 5.2.7.4 Normal Outputs..... | 82 |
| 5.2.7.5 Error Outputs..... | 82 |
| 5.2.8 REPORT REALMS EXT command – 4Ah/06h, DMA..... | 83 |
| 5.2.8.1 Feature Set..... | 83 |
| 5.2.8.2 Description..... | 83 |
| 5.2.8.3 Inputs..... | 83 |
| 5.2.8.3.1 Overview..... | 83 |
| 5.2.8.3.2 REPORTING OPTIONS field..... | 83 |
| 5.2.8.3.3 REALM LOCATOR field..... | 84 |
| 5.2.8.4 Normal Outputs..... | 84 |
| 5.2.8.5 Error Outputs..... | 84 |
| 5.2.8.6 Input From the Device to the Host Data Structure..... | 84 |
| 5.2.8.6.1 Overview..... | 84 |
| 5.2.8.6.2 Report realms header..... | 85 |
| 5.2.8.6.2.1 Overview..... | 85 |
| 5.2.8.6.2.2 REALMS COUNT field..... | 85 |
| 5.2.8.6.2.3 REALMS DESCRIPTOR LENGTH field..... | 85 |
| 5.2.8.6.2.4 NEXT REALM LOCATOR field..... | 85 |
| 5.2.8.6.3 Realm descriptor..... | 85 |

| | |
|---|----|
| 5.2.8.6.3.1 Overview | 85 |
| 5.2.8.6.3.2 REALM ID field | 86 |
| 5.2.8.6.3.3 REALM RESTRICTIONS field | 86 |
| 5.2.8.6.3.4 ACTIVE ZONE DOMAIN ID field | 86 |
| 5.2.8.6.3.5 Realm start/end descriptor | 86 |
| 5.2.8.6.4 Padding | 87 |
| 5.2.9 REPORT ZONE DOMAINS EXT command – 4Ah/07h, DMA | 88 |
| 5.2.9.1 Feature Set | 88 |
| 5.2.9.2 Description | 88 |
| 5.2.9.3 Inputs | 88 |
| 5.2.9.3.1 Overview | 88 |
| 5.2.9.3.2 REPORTING OPTIONS field | 89 |
| 5.2.9.3.3 ZONE DOMAIN LOCATOR field | 89 |
| 5.2.9.4 Normal Outputs | 89 |
| 5.2.9.5 Error Outputs | 89 |
| 5.2.9.6 Input From the Device to the Host Data Structure | 89 |
| 5.2.9.6.1 Overview | 89 |
| 5.2.9.6.2 Report zone domains header | 90 |
| 5.2.9.6.2.1 Overview | 90 |
| 5.2.9.6.2.2 LENGTH AVAILABLE field | 90 |
| 5.2.9.6.2.3 LENGTH RETURNED field | 90 |
| 5.2.9.6.2.4 NUMBER OF SUPPORTED DOMAINS field | 90 |
| 5.2.9.6.2.5 ZONE DOMAINS REPORTED field | 90 |
| 5.2.9.6.2.6 REPORTING OPTIONS field | 90 |
| 5.2.9.6.2.7 ZONE DOMAIN LOCATOR field | 90 |
| 5.2.9.6.3 Zone domain descriptor | 91 |
| 5.2.9.6.3.1 Overview | 91 |
| 5.2.9.6.3.2 ZONE DOMAIN ID field | 91 |
| 5.2.9.6.3.3 ZONE COUNT field | 91 |
| 5.2.9.6.3.4 START LBA field | 91 |
| 5.2.9.6.3.5 END LBA field | 91 |
| 5.2.9.6.3.6 ZONE DOMAIN ZONE TYPE field | 91 |
| 5.2.9.6.3.7 VALID ZONE DOMAIN ZONE TYPE bit | 91 |
| 5.2.9.6.3.8 SHIFTING REALM BOUNDARIES bit | 92 |
| 5.2.10 REPORT ZONES EXT command – 4Ah/00h, DMA | 93 |
| 5.2.10.1 Feature Set | 93 |
| 5.2.10.2 Description | 93 |
| 5.2.10.3 Inputs | 93 |
| 5.2.10.3.1 Overview | 93 |
| 5.2.10.3.2 PARTIAL bit | 93 |
| 5.2.10.3.3 REPORTING OPTIONS field | 94 |
| 5.2.10.3.4 ZONE LOCATOR field | 94 |
| 5.2.10.4 Normal Outputs | 94 |
| 5.2.10.5 Error Outputs | 94 |
| 5.2.10.6 Input From the Device to the Host Data Structure | 95 |
| 5.2.10.6.1 Overview | 95 |
| 5.2.10.6.2 ZONE LIST LENGTH field | 95 |
| 5.2.10.6.3 SAME field | 96 |
| 5.2.10.6.4 MAXIMUM LBA field | 96 |
| 5.2.10.6.5 Zone descriptor format | 96 |
| 5.2.10.6.5.1 Overview | 96 |
| 5.2.10.6.5.2 ZONE TYPE field | 97 |
| 5.2.10.6.5.3 ZONE CONDITION field | 98 |
| 5.2.10.6.5.4 PREDICTED UNRECOVERED ERRORS bit | 98 |
| 5.2.10.6.5.5 NON_SEQ bit | 98 |
| 5.2.10.6.5.6 RESET bit | 98 |
| 5.2.10.6.5.7 ZONE LENGTH field | 98 |

| | |
|--|-----|
| 5.2.10.6.5.8 ZONE START LBA field | 98 |
| 5.2.10.6.5.9 WRITE POINTER LBA field..... | 98 |
| 5.2.11 RESET WRITE POINTER EXT command – 9Fh/04h, Non-Data | 99 |
| 5.2.11.1 Feature Set | 99 |
| 5.2.11.2 Description..... | 99 |
| 5.2.11.3 Inputs..... | 99 |
| 5.2.11.3.1 Overview | 99 |
| 5.2.11.3.2 Zone range specification for the RESET WRITE POINTER EXT command..... | 99 |
| 5.2.11.3.3 RESET WRITE POINTER EXT command processing..... | 99 |
| 5.2.11.4 Normal Outputs..... | 100 |
| 5.2.11.5 Error Outputs | 100 |
| 5.2.12 SEQUENTIALIZE ZONE EXT command – 9Fh/05h, Non-Data | 101 |
| 5.2.12.1 Feature Set..... | 101 |
| 5.2.12.2 Description..... | 101 |
| 5.2.12.3 Inputs..... | 101 |
| 5.2.12.3.1 Overview | 101 |
| 5.2.12.3.2 Zone range specification for the SEQUENTIALIZE ZONE EXT command..... | 101 |
| 5.2.12.3.3 SEQUENTIALIZE ZONE EXT command processing..... | 101 |
| 5.2.12.4 Normal Outputs..... | 102 |
| 5.2.12.5 Error Outputs | 102 |
| 5.2.13 ZONE ACTIVATE EXT command – 4Ah/08h, DMA | 103 |
| 5.2.13.1 Feature Set..... | 103 |
| 5.2.13.2 Description..... | 103 |
| 5.2.13.2.1 Overview | 103 |
| 5.2.13.2.2 Selecting the candidate zones to activate and deactivate | 103 |
| 5.2.13.2.3 Prerequisites reported by sense codes..... | 106 |
| 5.2.13.2.4 Prerequisites reported in the Zone Activation Results Header..... | 106 |
| 5.2.13.2.5 Zone Activation processing | 107 |
| 5.2.13.3 Inputs..... | 109 |
| 5.2.13.3.1 Overview | 109 |
| 5.2.13.3.2 OTHER ZONE DOMAIN ID field | 109 |
| 5.2.13.3.3 ALL bit | 109 |
| 5.2.13.3.4 NOZSRC field..... | 109 |
| 5.2.13.3.5 RETURN PAGE COUNT field | 110 |
| 5.2.13.3.6 ZONE ID field..... | 110 |
| 5.2.13.3.7 AUXNOZ field..... | 110 |
| 5.2.13.4 Normal Outputs..... | 110 |
| 5.2.13.5 Error Outputs | 110 |
| 5.2.13.6 Input From the Device to the Host Data Structure..... | 110 |
| 5.2.13.6.1 Overview | 110 |
| 5.2.13.6.2 Zone Activation Results Header..... | 111 |
| 5.2.13.6.2.1 Overview..... | 111 |
| 5.2.13.6.2.2 ZONE ACTIVATION RESULTS LENGTH field | 112 |
| 5.2.13.6.2.3 ZONE ACTIVATION RESULTS RETURNED field..... | 112 |
| 5.2.13.6.2.4 NZP_VALIDITY bit | 112 |
| 5.2.13.6.2.5 ZIWUP_VALIDITY bit..... | 112 |
| 5.2.13.6.2.6 ACTIVATED bit..... | 112 |
| 5.2.13.6.2.7 SECURITY PREREQ bit | 112 |
| 5.2.13.6.2.8 MULTIPLE DOMAINS bit | 112 |
| 5.2.13.6.2.9 REALM RESTRICTIONS bit..... | 112 |
| 5.2.13.6.2.10 MULTIPLE ZONE TYPES bit | 113 |
| 5.2.13.6.2.11 REALM ALIGNMENT bit | 113 |
| 5.2.13.6.2.12 NOT EMPTY bit..... | 113 |
| 5.2.13.6.2.13 NOT INACTIVE bit..... | 113 |
| 5.2.13.6.2.14 OTHER ZONE DOMAIN ID field..... | 113 |
| 5.2.13.6.2.15 NOZSRC field | 113 |
| 5.2.13.6.2.16 ALL bit..... | 113 |

| | |
|--|-----|
| 5.2.13.6.2.17 NUMBER OF ZONES TO PROCESS field..... | 114 |
| 5.2.13.6.2.18 ZONE ID WITH UNMET PREREQUISITE field | 114 |
| 5.2.13.6.3 Zone Activation Descriptor | 114 |
| 5.2.13.6.3.1 Overview | 114 |
| 5.2.13.6.3.2 ZONE TYPE field..... | 115 |
| 5.2.13.6.3.3 ZONE CONDITION field | 115 |
| 5.2.13.6.3.4 ZONE DOMAIN ID field | 115 |
| 5.2.13.6.3.5 ZONE RANGE SIZE field..... | 115 |
| 5.2.13.6.3.6 STARTING ZONE LOCATOR field | 115 |
| 5.2.14 ZONE QUERY EXT command – 4Ah/09h, DMA | 116 |
| 5.2.14.1 Feature Set..... | 116 |
| 5.2.14.2 Description..... | 116 |
| 5.2.14.3 Inputs | 116 |
| 5.2.14.4 Normal Outputs..... | 116 |
| 5.2.14.5 Error Outputs | 116 |
| 5.2.14.6 Input From the Device to the Host Data Structure | 116 |
| 5.3 REMOVE ELEMENT AND MODIFY ZONES – 7Eh, Non-Data | 117 |
| 5.3.3.1 Overview | 117 |
| 5.3.3.2 ELEMENT IDENTIFIER field..... | 117 |
| 5.3.3.3 Normal Outputs..... | 117 |
| 5.3.3.4 Error Outputs | 117 |
| 5.4 SET FEATURES subcommand additions..... | 119 |
| 5.4.1 Update urswrz | 119 |
| 5.4.2 Zone Activation Control..... | 119 |
| 6 Log definitions | 120 |
| 6.1 Introduction..... | 120 |
| 6.2 IDENTIFY DEVICE data log (Log Address 30h)..... | 120 |
| 6.2.1 Overview | 120 |
| 6.2.2 Zoned Device Information (page 09h)..... | 120 |
| 6.2.2.1 Overview | 120 |
| 6.2.2.2 REMOVE ELEMENT AND MODIFY ZONES SUPPORTED bit | 122 |
| 6.2.2.3 URSWRZ bit | 122 |
| 6.2.2.4 OPTIMAL NUMBER OF OPEN SEQUENTIAL WRITE PREFERRED ZONES field | 122 |
| 6.2.2.5 OPTIMAL NUMBER OF NON-SEQUENTIALLY WRITTEN SEQUENTIAL WRITE PREFERRED ZONES field..... | 122 |
| 6.2.2.6 MAXIMUM NUMBER OF OPEN SEQUENTIAL WRITE REQUIRED ZONES field | 122 |
| 6.2.2.7 Version information..... | 123 |
| 6.2.2.7.1 ZAC MINOR VERSION field | 123 |
| 6.2.2.8 Zone Activation Capabilities | 123 |
| 6.2.2.8.1 ZONE DOMAINS FEATURE SUPPORTED bit..... | 123 |
| 6.2.2.8.2 ZONE REALMS FEATURE SUPPORTED bit | 123 |
| 6.2.2.8.3 UPDATE URSWRZ SUPPORTED bit | 123 |
| 6.2.2.8.4 ZONE ACTIVATION CONTROL SUPPORTED bit | 123 |
| 6.2.2.8.5 NOZSRC SUPPORTED bit | 124 |
| 6.2.2.8.6 REPORT REALMS COMMAND SUPPORTED bit..... | 124 |
| 6.2.2.8.7 MAXIMUM ACTIVATION field | 124 |
| 6.2.2.9 Subsequent Number Of Zones | 124 |
| 6.2.2.9.1 SUBSEQUENT NUMBER OF ZONES field | 124 |
| 6.2.2.10 Supported Zone Types | 124 |
| 6.2.2.10.1 CONVENTIONAL SUPPORTED bit..... | 124 |
| 6.2.2.10.2 SEQUENTIAL WRITE PREFERRED SUPPORTED bit | 124 |
| 6.2.2.10.3 SEQUENTIAL WRITE REQUIRED SUPPORTED bit..... | 124 |
| 6.2.2.10.4 SEQUENTIAL OR BEFORE SUPPORTED bit | 124 |
| 6.2.2.10.5 GAP ZONE TYPE SUPPORTED bit..... | 124 |
| 6.3 Device Statistics log (Log Address 04h)..... | 125 |
| 6.3.1 Overview | 125 |

| | |
|--|-----|
| 6.3.2 Zoned Device Statistics (page 08h) | 125 |
| 6.3.2.1 Overview | 125 |
| 6.3.2.2 Device Statistics Information Header | 127 |
| 6.3.2.3 MAX OPEN ZONES field | 127 |
| 6.3.2.3.1 Description | 127 |
| 6.3.2.3.2 Update Interval | 127 |
| 6.3.2.3.3 Measurement Units | 127 |
| 6.3.2.3.4 Initialization | 127 |
| 6.3.2.4 MAX EXPLICITLY OPEN ZONES field | 127 |
| 6.3.2.4.1 Description | 127 |
| 6.3.2.4.2 Update Interval | 127 |
| 6.3.2.4.3 Measurement Units | 128 |
| 6.3.2.4.4 Initialization | 128 |
| 6.3.2.5 MAX IMPLICITLY OPEN ZONES field | 128 |
| 6.3.2.5.1 Description | 128 |
| 6.3.2.5.2 Update Interval | 128 |
| 6.3.2.5.3 Measurement Units | 128 |
| 6.3.2.5.4 Initialization | 128 |
| 6.3.2.6 MIN EMPTY ZONES field | 128 |
| 6.3.2.6.1 Description | 128 |
| 6.3.2.6.2 Update Interval | 128 |
| 6.3.2.6.3 Measurement Units | 128 |
| 6.3.2.6.4 Initialization | 128 |
| 6.3.2.7 MAX NON SEQUENTIAL ZONES field | 129 |
| 6.3.2.7.1 Description | 129 |
| 6.3.2.7.2 Update Interval | 129 |
| 6.3.2.7.3 Measurement Units | 129 |
| 6.3.2.7.4 Initialization | 129 |
| 6.3.2.8 ZONES EMPTIED field | 129 |
| 6.3.2.8.1 Description | 129 |
| 6.3.2.8.2 Update Interval | 129 |
| 6.3.2.8.3 Measurement Units | 129 |
| 6.3.2.8.4 Initialization | 129 |
| 6.3.2.9 SUBOPTIMAL WRITE CMDS field | 129 |
| 6.3.2.9.1 Description | 129 |
| 6.3.2.9.2 Update Interval | 129 |
| 6.3.2.9.3 Measurement Units | 130 |
| 6.3.2.9.4 Initialization | 130 |
| 6.3.2.10 CMDS EXCEEDING OPTIMAL LIMIT field | 130 |
| 6.3.2.10.1 Description | 130 |
| 6.3.2.10.2 Update Interval | 130 |
| 6.3.2.10.3 Measurement Units | 130 |
| 6.3.2.10.4 Initialization | 130 |
| 6.3.2.11 FAILED EXPLICIT OPENS field | 130 |
| 6.3.2.11.1 Description | 130 |
| 6.3.2.11.2 Update Interval | 130 |
| 6.3.2.11.3 Measurement Units | 130 |
| 6.3.2.11.4 Initialization | 130 |
| 6.3.2.12 READ RULE VIOLATIONS field | 130 |
| 6.3.2.12.1 Description | 130 |
| 6.3.2.12.2 Update Interval | 131 |
| 6.3.2.12.3 Measurement Units | 131 |
| 6.3.2.12.4 Initialization | 131 |
| 6.3.2.13 WRITE RULE VIOLATIONS field | 131 |
| 6.3.2.13.1 Description | 131 |
| 6.3.2.13.2 Update Interval | 131 |
| 6.3.2.13.3 Measurement Units | 131 |

| | |
|--|-----|
| 6.3.2.13.4 Initialization | 131 |
| 6.3.2.14 MAX IMPLICITLY OPEN SEQUENTIAL OR BEFORE REQUIRED ZONES field | 131 |
| 6.3.2.14.1 Description | 131 |
| 6.3.2.14.2 Update Interval | 132 |
| 6.3.2.14.3 Measurement Units | 132 |
| 6.3.2.14.4 Initialization | 132 |
| 7 Normal and Error Outputs | 133 |
| 7.1 Overview | 133 |
| 7.2 Normal Outputs | 133 |
| 7.3 Error Outputs | 134 |
| 7.4 Sense code definitions | 134 |
| 7.4.1 Overview | 134 |
| 7.4.2 ATTEMPT TO ACCESS GAP ZONE | 135 |
| 7.4.3 ATTEMPT TO READ INVALID DATA | 135 |
| 7.4.4 DEPOPULATION INTERRUPTED | 135 |
| 7.4.5 INSUFFICIENT ZONE RESOURCES | 135 |
| 7.4.6 READ BOUNDARY VIOLATION | 135 |
| 7.4.7 RESET WRITE POINTER NOT ALLOWED | 135 |
| 7.4.8 UNALIGNED WRITE COMMAND | 135 |
| 7.4.9 UNWRITTEN DATA IN ZONE | 136 |
| 7.4.10 WRITE BOUNDARY VIOLATION | 136 |
| 7.4.11 WRITE ERROR - INSUFFICIENT ZONE RESOURCES | 136 |
| 7.4.12 WRITE ERROR - RECOVERY NEEDED | 136 |
| 7.4.13 WRITE ERROR - RECOVERY SCAN NEEDED | 136 |
| 7.4.14 ZONE IS INACTIVE | 136 |
| 7.4.15 ZONE IS OFFLINE | 136 |
| 7.4.16 ZONE IS READ ONLY | 136 |
| 7.4.17 ZONE RESET WRITE POINTER RECOMMENDED | 136 |
| 7.4.18 ZONE TRANSITION TO FULL | 136 |
| Annex A (informative) Host Considerations for Zoned Devices | 137 |
| A.1 Introduction | 137 |
| A.2 Writing to write pointer zones | 137 |
| A.3 Open zone considerations | 137 |
| A.3.1 Overview | 137 |
| A.3.2 Explicitly opened zones and implicitly opened zones | 138 |
| A.3.3 Opening and closing zones | 139 |
| A.3.4 Finish Zone function considerations | 139 |
| A.4 Open zone resources considerations based on zone type | 139 |
| A.4.1 Sequential Write Preferred zones | 139 |
| A.4.2 Sequential Write Required zones | 140 |
| A.5 Partial failures | 140 |
| A.5.1 Overview | 140 |
| A.5.2 Sanitize considerations | 140 |
| Annex B (informative) Zone Activation | 142 |
| B.1 Introduction | 142 |
| B.2 Differences between Zone Domains and Zone Realms | 142 |
| B.3 ZONE ACTIVATION EXT / ZONE QUERY EXT iteration example | 142 |
| B.4 Typical ZONE QUERY EXT process | 143 |
| B.5 ZONE QUERY EXT resulting in a failed security prerequisite | 143 |
| B.6 Typical ZONE ACTIVATION EXT process | 143 |
| B.7 ZONE ACTIVATION EXT resulting in no zones activated | 145 |
| B.8 ZONE ACTIVATE resulting in Realm boundaries moving | 146 |
| Bibliography | 147 |

Tables

| | Page |
|---|------|
| Table 1 - Numbering conventions | 12 |
| Table 2 - Zone domain ID values | 19 |
| Table 3 - Summary of realm attributes | 25 |
| Table 4 - Summary of zone attributes | 27 |
| Table 5 - Zone Type zone attribute | 27 |
| Table 6 - Relationships between zone attributes | 28 |
| Table 7 - Zone Condition zone attribute | 29 |
| Table 8 - Characteristics associated with zone state | 32 |
| Table 9 - Zone Condition state machine functions | 43 |
| Table 10 - Characteristics and attributes associated with zone state | 44 |
| Table 11 - ZAC OPTIONS field | 60 |
| Table 12 - ZONE POST PROCESSING field | 61 |
| Table 13 - Example Command Structure | 66 |
| Table 14 - Example Normal Output | 67 |
| Table 15 - Example Error Output | 68 |
| Table 16 - Zone management commands | 69 |
| Table 17 - ZAC Management In command template inputs | 70 |
| Table 18 - RECEIVE FPDMA QUEUED command encapsulation for the subcommand specific inputs used by the ZAC Management In command | 71 |
| Table 19 - ZAC Management Out, DMA command template inputs | 72 |
| Table 20 - SEND FPDMA QUEUED command encapsulation for the subcommand specific inputs used by the ZAC Management Out command | 73 |
| Table 21 - ZAC Management Out, Non-Data command template inputs | 74 |
| Table 22 - NCQ NON-DATA command encapsulation for the subcommand specific inputs used by the ZAC Management Out command | 76 |
| Table 23 - CLOSE ZONE EXT command inputs | 77 |
| Table 24 - CLOSE ZONE EXT command processing | 78 |
| Table 25 - FINISH ZONE EXT command inputs | 79 |
| Table 26 - FINISH ZONE EXT command processing | 80 |
| Table 27 - OPEN ZONE EXT command inputs | 81 |
| Table 28 - OPEN ZONE EXT command processing | 82 |
| Table 29 - REPORT REALMS EXT command inputs | 83 |
| Table 30 - REPORTING OPTIONS field | 84 |
| Table 31 - REPORT REALMS EXT input from device to host | 84 |
| Table 32 - Report realms header | 85 |
| Table 33 - Realm descriptor | 86 |
| Table 34 - REALM RESTRICTIONS field | 86 |
| Table 35 - Realm start/end descriptor | 87 |
| Table 36 - REPORT ZONE DOMAINS EXT command inputs | 88 |
| Table 37 - REPORT ZONE DOMAINS REPORTING OPTIONS field | 89 |
| Table 38 - REPORT ZONE DOMAINS input from device to host | 89 |
| Table 39 - Report zone domains header | 90 |
| Table 40 - Zone domain descriptor | 91 |
| Table 41 - REPORT ZONES EXT command inputs | 93 |
| Table 42 - REPORTING OPTIONS field | 94 |
| Table 43 - REPORT ZONES EXT input from device to host | 95 |
| Table 44 - SAME field | 96 |
| Table 45 - Zone descriptor format | 97 |
| Table 46 - ZONE TYPE field | 97 |
| Table 47 - ZONE CONDITION field | 98 |
| Table 48 - RESET WRITE POINTER EXT command inputs | 99 |
| Table 49 - RESET WRITE POINTER EXT command processing | 100 |
| Table 50 - SEQUENTIALIZE ZONE EXT command inputs | 101 |
| Table 51 - SEQUENTIALIZE ZONE EXT command processing | 102 |
| Table 52 - Selecting candidate zones to activate and deactivate with ALL bit cleared to zero | 105 |

| | |
|--|-----|
| Table 53 - ZONE ACTIVATE EXT command and ZONE QUERY EXT command inputs | 109 |
| Table 54 - Zone Activation Results | 110 |
| Table 55 - Zone Activation Results Header | 111 |
| Table 56 - Zone Activation Descriptor | 115 |
| Table 57 - REMOVE ELEMENT AND MODIFY ZONES command inputs | 117 |
| Table 58 - Update urswrz subcommand inputs..... | 119 |
| Table 59 - Zone Activation Control subcommand inputs | 119 |
| Table 60 - Zoned Device Information | 120 |
| Table 61 - ZAC MINOR VERSION field | 123 |
| Table 62 - Zoned Device Statistics | 125 |
| Table 63 - Generic ZAC Extended Normal Output..... | 133 |
| Table 64 - Generic ZAC Extended Error Output | 134 |
| Table 65 - Additional sense codes | 135 |
| Table B.1 - Comparison between Zone Domains and Zone Realms | 142 |

Figures

| | Page |
|--|------|
| Figure 1 - ATA document relationships | 1 |
| Figure 2 - State diagram convention | 13 |
| Figure 3 - Zones in a zoned device | 15 |
| Figure 4 - Zone domain | 19 |
| Figure 5 - Example of two zone domains | 20 |
| Figure 6 - Example of zone activation in the Zone Domains feature set..... | 21 |
| Figure 7 - Zone Realms feature set model..... | 22 |
| Figure 8 - Example of conventional and shingled recording technologies using two zone domains | 24 |
| Figure 9 - Example of zone activation in the Zone Realms feature set..... | 25 |
| Figure 10 - Conventional zone state machine..... | 33 |
| Figure 11 - Write pointer zone and write pointer after Reset Write Pointer function with no subsequent writes | 34 |
| Figure 12 - Write pointer zone and write pointer example | 34 |
| Figure 13 - Example effects of host actions on a write pointer zone..... | 35 |
| Figure 14 - Example write command that starts at the write pointer | 37 |
| Figure 15 - Examples of write commands that do not start at the write pointer | 38 |
| Figure 16 - Zone Condition state machine | 45 |
| Figure B.1 - Example of typical zone activation | 144 |
| Figure B.2 - Example of ZONE ACTIVATION that results in no zones activated | 145 |
| Figure B.3 - Example of zone deactivation that results in realm boundaries moving..... | 146 |