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Information technology – AT attachment – Part 103: ATA/ATAPI Command Set - 3 (ACS-3)



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CONTENTS

FOREWORD 16

INTRODUCTION 18

1 Scope 20

2 Normative references 20

3 Terms, definitions, abbreviations, and conventions 21
3.1 Terms and definitions 21
3.2 Symbols and abbreviations 30
3.2.1 Abbreviations 30
3.2.2 Units: 31
3.2.3 Mathematical operators: 31
3.2.4 Other Symbols 31
3.3 Conventions 31
3.3.1 Overview 31
3.3.2 Precedence 32
3.3.3 Lists 32
3.3.4 Keywords 33
3.3.5 Numbering 34
3.3.6 Bit conventions 35
3.3.7 Number range convention 35
3.3.8 State diagram conventions 35
3.3.9 Byte, word, DWord, QWord, and DQWord Relationships 37
3.3.10 ATA string convention 38
3.3.11 Offset Convention 39

4 Feature set definitions 40
4.1 Overview 40
4.1.1 Feature set summary 40
4.1.2 Capacity reporting 41
4.2 General feature set 42
4.3 The PACKET feature set 42
4.3.1 Overview 42
4.3.2 Identification of PACKET feature set devices 43
4.3.3 Signature for ATAPI devices 43
4.3.4 The PACKET command 43
4.4 48-bit Address feature set 43
4.5 Accessible Max Address Configuration feature set 44
4.5.1 Overview 44
4.5.2 SET ACCESSIBLE MAX ADDRESS EXT description 44
4.5.3 Device Statistics data 44
4.6 Advanced Power Management (APM) feature set 44
4.7 CompactFlash Association (CFA) feature set 45
4.8 Device Statistics Notification (DSN) feature set 45
4.8.1 Overview 45
4.8.2 DSN notifications 46
4.8.3 DSN notifications setup 46
4.9 Extended Power Conditions (EPC) feature set 47
4.9.1 Overview 47
4.9.2 Power conditions 47
4.9.3 Power condition timers 47
4.9.4 Interaction with resets, commands, and other features if the EPC feature set is enabled 48

4.10 Free-fall Control feature set 49
4.11 General Purpose Logging (GPL) feature set 49
4.12 Long Logical Sector (LLS) feature set 50
4.13 Long Physical Sector (LPS) feature set 51
4.14 Native Command Queuing (NCQ) feature set 53
4.14.1 Overview 53
4.14.2 Priority 54
4.14.3 Unload with NCQ commands outstanding 54
4.14.4 Command Phases 54
4.15 Power Management feature set 55
4.15.1 Overview 55
4.15.2 Power management commands 55
4.15.3 Standby timer 56
4.15.4 Power Management states and transitions 57
4.16 Power-Up In Standby (PUIS) feature set 60
4.16.1 Overview 60
4.16.2 Interactions with IDENTIFY DEVICE and IDENTIFY PACKET DEVICE commands 60
4.16.3 PUIS feature set device spin-up subcommand 60
4.17 Sanitize Device feature set 61
4.17.1 Overview 61
4.17.2 Sanitize operation scope 61
4.17.3 Sanitize commands 61
4.17.4 Sanitize operations 61
4.17.5 Command processing during sanitize operations 62
4.17.6 Sanitize Operation Completed Without Error value 62
4.17.7 Failure Mode Policy value 62
4.17.8 Sanitize Antifreeze value 63
4.17.9 Sanitize Device state machine 63
4.18 Security feature set 66
4.18.1 Overview 66
4.18.2 Disabling and enabling the Security feature set 66
4.18.3 Passwords 66
4.18.4 Master password capability 67
4.18.5 Frozen mode 67
4.18.6 Commands 67
4.18.7 Security initial setting 67
4.18.8 Password Rules 67
4.18.9 Password attempt counter and SECURITY COUNT EXPIRED bit 68
4.18.10 Master Password Identifier feature 68
4.18.11 Security states 69
4.19 Self-Monitoring, Analysis, and Reporting Technology (SMART) feature set 78
4.19.1 Overview 78
4.19.2 Device SMART data structure 78
4.19.3 Background data collection 78
4.19.4 Off-line/Captive mode data collection 78
4.19.5 Threshold exceeded condition 79
4.19.6 SMART feature set commands 79
4.19.7 SMART operation with power management modes 79
4.19.8 SMART device error log reporting 79
4.20 Sense Data Reporting feature set 79
4.21 Software Settings Preservation (SSP) feature set 80
4.22 SATA Hardware Feature Control 81
4.23 Streaming feature set 82
4.23.1 Streaming feature set overview 82
4.23.2 Streaming commands 82
4.24 Trusted Computing feature set 83
4.25 Write-Read-Verify feature set 84

5 ATA protocols 85

6 Normal and Error Output field descriptions 86
6.1 Overview 86
6.2 STATUS field 86
6.2.1 Overview 86
6.2.2 ALIGNMENT ERROR bit 86
6.2.3 BUSY bit 87
6.2.4 CHECK CONDITION bit 87
6.2.5 DATA REQUEST bit 87
6.2.6 DEFERRED WRITE ERROR bit 87
6.2.7 DEVICE FAULT bit 87
6.2.8 DEVICE READY bit 87
6.2.9 ERROR bit 87
6.2.10 SENSE DATA AVAILABLE bit 88
6.2.11 STREAM ERROR bit 88
6.2.12 Transport Dependent bits and fields 88
6.3 ERROR field 89
6.3.1 Overview 89
6.3.2 ABORT bit 89
6.3.3 COMMAND COMPLETION TIME OUT bit 89
6.3.4 END OF MEDIA bit 89
6.3.5 ID NOT FOUND bit 89
6.3.6 ILLEGAL LENGTH INDICATOR bit 90
6.3.7 INTERFACE CRC bit 90
6.3.8 SENSE KEY field 90
6.3.9 UNCORRECTABLE ERROR bit 90
6.4 INTERRUPT REASON field 90
6.4.1 Overview 90
6.4.2 COMMAND/DATA bit 90
6.4.3 INPUT/OUTPUT bit 90
6.5 COUNT field 90
6.5.1 Overview 90
6.5.2 Contiguous stream logical sectors that contain potentially bad data 90
6.5.3 NCQ Tag 91
6.6 SACTIVE field 91
6.7 SATA STATUS field 91
6.8 LBA field 91
6.8.1 Overview 91
6.8.2 LBA of First Unrecoverable Error 91

7 Command descriptions 92
7.1 Command description introduction 92
7.1.1 Overview 92
7.1.10 Command Code Usage 96
7.2 Accessible Max Address Configuration 97
7.2.1 Accessible Max Address Configuration overview 97
7.2.2 GET NATIVE MAX ADDRESS EXT – 78h/0000h, Non-Data 97
7.2.3 SET ACCESSIBLE MAX ADDRESS EXT – 78h/0001h, Non-Data 98
7.2.4 FREEZE ACCESSIBLE MAX ADDRESS EXT – 78h/0002h, Non-Data 99
7.3 CHECK POWER MODE – E5h, Non-Data 100
7.4 CONFIGURE STREAM – 51h, Non-Data 101
7.5 DATA SET MANAGEMENT – 06h, DMA 103
7.6 DEVICE RESET – 08h, Device Reset 106
7.7 DOWNLOAD MICROCODE – 92h, PIO Data-Out/Non-Data 107
7.8 DOWNLOAD MICROCODE DMA – 93h, DMA 120
7.9 EXECUTE DEVICE DIAGNOSTIC – 90h, Execute Device Diagnostic 121

7.10 FLUSH CACHE – E7h, Non-Data 123
7.11 FLUSH CACHE EXT – EAh, Non-Data 124
7.12 IDENTIFY DEVICE – ECh, PIO Data-In 125
7.13 IDENTIFY PACKET DEVICE – A1h, PIO Data-In 162
7.14 IDLE – E3h, Non-Data 182
7.15 IDLE IMMEDIATE – E1h, Non-Data 184
7.16 NCQ QUEUE MANAGEMENT – 63h, Non-Data 186
7.16.8 ABORT NCQ QUEUE – 63h/0h, Non-Data 188
7.16.9 DEADLINE HANDLING – 63h/1h, Non-Data 191
7.17 NOP – 00h, Non-Data 194
7.18 PACKET – A0h, Packet 195
7.19 READ BUFFER – E4h, PIO Data-In 198
7.20 READ BUFFER DMA – E9h, DMA 199
7.21 READ DMA – C8h, DMA 200
7.22 READ DMA EXT – 25h, DMA 201
7.23 READ FPDMA QUEUED – 60h, DMA Queued 202
7.24 READ LOG EXT – 2Fh, PIO Data-In 204
7.25 READ LOG DMA EXT – 47h, DMA 206
7.26 READ MULTIPLE – C4h, PIO Data-In 207
7.27 READ MULTIPLE EXT – 29h, PIO Data-In 208
7.28 READ SECTOR(S) – 20h, PIO Data-In 209
7.29 READ SECTOR(S) EXT – 24h, PIO Data-In 210
7.30 READ STREAM DMA EXT – 2Ah, DMA 211
7.31 READ STREAM EXT – 2Bh, PIO Data-In 214
7.32 READ VERIFY SECTOR(S) – 40h, Non-Data 215
7.33 READ VERIFY SECTOR(S) EXT – 42h, Non-Data 216
7.34 RECEIVE FPDMA QUEUED – 65h, DMA Queued 217
7.35 REQUEST SENSE DATA EXT – 0Bh, Non-Data 219
7.36 Sanitize Device 220
7.36.2 BLOCK ERASE EXT – B4h/0012h, Non-Data 221
7.36.3 CRYPTO SCRAMBLE EXT – B4h/0011h, Non-Data 224
7.36.4 OVERWRITE EXT – B4h/0014h, Non-Data 226
7.36.5 SANITIZE ANTIFREEZE LOCK EXT – B4h/0040h, Non-Data 229
7.36.6 SANITIZE FREEZE LOCK EXT – B4h/0020h, Non-Data 231
7.36.7 SANITIZE STATUS EXT – B4h/0000h, Non-Data 232
7.37 SECURITY DISABLE PASSWORD – F6h, PIO Data-Out 234
7.38 SECURITY ERASE PREPARE – F3h, Non-Data 236
7.39 SECURITY ERASE UNIT – F4h, PIO Data-Out 237
7.40 SECURITY FREEZE LOCK – F5h, Non-Data 239
7.41 SECURITY SET PASSWORD – F1h, PIO Data-Out 240
7.42 SECURITY UNLOCK – F2h, PIO Data-Out 242
7.43 SEND FPDMA QUEUED – 64h, DMA Queued 244
7.43.4 SFQ DATA SET MANAGEMENT – 64h/00h, DMA Queued 246
7.44 SET DATE & TIME EXT – 77h, Non-Data 248
7.45 SET FEATURES – EFh, Non-Data 249
7.45.6 SET FEATURES subcommands 250
7.45.7 Enable/disable volatile write cache 252
7.45.8 Set transfer mode 253
7.45.9 Enable/disable the APM feature set 254
7.45.10 Enable/disable the PUIS feature set 254
7.45.11 PUIS feature set device spin-up 254
7.45.12 Enable/Disable Write-Read-Verify feature set 255
7.45.13 Set Maximum Host Interface Sector Times 256
7.45.14 Enable/disable read look-ahead 256
7.45.15 Enable/disable reverting to defaults 256
7.45.16 Enable/Disable the Free-fall Control feature set 257
7.45.17 Enable/Disable SATA feature 257

7.45.18 Enable/Disable the Sense Data Reporting feature set 259
7.45.19 Long Physical Sector Alignment Error Reporting Control 259
7.45.20 Extended Power Conditions subcommand 260
7.45.21 Enable/Disable the DSN feature set 270
7.46 SET MULTIPLE MODE – C6h, Non-Data 271
7.47 SLEEP – E6h, Non-Data 273
7.48 SMART 274
7.48.2 SMART DISABLE OPERATIONS – B0h/D9h, Non-Data 275
7.48.3 SMART ENABLE/DISABLE ATTRIBUTE AUTOSAVE – B0h/D2h, Non-Data 276
7.48.4 SMART ENABLE OPERATIONS – B0h/D8h, Non-Data 278
7.48.5 SMART EXECUTE OFF-LINE IMMEDIATE – B0h/D4h, Non-Data 279
7.48.6 SMART READ DATA – B0h/D0h, PIO Data-In 283
7.48.7 SMART READ LOG – B0h/D5h, PIO Data-In 288
7.48.8 SMART RETURN STATUS – B0h/DAh, Non-Data 289
7.48.9 SMART WRITE LOG – B0h/D6h, PIO Data-Out 290
7.49 STANDBY – E2h, Non-Data 291
7.50 STANDBY IMMEDIATE – E0h, Non-Data 292
7.51 TRUSTED NON-DATA – 5Bh, Non-Data 293
7.52 TRUSTED RECEIVE – 5Ch, PIO Data-In 295
7.53 TRUSTED RECEIVE DMA – 5Dh, DMA 302
7.54 TRUSTED SEND – 5Eh, PIO Data-Out 303
7.55 TRUSTED SEND DMA – 5Fh, DMA 305
7.56 WRITE BUFFER – E8h, PIO Data-Out 306
7.57 WRITE BUFFER DMA – EBh, DMA 307
7.58 WRITE DMA – CAh, DMA 308
7.59 WRITE DMA EXT – 35h, DMA 309
7.60 WRITE DMA FUA EXT – 3Dh, DMA 310
7.61 WRITE FPDMA QUEUED – 61h, DMA Queued 311
7.62 WRITE LOG EXT – 3Fh, PIO Data-Out 313
7.63 WRITE LOG DMA EXT – 57h, DMA 315
7.64 WRITE MULTIPLE – C5h, PIO Data-Out 316
7.65 WRITE MULTIPLE EXT – 39h, PIO Data-Out 317
7.66 WRITE MULTIPLE FUA EXT – CEh, PIO Data-Out 319
7.67 WRITE SECTOR(S) – 30h, PIO Data-Out 321
7.68 WRITE SECTOR(S) EXT – 34h, PIO Data-Out 322
7.69 WRITE STREAM DMA EXT – 3Ah, DMA 323
7.70 WRITE STREAM EXT – 3Bh, PIO Data-Out 326
7.71 WRITE UNCORRECTABLE EXT – 45h, Non-Data 327

8 SCT Command Transport 329
8.1 Introduction 329
8.1.1 Overview 329
8.1.2 SCT command interactions with ATA commands 330
8.1.3 Resets 330
8.2 Processing SCT commands 331
8.2.1 Processing SCT commands overview 331
8.2.2 SCT capability identification 331
8.2.3 SCT Command transfer 331
8.2.4 SCT data transfer 336
8.2.5 SCT status 342
8.3 SCT Command Set 348
8.3.1 Overview 348
8.3.2 SCT Write Same command 349
8.3.3 SCT Error Recovery Control command 354
8.3.4 SCT Feature Control command 356
8.3.5 SCT Data Table command 360

9 Normal and Error Outputs 364
9.1 Overview 364
9.2 Normal Outputs 364
9.3 Error Outputs 380

Annex A (normative) Log Definitions 409
A.1 Overview 409
A.2 General Purpose Log Directory (GPL Log Address 00h) 412
A.3 SMART Log Directory (SMART Logging Log Address 00h) 412
A.4 Comprehensive SMART Error log (Log Address 02h) 413
A.5 Device Statistics log (Log Address 04h) 414
A.5.1 Overview 414
A.5.2 List of Supported Device Statistics log pages (log page 00h) 416
A.5.3 Free Fall Statistics (log page 02h) 417
A.5.4 General Statistics (log page 01h) 419
A.5.5 General Errors Statistics (log page 04h) 423
A.5.6 Rotating Media Statistics (log page 03h) 425
A.5.7 Solid State Device Statistics (log page 07h) 430
A.5.8 Temperature Statistics (log page 05h) 431
A.5.9 Transport Statistics (log page 06h) 439
A.5.10 Reserved (log page 08h..FFh) 441
A.6 Device Vendor Specific logs (Log Addresses A0h-DFh) 441
A.7 Extended Comprehensive SMART Error log (Log Address 03h) 441
A.8 Power Conditions log (Log Address 08h) 445
A.8.2 Idle power conditions (log page 00h) 445
A.8.3 Standby power conditions (log page 01h) 446
A.8.4 Power Conditions log descriptor 446
A.9 Extended SMART Self-Test log (Log Address 07h) 449
A.10 Host Specific logs (Log Addresses 80h-9Fh) 451
A.11 IDENTIFY DEVICE data log (Log Address 30h) 452
A.11.1 Overview 452
A.11.2 List of Supported IDENTIFY DEVICE data log pages (Page 00h) 452
A.11.3 Copy of IDENTIFY DEVICE data (page 01h) 453
A.11.4 Capacity (page 02) 453
A.11.5 Supported Capabilities (page 03h) 456
A.11.6 Current Settings (page 04h) 469
A.11.7 Strings (page 05h) 477
A.11.8 Security (page 06h) 478
A.11.9 Parallel ATA (page 07h) 484
A.11.10 Serial ATA (page 08h) 496
A.12 LBA Status log (Log Address 19h) 502
A.12.1 Overview 502
A.12.2 Number of LBA Valid Ranges log page (Page 0000h) 503
A.12.3 LBA Status log pages 503
A.12.4 LBA Status Descriptor 504
A.13 LPS Mis-alignment log (Log Address 0Dh) 505
A.14 NCQ Command Error log (Log Address 10h) 507
A.14.1 Overview 507
A.14.2 NCQ TAG field 507
A.14.3 NQ bit 507
A.14.4 UNL bit 508
A.14.5 Return Fields 508
A.14.6 NCQ Autosense 508
A.14.7 Checksum 508
A.15 Read Stream Error log (Log Address 22h) 509
A.16 SATA Phy Event Counters log (Log Address 11h) 510
A.17 SATA NCQ Queue Management log (Log Address 12h) 512

A.17.1 Overview 512
A.17.2 SUPPORTS ABORT NCQ QUEUE bit 512
A.17.3 SUPPORTS ABORT ALL AT bit 512
A.17.4 SUPPORTS ABORT STREAMING AT bit 512
A.17.5 SUPPORTS ABORT NON-STREAMING AT bit 513
A.17.6 SUPPORTS ABORT SELECTED TTAG AT bit 513
A.17.7 SUPPORTS DEADLINE HANDLING bit 513
A.17.8 SUPPORTS WDNC bit 513
A.17.9 SUPPORTS RDNC bit 513
A.18 SATA NCQ Send and Receive log (Log Address 13h) 514
A.18.1 Overview 514
A.18.2 SFQ DATA SET MANAGEMENT SUPPORTED bit 514
A.18.3 SFQ DATA SET MANAGEMENT SUPPORTS TRIM bit 514
A.19 Selective Self-Test log (Log Address 09h) 515
A.20 SMART Self-Test log (Log Address 06h) 517
A.21 Summary SMART Error log (Log Address 01h) 518
A.22 Write Stream Error log (Log Address 21h) 521
A.23 Current Device Internal Status Data log (Log Address 24h) 522
A.23.1 Overview 522
A.23.2 Current Device Internal Status Data header page 523
A.23.3 Current Device Internal Status data pages 525
A.23.4 Examples of data area usage 525
A.24 Saved Device Internal Status Data log (Log Address 25h) 527
A.24.1 Overview 527
A.24.2 Saved Device Internal Status Data header page 527
A.24.3 Current Device Internal Status data pages 528
A.25 Device Statistics Notifications log (Log Address 0Ah) 528

Annex B (informative) Command Set Summary 532

Annex C (informative) How to Use SCT Commands 559
C.1 How to Use SCT Commands Overview 559
C.2 Examples of Log Page Command Sequences 561
C.3 Issuing an SCT Command to a Device 566
C.3.1 Step 1 – Build a Key Page 566
C.3.2 Step 2 – Issue the SCT command 567
C.3.3 Step 3 – Transfer Data if Required 568
C.3.4 Step 4 – Final Status/SCT Command Completion 569

Annex D (informative) Implementation Guidelines for 1 024- and 4 096-Byte Sector Sizes 570
D.1 General 570
D.2 Overview 570
D.3 Implementation 572
D.3.1 4 096-Byte Physical Sector Size Implementation 572
D.3.2 Reporting Alignment (512-Byte LBA Only) 572
D.3.3 RMW operations (512-Byte LBA Only) 573
D.4 Implementation Issues (512-Byte LBA Only) 573
D.4.1 Overview 573
D.4.2 Drive Partitioning 574
D.4.3 File System Formatting 575
D.4.4 Virtual Memory accessing 575
D.4.5 Booting 575

Bibliography 576

Numbering conventions 34
ATA string byte swapping 39
FIRMWARE REVISION field example 39
Feature set summary 40
IDENTIFY DEVICE capacity reporting 41
Words Transferred Per COUNT Field Unit by Command 50
PRIO field 54
Summary of Security States and Security Characteristics 69
Security Command Actions 70
Security page settings for the SEC1: Security Disabled/Not Locked/Not Frozen state 74
Security page settings for the SEC2: Security Disabled/Not Locked/Frozen state 75
Security page settings for the SEC4: Security Enabled/Locked/Not Frozen state 76
Security page settings for the SEC5: Security Enabled/Not Locked/Not Frozen state 77
Security page settings for the SEC6: Security Enabled/Not Locked/Frozen state 78
Preserved Feature Sets and Settings 81
STATUS field 86
ERROR field 89
INTERRUPT REASON field 90
COUNT field use for NCQ Tag 91
Example Command Structure 93
Example Normal Output 94
Example Error Output 95
Command Code Usage Matrix 96
Accessible Max Address Configuration FEATURE field values 97
GET NATIVE MAX ADDRESS EXT command inputs 97
SET ACCESSIBLE MAX ADDRESS EXT command inputs 98
FREEZE ACCESSIBLE MAX ADDRESS EXT command inputs 99
CHECK POWER MODE command inputs. 100
CONFIGURE STREAM command inputs 101
DATA SET MANAGEMENT command inputs 103
Trim related interactions 104
LBA Range Entries 105
DEVICE RESET command inputs 106
DOWNLOAD MICROCODE SUBCOMMAND field 108
DOWNLOAD MICROCODE command inputs 118
COUNT field output for DOWNLOAD MICROCODE requesting the offset transfer method 119
DOWNLOAD MICROCODE DMA command inputs 120
EXECUTE DEVICE DIAGNOSTIC command inputs 121
Diagnostic codes 122
FLUSH CACHE command inputs 123
FLUSH CACHE EXT command inputs 124
IDENTIFY DEVICE command inputs 125
IDENTIFY DEVICE data 126
Specific configuration 146
Minor version number 151
Transport minor version number 161
IDENTIFY PACKET DEVICE command inputs 162
IDENTIFY PACKET DEVICE data 163
IDLE command inputs 182
Standby timer periods 182
IDLE IMMEDIATE command inputs 184
IDLE IMMEDIATE with Unload feature command inputs 185
NCQ QUEUE MANAGEMENT command inputs 186
NCQ QUEUE MANAGEMENT Subcommands 187
ABORT NCQ QUEUE command inputs 189
ABORT NCQ QUEUE Abort Types 190
DEADLINE HANDLING command inputs 192

NOP command inputs 194
NOP Subcommand Code 194
PACKET command inputs 195
READ BUFFER command inputs 198
READ BUFFER DMA command inputs 199
READ DMA command inputs 200
READ DMA EXT command inputs 201
READ FPDMA QUEUED command inputs 202
READ LOG EXT command inputs 204
READ LOG DMA EXT command inputs 206
READ MULTIPLE command inputs 207
READ MULTIPLE EXT command inputs 208
READ SECTOR(S) command inputs 209
READ SECTOR(S) EXT command inputs 210
READ STREAM DMA EXT command inputs 211
READ STREAM EXT command inputs 214
READ VERIFY SECTOR(S) command inputs 215
READ VERIFY SECTOR(S) EXT command inputs 216
RECEIVE FPDMA QUEUED command inputs 217
RECEIVE FPDMA QUEUED Subcommands 217
REQUEST SENSE DATA EXT command inputs 219
Sanitize Device FEATURE field values 220
BLOCK ERASE EXT command inputs 222
CRYPTO SCRAMBLE EXT command inputs 224
OVERWRITE EXT command inputs 227
SANITIZE ANTIFREEZE LOCK EXT command inputs 229
SANITIZE FREEZE LOCK EXT command inputs 231
SANITIZE STATUS EXT command inputs 232
SECURITY DISABLE PASSWORD command inputs 234
SECURITY DISABLE PASSWORD data content 235
SECURITY ERASE PREPARE command inputs 236
Erase Mode characteristics 237
SECURITY ERASE UNIT command inputs 238
SECURITY ERASE UNIT data content 238
SECURITY FREEZE LOCK command inputs 239
SECURITY SET PASSWORD command inputs 241
SECURITY SET PASSWORD data content 241
SECURITY UNLOCK command inputs 243
SECURITY UNLOCK data content 243
SEND FPDMA QUEUED command inputs 244
SEND FPDMA QUEUED Subcommands 244
SFQ DATA SET MANAGEMENT command inputs 246
SET DATE & TIME EXT command inputs 248
SET FEATURES command inputs 249
SET FEATURES command subcommand codes 250
Transfer modes 253
APM levels 254
Write-Read-Verify modes 255
Maximum Host Interface Sector Times 256
SATA features 257
Hardware Feature Control Reset Responses 258
EPC subcommands 260
POWER CONDITION ID field 260
Restore Power Condition Settings inputs 261
Go To Power Condition inputs 262
Set Power Condition Timer inputs 264
Set Power Condition State inputs 266

Enable the EPC feature set inputs 267
Disable the EPC feature set inputs 268
Set EPC Power Source inputs 269
DSN feature set subcommands 270
SET MULTIPLE MODE command inputs 272
SLEEP command inputs 273
FEATURE field values 274
SMART DISABLE OPERATIONS command inputs 275
SMART ENABLE/DISABLE ATTRIBUTE AUTOSAVE command inputs 276
SMART ENABLE OPERATIONS command inputs 278
SMART EXECUTE OFF-LINE IMMEDIATE Subcommands 279
SMART EXECUTE OFF-LINE IMMEDIATE command inputs 282
SMART READ DATA command inputs 283
Device SMART data structure 284
Off-line data collection status byte values 285
Self-test execution status values 286
Offline Data Collection Capabilities 286
SMART READ LOG command inputs 288
SMART RETURN STATUS command inputs 289
SMART WRITE LOG command inputs 290
STANDBY command inputs 291
STANDBY IMMEDIATE command inputs 292
TRUSTED NON-DATA command inputs 293
TRUSTED RECEIVE command inputs 296
TRUSTED RECEIVE SECURITY PROTOCOL field 296
Security Protocol 00h SP SPECIFIC field 297
TRUSTED RECEIVE parameter data for SP Specific=0000h 298
TRUSTED RECEIVE parameter data for SP Specific=0001h 299
TRUSTED RECEIVE parameter data for SP Specific=0002h 300
Compliance Descriptor Type 300
Compliance Descriptor Header 300
Security Requirements for Cryptographic Modules descriptor 301
TRUSTED RECEIVE DMA command inputs 302
TRUSTED SEND command inputs 303
TRUSTED SEND – SECURITY PROTOCOL field 304
TRUSTED SEND DMA command inputs 305
WRITE BUFFER command inputs 306
WRITE BUFFER DMA command inputs 307
WRITE DMA command inputs 308
WRITE DMA EXT command inputs 309
WRITE DMA FUA EXT command inputs 310
WRITE FPDMA QUEUED command inputs 311
WRITE LOG EXT command inputs 313
WRITE LOG DMA EXT command inputs 315
WRITE MULTIPLE command inputs 316
WRITE MULTIPLE EXT command inputs 317
WRITE MULTIPLE FUA EXT command inputs 319
WRITE SECTOR(S) command inputs 321
WRITE SECTOR(S) EXT command inputs 322
WRITE STREAM DMA EXT command inputs 323
WRITE STREAM EXT command inputs 326
WRITE UNCORRECTABLE EXT command inputs 328
Summary of SCT Command Transport logs 329
Summary of ATA commands used by the SCT Command Transport 329
Fields to send an SCT Command using SMART WRITE LOG 331
Fields to send an SCT Command using GPL write logs 332
Successful SCT Command response 333

SCT Command error response 334
EXTENDED STATUS CODE field 335
SCT data transfer using the SMART feature set 336
SCT data transfer using the GPL feature set 337
Successful SMART SCT data transfer response 338
Successful GPL SCT data transfer response 339
SMART SCT data transfer error response 340
GPL SCT data transfer error response 341
SCT status request using the SMART feature set 342
SCT status request using the GPL feature set 343
Successful SMART SCT status response 344
Successful GPL SCT status response 345
Format of SCT status response 346
SMART and GPL SCT status error response 347
SCT command basic key page structure 348
ACTION CODE field 348
SCT Write Same command key page 352
SCT Write Same command status response 353
SCT Error Recovery Control command 354
SCT Error Recovery Control command status response 355
SCT Feature Control command key page 356
Feature Code list 357
Options Flags for each Feature Code 358
SCT Feature Control command status response 359
SCT Data Table command 360
TABLE ID field 360
HDA Temperature History table 361
SCT Data Table command status response 363
Generic Normal Output (No LBA Return Value) for Normal Output 364
Download Microcode Normal Output 365
Check Power Mode Normal Output 366
Stream Normal Output 368
Device Signatures for Normal Output 369
IDLE Unload Normal Output 370
ATAPI Normal Output 371
SMART Off-Line Immediate Normal Output 372
SMART Return Status Normal Output 373
Generic Extended Normal Output 374
NCQ Command Acceptance Normal Output 375
NCQ Normal Output 376
REQUEST SENSE DATA EXT Normal Output 377
GET NATIVE MAX ADDRESS EXT Normal Output 378
Sanitize Device Normal Output 379
Unsupported Command Error 381
Check Power Mode Abort Error 382
Generic Abort wo/ICRC Error 383
Generic Abort Error 384
Trusted Abort Error 385
Configure Stream Error 386
Flush Cache Error 387
Flush Cache Ext Error 388
Read DMA Ext Error 389
Read Log Ext Error 390
Read PIO Error 391
Read Stream Error 392
Write Log Error 393
Write Log Ext Error or Data Set Management Error 394

SMART Error 395
Write Extended Error 396
Write Stream Error 397
NOP Error 398
PACKET command Error 399
SMART Read Log/SMART Read Data Error 400
Read PIO Extended Error 401
SET ACCESSIBLE MAX ADDRESS EXT Error 402
Write Error 403
Write DMA Error 404
NCQ Command Acceptance Error 405
NCQ Write Command Aborted Error 406
NCQ Read Command Aborted Error 407
Sanitize Device Error 408
Example Log Structure 409
Log address definition 410
General Purpose Log Directory 412
SMART Log Directory 412
Comprehensive SMART Error log 413
Defined Device Statistics log pages 414
Device Statistic format 415
DEVICE STATISTIC FLAGS field 415
List of supported Device Statistics log pages 417
Free Fall Statistics 418
General Statistics 419
General Error Statistics 424
Rotating Media Statistics 425
Solid State Device Statistics 430
Temperature Statistics 431
Transport Statistics 439
Extended Comprehensive SMART Error log 441
Extended Error log data structure 442
Command data structure 443
Error data structure 444
State field values 444
Idle Power Conditions log page 445
Standby Power Conditions log page 446
Power Conditions log descriptor 446
Extended Self-test log data structure 450
Extended Self-test log descriptor entry 451
Defined IDENTIFY DEVICE data pages 452
List of supported IDENTIFY DEVICE data pages 452
Capacity 453
Supported Capabilities 456
Nominal Media Rotation Rate 466
NOMINAL FORM FACTOR field 467
World wide name format (word-based view) 468
IDENTIFY DEVICE data WWN format (word-based view) 468
IDENTIFY DEVICE data WWN format (byte-based view) 469
Current Settings 469
POWER SOURCE field 473
Strings 477
Security 478
Short format ENHANCED SECURITY ERASE TIME field 481
Extended format ENHANCED SECURITY ERASE TIME field 481
Short format NORMAL SECURITY ERASE TIME field 482
Extended format NORMAL SECURITY ERASE TIME field 482

Parallel ATA 484
PATA device number detected coded values 492
Serial ATA 496
CURRENT NEGOTIATED SERIAL ATA SIGNAL SPEED field 501
Defined LBA Status log pages 503
Number of Valid LBA Ranges log page 503
LBA Status log page 504
LBA Status Descriptor 504
LPS Mis-alignment log (log page 0) 505
LPS Mis-alignment log (log pages 1..x) 506
NCQ Command Error log 507
Read Stream Error log 509
Stream Error Log Entry 510
SATA Phy Event Counters log Format 511
SATA NCQ Queue Management log (log page 00h) 512
SATA NCQ Send and Receive log (log page 00h) 514
Selective Self-Test log 515
FEATURE FLAGS field 516
Self-test log data structure 517
Self-test log descriptor entry 517
Summary SMART Error log 518
Error log data structure 519
Command data structure 520
Error data structure 520
State values 521
Write Stream Error log 522
Current Device Internal Status Data header (page 0) 523
Current Device Internal Status Data (pages 1..n) 525
Saved Device Internal Status Data header (page 0) 527
Saved Device Internal Status Data (pages 1..n) 528
Device Statistics Notifications pages 528
Summary Page of the Device Statistics Notifications log 529
DSN Match Entry 529
Definition pages of the Device Statistics Notifications log 530
DSN CONDITION FLAGS field 531
Command codes (sorted by command code) 532
Command codes (sorted by command name) 537
Historical Command Assignments 540
Historical SET FEATURE Code Assignments 549
SCT command using SMART WRITE LOG command 567
SCT command using WRITE LOG EXT command 568

ATA document relationships 18
State diagram convention 35
Byte, word, DWord, QWord, and DQWord relationships 37
LLS and LPS Example 52
Alignment 0 52
Alignment 1 52
Alignment 3 53
Power management state diagram 57
Sanitize Device state machine 64
Security state diagram 73
DOWNLOAD MICROCODE State Machine 110
Selective self-test span example 281
Example of a Device Internal Status log with data in all three data areas 525
Example of a Device Internal Status log with no data 526
Example of a Device Internal Status log with mixed data areas 526
Example flowchart for SCT commands 560
Example sequence for foreground write same with a repeating write pattern 561
Example sequence for foreground write same with a repeating pattern 561
Example sequence for writing data using an SCT command with no background activity 562
Example sequence for reading data using an SCT command with no background activity 562
Example sequence for a Non-Data SCT command with no background activity 563
Example sequence for writing data using an SCT command with background activity 564
Example sequence for writing data using multiple write data transfers 565
Example sequence for a Non-Data SCT command with background activity 566
System Dependency Chain 570
Mapping Proposals 571
Logical Sector to Physical Mapping 571
Uncorrectable Error Handling 573
Typical HDD Layout Using A Master Boot Record 574

INFORMATION TECHNOLOGY – AT ATTACHMENT –

Part 103: ATA/ATAPI Command Set - 3 (ACS-3)

FOREWORD

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International Standard ISO/IEC 17760-103 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 and ISO web sites.

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

The text of this document is based on the following documents:

FDIS	Report on voting
JTC1-SC25/3012/FDIS	JTC1-SC25/3021/RVD

Full information on the voting for the approval of this document can be found in the report on voting indicated in the above table.

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 document 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.
Annex A describes logs.
Annex B provides command summaries.
Annex C provides a tutorial on how to use SCT.
Annex D provides implementation guidelines for 1 024/4 096 byte sectors.

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

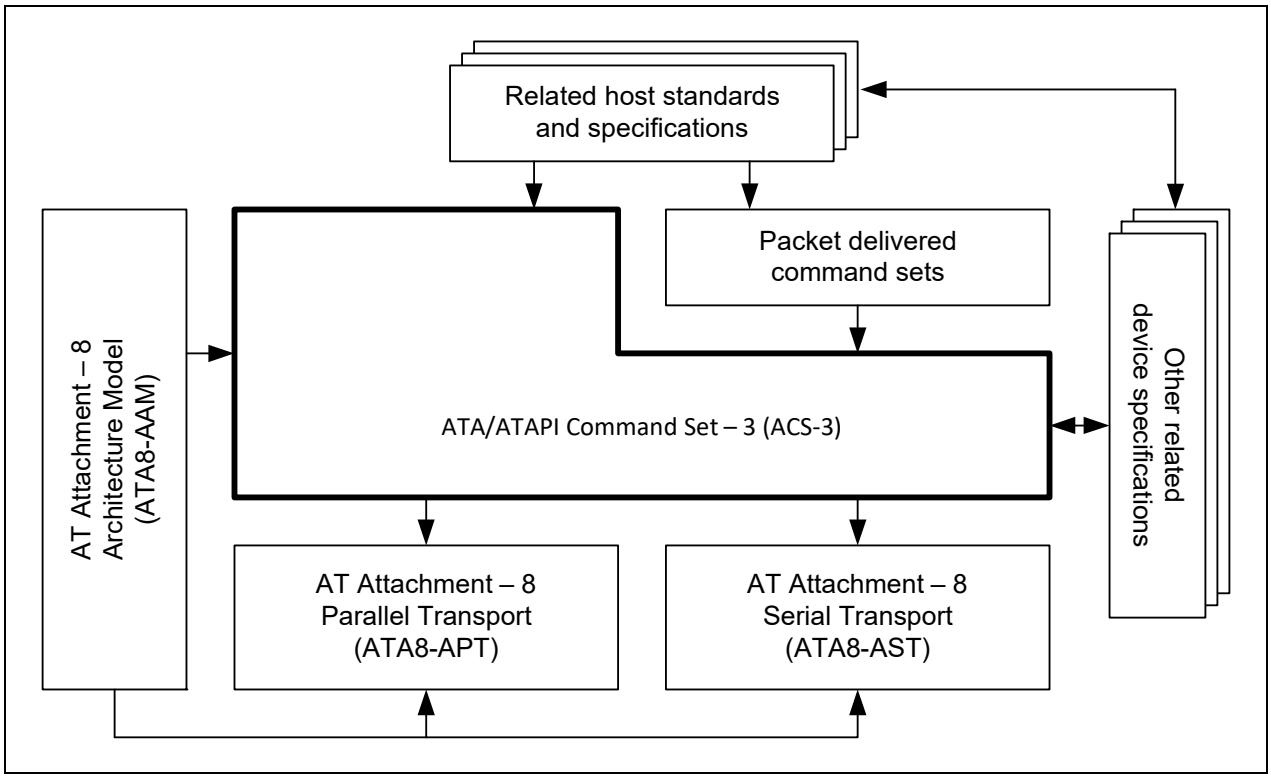


Figure 1 — ATA document relationships

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INFORMATION TECHNOLOGY – AT ATTACHMENT –

Part 103: ATA/ATAPI Command Set - 3 (ACS-3)

1 Scope

This part of ISO/IEC 17760 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 ACS-2 standard, ISO/IEC 17760-102, while providing additional functions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7779, *Acoustics – Measurement of airborne noise emitted by information technology and telecommunications equipment*

ISO/IEC 14776-454, *Information technology - Small computer system interface (SCSI) - Part 454: SCSI Primary Commands - 4 (SPC-4)*

ISO/IEC 17760-102, *Information technology – AT Attachment - Part 102: ATA/ATAPI Command Set - 2 (ACS-2)*

INCITS 451, *Information Technology - AT Attachment-8 ATA/ATAPI Architecture Model (ATA8-AAM)*

INCITS 493, *Information Technology - AT Attachment-8 - Serial Transport (ATA8-AST)*

INCITS 524, *Information Technology - AT Attachment 8 – ATA/ATAPI Parallel Transport (ATA8-APT)*

Serial ATA revision 3.1 (SATA 3.1) [2]

RFC 5280, Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile, IETF, 2008.[3]

RFC 5755, An Internet Attribute Certificate Profile for Authorization, IETF, 2010 [3]

IEEE 1667-2015 – Standard Protocol for Authentication in Host Attachments of Transient Storage Devices [4]

FIPS PUB 140-2 – Security Requirements for Cryptographic Modules, May 25, 2001 [5]

FIPS PUB 140-3 – Security Requirements for Cryptographic Modules, March 22, 2019 [5]

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1. INCITS 4-1986 (R2002), *Information Systems – Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII).*
2. Serial ATA specifications are available from the Serial ATA International Organization (see http://www.sata-io.org).
3. RFCs are available from the Internet Engineering Task Force (IETF) (see http://www.ietf.org/).
4. IEEE documents are available from the IEEE (see http://ieeexplore.ieee.org/).
5. FIPS standards are available from the National Institute of Standards and Technology (see http://csrc.nist.gov/publications/).

3 Terms, definitions, abbreviations, and conventions

3.1 Terms and definitions

3.1.1
28-bit command
command that uses the FEATURE field (7:0), COUNT field (7:0), LBA field (27:0), DEVICE field (15:8) and COMMAND field (7:0) to specify its arguments

3.1.2
48-bit command
command that uses the FEATURE field (15:0), COUNT field (15:0), LBA field (47:0), DEVICE field (15:8) and COMMAND field (7:0) to specify its arguments

3.1.3
accessible max address
maximum LBA that is accessible by read commands and write commands that return command completion without error

3.1.4
Active mode
power condition specified by the PM0: Active state (see 4.15.4)

3.1.5
additional sense code
combination of ADDITIONAL SENSE CODE field and ADDITIONAL SENSE CODE QUALIFIER field (see 7.35 and A.14)

3.1.6
administrator
person who is responsible for the administration of one or more devices (e.g., the establishment of passwords in the Security feature set (see 4.18))

3.1.7
application client
object in the host that is the source of commands and device management functions

Note 1 to entry: See ATA8-AAM.

3.1.8
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.

3.1.9
ATA device
AT Attachment device
device that implements the General feature set (see 4.2)

3.1.10
ATA string
set of ASCII characters (see 3.1.8) in the format specified in 3.3.10

3.1.11
ATAPI
AT Attachment Packet Interface device
device that implements the PACKET feature set (see 4.3)

3.1.12
background activity
activity initiated by a command that occurs after command completion has been reported

3.1.13
BIOS
application client, whose primary function is to initialize various components (e.g., storage devices), that is run when power is applied

3.1.14
byte
sequence of eight contiguous bits considered as a unit

Note 1 to entry: See 3.3.9.

3.1.15
cache
data storage area outside the area accessible by application clients that may contain a subset of the data stored in the non-volatile media

3.1.16
CFA-APT device
device that implements the CFA feature set

Note 1 to entry: CFA-APT devices implement the ATA8-APT transport, and not the ATA8-AST transport.

Note 2 to entry: See 4.7

3.1.17
circular buffer
buffer that is filled starting at the first byte continuing to the last byte and then wrapping to store data in the first byte of the buffer again

3.1.18
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

3.1.19
command acceptance
positive acknowledgement of a command being received by a device

3.1.20
command completion
completion by the device of processing in which the device:

a) completes the action requested by the command or terminates the command with an error; and
b) sets the appropriate bits in the ERROR field and the STATUS field

3.1.21
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.

3.1.22
COMRESET
commanded hardware reset in the Serial ATA transport

Note 1 to entry: See ATA8-AST.

3.1.23
device
data storage peripheral

EXAMPLE - A disk drive is an example of a device.

Note 1 to entry: See 3.1.9 and 3.1.11.

3.1.24
DMA
direct memory access data transfer
means of data transfer between device and host memory without application client intervention

3.1.25
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

3.1.26
DQWord
sequence of 16 contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.27
DWord
sequence of four contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.28
FIS
frame structure used by the Serial ATA transport

Note 1 to entry: See ATA8-AST.

3.1.29
flush command
command that flushes the volatile write cache

Note 1 to entry: The following commands are flush commands: the FLUSH CACHE (see 7.10) command and the FLUSH CACHE EXT (see 7.11) command.

3.1.30
free-fall
vendor specific condition of acceleration

3.1.31
hardware reset
routine performed by a device after a hardware reset event as defined in ATA8-AAM

3.1.32
host
object that originates commands and device management functions

Note 1 to entry: See ATA8-AAM.

3.1.33
host interface
service delivery subsystem

Note 1 to entry: See ATA8-AAM.

3.1.34
ID Not Found error
command completion with the ID NOT FOUND bit set to one

Note 1 to entry: See 6.3.5.

3.1.35
Idle mode
one or all of the power conditions associated with the PM1: Idle state (see 4.15.4)

3.1.36
Invalid LBA
LBA that is greater than or equal to the largest value reported in IDENTIFY DEVICE data words 60..61 (see 7.12.7.22), the ACCESSIBLE CAPACITY field (see A.11.4.2), or IDENTIFY DEVICE data words 230..233 (see 7.12.7.87)

3.1.37
LBA
value used to reference a logical sector

3.1.38
logical block
logical sector
set of words accessed and referenced as a unit (see IDENTIFY DEVICE data words 118..117 (see 7.12.7.61)) that contain user data and are referenced by LBA (see 3.1.37)

3.1.39
log
named sequence of one or more log pages

Note 1 to entry: See Annex A.

3.1.40
log address
numeric value that a log command uses to identify a specific log

3.1.41
log command
SMART READ LOG command (see 7.48.7), SMART WRITE LOG command (see 7.48.9), or GPL feature set (see 4.11) command

3.1.42
log page
512-byte block of data associated with a log

Note 1 to entry: See Annex A.

3.1.43
least significant bit
LSB
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.

3.1.44
media
material on which user data is stored

3.1.45
media access command
command that causes the device to access non-volatile media

3.1.46
most significant bit
MSB
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.

3.1.47
native max address
LBA that a device reports by GET NATIVE MAX ADDRESS EXT command (see 7.2.2) and the maximum LBA accepted by a device using the SET ACCESSIBLE MAX ADDRESS EXT command (see 7.2.3)

3.1.48
NCQ command
command in the NCQ feature set

Note 1 to entry: See 4.14.

3.1.49
non-volatile media
physical storage media that retains user data written to it through all reset events (e.g., power-on reset)

3.1.50
Organizationally Unique Identifier
OUI
numeric identifier that is assigned by the IEEE such that no assigned identifiers are identical

Note 1 to entry: The IEEE maintains a tutorial describing the OUI at https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/tutorials/eui.pdf.

3.1.51
partition
range of LBAs specified by an application client

3.1.52
PATA device
Parallel ATA device
device that implements the parallel ATA transport

Note 1 to entry: See ATA8-APT.

3.1.53
physical sector
one or more contiguous logical sectors that are read from or written to the device media in a single operation

3.1.54
PIO
data transfers performed using PIO commands and protocol

3.1.55
power condition
PM0: Active state (see 4.15.4), PM3: Sleep state (see 4.15.4), or one of the following power management substates: Idle_a, Idle_b, Idle_c, Standby_y or Standby_z

Note 1 to entry: See 4.9.

3.1.56
power cycle
period of time from when power is removed from a host or device until the subsequent power-on event

Note 1 to entry: See ATA8-AAM.

3.1.57
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.

3.1.58
queued command
NCQ command that has reported command acceptance but not command completion

3.1.59
QWord
sequence of eight contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.60
read command
command that causes the device to transfer user data from the device to the host

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

3.1.61
read stream command
command that causes the device to transfer user data from the device to the host

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

3.1.62
SATA device
Serial ATA device
device implementing the serial ATA transport

Note 1 to entry: See ATA8-AST.

3.1.63
SCSI CDB
structure used to communicate a SCSI command

Note 1 to entry: See SPC-4.

3.1.64
SCT Command
command that writes to the SCT command/status log

Note 1 to entry: See clause 8.

3.1.65
SCT Status
command that reads from the SCT command/status log

Note 1 to entry: See clause 8.

3.1.66
SEND FPDMA QUEUED
SFQ
prefix that identifies a subcommand of the SEND FPDMA QUEUED command (see 7.43)

3.1.67
sense data
sense key and additional sense code (see 3.1.5)

3.1.68
Serial ATAPI device
device that implements the Serial ATA transport (see ATA8-AST) and the PACKET feature set

3.1.69
signature
unique set of values placed in the return parameters used to distinguish device types (e.g., ATA device, ATAPI device)

Note 1 to entry: See table 204.

3.1.70
signed
value that is encoded using two’s complement

3.1.71
Sleep mode
power condition specified by the PM3: Sleep state

Note 1 to entry: See 4.15.4.

3.1.72
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.

3.1.73
spin-down
process of bringing a rotating media device’s media to a stop

3.1.74
spin-up
process of bringing a rotating media device’s media to operational speed

3.1.75
Standby mode
one or all of the power conditions associated with the PM2: Standby state

Note 1 to entry: See 4.15.4.

3.1.76
stream
set of operating parameters specified by a host using the CONFIGURE STREAM command (see 7.4) to be used for subsequent read stream commands and write stream commands

3.1.77
transport
mechanism used to communicate with a device

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

3.1.78
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

3.1.79
unrecoverable error
error that causes the device to set either the ERROR bit or the DEVICE FAULT bit to one in the STATUS field at command completion

3.1.80
user data
data that is transferred between the application client and the device using read commands and write commands

3.1.81
user data area
area of the media that is addressable from LBA 0 to the native max address if the Accessible Max Address Configuration feature set is supported or LBA 0 to the maximum value defined in table 5 if the Accessible Max Address Configuration feature set is not supported

3.1.82
volatile cache
cache that does not retain data through power cycles

3.1.83
word
sequence of two contiguous bytes considered as a unit

Note 1 to entry: See 3.3.9.

3.1.84
write command
command that causes the device to transfer user data from the host to the device

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

3.1.85
write stream command
command that causes the device to transfer user data from the host to the device

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

3.1.86
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 7.12.7.58) and IDENTIFY PACKET DEVICE data words 108..111 (see 7.13.6.44)

3.2 Symbols and abbreviations

3.2.1 Abbreviations

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	AT Attachment with Packet Interface Extension
ATA8-AAM	AT Attachment - 8 - ATA/ATAPI Architecture Model (see clause 2)
ATA8-ACS	AT Attachment - 8 - ATA/ATAPI Command Set (see clause 2)
ATA8-APT	AT Attachment - 8 - Parallel Transport (see clause 2)
ATA8-AST	AT Attachment - 8 - Serial Transport (see clause 2)
BIOS	Basic Input/Output System
CCTL	Command Completion Time Limit (see 7.4.3.4 and 7.30.3.2)
CDB	Command Descriptor Block (see SPC-4)
CFA	CompactFlash™ Association (see www.compactflash.org)
CFA-CF	CompactFlash specification (see bibliography)
CFast™	CompactFlash ATA Serial Transport (see bibliography)
CRC	Cyclic Redundancy Check
DMA	Direct Memory Access
DRQ	Data ReQuest
DSN	Device Statistics Notification
EPC	Extended Power Conditions
EXT	Command that uses the extended (48-bit LBA) format parameters
FIS	Frame Information Structure
FUA	Forced Unit Access
GPL	General Purpose Logging
IEC	International Electrotechnical Commission (see www.iec.ch)
INCITS	InterNational Committee for Information Technology Standards (see www.incits.org)
ISO	International Organization for Standardization (see www.iso.org)
LBA	Logical Block Address
LLS	Long Logical Sector
LPS	Long Physical Sector
LSB	Least Significant Bit
MSB	Most Significant Bit
NCQ	Native Command Queueing
OUI	Organizationally Unique Identifier
PATA	Parallel ATA
PIO	Programmed Input/Output
PUIS	Power-Up In Standby
RMW	Read-Modify-Write

Abbreviation	Meaning
SATA	Serial ATA
SATA-IO	Serial ATA International Organization (see www.sata-io.org)
SCT	SMART Command Transport (see clause 8)
SFQ	SEND FPDMA QUEUED
SMART	Self-Monitoring Analysis and Reporting Technology
SPC-4	SCSI Primary Commands - 4 (see clause 2)
SSP	Software Settings Preservation
T10	INCITS Technical Committee T10
TCG	Trusted Computing Group (see www.trustedcomputinggroup.org)
VS	Vendor Specific
WWN	World Wide Name

3.2.2 Units:

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 Mathematical operators:

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

3.2.4 Other Symbols

Symbol	Meaning
®	registered trademark

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).

Names of fields are in small uppercase (e.g., DRAT SUPPORTED). Normal case is used when the contents of a field are being discussed. Fields containing only one bit are usually referred to as the NAME bit instead of the NAME field.

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

Each item in a list ends with a semicolon, except the last item, which ends in a period. The next to the last entry in the list ends 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:

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 a 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:

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

Note 1 to entry: A field defined as N/A 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, then 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.

Note 3 to entry: The recipient shall not check reserved bits, bytes, words, or fields.

Note 4 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: This keyword is equivalent to the phrase “it is recommended”.

3.3.4.12
vendor specific
keyword indicating that specification of the referenced item (e.g., a bit, byte, field, code value) is determined by the device vendor

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

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

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 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 is greater than m, denotes a set of bits (e.g., Feature (7:0)). n:m where n is 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.

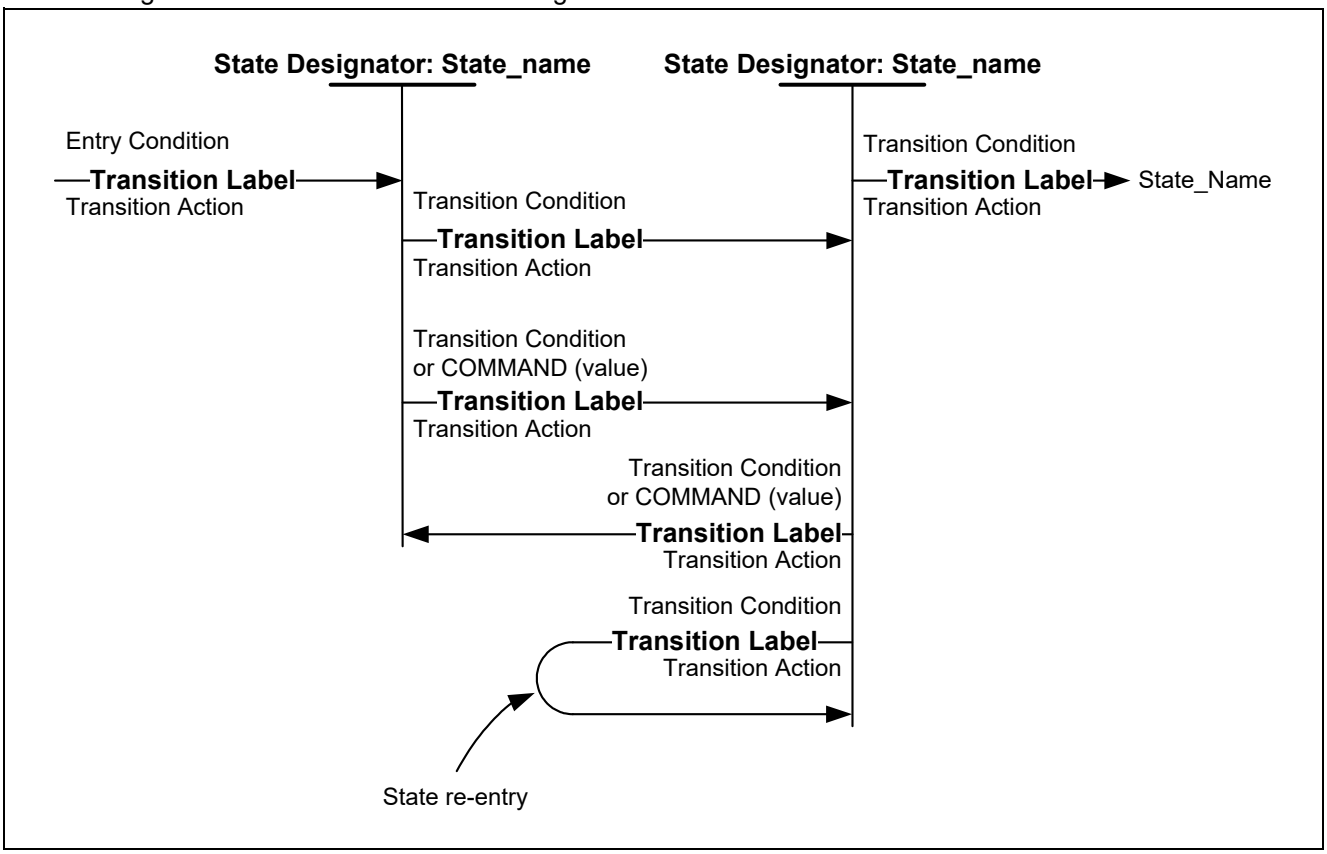


Figure 2 — State diagram convention

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. For example:

a) CRYPTO SCRAMBLE EXT (failure exit allowed) means the device processes a CRYPTO SCRAMBLE EXT command with the FAILURE MODE bit set to one; or
b) CRYPTO SCRAMBLE EXT (hard failure required) means the device processes CRYPTO SCRAMBLE EXT command with the FAILURE MODE bit cleared to zero.

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, QWord, and DQWord Relationships

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

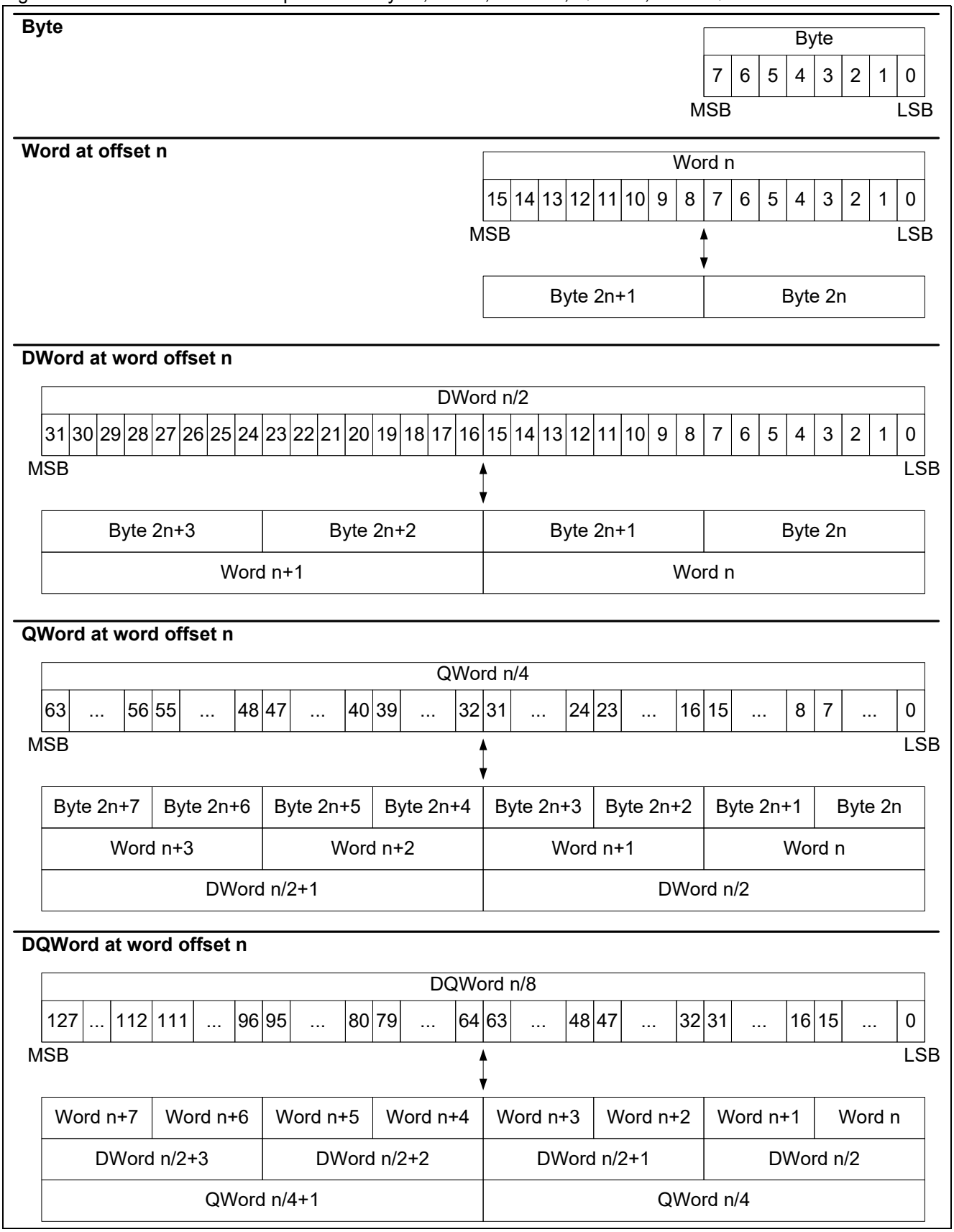


Figure 3 — Byte, word, DWord, QWord, and DQWord relationships

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. For example:

EXAMPLE 1 - if the two-byte field (i.e., word) in SCT command (see table 186) 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 43) 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 188) 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 7.12.7.58;
c) the command packet in the PACKET command (see 7.18) is formatted as defined by the applicable command standard); and
d) parameter data in the TRUSTED RECEIVE command (see 7.52), TRUSTED RECEIVE DMA command (see 7.53), TRUSTED SEND command (see 7.54), and TRUSTED SEND DMA command (see 7.55) is formatted as defined in those sections or in the standard defining the security protocol.

3.3.10 ATA string convention

ATA strings (e.g., the MODEL NUMBER field (see A.11.7.4)) 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.

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

Using the ATA string that contains firmware revision information as an example, table 3 shows the contents of the FIRMWARE REVISION field (see A.11.7.3) in the Strings page (see A.11.7) in IDENTIFY DEVICE data log (see A.11). In this example, the firmware revision string is “abcdefg ”, including one padding space character at the end of the string. Table 3 also shows the copy of the FIRMWARE REVISION field that uses the word format of the IDENTIFY DEVICE input from device to host data structure (see 7.12.7).

Table 3 — FIRMWARE REVISION field example

Strings page [a] offset	Value	Copy of FIRMWARE REVISION field in IDENTIFY DEVICE data [b]		
		Offset	Word	Value
32	62h (i.e., “b”)	46	23	6162h (i.e., “ba”)
33	61h (i.e., “a”)	47		
34	64h (i.e., “d”)	48	24	6364h (i.e., “dc”)
35	63h (i.e., “c”)	49		
36	66h (i.e., “f”)	50	25	6566h (i.e., “fe”)
37	65h (i.e., “e”)	51		
38	20h (i.e., “ “, the space character)	52	26	6720h (i.e., “ g”)
39	67h (i.e., “g”)	53		

[a] See Strings page (see A.11.7) in IDENTIFY DEVICE data log (see A.11).
[b] See table 43.

3.3.11 Offset Convention

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