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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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CONTENTS

FOREWORD ... 14
INTRODUCTION ... 16

1 Scope ... 18

2 Normative references ... 18

3 Terms, definitions, symbols, abbreviations, keywords, and conventions ... 20
3.1 Terms and definitions ... 20
3.2 Symbols and abbreviations ... 33
3.2.1 Abbreviations ... 33
3.2.2 Symbols ... 36
3.2.2.1 Units ... 36
3.2.2.2 Mathematical operators ... 36
3.2.2.3 Other symbols ... 37
3.3 Keywords ... 38
3.4 Editorial conventions ... 39
3.5 Numeric and character conventions ... 40
3.5.1 Numeric conventions ... 40
3.5.2 Units of measure ... 40
3.5.3 Byte encoded character strings conventions ... 41

4 General ... 42
4.1 Physical links and phys ... 42
4.2 Phy test functions ... 42

5 Physical layer ... 43
5.1 Physical layer overview ... 43
5.2 Conventions for defining maximum limits for S-parameters ... 43
5.3 Compliance points ... 44
5.3.1 Compliance points overview ... 44
5.3.2 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s compliance points ... 45
5.3.3 12 Gbit/s compliance points ... 53
5.4 Interconnects ... 55
5.4.1 SATA connectors and cable assemblies ... 55
5.4.2 SAS connectors and cables ... 56
5.4.3 Connectors ... 60
5.4.3.1 Connectors overview ... 60
5.4.3.2 Connector categories ... 62
5.4.3.3 Recommended electrical performance limits for mated connector pairs supporting rates of 12 Gbit/s ... 63
5.4.3.4 SAS internal connectors ... 64
5.4.3.4.1 SAS Drive connectors ... 64
5.4.3.4.1.1 SAS Drive plug connector ... 64
5.4.3.4.1.2 SAS Drive cable receptacle connector ... 65
5.4.3.4.1.3 SAS Drive backplane receptacle connector ... 66
5.4.3.4.1.4 SAS Drive connector pin assignments ... 67
5.4.3.4.1.5 SAS MultiLink Drive plug connector ... 69
5.4.3.4.1.6 SAS MultiLink Drive cable receptacle connector ... 69
5.4.3.4.1.7 SAS MultiLink Drive backplane receptacle connector ... 70
5.4.3.4.1.8 SAS MultiLink Drive connector pin assignments ... 70
5.4.3.4.1.9 Micro SAS plug connector ... 74
5.4.3.4.1.10 Micro SAS receptacle connector ... 74
5.4.3.4.1.11 Micro SAS connector pin assignments ... 75
5.4.3.4.2 SAS 4i connectors ... 76
5.4.3.4.2.1 SAS 4i cable receptacle connector ... 76

5.4.3.4.2.2 SAS 4i plug connector 76
5.4.3.4.2.3 SAS 4i connector pin assignments 77
5.4.3.4.3 Mini SAS 4i connectors 79
5.4.3.4.3.1 Mini SAS 4i cable plug connector 79
5.4.3.4.3.2 Mini SAS 4i receptacle connector 79
5.4.3.4.3.3 Mini SAS 4i connector pin assignments 80
5.4.3.4.4 Mini SAS HD internal connectors 82
5.4.3.4.4.1 Mini SAS HD 4i cable plug connector 82
5.4.3.4.4.2 Mini SAS HD 8i cable plug connector 83
5.4.3.4.4.3 Mini SAS HD 4i receptacle connector 84
5.4.3.4.4.4 Mini SAS HD 8i receptacle connector 85
5.4.3.4.4.5 Mini SAS HD 16i receptacle connector 86
5.4.3.4.4.6 Mini SAS HD 4i connector pin assignments 87
5.4.3.5 SAS external connectors 90
5.4.3.5.1 Mini SAS 4x connectors 90
5.4.3.5.1.1 Mini SAS 4x cable plug connector 90
5.4.3.5.1.2 Mini SAS 4x receptacle connector 97
5.4.3.5.1.3 Mini SAS 4x connector pin assignments 103
5.4.3.5.1.4 Mini SAS 4x active connector pin assignments 104
5.4.3.5.1.5 Mini SAS 4x active cable power requirements 105
5.4.3.5.2 Mini SAS HD external connectors 106
5.4.3.5.2.1 Mini SAS HD 4x cable plug connector 106
5.4.3.5.2.2 Mini SAS HD 8x cable plug connector 107
5.4.3.5.2.3 Mini SAS HD 4x receptacle connector 108
5.4.3.5.2.4 Mini SAS HD 8x receptacle connector 109
5.4.3.5.2.5 Mini SAS HD 16x receptacle connector 110
5.4.3.5.2.6 Mini SAS HD 4x connector pin assignments 111
5.4.3.5.2.7 Mini SAS HD external connector management interface 112
5.4.3.5.2.8 Mini SAS HD external connector memory map 113
5.4.3.5.3 QSFP+ connectors 113
5.4.3.5.3.1 QSFP+ cable plug 113
5.4.3.5.3.2 QSFP+ receptacle 114
5.4.3.5.3.3 QSFP+ connector pin assignments 115
5.4.3.5.3.4 QSFP+ memory map 116
5.4.4 Cable assemblies 117
5.4.4.1 SAS internal cable assemblies 117
5.4.4.1.1 SAS Drive cable assemblies 117
5.4.4.1.2 SAS internal symmetric cable assemblies 119
5.4.4.1.2.1 SAS internal symmetric cable assemblies overview 119
5.4.4.1.2.2 SAS internal symmetric cable assembly - SAS 4i 120
5.4.4.1.2.3 SAS internal symmetric cable assembly - Mini SAS 4i 121
5.4.4.1.2.4 SAS internal symmetric cable assembly - Mini SAS HD 4i 122
5.4.4.1.2.5 SAS internal symmetric cable assembly - Mini SAS HD 8i 123
5.4.4.1.2.6 SAS internal symmetric cable assembly - SAS 4i to Mini SAS 4i with vendor-specific sidebands 124
5.4.4.1.2.7 SAS internal symmetric cable assembly - SAS 4i controller to Mini SAS 4i backplane with SGPIO 125
5.4.4.1.2.8 SAS internal symmetric cable assembly - Mini SAS 4i controller to SAS 4i backplane with SGPIO 126
5.4.4.1.2.9 SAS internal symmetric cable assembly - Mini SAS 4i to Mini SAS HD 4i 127
5.4.4.1.3 SAS internal fanout cable assemblies 128
5.4.4.1.3.1 SAS internal fanout cable assemblies overview 128
5.4.4.1.3.2 SAS internal controller-based fanout cable assemblies 129
5.4.4.1.3.3 SAS internal backplane-based fanout cable assemblies 132
5.4.4.2 SAS external cable assemblies 135
5.4.4.2.1 SAS external cable assemblies overview 135
5.4.4.2.2 SAS external cable assembly - Mini SAS 4x 136
5.4.4.2.3 SAS external cable assembly - Mini SAS HD 4x 139

5.4.4.2.4 SAS external cable assembly - Mini SAS HD 8x 141
5.4.4.2.5 SAS external cable assembly - Mini SAS HD 8x to Mini SAS HD 4x 143
5.4.4.2.6 SAS external cable assembly - Mini SAS HD 4x to Mini SAS 4x 145
5.4.4.2.7 SAS external cable assembly - QSFP+ 146
5.4.5 Backplanes 146
5.5 TxRx connection characteristics 147
5.5.1 TxRx connection characteristics overview 147
5.5.2 TxRx connection general characteristics 148
5.5.3 Passive TxRx connection S-parameter limits 149
5.5.4 Passive TxRx connection characteristics for untrained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 151
5.5.5 Passive TxRx connection characteristics for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 152
5.5.6 Passive TxRx connection characteristics for trained 12 Gbit/s 153
5.5.7 TxRx connection characteristics for active cable assemblies 157
5.5.7.1 Active cable assembly electrical characteristics for trained 6 Gbit/s overview 157
5.5.7.2 Active cable assembly output electrical characteristics for trained 6 Gbit/s 157
5.5.7.3 Active cable assembly S-parameter limits for trained 6 Gbit/s and trained 12 Gbit/s 158
5.5.7.4 Active cable assembly electrical characteristics overview for 12 Gbit/s 159
5.5.7.5 Active cable assembly electrical characteristics for 12 Gbit/s 160
5.6 Test loads 161
5.6.1 Test loads overview 161
5.6.2 Zero-length test load 162
5.6.3 TCTF test load 163
5.6.4 Low-loss TCTF test load 168
5.6.5 Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter test load 169
5.7 End to end simulation for trained 12 Gbit/s 173
5.7.1 End to end simulation for trained 12 Gbit/s overview 173
5.7.2 Usage models for end to end simulation for trained 12 Gbit/s 174
5.7.3 Reference transmitter equalization for trained 12 Gbit/s 175
5.7.4 Crosstalk measurement for end to end simulations and 12 Gbit/s jitter tolerance 177
5.8 Transmitter device and receiver device electrical characteristics 178
5.8.1 General electrical characteristics 178
5.8.2 Transmitter device and receiver device transients 179
5.8.3 Eye masks and the JTF 180
5.8.3.1 Eye masks overview 180
5.8.3.2 JTF 180
5.8.3.3 Transmitter device eye mask for untrained 1.5 Gbit/s and 3 Gbit/s 181
5.8.3.4 Receiver device eye mask for untrained 1.5 Gbit/s and 3 Gbit/s 182
5.8.3.5 Receiver device jitter tolerance eye mask for untrained 1.5 Gbit/s and 3 Gbit/s 182
5.8.4 Transmitter device characteristics 184
5.8.4.1 Transmitter device characteristics overview 184
5.8.4.2 Transmitter device coupling requirements 184
5.8.4.3 Transmitter device general electrical characteristics 184
5.8.4.4 Transmitter device signal output characteristics for untrained 1.5 Gbit/s and 3 Gbit/s as measured with the zero-length test load 186
5.8.4.5 Transmitter device signal output characteristics for untrained 1.5 Gbit/s and 3 Gbit/s as measured with each test load 187
5.8.4.6 Transmitter device signal output characteristics for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 189
5.8.4.6.1 Transmitter device signal output characteristics for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s overview 189
5.8.4.6.2 Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s transmitter device test procedure 190
5.8.4.6.3 Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s Transmitter device S-parameter limits 191
5.8.4.6.4 Recommended trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s transmitter device settings for interoperability 192
5.8.4.6.5 Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter device characteristics 193
5.8.4.6.6 Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s Transmitter equalization, VMA, and V_{P-P} measurement 194
5.8.4.7 Transmitter device signal output characteristics for trained 12 Gbit/s 196
5.8.4.7.1 Transmitter device signal output characteristics for trained 12 Gbit/s overview 196

5.8.4.7.2 12 Gbit/s Transmitter device S-parameter limits 203
5.8.4.7.3 12 Gbit/s reference transmitter device 205
5.8.4.7.4 Transmitter device end to end simulation characteristics for trained 12 Gbit/s 207
5.8.4.7.5 Transmitter device signal output characteristics at CTS for 12 Gbit/s when an active cable is connected 208
5.8.4.8 Transmitter device signal output characteristics for OOB signals 208
5.8.5 Receiver device characteristics 210
5.8.5.1 Receiver device characteristics overview 210
5.8.5.2 Receiver device coupling requirements 210
5.8.5.3 Receiver device general electrical characteristics 211
5.8.5.4 Delivered signal characteristics for untrained 1.5 Gbit/s and 3 Gbit/s 213
5.8.5.5 Maximum delivered jitter for untrained 1.5 Gbit/s and 3 Gbit/s 214
5.8.5.6 Receiver device jitter tolerance for untrained 1.5 Gbit/s and 3 Gbit/s 215
5.8.5.7 Receiver device and delivered signal characteristics for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s 216
5.8.5.7.1 Delivered signal characteristics for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s 216
5.8.5.7.2 Receiver device S-parameter limits 216
5.8.5.7.3 Reference receiver device characteristics 218
5.8.5.7.3.1 Reference receiver device overview 218
5.8.5.7.3.2 Reference receiver device DFE 219
5.8.5.7.3.3 Reference receiver device equalization for trained 12 Gbit/s 219
5.8.5.7.4 Reference receiver device termination characteristics for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 220
5.8.5.7.5 Reference receiver device termination characteristics for trained 12 Gbit/s 220
5.8.5.7.6 Stressed receiver device jitter tolerance test 221
5.8.5.7.6.1 Stressed receiver device jitter tolerance test overview for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 221
5.8.5.7.6.2 Stressed receiver device jitter tolerance test procedure for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 223
5.8.5.7.6.3 Test equipment calibration and ISI generator calibration for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 224
5.8.5.7.6.4 Crosstalk source calibration for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 224
5.8.5.7.6.5 Stressed receiver device jitter tolerance test procedure for trained 12 Gbit/s 225
5.8.5.7.6.6 ISI generator calibration for trained 12 Gbit/s 225
5.8.5.7.6.7 Crosstalk calibration for the trained 12 Gbit/s stressed receiver device jitter tolerance test 228
5.8.5.7.6.8 Applied RJ for trained 12 Gbit/s stressed receiver device jitter tolerance test 228
5.8.5.7.6.9 Applied SJ 228
5.8.5.8 Delivered signal characteristics for OOB signals 230
5.8.6 Spread spectrum clocking (SSC) 230
5.8.6.1 SSC overview 230
5.8.6.2 Transmitter SSC modulation 231
5.8.6.3 Receiver SSC modulation tolerance 232
5.8.6.4 Expander device center-spreading tolerance buffer 233
5.8.7 Non-tracking clock architecture 234
5.9 READY LED signal electrical characteristics 234
5.10 POWER DISABLE signal electrical characteristics 235
5.11 Out of band (OOB) signals 237
5.11.1 OOB signals overview 237
5.11.2 Transmitting OOB signals 238
5.11.3 Receiving OOB signals 240
5.11.4 Transmitting the SATA port selection signal 241

Annex A (normative) Jitter tolerance pattern (JTPAT) 242

Annex B (normative) SASWDP 244
B.1 SASWDP introduction 244
B.2 SASWDP.m 244

B.3 SASWDP_testcase.m 251

Annex C (informative) StatEye 253
C.1 StatEye introduction 253
C.2 analysis.py 253
C.3 cdr.py 254
C.4 extractJitter.py 255
C.5 penrose.py 257
C.6 portalocker.py 259
C.7 stateye.py 262
C.8 touchstone.py 277
C.9 testcase.py 285
C.10 testall.py 290
C.11 File StatEye_readme.pdf 293
C.11.1 How to install and run the SAS-2.1 StatEye 293

Annex D (normative) End to end simulation for trained 12 Gbit/s 294
D.1 Detailed end to end simulation procedure description for trained 12 Gbit/s 294
D.2 Trained 12 Gbit/s usage models, S-parameter files, and crosstalk amplitude 296
D.2.1 Transmitter device connected to a separable passive TxRx connection segment 296
D.2.2 Transmitter device connected to a non-separable passive TxRx connection segment 298
D.2.3 TxRx connection segment 301
D.2.4 Stressed Receiver device delivered signal calibration end to end simulation diagram 302

Annex E (informative) 12 Gbit/s S-parameters and end to end simulation 304
E.1 S-parameters for 12 Gbit/s simulation 304
E.1.1 Measurement procedure 304
E.1.2 Multiple channel segments 305
E.2 End to end simulation using SAS3_EYEOPENING 306

Annex F (informative) Signal performance measurements 307
F.1 Signal performance measurements overview 307
F.2 Glossary 307
F.3 Simple physical link 307
F.3.1 Simple physical link overview 307
F.3.2 Assumptions for the structure of the transmitter device and the receiver device 308
F.3.3 Definition of receiver sensitivity and receiver device sensitivity 309
F.4 Signal measurement architecture 310
F.4.1 General 310
F.4.2 Relationship between signal compliance measurements at interoperability points and operation in systems 310
F.5 De-embedding connectors in test fixtures 311
F.6 De-embedding test fixture for 12 Gbit/s transmitter compliance 311
F.7 Measurement conditions for signal output at the transmitter device 312
F.8 Measurement conditions for signal tolerance at the transmitter device 313
F.9 Measurement conditions for signal output at the receiver device 315
F.10 Measurement conditions for signal tolerance at the receiver device 315
F.11 S-parameter measurements 316
F.11.1 S-parameter overview 316
F.11.2 S-parameter naming conventions 316
F.11.3 Use of single ended instrumentation in differential applications 317
F.11.4 Measurement configurations for physical link elements 319
F.11.4.1 Measurement configuration overview 319
F.11.4.2 Transmitter device S_{22} measurements 319
F.11.4.3 Receiver device S_{11} measurements 320
F.11.4.4 TxRx connection S_{11} measurements at IT or CT 320
F.11.4.5 TxRx connection S_{22} measurements at IR or CR 321
F.12 Calibration of JMDs 322

F.12.1 Calibration of JMDs overview 322
F.12.1.1 Purpose of JMD calibration 322
F.12.1.2 Overview of low frequency calibration for SSC configurations 322
F.12.1.3 Overview of low frequency calibration for non-SSC configurations 324
F.12.1.4 High frequency calibration 324
F.12.2 JMD calibration procedure 325
F.12.2.1 General characteristics and equipment 325
F.12.2.2 Calibration of the JMD for testing SSC configurations 326
F.12.2.3 Calibration of the JMD for testing non-SSC configurations 327

Annex G (informative) Description of the included Touchstone models for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 329
G.1 Description of included Touchstone models for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s overview 329
G.2 Reference transmitter device termination model for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 329
G.3 Reference receiver device termination model for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 330
G.4 Generic return loss circuit model for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 331
G.5 Reference transmitter test load for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 332

Annex H (informative) Mini SAS 4x active cable assembly power supply and voltage detection circuitry 335

Annex I (informative) SAS icons 336

Annex J (informative) Standards bodies contact information 338
Bibliography 339

Figure 1 – SCSI document relationships 16
Figure 2 – ATA document relationships 17
Figure 3 – Physical links and phys 42
Figure 4 – Maximum limits for S-parameters definitions 44
Figure 5 – 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s External cable assembly CT compliance points and CR compliance points 46
Figure 6 – Backplane with SAS Drive connector 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s IT compliance points and IR compliance points 47
Figure 7 – Backplane with SAS Drive connector 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s compliance points with SATA phy attached 48
Figure 8 – SAS multilane internal cable assembly 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s IT compliance points and IR compliance points 49
Figure 9 – SAS multilane internal cable assembly and backplane 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s IT compliance points and IR compliance points 50
Figure 10 – SAS multilane internal cable assembly and backplane 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s IT compliance points and IR compliance points with SATA device attached 51
Figure 11 – SAS Drive cable assembly 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s IT compliance points and IR compliance points 52
Figure 12 – 12 Gbit/s TxRx connection and compliance points 53
Figure 13 – Simulated 12 Gbit/s TxRx connection and compliance points 53
Figure 14 – 12 Gbit/s CTS and CR compliance points 54
Figure 15 – SATA connectors and cables 55
Figure 16 – SAS Drive cable environments 56
Figure 17 – SAS Drive backplane environment 57
Figure 18 – SAS external cable environment 57
Figure 19 – SAS internal symmetric cable environment - controller to backplane 58
Figure 20 – SAS internal symmetric cable environment - controller to controller 58
Figure 21 – SAS internal controller-based fanout cable environment 59
Figure 22 – SAS internal backplane-based fanout cable environment 59
Figure 23 – Recommended $|S_{DD21}|$, $|S_{CC22}|$, $|S_{DD22}|$, NEXT, and FEXT limits for connector mated pairs supporting rates of 12 Gbit/s 64
Figure 24 – SAS Drive plug connector 65
Figure 25 – Single-port SAS Drive cable receptacle connector 65
Figure 26 – Dual-port SAS Drive cable receptacle connector 66
Figure 27 – SAS Drive backplane receptacle connector 66
Figure 28 – SAS MultLink Drive plug connector 69
Figure 29 – SAS MultiLink Drive cable receptacle connector 69
Figure 30 – SAS MultiLink Drive backplane receptacle connector 70
Figure 31 – Micro SAS plug connector 74
Figure 32 – Micro SAS receptacle connector 74
Figure 33 – SAS 4i cable receptacle connector 76
Figure 34 – SAS 4i plug connector 76
Figure 35 – Mini SAS 4i cable plug connector 79
Figure 36 – Mini SAS 4i receptacle connector 79
Figure 37 – Mini SAS HD 4i cable plug connector 82
Figure 38 – Mini SAS HD 8i cable plug connector 83
Figure 39 – Mini SAS HD 4i receptacle connector 84
Figure 40 – Mini SAS HD 8i receptacle connector 85
Figure 41 – Mini SAS HD 16i receptacle connector 86
Figure 42 – Mini SAS 4x cable plug connector 90
Figure 43 – Mini SAS 4x cable plug connector for untrained 1.5 Gbit/s and 3 Gbit/s that attaches to an enclosure out port or an enclosure in port 92
Figure 44 – Mini SAS 4x cable plug connector for untrained 1.5 Gbit/s and 3 Gbit/s that attaches to an enclosure out port 92
Figure 45 – Mini SAS 4x cable plug connector for untrained 1.5 Gbit/s and 3 Gbit/s that attaches to an enclosure in port 93
Figure 46 – Mini SAS 4x cable plug connector for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s that attaches to an enclosure out port or an enclosure in port 93

Figure 47 – Mini SAS 4x cable plug connector for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s that attaches to an enclosure out port 94
Figure 48 – Mini SAS 4x cable plug connector for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s that attaches to an enclosure in port 94
Figure 49 – Mini SAS 4x active cable plug connector for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s that attaches to an enclosure out port or an enclosure in port 95
Figure 50 – Mini SAS 4x active cable plug connector for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s that attaches to an enclosure out port 95
Figure 51 – Mini SAS 4x active cable plug connector for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s that attaches to an enclosure in port 96
Figure 52 – Mini SAS 4x receptacle connector 97
Figure 53 – Mini SAS 4x receptacle connector - end device or enclosure universal port for untrained 1.5 Gbit/s and 3 Gbit/s 98
Figure 54 – Mini SAS 4x receptacle connector - enclosure out port for untrained 1.5 Gbit/s and 3 Gbit/s 99
Figure 55 – Mini SAS 4x receptacle connector - enclosure in port for untrained 1.5 Gbit/s and 3 Gbit/s 99
Figure 56 – Mini SAS 4x receptacle connector - end device or enclosure universal port for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s and for untrained 1.5 Gbit/s and 3 Gbit/s 100
Figure 57 – Mini SAS 4x receptacle connector - enclosure out port for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s and for untrained 1.5 Gbit/s and 3 Gbit/s 100
Figure 58 – Mini SAS 4x receptacle connector - enclosure in port for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s and for untrained 1.5 Gbit/s and 3 Gbit/s 101
Figure 59 – Mini SAS 4x active receptacle connector - end device or enclosure universal port 101
Figure 60 – Mini SAS 4x active receptacle connector - enclosure out port 102
Figure 61 – Mini SAS 4x active receptacle connector - enclosure in port 102
Figure 62 – Mini SAS HD 4x cable plug connector 106
Figure 63 – Mini SAS HD 8x cable plug connector 107
Figure 64 – Mini SAS HD 4x receptacle connector 108
Figure 65 – Mini SAS HD 8x receptacle connector 109
Figure 66 – Mini SAS HD 16x receptacle connector 110
Figure 67 – QSFP+ cable plug connector 113
Figure 68 – QSFP+ receptacle connector 114
Figure 69 – Single-port SAS Drive cable assembly 117
Figure 70 – Dual-port SAS Drive cable assembly 118
Figure 71 – MultiLink SAS Drive cable assembly 119
Figure 72 – SAS internal symmetric cable assembly - SAS 4i 120
Figure 73 – SAS internal symmetric cable assembly - Mini SAS 4i 121
Figure 74 – SAS internal symmetric cable assembly - Mini SAS HD 4i 122
Figure 75 – SAS internal symmetric cable assembly - Mini SAS HD 8i 123
Figure 76 – SAS internal symmetric cable assembly - SAS 4i to Mini SAS 4i with vendor-specific sideband signals 124
Figure 77 – SAS internal symmetric cable assembly - SAS 4i controller to Mini SAS 4i backplane with SGPIO connections 125
Figure 78 – SAS internal symmetric cable assembly - Mini SAS 4i controller to SAS 4i backplane with SGPIO connections 126
Figure 79 – SAS internal symmetric cable assembly - Mini SAS 4i to Mini SAS HD 4i 127
Figure 80 – SAS internal controller-based fanout cable assembly - SAS 4i 129
Figure 81 – SAS internal controller-based fanout cable assembly - Mini SAS 4i 130
Figure 82 – SAS internal controller-based fanout cable assembly - Mini SAS HD 4i 131
Figure 83 – SAS internal backplane-based fanout cable assembly - SAS 4i 132
Figure 84 – SAS internal backplane-based fanout cable assembly - Mini SAS 4i 133
Figure 85 – SAS internal backplane-based fanout cable assembly - Mini SAS HD 4i 134
Figure 86 – Mini SAS 4x external cable assembly 136
Figure 87 – Mini SAS 4x active external cable assembly 137
Figure 88 – SAS external cable assembly with Mini SAS 4x cable plug connectors 138
Figure 89 – SAS external cable assembly - Mini SAS HD 4x 139
Figure 90 – SAS external cable assembly with Mini SAS HD 4x cable plug connectors 140
Figure 91 – SAS external cable assembly - Mini SAS HD 8x 141
Figure 92 – SAS external cable assembly with Mini SAS HD 8x cable plug connectors 142

Figure 93 – SAS external cable assembly - Mini SAS HD 8x to Mini SAS HD 4x 143
Figure 94 – SAS external cable assembly with a Mini SAS HD 8x cable plug connector and two Mini SAS HD 4x cable plug connectors 144
Figure 95 – SAS external cable assembly - Mini SAS HD 4x to Mini SAS 4x 145
Figure 96 – SAS external cable assembly with a Mini SAS HD 4x cable plug connector and a Mini SAS 4x cable plug connector 146
Figure 97 – Passive TxRx connection $|S_{DD22}|$, $|S_{CD22}|$, $|S_{CD21}|$, and NEXT limits 151
Figure 98 – Example of a passive TxRx connection compliance testing for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 152
Figure 99 – Example passive TxRx connection compliance testing for trained 12 Gbit/s 154
Figure 100 – Passive TxRx connection segment between CTS and CR or ITS and IR end to end simulation diagram for trained 12 Gbit/s 155
Figure 101 – Active cable S-parameter limits 159
Figure 102 – Active cable eye mask for 12 Gbit/s 160
Figure 103 – Zero-length test load for transmitter device compliance point 162
Figure 104 – Zero-length test load for receiver device compliance point 162
Figure 105 – Zero-length test load $|S_{DD21}(f)|$ requirements 163
Figure 106 – TCTF test load 163
Figure 107 – TCTF test load $|S_{DD21}(f)|$ and ISI loss requirements at IT for untrained 3 Gbit/s 164
Figure 108 – TCTF test load $|S_{DD21}(f)|$ and ISI loss requirements at CT for untrained 3 Gbit/s 165
Figure 109 – TCTF test load $|S_{DD21}(f)|$ and ISI loss requirements at IT for untrained 1.5 Gbit/s 166
Figure 110 – TCTF test load $|S_{DD21}(f)|$ and ISI loss requirements at CT for untrained 1.5 Gbit/s 167
Figure 111 – Low-loss TCTF test load 168
Figure 112 – Low-loss TCTF test load $|S_{DD21}(f)|$ and ISI loss requirements 169
Figure 113 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter with a test load $|S_{DD21}(f)|$ up to 6 GHz 170
Figure 114 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter test load pulse response 171
Figure 115 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter test load impulse response for 6 Gbit/s 172
Figure 116 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter test load D24.3 response 173
Figure 117 – NEXT and FEXT measurement definition 174
Figure 118 – Reference sampling point and reference pulse response cursor 175
Figure 119 – Reference transmitter coefficient error computation 176
Figure 120 – Convergence of reference transmitter equalization 177
Figure 121 – Transmitter device transient test circuit 179
Figure 122 – Receiver device transient test circuit 179
Figure 123 – Transmitter device eye mask 181
Figure 124 – Receiver device eye mask 182
Figure 125 – Deriving a receiver device jitter tolerance eye mask for untrained 1.5 Gbit/s and 3 Gbit/s 183
Figure 126 – Transmitter device common mode voltage limit 190
Figure 127 – Transmitter device $|S_{CC22}|$, $|S_{DD22}|$, and $|S_{CD22}|$ limits 192
Figure 128 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter device 193
Figure 129 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter device termination S-parameters model 194
Figure 130 – Transmitter equalization measurement 195
Figure 131 – Minimum and maximum coefficient ranges at maximum peak to peak voltage 198
Figure 132 – 12 Gbit/s transmitter device common mode voltage limit 199
Figure 133 – Transmitter circuit compliance test configuration 201
Figure 134 – 12 Gbit/s transmitter circuit output waveform 202
Figure 135 – 12 Gbit/s transmitter device $|S_{CC22}|$, $|S_{DD22}|$, and $|S_{CD22}|$ limits 204
Figure 136 – 12 Gbit/s reference transmitter device 205
Figure 137 – 12 Gbit/s reference transmitter 205
Figure 138 – Simulation of the reference transmitter from a captured signal 208
Figure 139 – Applied SJ for untrained 1.5 Gbit/s and 3 Gbit/s 215
Figure 140 – Receiver device $|S_{CC11}|$, $|S_{DD11}|$, and $|S_{CD11}|$ limits 217
Figure 141 – Reference receiver device for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 218
Figure 142 – Reference receiver device for trained 12 Gbit/s 218

Figure 143 – Reference receiver device termination S-parameters for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 220
Figure 144 – Stressed receiver device jitter tolerance test block diagram for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 221
Figure 145 – Stressed receiver device jitter tolerance test D24.3 eye opening for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 223
Figure 146 – Stressed receiver transmitter equalization adjustment for 12 Gbit/s 225
Figure 147 – Simulation of the reference transmitter from a captured signal 226
Figure 148 – Applied SJ for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s without SSC support 228
Figure 149 – Applied SJ for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s and 12 Gbit/s with SSC support 229
Figure 150 – Center-spreading tolerance buffer 234
Figure 151 – OOB signal transmission 239
Figure 152 – SATA port selection signal 241
Figure C.1 – Reference channel eye opening 293
Figure D.1 – Trained 12 Gbit/s die to die insertion loss model 294
Figure D.2 – Transmitter device end to end simulation diagram that includes a separable TxRx connection segment 297
Figure D.3 – End to end simulation diagram from target device usage model for a transmitter device connected to a non-separable TxRx connection segment 299
Figure D.4 – End to end simulation diagram of the target device usage model for a transmitter device connected to a non-separable TxRx connection segment 300
Figure D.5 – Stressed receiver device delivered signal calibration end to end simulation diagram 302
Figure E.1 – S-parameter measurement connections for a four port VNA 304
Figure E.2 – Example of a SAS three TxRx connection segment 305
Figure F.1 – A simple physical link 307
Figure F.2 – Transmitter device details 308
Figure F.3 – Receiver device details 309
Figure F.4 – De-embedding of connectors in test fixtures 311
Figure F.5 – De-embedding to ET for 12 Gbit/s transmitter compliance 312
Figure F.6 – De-embedding calibration test structure 312
Figure F.7 – Measurement conditions for signal output at the transmitter device 313
Figure F.8 – Transmitter device signal output measurement test fixture details 313
Figure F.9 – Measurement conditions for signal tolerance at the transmitter device 314
Figure F.10 – Calibration of test fixture for signal tolerance at the transmitter device 314
Figure F.11 – Measurement conditions for signal output at the receiver device 315
Figure F.12 – Measurement conditions for signal tolerance at the receiver device 315
Figure F.13 – Calibration of test fixture for signal tolerance at the receiver device 316
Figure F.14 – S-parameter port naming conventions 317
Figure F.15 – Four single ended port or two differential port element 318
Figure F.16 – S-parameters for single ended and differential systems 318
Figure F.17 – Measurement conditions for S_{22} at the transmitter device connector 319
Figure F.18 – Measurement conditions for S_{11} at the receiver device connector 320
Figure F.19 – Measurement conditions for S_{11} at IT or CT 321
Figure F.20 – Measurement conditions for S_{22} at IR or CR 322
Figure G.1 – Reference transmitter device and reference receiver device termination circuit model 329
Figure G.2 – Generic return loss circuit model 331
Figure G.3 – Generic return loss model $|S_{11}|$ 332
Figure G.4 – Reference transmitter test load measurement setup 333
Figure G.5 – Reference transmitter test load $|S_{DD21}(f)|$ up to 20 GHz 334
Figure H.1 – Dual comparator design for active cable assembly detection 335
Figure I.1 – SAS primary icon 336
Figure I.2 – SAS alternate icon 336
Figure I.3 – MultiLink SAS icon 337

Table 1 – Numbering conventions 40
Table 2 – Comparison of decimal prefixes and binary prefixes 41
Table 3 – Compliance points 45
Table 4 – Connectors 60
Table 5 – Connector categories 62
Table 6 – Recommended electrical performance limits for the mated connector pairs that support rates of 12 Gbit/s 63
Table 7 – SAS Drive connector pin assignments 67
Table 8 – SAS MultiLink connector pin assignments 71
Table 9 – Micro SAS connector pin assignments 75
Table 10 – Controller SAS 4i connector pin assignments and physical link usage 77
Table 11 – Backplane SAS 4i connector pin assignments and physical link usage 78
Table 12 – Controller Mini SAS 4i connector pin assignments and physical link usage 80
Table 13 – Backplane Mini SAS 4i connector pin assignments and physical link usage 81
Table 14 – Controller Mini SAS HD 4i connector pin assignments and physical link usage 87
Table 15 – Backplane Mini SAS HD 4i connector pin assignments and physical link usage 88
Table 16 – Mini SAS 4x cable plug connector and Mini SAS 4x active cable plug connector icons, key slot positions, and key positions 91
Table 17 – Mini SAS 4x receptacle connector icons, key positions, and key slot positions 98
Table 18 – Mini SAS 4x connector pin assignments and physical link usage 103
Table 19 – Mini SAS 4x active connector pin assignments and physical link usage 104
Table 20 – Mini SAS 4x active cable supplied power requirements 105
Table 21 – Mini SAS HD 4x connector pin assignments and physical link usage 111
Table 22 – Management interface connection requirements 112
Table 23 – QSFP+ connector pin assignments 115
Table 24 – TxRx connection general characteristics 148
Table 25 – Maximum limits for S-parameters of the passive TxRx connection between ITS and IR or CTS and CR 150
Table 26 – Passive TxRx connection characteristics for trained 6 Gbit/s 152
Table 27 – Passive TxRx connection characteristics for trained 12 Gbit/s at ET and ER 156
Table 28 – Active cable assembly output electrical characteristics for trained 6 Gbit/s 157
Table 29 – Maximum limits for S-parameters for active cable assemblies 158
Table 30 – Active cable assembly electrical characteristics for 12 Gbit/s 160
Table 31 – General electrical characteristics 178
Table 32 – JTF parameters 181
Table 33 – Transmitter device general electrical characteristics 184
Table 34 – Transmitter device termination characteristics 185
Table 35 – Transmitter device signal output characteristics for untrained 1.5 Gbit/s and 3 Gbit/s as measured with the zero-length test load at IT and CT 186
Table 36 – Transmitter device signal output characteristics for untrained 1.5 Gbit/s and 3 Gbit/s as measured with each test load at IT and CT 188
Table 37 – Transmitter device signal output characteristics for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s at IT and CT 189
Table 38 – Transmitter device common mode voltage limit characteristics 190
Table 39 – Maximum limits for S-parameters at IT_S or CT_S 191
Table 40 – Recommended trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s transmitter device settings at IT and CT compliance point 192
Table 41 – Trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s reference transmitter device characteristics at IT and CT compliance point 193
Table 42 – Transmitter device signal output characteristics for trained 12 Gbit/s at ET, IT, and CT 196
Table 43 – 12 Gbit/s transmitter device common mode voltage limit characteristics 199
Table 44 – Transmitter coefficient requests and corresponding transmitter circuit response 200
Table 45 – Transmitter circuit coefficient presets at ET 203
Table 46 – 12 Gbit/s maximum limits for S-parameters at IT_S or CT_S 204
Table 47 – 12 Gbit/s reference transmitter device characteristics at ET 206
Table 48 – Transmitter device characteristics for trained 12 Gbit/s at ET and ER 207
Table 49 – Transmitter device signal output characteristics for 12 Gbit/s at CTS when an active cable is connected 208

Table 50 – Transmitter device signal output characteristics for OOB signals 209
Table 51 – Receiver device general electrical characteristics 211
Table 52 – Recommended receiver device common mode tolerance for 6 Gbit/s, and 12 Gbit/s 211
Table 53 – Receiver device termination characteristics 212
Table 54 – Delivered signal characteristics for untrained 1.5 Gbit/s and 3 Gbit/s as measured with the zero-length test load at IR and CR 213
Table 55 – Maximum delivered jitter for untrained 1.5 Gbit/s and 3 Gbit/s at IR and CR 214
Table 56 – Receiver device jitter tolerance for untrained 1.5 Gbit/s and 3 Gbit/s at IR and CR 215
Table 57 – f_{min}, f_c, and f_{max} for untrained 1.5 Gbit/s and 3 Gbit/s 216
Table 58 – Delivered signal characteristics for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s at IR and CR compliance point 216
Table 59 – Maximum limits for S-parameters at IR or CR 217
Table 60 – Reference receiver equalization stage characteristics for trained 12 Gbit/s 219
Table 61 – Stressed receiver device jitter tolerance test characteristics for trained 1.5 Gbit/s, 3 Gbit/s, and 6 Gbit/s 222
Table 62 – Number of bits received per number of errors for desired BER 224
Table 63 – ISI generator characteristics for trained 12 Gbit/s at ET and ER 227
Table 64 – RJ characteristics for trained 12 Gbit/s stressed receiver device tolerance test 228
Table 65 – f_{min}, f_c, and f_{max} for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s without SSC support 229
Table 66 – f_{min}, f_c, f_{max}, and SJ_{lf} for trained 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s with SSC support 229
Table 67 – Delivered signal characteristics for OOB signals 230
Table 68 – SSC modulation types 230
Table 69 – SAS phy transmitter SSC modulation types 231
Table 70 – Expander phy transmitter SSC modulation types 232
Table 71 – Receiver SSC modulation types tolerance 232
Table 72 – Expander device center-spreading tolerance buffer 233
Table 73 – Output characteristics of the READY LED signal 235
Table 74 – Characteristics of the POWER DISABLE signal applied to the SAS target device 236
Table 75 – OOB signal timing specifications 237
Table 76 – OOB signal transmitter device requirements 238
Table 77 – OOB signal receiver device burst time detection requirements 240
Table 78 – OOB signal receiver device idle time detection requirements 240
Table 79 – OOB signal receiver device negation time detection requirements 240
Table 80 – SATA port selection signal transmitter device requirements 241
Table A.1 – JTPAT for RD+ 242
Table A.2 – JTPAT for RD- 243
Table D.1 – Crosstalk transmitter characteristics 295
Table D.2 – S-parameter files for transmitter devices connected to separable TxRx connection segment 296
Table D.3 – The S-parameter files for a transmitter device connected to a non-separable TxRx connection segment 298
Table D.4 – S-parameter files for a TxRx connection segment 301
Table D.5 – S-parameter files for stressed receiver device delivered signal calibration 303
Table F.1 – High frequency jitter source amplitudes 325
Table F.2 – Low frequency jitter source calibration amplitudes 327
Table F.3 – Low frequency jitter attenuation targets 328
Table J.1 – Standards bodies 338

INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

Part 154: Serial Attached SCSI - 3 (SAS-3)

FOREWORD

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International Standard ISO/IEC 14776-154 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This publication contains attached files in the form of S-parameter files required for electrical performance measurements and examples of scripts for running simulations.

The list of all currently available parts of the ISO/IEC 14776 series, under the general title *Information technology – Small computer system interface (SCSI)*, can be found on the IEC web site.

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2, except as described in 3.4 and 3.5..

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

General

The SCSI family of standards provides for many different transport protocols that define the rules for exchanging information between different SCSI devices. This document specifies the functional requirements for the Serial Attached SCSI (SAS) physical interconnect, which is compatible with the Serial ATA physical interconnect. The SAS Protocol Layer - 3 (SPL-3) standard documents the SAS protocol layer corresponding to the Serial Attached SCSI - 3 (SAS-3), defining the rules for exchanging information between SCSI devices using a serial interconnect. Other SCSI transport protocol standards define the rules for exchanging information between SCSI devices using other interconnects.

Figure 1 shows the relationship of this document to the other standards and related projects in the SCSI family of standards.

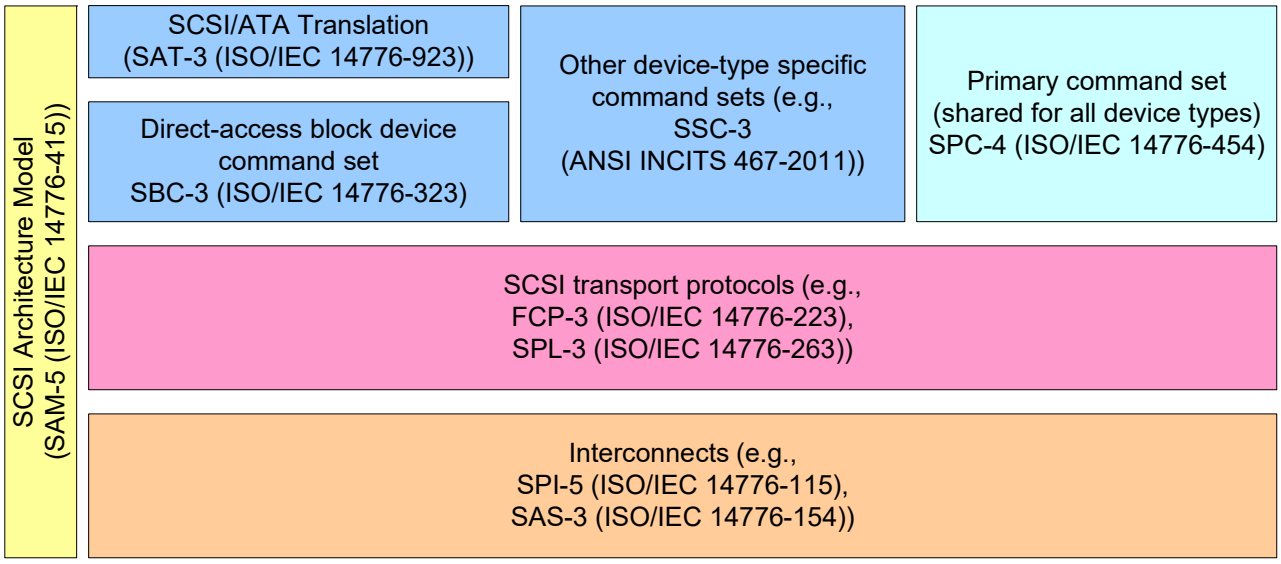


Figure 1 – SCSI document relationships

Figure 2 shows the relationship of this document to other standards and related projects in the ATA family of standards.

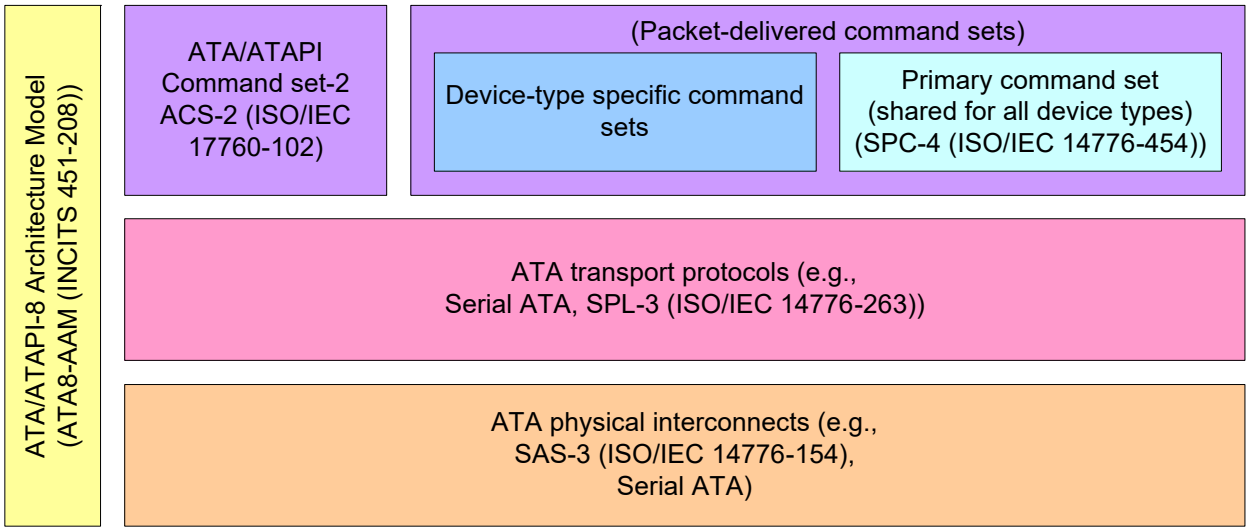


Figure 2 – ATA document relationships

Figure 1 and figure 2 show the general relationship of the documents to one another, and do not imply a relationship such as a hierarchy, protocol stack or system architecture.

These standards specify the interfaces, functions and operations necessary to ensure interoperability between conforming implementations. This document is a functional description. Conforming implementations may employ any design technique that does not violate interoperability.

INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

Part 154: Serial Attached SCSI - 3 (SAS-3)

1 Scope

This part of ISO/IEC 14776 defines the physical layer of the Serial Attached SCSI (SAS) interconnect.

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 TR 14165-117, *Information technology – Fibre channel – Part 117: Methodologies for jitter and signal quality (MJSQ)* [1] [2]

ISO/IEC 14776-151, *Information technology - Small Computer System Interface (SCSI) – Part 151: Serial Attached SCSI -1.1 (SAS-1.1)*

ISO/IEC 14776-153, *Information Technology - Small Computer System Interface (SCSI) – Part 153: Serial Attached SCSI - 2.1 (SAS-2.1)*

INCITS 457-2010, *Information Technology - Serial Attached SCSI - 2 (SAS-2)*

INCITS 492-2015, *SAS Protocol Layer-3 (SPL-3)*

INCITS 515-2016, *SCSI Architecture Model - 5 (SAM-5)*

Serial ATA Revision 3.1 (SATA). 18 July 2011 [3]

SFF-8086, *Compact Multilane Series: Common Elements* [4]

SFF-8087, *Compact Multilane Series: Unshielded* [4]

SFF-8088, *Compact Multilane Series: Shielded* [4]

SFF-8147, *54mm x 71mm Form Factor w/micro SAS Connector* [4]

SFF-8223, *2.5" Drive Form Factor with Serial Connector* [4]

SFF-8323, *3.5" Drive Form Factor with Serial Connector* [4]

SFF-8410, *HSS Copper Testing and Performance Requirements* [4]

SFF-8416, *Measurement and Performance Requirements for HPEI Bulk Cable* [4]

SFF-8449, *Mini Multilane Series Management Interface* [4]

SFF-8460, *HSS Backplane Design Guidelines* [4]

SFF-8484, *Multi-Lane Unshielded Serial Attachment Connectors* [4]

SFF-8485, *Serial GPIO (SGPIO) Bus* [4]

SFF-8486, *Serial Attachment Micro Connector* [4]

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1. INCITS TR-35-2004
2. When MJSQ is referenced from this document, the FC Port terminology used within MJSQ is substituted with SAS phy terminology.
3. Serial ATA specifications are available from the Serial ATA International Organization (see http://www.sata-io.org).
4. SFF specifications are available from the SNIA SFF Technology Affiliate (see http://www.snia.org/sff).

SFF-8523, *5.25" Drive Form Factor with Serial Connector* [4]

SFF-8630, *Serial Attachment 12 Gbs 4X Unshielded Connector (Style B)* [4]

SFF-8636, *Shielded Cables Common Management Interface* [4]

SFF-8639, *Multifunction 12 Gb/s 6X Unshielded Connector* [4]

SFF-8643, *Mini Multilane Series: Unshielded HD Integrated Connector* [4]

SFF-8644, *Mini Multilane Series: Shielded HD Integrated Connector* [4]

SFF-8680, *Serial Attachment 12 Gb/s 2X Unshielded Connector* [4]

SFF-8685, *QSFP+ 14 Gb/s 4X Pluggable Transceiver Solution (QSFP14)* [4]

SFF-9639, *Multifunction 12 Gb/s 6X Unshielded Connector Pinouts* [4]

Touchstone® File Format Specification. Revision 1.1. IBIS Open Forum [1]

1. Touchstone® is a registered trademark of Agilent Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC or ISO. For more information on the Touchstone specification, contact the IBIS Open Forum (see http://www.eigroup.org).

3 Terms, definitions, symbols, abbreviations, keywords, and conventions

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

"IEC Electropedia: available at http://www.electropedia.org/
"ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
active cable assembly
cable assembly (see 3.1.9) that requires power for internal circuitry used in the transmission of the signal through the cable assembly

3.1.2
alternating current
A.C.
non-D.C. component of a signal

Note 1 to entry: In this document, all frequency components greater than or equal to 100 kHz.

3.1.3
baud rate
nominal signaling speed, expressed as the maximum number of times per second that the signal (see 3.1.97) may change the state of the physical link (see 3.1.67)

Note 1 to entry: Each state change produces a transition (i.e., signal edge).

Note 2 to entry: Baud rate is the reciprocal of the UI (i.e., $f_{baud} = 1 / UI$) (see 3.1.116).

3.1.4
bit error ratio
BER
number of logical bits output from a receiver circuit that differ from the correct transmitted logical bits, divided by the number of transmitted logical bits

Note 1 to entry: BER is computed on the raw bit stream before 10b8b decoding.

Note 2 to entry: BER is usually expressed as a coefficient and a power of 10 (e.g., 2 erroneous bits out of 100 000 bits transmitted is expressed as 2 out of 10^5 or 2×10^{-5}).

Note 3 to entry: See MJSQ.

3.1.5
bit time
nominal duration of a signal transmission bit (e.g., 666.$\overline{6}$ ps at 1.5 Gbit/s, 333.$\overline{3}$ ps at 3 Gbit/s, 166.$\overline{6}$ ps at 6 Gbit/s, and 83.$\overline{3}$ ps at 12 Gbit/s)

3.1.6
bounded uncorrelated jitter
BUJ
part of DJ (see 3.1.24) not aligned in time with the signal being measured

Note 1 to entry: Specifically, BUJ excludes ISI (see 3.1.48) and duty cycle distortion.

Note 2 to entry: See MJSQ.

3.1.7
burst time
part of an OOB signal (see 3.1.61) where the OOB burst (see 3.1.57) is transmitted

Note 1 to entry: See 5.11.

3.1.8
byte
sequence of eight contiguous bits considered as a unit

3.1.9
cable assembly
bulk cable with a separable connector at each end plus any retention, backshell, shielding features, or circuitry used for cable management or signal transmission

Note 1 to entry: See 5.4.3.

3.1.10
clock data recovery
CDR
function provided by the receiver circuit responsible for producing a regular clock signal (i.e., the recovered clock) from the received signal and for aligning the recovered clock to the symbols (i.e., bits) being transmitted with the signal

Note 1 to entry: CDR uses the recovered clock to recover the bits.

Note 2 to entry: See MJSQ.

3.1.11
common SSC transmit clock
implementation that employs a single transmit clock for multiple transmitter devices and enables or disables SSC (see 5.8.6) on the transmit clock signal to all transmitter devices in common rather than allowing each transmitter device to independently control SSC

3.1.12
compliance point
interoperability point where interoperability specifications are met

Note 1 to entry: See 5.3.

3.1.13
compliant jitter tolerance pattern
CJTPAT
test pattern for jitter testing

Note 1 to entry: See 5.8.3.5 and Annex A.

3.1.14
connector
electro-mechanical components consisting of a receptacle and a plug that provide a separable interface between two transmission segments

Note 1 to entry: See 5.4.3.

3.1.15
consecutive identical digits
CID
serial bit stream with repeated data bits of the same binary value

3.1.16
cumulative distribution function
CDF
probability that jitter (see 3.1.49) is less than a given value

Note 1 to entry: See MJSQ.

3.1.17
D.C. idle
differential signal level that is nominally 0 V(P-P), used during the idle time (see 3.1.46) and negation time (see 3.1.56) of an OOB signal (see 3.1.61) when D.C. mode (see 3.1.18) is enabled

Note 1 to entry: See 5.8.4.

3.1.18
D.C. mode
mode in which D.C. idle (see 3.1.17) is used during the idle time (see 3.1.46) and negation time (see 3.1.56) of an OOB signal (see 3.1.61)

3.1.19
data dependent jitter
DDJ
jitter (see 3.1.49) that is added when the transmission pattern is changed from a clock-like to a non-clock-like pattern

Note 1 to entry: See MJSQ.

3.1.20
decibel
dB
ten times the common logarithm (i.e., $\log_{10}$) of the ratio of relative powers

Note 1 to entry: The ratio of powers P_1 and P_2 in dB is $10 \times \log_{10} (P_1 / P_2)$. If $P_1 = V_1^2 / R_1$, $P_2 = V_2^2 / R_2$, and $R_1 = R_2$, then this ratio is equivalent to 20 times the common logarithm of the relative voltage ratio (i.e., dB is $20 \times \log_{10} (V_1 / V_2)$). A ratio of 1 results in a dB value of 0 (e.g., $20 \times \log_{10} (1) = 0$ dB), a ratio greater than 1 results in a positive dB value (e.g., $20 \times \log_{10} (2) = 6$ dB) and a ratio less than 1 results in a negative dB value (e.g., $20 \times \log_{10} (0.5) = -6$ dB).

3.1.21
dB millivolts
dBmV
decibel ratio of an rms voltage value relative to 1 mV

Note 1 to entry: 20 mV(rms) is equal to $20 \times \log_{10}(20 \text{ mV} / 1 \text{ mV}) = 26$ dBmV. This does not depend on the impedance level.

3.1.22
dB milliwatts
dBm
decibel ratio of a power value relative to 1 mW

Note 1 to entry: 20 mW is equal to $10 \times \log_{10}(20 \text{ mW} / 1 \text{ mW}) = 13$ dBm. If power is measured with a 50 Ω impedance level, then 20 mW is equivalent to $(0.02 \text{ W} \times 50\ \Omega)^{(1/2)} = 1$ V or 60 dBmV. If power is measured with a 25 Ω impedance level (i.e., the reference impedance for common mode measurements), then 20 mW is equivalent to $(0.02 \text{ W} \times 25\ \Omega)^{(1/2)} = 0.707$ V or 57 dBmV.

3.1.23
decision feedback equalizer
DFE
nonlinear equalizer that uses a feedback loop based on previously decoded symbols

3.1.24
deterministic jitter
DJ
jitter (see 3.1.49) with non-Gaussian distribution that is bounded in amplitude and has specific causes

Note 1 to entry: See MJSQ.

3.1.25
direct current
D.C.
non-A.C. component of a signal

Note 1 to entry: In this document, all frequency components below 100 kHz.

3.1.26
disparity
difference between the number of ones and zeros in a character

Note 1 to entry: See SPL-3.

3.1.27
dispersion
signal pulse broadening and distortion from all causes

3.1.28
duty cycle distortion
DCD
one-half of the difference of the average width of a one and the average width of a zero in a signal waveform eye pattern measurement

Note 1 to entry: See MJSQ.

3.1.29
dword
sequence of four contiguous bytes or four contiguous characters considered as a unit

Note 1 to entry: See SPL-3.

3.1.30
electromagnetic interference
EMI
any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment

3.1.31
enclosure
box, rack, or set of boxes providing the powering, cooling, mechanical protection, EMI protection, and external electronic interfaces for one or more end device(s) (see 3.1.35) and/or expander device(s) (see SPL-3)

Note 1 to entry: Provides the outermost electromagnetic boundary and acts as an EMI barrier.

3.1.32
enclosure in port
set of expander phys with subtractive routing attributes using the same external connector (see 5.4.3.5)

Note 1 to entry: See SPL-3.

3.1.33
enclosure out port
set of expander phys with table routing attributes in an expander device that does not support table-to-table attachment using the same external connector (see 5.4.3.5)

Note 1 to entry: See SPL-3.

3.1.34
enclosure universal port
set of expander phys with table routing attributes in an expander device that supports table-to-table attachment using the same external connector (see 5.4.3.5)

Note 1 to entry: See SPL-3.

3.1.35
end device
SAS device or SATA device that is not contained within an expander device (see 3.1.38)

Note 1 to entry: See SPL-3.

3.1.36
end to end simulation
simulation performed from a reference transmitter or from a captured signal to a reference receiver device

3.1.37
etch
printed circuit board copper conductor path

3.1.38
expander device
device that is part of a service delivery subsystem (see SAM-5), facilitates communication between SAS devices (see 3.1.89) and SATA devices (see 3.1.93)

Note 1 to entry: See SPL-3.

3.1.39
expander phy
phy in an expander device that interfaces to a service delivery subsystem (see SAM-5)

Note 1 to entry: See SPL-3.

3.1.40
expander port
expander device object that interfaces to a service delivery subsystem (see SAM-5) and to SAS ports in other devices

Note 1 to entry: See SPL-3.

3.1.41
external connector
bulkhead connector (see 3.1.14) that carries signals into and out of an enclosure (see 3.1.31) and exits the enclosure with only minor compromise to the shield effectiveness of the enclosure (e.g., a Mini SAS 4x receptacle or Mini SAS HD receptacle)

Note 1 to entry: See 5.4.3.5.

3.1.42
eye contour
locus of points in a signal level versus time eye diagram where the CDF of 10^{-12} in the actual signal population exists

Note 1 to entry: Comparison of the measured eye contour to the jitter eye mask determines whether a jitter eye mask violation has occurred.

Note 2 to entry: For simulations, a CDF of 10^{-15} is used.

Note 3 to entry: See 5.8.3 and MJSQ.

3.1.43
fall time
time interval for the falling signal edge to transit between specified percentages of the signal amplitude

Note 1 to entry: In this document, the measurement points are the 80 % and 20 % voltage levels.

Note 2 to entry: Also see rise time (see 3.1.88).

3.1.44
fanout cable assembly
cable assembly with one connector on one end and multiple connectors on the other end

Note 1 to entry: See 5.4.4.1.3.

3.1.45
field
group of one or more contiguous bits

3.1.46
idle time
part of an OOB signal (see 3.1.61) where OOB idle (see 3.1.17) is being transmitted

Note 1 to entry: See 5.11.

3.1.47
insertion loss
ratio, usually expressed in dB, of incident power to delivered power

Note 1 to entry: The dB magnitude of S_{12} or S_{21} is the negative of insertion loss in dB.

Note 2 to entry: See clause F.11.

3.1.48
intersymbol interference
ISI
reduction in the distinction of a pulse caused by overlapping energy from neighboring pulses

Note 1 to entry: Neighboring pulses are pulses that are close enough to have significant energy overlapping the affected pulse and does not imply or exclude adjacent pulses (i.e., many bit times (see 3.1.5) may separate the pulses, especially in the case of reflections).

Note 2 to entry: May result in DDJ and vertical eye closure.

Note 3 to entry: Produced by several mechanisms (e.g., dispersion, reflections, and circuits that lead to baseline wander).

Note 4 to entry: See MJSQ.

3.1.49
jitter
collection of instantaneous deviations of signal edge times at a defined signal level of the signal from the reference times (e.g., as defined by the jitter timing reference) for those events

Note 1 to entry: See MJSQ.

3.1.50
jitter timing reference
signal used as the basis for calculating the jitter in the signal under test

Note 1 to entry: See MJSQ.

3.1.51
jitter tolerance
ability of the receiver device to recover transmitted bits in an incoming data stream in the presence of specified jitter in the signal applied to the receiver device compliance point

Note 1 to entry: See MJSQ.

3.1.52
jitter tolerance pattern
JTPAT
data test pattern for jitter testing of a receiver device contained within CJTPAT

Note 1 to entry: See Annex A.

3.1.53
least mean square
LMS
algorithm for adaptively adjusting the tap coefficients of a DFE (see 3.1.23) based on the difference between the desired and actual signal

3.1.54
managed connector category
category of connectors that support a cable management interface

Note 1 to entry: See 5.4.3.2.

3.1.55
near-end crosstalk
NEXT
crosstalk that is propagated in a disturbed channel in the opposite direction as the propagation of a signal in the disturbing channel

Note 1 to entry: The terminals of the disturbed channel, at which the near-end crosstalk is present, and the energized terminals of the disturbing channel are usually near each other.

3.1.56
negation time
part of an OOB signal (see 3.1.61) during which OOB idle (see 3.1.58) is transmitted after the last OOB burst (see 3.1.57)

Note 1 to entry: See 5.11.

3.1.57
OOB burst
transmission of signal transitions or ALIGN3 primitives for a burst time (see 3.1.7)

Note 1 to entry: See 5.11.1.

3.1.58
OOB idle
transmission of D.C. idle (see 3.1.17) when D.C. mode (see 3.1.18) is enabled or a defined sequence of dwords when optical mode (see 3.1.62) is enabled

3.1.59
OOB interval
time basis for burst times (see 3.1.7), idle times (see 3.1.46), negation times (see 3.1.56), and signal times (see 3.1.100) used to create OOB signals (see 3.1.61)

Note 1 to entry: See 5.11.1.

3.1.60
OOB sequence
sequence where two phys exchange OOB signals (see 3.1.61)

Note 1 to entry: See SPL-3.

3.1.61
OOB signal
pattern of idle time (see 3.1.46), burst time (see 3.1.7), and negation time (see 3.1.56) used during the link reset sequence

Note 1 to entry: See 5.11.

3.1.62
optical mode
mode in which a defined sequence of dwords is used during the idle time (see 3.1.46) and negation time (see 3.1.56) of an OOB signal (see 3.1.61)

Note 1 to entry: See 5.11.

3.1.63
passive cable assembly
cable assembly (see 3.1.9) that does not require external power for internal circuitry used in the transmission of the signal through the cable assembly

3.1.64
passive TxRx connection
complete simplex signal path between the transmitter circuit (see 3.1.109) and receiver circuit (see 3.1.75) that does not include powered circuitry used in the transmission of the signal through the TxRx connection (see 3.1.114)

Note 1 to entry: See 5.5.1.

3.1.65
phy
object in a device that is used to interface to other devices

EXAMPLE - An expander phy (see 3.1.39) or a SAS phy (see 3.1.90).

Note 1 to entry: See 4.1.

3.1.66
physical interconnect TxRx connection segment
PICS
TxRx connection segment (see 3.1.115) used to model channel loss between the TDCS (see 3.1.113) and the RDCS (see 3.1.79)

Note 1 to entry: See 5.3.3.

3.1.67
physical link
two differential signal pairs, one pair in each direction, that connect two physical phys (see 3.1.65)

Note 1 to entry: See 4.1.

3.1.68
physical link rate
link rate between two physical phys established as a result of speed negotiation between those phys

3.1.69
power on
power being applied

3.1.70
probe point
physical position in a test load where signal characteristics for compliance points are measured

Note 1 to entry: See 5.6.

3.1.71
post cursor equalization ratio
R_{post}
ratio of the equalization peak signal voltage to the nominal signal voltage after a signal voltage change

Note 1 to entry: See 5.8.4.7.1.

3.1.72
precursor equalization ratio
R_{pre}
ratio of the equalization peak signal voltage to the nominal signal voltage prior to a signal voltage change

Note 1 to entry: See 5.8.4.7.1.

3.1.73
random jitter
RJ
jitter (see 3.1.49) that is characterized by a Gaussian distribution and is unbounded

Note 1 to entry: See MJSQ.

3.1.74
rate
data transfer rate of a physical or logical link

EXAMPLE - 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, or 12 Gbit/s.

3.1.75
receiver circuit
electronic circuit that converts an analog serial input signal to a logic signal

3.1.76
receiver circuit TxRx connection segment
RCCS
TxRx connection segment (see 3.1.115) used to model package loss within the simulated receiver circuit (see 3.1.75)

3.1.77
reference clock
clock generated by the PLL

Note 1 to entry: This clock is filtered by the JTF (see 5.8.3.2) and aligned with the zero-crossing instants.

3.1.78
receiver device
Rx
device downstream from a receiver device compliance point (see 3.1.12) containing a portion of the physical link and a receiver circuit (see 3.1.75)

3.1.79
receiver device TxRx connection segment
RDCS
TxRx connection segment (see 3.1.115) between the simulated receiver circuit (see 3.1.75) and a separable connector

3.1.80
reference pulse response cursor
peak to peak
cursor that is twice the amplitude of the response to a one UI wide positive pulse of the same amplitude and transmitter equalization as the data stream it represents (see 5.7.3), sampled at the reference sampling instant (see 3.1.83)

3.1.81
reference receiver device
set of parameters defining electrical performance characteristics that provide a set of minimum electrical performance requirements for a receiver device and that are also used in mathematical modeling to determine compliance of a TxRx connection or transmitter device

Note 1 to entry: See 5.8.5.7.3.

3.1.82
reference sampling clock
reference clock (see 3.1.77) shifted by 0.5 UI (see 3.1.116)

3.1.83
reference sampling instant
instant at which a reference sampling clock (see 3.1.82) samples the maximum amplitude of the response to a positive pulse generated using the reference sampling clock

Note 1 to entry: See figure 118.

3.1.84
reference transmitter device
set of parameters defining electrical performance characteristics of a transmitter device that are used in mathematical modeling to determine compliance of a TxRx connection

Note 1 to entry: See 5.8.4.6.5 and 5.8.4.7.3.

3.1.85
reference transmitter test load
set of S-parameters defining the electrical characteristics of a TxRx connection used as the basis for transmitter device and receiver device performance evaluation through mathematical modeling

Note 1 to entry: See 5.6.5.

3.1.86
reflection coefficient
ρ
ratio of reflected voltage to incident voltage

3.1.87
return loss
ratio, usually expressed in dB, of incident power to reflected power

Note 1 to entry: The dB magnitude of S_{11} or S_{22} is the negative of return loss in dB.

Note 2 to entry: See clause F.11

3.1.88
rise time
time interval for the rising signal edge to transit between specified percentages of the signal amplitude

Note 1 to entry: In this document, the measurement points are the 20 % and 80 % voltage levels.

Note 2 to entry: Also see fall time (see 3.1.43).

3.1.89
SAS device
SAS initiator device (see SPL-3) and/or SAS target device (see SPL-3)

3.1.90
SAS phy
phy in a SAS device (see 3.1.89) that interfaces to a service delivery subsystem (see SAM-5)

3.1.91
SAS target device
device containing SSP, STP, and/or SMP target ports in a SAS domain

Note 1 to entry: See SPL-3.

3.1.92
SAS target device circuitry
at a minimum, the circuitry in the SAS target device (see SPL-3) providing control of the SAS phy (see 3.1.90) and protocol support for communication through the physical link (see 3.1.67)

Note 1 to entry: Application of power to the SAS target device circuitry results in actions defined for power on (see SPL-3).

3.1.93
SATA device
ATA device that contains a SATA device port in an ATA domain

Note 1 to entry: See SPL-3.

3.1.94
SATA phy
phy in a SATA device (see SPL-3) or SATA port selector (see SPL-3) that interfaces to a service delivery subsystem (see SAM-5)

Note 1 to entry: Analogous to a SAS phy (see 3.1.90).

3.1.95
Serial ATA
SATA
protocol defined by SATA (see clause 2)

3.1.96
Serial Attached SCSI
SAS
set of protocols defined in SPL-3 and the interconnect defined by this document

3.1.97
signal
detectable transmitted energy that is used to carry information

3.1.98
signal amplitude
property of the overall signal (see 3.1.97) that describes the peak or peak to peak values of the signal level (see 3.1.99)

3.1.99
signal level
instantaneous intensity of a signal (see 3.1.97) measured in volts

3.1.100
signal time
time of an OOB signal (see 3.1.61), consisting of six burst times (see 3.1.7), six idle times (see 3.1.46), and one negation time (see 3.1.56)

Note 1 to entry: See 5.11.

3.1.101
signal tolerance
ability of the receiver device to recover transmitted bits in an incoming data stream with maximum jitter and minimum amplitude

Note 1 to entry: See MJSQ.

3.1.102
significant crosstalk
crosstalk source having a magnitude point of its transfer function in excess of -50 dB in the range of frequencies up to 6 GHz

3.1.103
sinusoidal jitter
SJ
single frequency jitter applied during signal tolerance testing

Note 1 to entry: See MJSQ.

3.1.104
spread spectrum clocking
SSC
technique of modulating the operating frequency of a transmitted signal (i.e., the physical link rate) to reduce the measured peak amplitude of radiated emissions

Note 1 to entry: See SPL-3.

3.1.105
symbol
smallest unit of data transmission on a physical link (i.e., a bit)

Note 1 to entry: A symbol represents a single transition if the maximum transition rate (i.e., a 0101b pattern) is occurring.

3.1.106
total jitter
TJ
jitter (see 3.1.73) from all sources

Note 1 to entry: See MJSQ.

3.1.107
trained
physical link rate negotiated with Train_Rx-SNW

Note 1 to entry: See SPL-3.

3.1.108
transceiver
physical entity that contains both a transmitter device (see 3.1.112) and a receiver device (see 3.1.78)

3.1.109
transmitter circuit
electronic circuit that converts a logic signal to an analog serial output signal

3.1.110
transmitter circuit TxRx connection segment
TCCS
TxRx connection segment (see 3.1.115) used to model package loss within the simulated transmitter circuit (see 3.1.109)

3.1.111
transmitter compliance transfer function
TCTF
mathematical statement of the transfer function through which the transmitter shall be capable of producing acceptable signals as defined by a receive mask

Note 1 to entry: See 5.8.4.1.

3.1.112
transmitter device
Tx
device upstream from a transmitter device compliance point (see 3.1.12) containing a portion of the physical link and a transmitter circuit (see 3.1.109)

3.1.113
transmitter device TxRx connection segment
TDCS
TxRx connection segment (see 3.1.115) between the transmitter circuit (see 3.1.109) and a separable connector

3.1.114
TxRx connection
complete simplex signal path between the transmitter circuit (see 3.1.109) and receiver circuit (see 3.1.75)

Note 1 to entry: See 5.5.1.

3.1.115
TxRx connection segment
portion of a TxRx connection (see 3.1.114) delimited by separable connectors or changes in the conductive material

Note 1 to entry: See 5.5.1.

3.1.116
unit interval
UI
normalized, dimensionless, nominal duration of a symbol (see 3.1.105)

EXAMPLE - 666.$\overline{6}$ ps at 1.5 Gbit/s, 333.$\overline{3}$ ps at 3 Gbit/s, 166.$\overline{6}$ ps at 6 Gbit/s, and 83.$\overline{3}$ ps at 12 Gbit/s.

Note 1 to entry: The UI is the reciprocal of the baud rate (i.e., UI = 1 / f_{baud}) (see 3.1.3).

3.1.117
unmanaged active connector category
category of connectors that support power for Mini SAS 4x active external cable assemblies (see 5.4.4.2.2) but do not support cable assemblies with a cable management interface

Note 1 to entry: See 5.4.3.2.

3.1.118
unmanaged passive connector category
category of connectors that do not support power for Mini SAS 4x active external cable assemblies (see 5.4.4.2.2) and do not support cable assemblies with a cable management interface

Note 1 to entry: See 5.4.3.2.

3.1.119
untrained
physical link rate not negotiated with Train_Rx-SNW

Note 1 to entry: See SPL-3.

3.1.120
usage variable
SASWDP parameter set to a value that determines if the stressor file is to be added to the simulation

Note 1 to entry: See Annex B.

3.1.121
voltage modulation amplitude
VMA
difference in electrical voltage of a signal (see 3.1.97) between the stable one level and the stable zero level

3.1.122
waveform dispersion penalty
WDP
simulated measure of the deterministic penalty of the signal waveform from a particular transmitter device transmitting a particular pattern and a particular test load with a reference receiver device

Note 1 to entry: See 5.8.4.6.1 and Annex B.

3.2 Symbols and abbreviations

3.2.1 Abbreviations

See Annex J for abbreviations of standards bodies (e.g., ISO).

Units and abbreviations used in this Document:

Abbreviation	Meaning
A.C.	alternating current (see 3.1.2)
ATA	AT attachment

Abbreviation	Meaning
AWG	American wire gauge (see ASTM Standard B 258-02) (see Bibliography)
BER	bit error ratio (see 3.1.4)
BUJ	bounded uncorrelated jitter (see 3.1.6)
C1	coefficient 1 (see 5.8.4.7.3)
C2	coefficient 2 (see 5.8.4.7.3)
C3	coefficient 3 (see 5.8.4.7.3)
CDF	cumulative distribution function (see 3.1.16)
CDR	clock data recovery (see 3.1.10)
CIC	compliance interconnect channel (see SATA)
CID	consecutive identical digits (see 3.1.15)
CJTPAT	compliant jitter tolerance pattern (see 3.1.13)
CR	inter-enclosure (i.e., cabinet) receiver device compliance point (see 5.3)
CT	inter-enclosure (i.e., cabinet) transmitter device compliance point (see 5.3)
D.C.	direct current (see 3.1.25)
DCD	duty cycle distortion (see 3.1.28)
DDJ	data dependent jitter (see 3.1.19)
DFE	decision feedback equalizer (see 3.1.23)
DJ	deterministic jitter (see 3.1.24)
EMI	electromagnetic interference (see 3.1.30)
ER	end to end transmitter device compliance point (see 5.3)
ESD	electrostatic discharge
ET	end to end receiver device compliance point (see 5.3)
G1	generation 1 physical link rate (i.e., 1.5 Gbit/s)
G2	generation 2 physical link rate (i.e., 3 Gbit/s)
G3	generation 3 physical link rate (i.e., 6 Gbit/s)
G4	generation 4 physical link rate (i.e., 12 Gbit/s)
Gbit/s	gigabit per second (i.e., 10^9 bits per second)
Gen1i	SATA generation 1 physical link rate (i.e., 1.5 Gbit/s) (see SATA)
Gen2i	SATA generation 2 physical link rate (i.e., 3 Gbit/s) (see SATA)
Gen3i	SATA generation 3 physical link rate (i.e., 6 Gbit/s) (see SATA)
GPIO	general purpose input/output
HD	high-density
IR	intra-enclosure (i.e., internal) receiver device compliance point (see 5.3)
ISI	intersymbol interference (see 3.1.48)
IT	intra-enclosure (i.e., internal) transmitter device compliance point (see 5.3)
JMD	jitter measurement device
JTF	jitter transfer function (see 5.8.3.2)
JTPAT	jitter tolerance pattern (see 3.1.52)
LED	light-emitting diode
LMS	least mean square (see 3.1.53)
MJSQ	Methodologies for Jitter and Signal Quality Specification (see clause 2)
N/A	not applicable

Abbreviation	Meaning
NEXT	near-end crosstalk (see 3.1.55)
OOB	out-of-band
OOBI	out-of-band interval (see 3.1.59)
PCB	printed circuit board
PICS	physical interconnect TxRx connection segment (see 3.1.66)
PJ	periodic jitter
PLL	phase lock loop
P-P	peak to peak
RCCS	receiver circuit TxRx connection segment (see 3.1.76)
RD	running disparity (see SPL-3)
RDCS	receiver device TxRx connection segment (see 3.1.79)
RJ	random jitter (see 3.1.73)
RR	receiver device die attachment point to RCCS
Rx	receiver device (see 3.1.78)
RTTL	reference transmitter test load (see 3.1.85)
SAM-5	SCSI Architecture Model - 5 standard (see clause 2)
SAS	Serial Attached SCSI (see 3.1.96)
SAS-1.1	Serial Attached SCSI 1.1 (see clause 2)
SAS-2	Serial Attached SCSI 2 (see clause 2)
SAS-2.1	Serial Attached SCSI 2.1 (see clause 2)
SATA	Serial ATA (see 3.1.95) or the Serial ATA 3.1 specification (see clause 2)
SCSI	Small Computer System Interface
SGPIO	serial GPIO (see clause 2)
SJ	sinusoidal jitter (see 3.1.103)
SMA	subminiature version A connector (see Bibliography)
SPC-4	SCSI Primary Commands - 4 standard (see Bibliography)
SPL-3	SAS Protocol Layer - 3 (see clause 2)
SSC	spread spectrum clocking
STP	Serial ATA Tunneled Protocol
TCCS	transmitter circuit TxRx connection segment (see 3.1.110)
TCTF	transmitter compliance transfer function (see 3.1.111)
TDCS	transmitter device TxRx connection segment (see 3.1.113)
TDNA	time domain network analyzer (i.e., TDR/TDT plus analysis software that performs a VNA-style output)
TDR	time domain reflectometer
TDT	time domain transmission
TJ	total jitter (see 3.1.106)
TTIU	transmitter training information unit (see SPL-3)
Tx	transmitter device (see 3.1.112)
UI	unit interval (see 3.1.116)
VMA	voltage modulation amplitude (see 3.1.121)
VNA	vector network analyzer

Abbreviation	Meaning
WDP	waveform dispersion penalty (see 3.1.122)
XCS	crosstalk connection segment (see 5.5.6)

3.2.2 Symbols

3.2.2.1 Units

Units used in this document:

Units	Meaning
dB	decibel (see 3.1.20)
dBm	decibel milliwatts (see 3.1.22)
dBmV	decibel millivolts (see 3.1.21)
GHz	gigahertz (i.e., 10^9 cycles per second)(i.e., s^{-9})
Hz	hertz (i.e., cycles per second)(i.e., s^{-1})
kHz	kilohertz (i.e., 10^3 cycles per second)(i.e., s^{-3})
kΩ	kiloohm (i.e., 10^3 ohms)
µA	microampere (i.e., 10^{-6} amperes)
µs	microsecond (i.e., 10^{-6} seconds)
m	meter
mA	milliampere (i.e., 10^{-3} amperes)
MBps	megabytes per second (i.e., 10^6 bytes per second)
MHz	megahertz (i.e., 10^6 cycles per second)(i.e., s^{-6})
ms	millisecond (i.e., 10^{-3} seconds)
mV	millivolt (i.e., 10^{-3} volts)
mW	milliwatt (i.e., 10^{-3} watts)
nF	nanofarad (i.e., 10^{-9} farads)
ns	nanosecond (i.e., 10^{-9} seconds)
ppm	parts per million (i.e., 10^{-6})
ps	picosecond (i.e., 10^{-12} seconds)
rms	root mean square (i.e., quadratic mean)
s	second (i.e., unit of time)
V	volt
W	watt

3.2.2.2 Mathematical operators

Mathematical operators used in this document:

Mathematical Operators	Meaning
e	2.718 28..., the base of the natural (i.e., hyperbolic) system of logarithms
sgn	signum function (i.e., sign function)
^	exclusive logical OR
<	less than
≤	less than or equal to

Mathematical Operators	Meaning
>	greater than
≥	greater than or equal to
±	plus or minus
×	multiplication
/	division
|v|	the absolute value (i.e., magnitude) of v
~	approximately equal to
⊗	convolution

3.2.2.3 Other symbols

Other symbols used in this document:

Symbols	Meaning
Dxx.y	data character (see 3.1.19)
K_0	output gain
R_{post}	post cursor equalization ratio (see 3.1.71)
R_{pre}	precursor equalization ratio (see 3.1.72)
®	registered trademark
S_{ij}	S-parameter for port j to port i (see clause F.11)
S_{CCij}	S-parameter for common mode to common mode port j to port i (see clause F.11)
S_{CDij}	S-parameter for differential to common mode port j to port i (see clause F.11)
S_{DCij}	S-parameter for common mode to differential port j to port i (see clause F.11)
S_{DDij}	S-parameter for differential to differential port j to port i (see clause F.11)
Δ (delta)	difference operator
ϕ (phi)	phase
π (pi)	3.141 59... , the ratio of the circumference of a circle to its diameter
ρ (rho)	reflection coefficient (see 3.1.86)
τ (tau)	time constant
Ω (omega)	ohm (i.e., unit of electrical resistance)

3.3 Keywords

3.3.1
invalid
keyword used to describe an illegal or unsupported bit, byte, word, field or code value

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

3.3.2
mandatory
keyword indicating an item that is required to be implemented as defined in this document

3.3.3
may
keyword that indicates flexibility of choice with no implied preference

3.3.4
may not
keyword that indicates flexibility of choice with no implied preference

3.3.5
obsolete
keyword indicating that an item was defined in prior SCSI standards but has been removed from this document

3.3.6
option, optional

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

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

3.3.7
prohibited
keyword used to describe a feature, function, or coded value that is defined in a a non-SCSI standard (i.e., a standard that is not a member of the SCSI family of standards) to which this document makes a normative reference where the use of said feature, function, or coded value is not allowed for implementations of this standard

3.3.8
reserved
keyword referring to bits, bytes, words, fields, and code values that are set aside for future standardization

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

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

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

3.3.9
restricted
keyword referring to bits, bytes, words, and fields that are set aside for other identified standardization purposes

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

3.3.10
shall
keyword indicating a mandatory requirement

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

3.3.11
should
keyword indicating flexibility of choice with a strongly preferred alternative

3.3.12
vendor specific
something (e.g., a bit, field, code value) that is not defined by this document

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

3.4 Editorial conventions

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

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

Quantities having a defined numeric value are identified by large capital letters (e.g., CHECK CONDITION). Quantities having a discrete but unspecified value are identified using small capital letters. (e.g., TASK COMPLETE, indicates a quantity returned by the **Execute Command** procedure call). Such quantities are associated with an event or indication whose observable behavior or value is specific to a given implementation standard.

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

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

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

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

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

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

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

If a conflict arises between text, tables, or figures, the order of precedence to resolve the conflicts is text; then tables; and finally figures. Not all tables or figures are fully described in the text. Tables show data format and values.

Notes and examples do not constitute any requirements for implementors and notes are numbered consecutively throughout this document.

3.5 Numeric and character conventions

3.5.1 Numeric conventions

A binary number is represented in this document by any sequence of digits comprised of only the Arabic numerals 0 and 1 immediately followed by a lower-case b (e.g., 0101b). Underscores or spaces may be included in binary number representations to increase readability or delineate field boundaries (e.g., 00010101 11001110b, 00010101_11001110b, 0 0101 1010b, or 0_0101_1010b).

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

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

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

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

This document uses the following conventions for representing decimal numbers:

a) the decimal separator (i.e., separating the integer and fractional portions of the number) is a period;
b) the thousands separator (i.e., separating groups of three digits in a portion of the number) is a space;
c) the thousands separator is used in both the integer portion and the fraction portion of a number; and
d) the decimal representation for a year is 1999 not 1 999.

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

Table 1 – Numbering conventions

ISO/IEC	United States	This document
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

3.5.2 Units of measure

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

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

    and

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

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

Table 2 – Comparison of decimal prefixes and binary prefixes

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

3.5.3 Byte encoded character strings conventions

When this document requires one or more bytes to contain specific encoded characters, the specific characters are enclosed in single quotation marks. The single quotation marks identify the start and end of the characters that are required to be encoded but are not themselves to be encoded. The characters that are to be encoded are shown in the case that is to be encoded.

An ASCII space character (i.e., 20h) may be represented in a string by the character '¬' (e.g., 'SCSI¬device').

The encoded characters and the single quotation marks that enclose them are preceded by text that specifies the character encoding methodology and the number of characters required to be encoded.

EXAMPLE - Using the notation described in this subclause, stating that eleven ASCII characters 'SCSI device' are to be encoded would be the same writing out the following sequence of byte values: 53h 43h 53h 49h 20h 64h 65h 76h 69h 63h 65h.