



ISO/IEC 14776-262

Edition 1.0 2017-02

INTERNATIONAL STANDARD



Information technology – Small Computer System Interface (SCSI) –
Part 262: SAS Protocol Layer – 2 (SPL-2)
standards.iteh.ai

[ISO/IEC 14776-262:2017](#)

<https://standards.iteh.ai/catalog/standards/sist/0262a445-0a6b-4647-a537-87e3ac152c5a/iso-iec-14776-262-2017>





THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2017 ISO/IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about ISO/IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

IEC STANDARD REVIEW
(standard.iec.ch)

ISO/IEC 14776-6:2017



ISO/IEC 14776-262

Edition 1.0 2017-02

INTERNATIONAL STANDARD



Information technology – Small Computer System Interface (SCSI) –
Part 262: SAS Protocol Layer – 2 (SPL-2)
standards.iteh.ai

ISO/IEC 14776-262:2017
<https://standards.iteh.ai/catalog/standards/sist/0262a445-0a6b-4647-a537-87e3ac152c5a/iso-iec-14776-262-2017>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 35.200

ISBN 978-2-8322-3952-0

Warning! Make sure that you obtained this publication from an authorized distributor.

FOREWORD	37
INTRODUCTION.....	38
General	38
SCSI standards family.....	39
1 Scope	40
2 Normative references.....	41
3 Terms, definitions, symbols, abbreviations, keywords, and conventions.....	42
3.1 Terms and definitions	42
3.2 Symbols and abbreviations	71
3.3 Keywords	74
3.4 Editorial conventions	75
3.5 UML notation conventions	76
3.5.1 Notation conventions overview	76
3.5.2 Constraint and note conventions	77
3.5.3 Class diagram conventions.....	77
3.5.4 Object diagram conventions	81
3.6 State machine conventions	83
3.6.1 State machine conventions overview.....	83
3.6.2 Transitions	84
3.6.3 Messages, requests, indications, confirmations, responses, and event notifications	84
3.6.4 State machine counters, timers, and variables	84
3.6.5 State machine arguments.....	85
3.7 Bit and byte ordering	85
3.8 Notation for procedures and functions.....	85
3 Teh STANDARD PREVIEW (standards.iteh.ai)	
4 General	87
4.1 Architecture	87
4.1.1 Architecture overview.....	87
4.1.2 Physical links and phys.....	88
4.1.3 Logical links	93
4.1.4 Narrow ports and wide ports	93
4.1.5 Application clients and device servers	96
4.1.6 SAS devices.....	97
4.1.7 Expander devices	98
4.1.8 Service delivery subsystem	99
4.1.9 Domains.....	99
4.1.10 Expander device topologies.....	102
4.1.10.1 Expander device topology overview	102
4.1.10.2 Expander device topologies	102
4.1.11 Pathways	104
4.1.12 Connections	104
4.1.13 Broadcasts	106
4.2 Names and identifiers.....	109
4.2.1 Names and identifiers overview	109
4.2.2 NAA IEEE Registered format identifier	109
4.2.3 NAA Locally Assigned format identifier.....	110
4.2.4 SAS address	111
4.2.5 Hashed SAS addresses.....	111
4.2.6 Device names and expander device SAS addresses	112
4.2.7 Device names for SATA devices with world wide names	112
4.2.8 Port names.....	113
4.2.9 Port identifiers and SAS port SAS addresses	113
4.2.10 Phy identifiers	114
4.3 State machines.....	115
4.3.1 State machine overview	115

4.3.2 Transmit data path	116
4.3.3 Receive data path	121
4.3.4 State machines and SAS Device, SAS Port, and SAS Phy classes	125
4.4 Events	126
4.4.1 Reset sequences	126
4.4.2 Hard reset	128
4.4.2.1 Hard reset overview	128
4.4.2.2 Additional hard reset processing by SAS ports	128
4.4.2.3 Additional hard reset processing by expander ports	128
4.4.3 I_T nexus loss	128
4.4.4 Power loss expected	129
4.5 Expander device model	129
4.5.1 Expander device model overview	129
4.5.2 Expander ports	131
4.5.3 Expander connection manager (ECM)	131
4.5.4 Expander connection router (ECR)	131
4.5.5 Broadcast propagation processor (BPP)	132
4.5.6 Expander device interfaces	132
4.5.6.1 Expander device interface overview	132
4.5.6.2 Expander device interfaces detail	134
4.5.6.3 ECM interface	135
4.5.6.4 ECR interface	137
4.5.6.5 BPP interface	138
4.5.7 Expander device routing	140
4.5.7.1 Routing attributes and routing methods	140
4.5.7.2 Expander device topology routing attribute restrictions	140
4.5.7.3 Connection request routing	141
4.5.7.4 Expander route table	141
4.5.7.4.1 Expander route table overview	141
4.5.7.4.2 Phy-based expander route table	142
4.5.7.4.3 Expander-based expander route table	143
4.5.8 Expander device reduced functionality	143
4.5.9 Broadcast (Expander) handling	144
4.6 Discover process	144
4.6.1 Discover process overview	144
4.6.2 Starting the discover process (Broadcast (Change) handling)	144
4.6.3 Discover process traversal	144
4.6.4 Discover process in a self-configuring expander device	146
4.6.5 Enabling multiplexing	147
4.7 Configuration subprocess	147
4.7.1 Configuration subprocess overview	147
4.7.2 Allowed expander device topologies	148
4.7.3 Externally configurable expander device route table optimization	149
4.7.4 Externally configurable expander device expander route index order	150
4.8 Zoning	157
4.8.1 Zoning overview	157
4.8.2 Zoning expander device requirements	161
4.8.3 Zoning operation	164
4.8.3.1 Zone phy information	164
4.8.3.2 Zone groups	166
4.8.3.3 Zone permission table	166
4.8.3.4 Zoning expander route table	168
4.8.3.5 Source zone group and destination zone group determination	169
4.8.4 Zone phy information and link reset sequences	169
4.8.5 Broadcast processing in a zoning expander device with zoning enabled	172
4.8.6 Zone configuration	172
4.8.6.1 Zone configuration overview	172
4.8.6.2 Lock step	173

4.8.6.3 Load step.....	173
4.8.6.4 Activate step.....	174
4.8.6.5 Unlock step.....	174
4.8.6.6 Zone lock inactivity timer	175
4.8.6.7 Enable a zoning expander device	175
4.9 SAS device and expander device power conditions.....	176
4.10 Phy power conditions	176
4.10.1 Low phy power conditions.....	176
4.10.1.1 Low phy power conditions overview.....	176
4.10.1.2 Active phy power condition.....	176
4.10.1.3 Partial phy power condition	176
4.10.1.4 Slumber phy power condition	177
4.10.1.5 End device low phy power conditions	177
4.10.1.6 Expander device low phy power conditions	177
4.10.2 SATA phy power conditions.....	178
4.11 Phy test functions	178
4.11.1 Phy test functions overview	178
4.11.2 Transmit pattern phy test function.....	179
4.12 Phy events.....	179
 5 Phy layer	184
5.1 Phy layer overview	184
5.2 8b10b coding	184
5.2.1 8b10b coding overview	184
5.2.2 8b10b coding notation conventions	184
5.3 Character encoding and decoding.....	185
5.3.1 Introduction	185
5.3.2 Bit transmission order	185
5.3.3 Character transmission order.....	185
5.3.4 Frame transmission order	185
5.3.5 Running disparity (RD).....	186
5.3.6 Data characters.....	186
5.3.7 Control characters.....	191
5.3.8 Encoding characters in the transmitter	192
5.3.9 Decoding characters in the receiver	193
5.4 Dwords, primitives, data dwords, and invalid dwords.....	193
5.5 Bit order	193
5.6 Out of band (OOB) signals	195
5.6.1 OOB signals overview.....	195
5.6.2 SP Transmission of OOB signals.....	195
5.6.3 Receiver detection of OOB signals	196
5.6.4 SATA port selection signal.....	198
5.6.5 Phy power conditions.....	199
5.7 Phy capabilities bits	199
5.8 BMC coding	203
5.8.1 BMC coding overview	203
5.8.2 TTIU bit cell encoding in the transmitter	204
5.8.3 TTIU bit transmission order.....	205
5.8.4 TTIU bit cell decoding in the receiver.....	205
5.9 Train_Tx-SNW TTIUs	206
5.9.1 Train_Tx-SNW TTIU format	206
5.9.2 Control/Status TTIU	207
5.9.3 Error Response TTIU	211
5.10 Phy reset sequences	213
5.10.1 Phy reset sequences overview	213
5.10.2 SATA phy reset sequence	214
5.10.2.1 SATA OOB sequence	214
5.10.2.2 SATA speed negotiation sequence	215

5.10.3 SAS to SATA phy reset sequence	216
5.10.4 SAS to SAS phy reset sequence	217
5.10.4.1 SAS OOB sequence.....	217
5.10.4.2 SAS speed negotiation sequence	219
5.10.4.2.1 SAS speed negotiation sequence overview	219
5.10.4.2.2 SAS speed negotiation sequence timing specifications	219
5.10.4.2.3 Speed negotiation window (SNW) definitions.....	221
5.10.4.2.3.1 SNW definitions overview	221
5.10.4.2.3.2 SNW-1, SNW-2, and Final-SNW	221
5.10.4.2.3.3 SNW-3.....	223
5.10.4.2.3.4 Train_Tx-SNW	224
5.10.4.2.3.4.1 Phy's transmitter initial condition	224
5.10.4.2.3.4.2 Transmitter training.....	224
5.10.4.2.3.4.3 Pattern marker.....	226
5.10.4.2.3.5 Train_Rx-SNW	227
5.10.4.2.4 SAS speed negotiation sequence.....	230
5.10.4.2.5 SAS speed negotiation sequence examples	231
5.10.4.2.6 Train_Tx pattern sequence.....	239
5.10.4.2.6.1 Train_Tx pattern sequence overview	239
5.10.4.2.6.2 Train_Tx pattern initial sequence.....	239
5.10.4.2.6.3 Train_Tx pattern handshake sequence.....	243
5.10.4.2.6.3.1 Train_Tx pattern handshake sequence overview	243
5.10.4.2.6.3.2 Attached phy's receiver increment or decrement request	243
5.10.4.2.6.3.3 Attached phy's receiver reference_1, reference_2, or no_equalization request	246
5.10.4.2.6.4 Train_Tx pattern completion sequence	248
5.10.4.2.6.5 Invalid TTIU sequence	251
5.10.4.3 Multiplexing sequence.....	252
5.10.5 Phy reset sequence after devices are attached.....	253
5.11 Phy power condition sequences.....	254
5.11.1 Transitioning from the active phy power condition to a low phy power condition	254
5.11.2 Transitioning from a low phy power condition to the active phy power condition	254
5.11.3 Events during low phy power condition.....	255
5.12 SP (phy layer) state machine	256
5.12.1 SP state machine overview.....	256
5.12.2 SP transmitter and SP receiver.....	259
5.12.3 OOB sequence states.....	262
5.12.3.1 OOB sequence states overview	262
5.12.3.2 SP0:OOB_COMINIT state.....	263
5.12.3.2.1 State description	263
5.12.3.2.2 Transition SP0:OOB_COMINIT to SP1:OOB_AwaitCOMX.....	264
5.12.3.2.3 Transition SP0:OOB_COMINIT to SP3:OOB_AwaitCOMINIT_Sent.....	264
5.12.3.2.4 Transition SP0:OOB_COMINIT to SP4:OOB_COMSAS.....	264
5.12.3.3 SP1:OOB_AwaitCOMX state	264
5.12.3.3.1 State description	264
5.12.3.3.2 Transition SP1:OOB_AwaitCOMX to SP0:OOB_COMINIT	264
5.12.3.3.3 Transition SP1:OOB_AwaitCOMX to SP4:OOB_COMSAS	264
5.12.3.4 SP2:OOB_NoCOMSASTimeout state.....	264
5.12.3.4.1 State description	264
5.12.3.4.2 Transition SP2:OOB_NoCOMSASTimeout to SP0:OOB_COMINIT	265
5.12.3.4.3 Transition SP2:OOB_NoCOMSASTimeout to SP4:OOB_COMSAS	265
5.12.3.5 SP3:OOB_AwaitCOMINIT_Sent state	265
5.12.3.5.1 State description	265
5.12.3.5.2 Transition SP3:OOB_AwaitCOMINIT_Sent to SP4:OOB_COMSAS	265
5.12.3.6 SP4:OOB_COMSAS state	265
5.12.3.6.1 State description	265
5.12.3.6.2 Transition SP4:OOB_COMSAS to SP5:OOB_AwaitCOMSAS_Sent	265
5.12.3.6.3 Transition SP4:OOB_COMSAS to SP6:OOB_AwaitNoCOMSAS	265
5.12.3.6.4 Transition SP4:OOB_COMSAS to SP7:OOB_AwaitCOMSAS	266

5.12.3.7 SP5:OOB_AwaitCOMSAS_Sent state	266
5.12.3.7.1 State description	266
5.12.3.7.2 Transition SP5:OOB_AwaitCOMSAS_Sent to SP6:OOB_AwaitNoCOMSAS	266
5.12.3.8 SP6:OOB_AwaitNoCOMSAS state	266
5.12.3.8.1 State description	266
5.12.3.8.2 Transition SP6:OOB_AwaitNoCOMSAS to SP0:OOB_COMINIT	266
5.12.3.8.3 Transition SP6:OOB_AwaitNoCOMSAS to SP8:SAS_Start	266
5.12.3.9 SP7:OOB_AwaitCOMSAS state	266
5.12.3.9.1 State description	266
5.12.3.9.2 Transition SP7:OOB_AwaitCOMSAS to SP2:OOB_NoCOMSASTimeout	266
5.12.3.9.3 Transition SP7:OOB_AwaitCOMSAS to SP6:OOB_AwaitNoCOMSAS	266
5.12.3.9.4 Transition SP7:OOB_AwaitCOMSAS to SP16:SATA_COMWAKE	266
5.12.3.9.5 Transition SP7:OOB_AwaitCOMSAS to SP26:SATA_SpinupHold	267
5.12.4 SAS speed negotiation states	267
5.12.4.1 SAS speed negotiation states overview	267
5.12.4.2 Negotiation idle	267
5.12.4.3 SP8:SAS_Start state	270
5.12.4.3.1 State description	270
5.12.4.3.2 Transition SP8:SAS_Start to SP0:OOB_COMINIT	270
5.12.4.3.3 Transition SP8:SAS_Start to SP1:OOB_AwaitCOMX	270
5.12.4.3.4 Transition SP8:SAS_Start to SP9:SAS_WindowNotSupported	271
5.12.4.3.5 Transition SP8:SAS_Start to SP10:SAS_AwaitALIGN	271
5.12.4.3.6 Transition SP8:SAS_Start to SP27:SAS_Settings	271
5.12.4.4 SP9:SAS_WindowNotSupported state	271
5.12.4.4.1 State description	271
5.12.4.4.2 Transition SP9:SAS_WindowNotSupported to SP0:OOB_COMINIT	271
5.12.4.4.3 Transition SP9:SAS_WindowNotSupported to SP14:SAS_Fail	271
5.12.4.5 SP10:SAS_AwaitALIGN state	271
5.12.4.5.1 State description	271
5.12.4.5.2 Transition SP10:SAS_AwaitALIGN to SP0:OOB_COMINIT	271
5.12.4.5.3 Transition SP10:SAS_AwaitALIGN to SP11:SAS_AwaitALIGN1	271
5.12.4.5.4 Transition SP10:SAS_AwaitALIGN to SP12:SAS_AwaitSNW	272
5.12.4.5.5 Transition SP10:SAS_AwaitALIGN to SP14:SAS_Fail	272
5.12.4.6 SP11:SAS_AwaitALIGN1 state	272
5.12.4.6.1 State description	272
5.12.4.6.2 Transition SP11:SAS_AwaitALIGN1 to SP0:OOB_COMINIT	272
5.12.4.6.3 Transition SP11:SAS_AwaitALIGN1 to SP12:SAS_AwaitSNW	272
5.12.4.6.4 Transition SP11:SAS_AwaitALIGN1 to SP14:SAS_Fail	272
5.12.4.7 SP12:SAS_AwaitSNW state	272
5.12.4.7.1 State description	272
5.12.4.7.2 Transition SP12:SAS_AwaitSNW to SP0:OOB_COMINIT	272
5.12.4.7.3 Transition SP12:SAS_AwaitSNW to SP13:SAS_Pass	272
5.12.4.8 SP13:SAS_Pass state	273
5.12.4.8.1 State description	273
5.12.4.8.2 Transition SP13:SAS_Pass to SP0:OOB_COMINIT	273
5.12.4.8.3 Transition SP13:SAS_Pass to SP8:SAS_Start	273
5.12.4.8.4 Transition SP13:SAS_Pass to SP15:SAS_PHY_Ready	273
5.12.4.9 SP14:SAS_Fail state	273
5.12.4.9.1 State description	273
5.12.4.9.2 Transition SP14:SAS_Fail to SP1:OOB_AwaitCOMX	273
5.12.4.9.3 Transition SP14:SAS_Fail to SP8:SAS_Start	273
5.12.4.10 SP15:SAS_PHY_Ready state	273
5.12.4.10.1 State description	273
5.12.4.10.2 Transition SP15:SAS_PHY_Ready to SP0:OOB_COMINIT	274
5.12.4.10.3 Transition SP15:SAS_PHY_Ready to SP31:SAS_PS_Low_Phys_Power	274
5.12.4.11 SP27:SAS_Settings state	274
5.12.4.11.1 State description	274
5.12.4.11.2 Transition SP27:SAS_Settings to SP0:OOB_COMINIT	274

5.12.4.11.3 Transition SP27:SAS_Settings to SP1:OOB_AwaitCOMX.....	275
5.12.4.11.4 Transition SP27:SAS_Settings to SP8:SAS_Start	275
5.12.4.11.5 Transition SP27:SAS_Settings to SP28:SAS_TrainSetup	275
5.12.4.12 SP28:SAS_TrainSetup.....	275
5.12.4.12.1 State description	275
5.12.4.12.2 Transition SP28:SAS_TrainSetup to SP0:OOB_COMINIT	275
5.12.4.12.3 Transition SP28:SAS_TrainSetup to SP29:SAS_Train_Rx.....	276
5.12.4.12.4 Transition SP28:SAS_TrainSetup to SP34:SAS_Train_Tx	276
5.12.4.13 SP34:SAS_Train_Tx state	276
5.12.4.13.1 State description	276
5.12.4.13.2 Transition SP34:SAS_Train_Tx to SP1:OOB_AwaitCOMX	276
5.12.4.13.3 Transition SP34:SAS_Train_Tx to SP28:SAS_TrainSetup	276
5.12.4.13.4 Transition SP34:SAS_Train_Tx to SP29:SAS_Train_Rx	277
5.12.4.14 SP29:SAS_Train_Rx state	277
5.12.4.14.1 State description	277
5.12.4.14.2 Transition SP29:SAS_Train_Rx to SP0:OOB_COMINIT	277
5.12.4.14.3 Transition SP29:SAS_Train_Rx to SP1:OOB_AwaitCOMX	277
5.12.4.14.4 Transition SP29:SAS_Train_Rx to SP28:SAS_TrainSetup	277
5.12.4.14.5 Transition SP29:SAS_Train_Rx to SP30:SAS_TrainingDone.....	278
5.12.4.15 SP30:SAS_TrainingDone state	278
5.12.4.15.1 State description	278
5.12.4.15.2 Transition SP30:SAS_TrainingDone to SP0:OOB_COMINIT	278
5.12.4.15.3 Transition SP30:SAS_TrainingDone to SP1:OOB_AwaitCOMX	278
5.12.4.15.4 Transition SP30:SAS_TrainingDone to SP28:SAS_TrainSetup	278
5.12.4.15.5 Transition SP30:SAS_TrainingDone to SP15:SAS_PHY_Ready	279
5.12.5 SAS phy power conditions states	279
5.12.5.1 SAS phy power conditions states overview.....	279
5.12.5.2 SP31:SAS_PS_Low_Phys_Power state	280
5.12.5.2.1 State description	280
5.12.5.2.2 Transition SP31:SAS_PS_Low_Phys_Power to SP0:OOB_COMINIT	281
5.12.5.2.3 Transition SP31:SAS_PS_Low_Phys_Power to SP32:SAS_PS_ALIGN0.....	281
5.12.5.3 SP32:SAS_PS_ALIGN0 state	281
5.12.5.3.1 State description	281
5.12.5.3.2 Transition SP32:SAS_PS_ALIGN0 state to SP0:OOB_COMINIT	281
5.12.5.3.3 Transition SP32:SAS_PS_ALIGN0 to SP33:SAS_PS_ALIGN1	281
5.12.5.4 SP33:SAS_PS_ALIGN1 state	282
5.12.5.4.1 State description	282
5.12.5.4.2 Transition SP33:SAS_PS_ALIGN1 state to SP0:OOB_COMINIT	282
5.12.5.4.3 Transition SP33:SAS_PS_ALIGN1 state to SP15:SAS_PHY_Ready	282
5.12.6 SATA host emulation states.....	282
5.12.6.1 SATA host emulation states overview	282
5.12.6.2 SP16:SATA_COMWAKE state	283
5.12.6.2.1 State description	283
5.12.6.2.2 Transition SP16:SATA_COMWAKE to SP0:OOB_COMINIT	284
5.12.6.2.3 Transition SP16:SATA_COMWAKE to SP17:SATA_AwaitCOMWAKE	284
5.12.6.3 SP17:SATA_AwaitCOMWAKE state	284
5.12.6.3.1 State description	284
5.12.6.3.2 Transition SP17:SATA_AwaitCOMWAKE to SP0:OOB_COMINIT	284
5.12.6.3.3 Transition SP17:SATA_AwaitCOMWAKE to SP18:SATA_AwaitNoCOMWAKE	284
5.12.6.4 SP18:SATA_AwaitNoCOMWAKE state	284
5.12.6.4.1 State description	284
5.12.6.4.2 Transition SP18:SATA_AwaitNoCOMWAKE to SP0:OOB_COMINIT	284
5.12.6.4.3 Transition SP18:SATA_AwaitNoCOMWAKE to SP19:SATA_AwaitALIGN	284
5.12.6.5 SP19:SATA_AwaitALIGN state	284
5.12.6.5.1 State description	284
5.12.6.5.2 Transition SP19:SATA_AwaitALIGN to SP0:OOB_COMINIT	284
5.12.6.5.3 Transition SP19:SATA_AwaitALIGN to SP20:SATA_AdjustSpeed	285
5.12.6.6 SP20:SATA_AdjustSpeed state	285

5.12.6.6.1 State description	285	
5.12.6.6.2 Transition SP20:SATA_AdjustSpeed to SP0:OOB_COMINIT	285	
5.12.6.6.3 Transition SP20:SATA_AdjustSpeed to SP21:SATA_TransmitALIGN	285	
5.12.6.7 SP21:SATA_TransmitALIGN state.....	285	
5.12.6.7.1 State description	285	
5.12.6.7.2 Transition SP21:SATA_TransmitALIGN to SP0:OOB_COMINIT	285	
5.12.6.7.3 Transition SP21:SATA_TransmitALIGN to SP22:SATA_PHY_Ready	285	
5.12.6.8 SP22:SATA_PHY_Ready state.....	286	
5.12.6.8.1 State description	286	
5.12.6.8.2 Transition SP22:SATA_PHY_Ready to SP0:OOB_COMINIT	286	
5.12.6.8.3 Transition SP22:SATA_PHY_Ready to SP23:SATA_PM_Partial	286	
5.12.6.8.4 Transition SP22:SATA_PHY_Ready to SP24:SATA_PM_Slumber	286	
5.12.6.9 SP23:SATA_PM_Partial state.....	286	
5.12.6.9.1 State description	286	
5.12.6.9.2 Transition SP23:SATA_PM_Partial to SP0:OOB_COMINIT	286	
5.12.6.9.3 Transition SP23:SATA_PM_Partial to SP16:SATA_COMWAKE	286	
5.12.6.9.4 Transition SP23:SATA_PM_Partial to SP19:SATA_AwaitALIGN	287	
5.12.6.10 SP24:SATA_PM_Slumber state.....	287	
5.12.6.10.1 State description	287	
5.12.6.10.2 Transition SP24:SATA_PM_Slumber to SP0:OOB_COMINIT	287	
5.12.6.10.3 Transition SP24:SATA_PM_Slumber to SP16:SATA_COMWAKE	287	
5.12.6.10.4 Transition SP24:SATA_PM_Slumber to SP19:SATA_AwaitALIGN	287	
5.12.7 SATA port selector state SP25:SATA_PortSel.....	288	
5.12.7.1 State description.....	288	
5.12.7.2 Transition SP25:SATA_PortSel to SP1:OOB_AwaitCOMX	288	
5.12.8 SATA spinup hold state SP26:SATA_SpinupHold.....	289	
5.12.8.1 State description.....	289	
5.12.8.2 Transition SP26:SATA_SpinupHold to SP0:OOB_COMINIT	289	
5.13 SP_DWS (phy layer dword synchronization) state machine	289	
5.13.1 SP_DWS state machine overview	289	
5.13.2 SP_DWS receiver	https://standards.iteh.ai/catalog/standards/sist/0262a445-0a6b-4647-a537-87e3ac152c5a/iso-iec-14776-262-2017	291
5.13.3 SP_DWS0:AcquireSync state.....	292	
5.13.3.1 State description.....	292	
5.13.3.2 Transition SP_DWS0:AcquireSync to SP_DWS1:Valid1	292	
5.13.4 SP_DWS1:Valid1 state	292	
5.13.4.1 State description.....	292	
5.13.4.2 Transition SP_DWS1:Valid1 to SP_DWS0:AcquireSync	293	
5.13.4.3 Transition SP_DWS1:Valid1 to SP_DWS2:Valid2	293	
5.13.5 SP_DWS2:Valid2 state	293	
5.13.5.1 State description.....	293	
5.13.5.2 Transition SP_DWS2:Valid2 to SP_DWS0:AcquireSync	293	
5.13.5.3 Transition SP_DWS2:Valid2 to SP_DWS3:SyncAcquired	293	
5.13.6 SP_DWS3:SyncAcquired state	293	
5.13.6.1 State description.....	293	
5.13.6.2 Transition SP_DWS3:SyncAcquired to SP_DWS0:AcquireSync	293	
5.13.6.3 Transition SP_DWS3:SyncAcquired to SP_DWS4:Lost1	293	
5.13.7 SP_DWS4:Lost1 state	293	
5.13.7.1 State description.....	293	
5.13.7.2 Transition SP_DWS4:Lost1 to SP_DWS0:AcquireSync	293	
5.13.7.3 Transition SP_DWS4:Lost1 to SP_DWS5:Lost1Recovered	294	
5.13.7.4 Transition SP_DWS4:Lost1 to SP_DWS6:Lost2.....	294	
5.13.8 SP_DWS5:Lost1Recovered state	294	
5.13.8.1 State description.....	294	
5.13.8.2 Transition SP_DWS5:Lost1Recovered to SP_DWS0:AcquireSync	294	
5.13.8.3 Transition SP_DWS5:Lost1Recovered to SP_DWS3:SyncAcquired	294	
5.13.8.4 Transition SP_DWS5:Lost1Recovered to SP_DWS6:Lost2	294	
5.13.9 SP_DWS6:Lost2 state	294	
5.13.9.1 State description.....	294	

5.13.9.2 Transition SP_DWS6:Lost2 to SP_DWS0:AcquireSync	294
5.13.9.3 Transition SP_DWS6:Lost2 to SP_DWS7:Lost2Recovered	294
5.13.9.4 Transition SP_DWS6:Lost2 to SP_DWS8:Lost3.....	294
5.13.10 SP_DWS7:Lost2Recovered state	294
5.13.10.1 State description.....	294
5.13.10.2 Transition SP_DWS7:Lost2Recovered to SP_DWS0:AcquireSync	295
5.13.10.3 Transition SP_DWS7:Lost2Recovered to SP_DWS4:Lost1	295
5.13.10.4 Transition SP_DWS7:Lost2Recovered to SP_DWS8:Lost3	295
5.13.11 SP_DWS8:Lost3 state	295
5.13.11.1 State description.....	295
5.13.11.2 Transition SP_DWS8:Lost3 to SP_DWS0:AcquireSync	295
5.13.11.3 Transition SP_DWS8:Lost3 to SP_DWS9:Lost3Recovered	295
5.13.12 SP_DWS9:Lost3Recovered state	295
5.13.12.1 State description.....	295
5.13.12.2 Transition SP_DWS9:Lost3Recovered to SP_DWS0:AcquireSync	295
5.13.12.3 Transition SP_DWS9:Lost3Recovered to SP_DWS6:Lost2	295
5.14 PTT (phy layer transmitter training) state machines	295
5.14.1 PTT state machines overview.....	295
5.14.2 SP transmitter additions for transmitter training	296
5.14.2.1 SP transmitter additions for transmitter training overview	296
5.14.2.2 TTIU transmit setup.....	296
5.14.2.3 No_equalization, reference_1, and reference_2 coefficient settings request.....	297
5.14.2.4 Coefficient limits	297
5.14.2.5 Coefficient request result of update complete	297
5.14.2.5.1 Coefficient request processing	297
5.14.2.5.2 Coefficient adjustment completes	297
5.14.2.5.3 No coefficient adjustment	298
5.14.2.6 Coefficient request result of maximum	298
5.14.2.6.1 Coefficient request processing	298
5.14.2.6.2 Coefficient adjustment completes	298
5.14.2.6.3 No coefficient adjustment	298
5.14.2.7 Coefficient request result of minimum	299
5.14.2.7.1 Coefficient request processing	299
5.14.2.7.2 Coefficient adjustment completes	299
5.14.2.7.3 No coefficient adjustment	299
5.14.3 SP receiver additions for transmitter training	299
5.14.4 PTT_T (phy layer transmitter training transmit pattern) state machine	300
5.14.4.1 PTT_T state machine overview	300
5.14.4.2 PTT_T0:Idle state	303
5.14.4.2.1 State description	303
5.14.4.2.2 Transition PTT_T0:Idle to PTT_T1:Initialize	303
5.14.4.3 PTT_T1:Initialize state	303
5.14.4.3.1 State description	303
5.14.4.3.2 Transition PTT_T1:Initialize to PTT_T0:Idle	303
5.14.4.3.3 Transition PTT_T1:Initialize to PTT_T2:Tx_Training	304
5.14.4.4 PTT_T2:Tx_Training state	304
5.14.4.4.1 State description	304
5.14.4.4.2 Entry conditions	304
5.14.4.4.3 Control word and status word mappings	304
5.14.4.4.4 Error message handling.....	305
5.14.4.4.5 Resetting attached phy's transmitter	306
5.14.4.4.6 Local phy's transmitter and attached phy's transmitter training completed	307
5.14.4.4.7 Transition PTT_T2:Tx_Training to PTT_T0:Idle	307
5.14.4.4.8 Transition PTT_T2:Tx_Training to PTT_T3:Local_Tx_Training	307
5.14.4.5 PTT_T3:Local_Tx_Training state	308
5.14.4.5.1 State description	308
5.14.4.5.2 Entry conditions	308
5.14.4.5.3 Status word mappings	308

5.14.4.5.4 Local phy's transmitter and attached phy's transmitter training completed	308
5.14.4.5.5 Error message handling.....	308
5.14.4.5.6 Transition PTT_T3:Local_Tx_Training to PTT_T0:Idle.....	309
5.14.5 PTT_R (phy layer transmitter training receive pattern) state machine.....	309
5.14.5.1 PTT_R0:Idle state	311
5.14.5.1.1 State description	311
5.14.5.1.2 Transition PTT_R0:Idle to PTT_R1:Initialize	311
5.14.5.2 PTT_R1:Initialize state	311
5.14.5.2.1 State description	311
5.14.5.2.2 Transition PTT_R1:Initialize to PTT_R0:Idle	311
5.14.5.2.3 Transition PTT_R1:Initialize to PTT_R2:Receive_Tx_Pattern	311
5.14.5.3 PTT_R2:Receive_Tx_Pattern state	311
5.14.5.3.1 State description	311
5.14.5.3.2 Transition PTT_R2:Receive_Tx_Pattern to PTT_R0:Idle.....	317
5.14.5.3.3 Transition PTT_R2:Receive_Tx_Pattern to PTT_R1:Initialize	317
5.14.6 PTT_SC (phy layer transmitter training set transmitter coefficient) state machines	317
5.14.6.1 PTT_SC (phy layer transmitter training set transmitter coefficient) state machines overview	317
5.14.6.2 PTT_SC1 state machine overview	319
5.14.6.3 PTT_SC1_0:Idle state	319
5.14.6.3.1 State description	319
5.14.6.3.2 Transition PTT_SC1_0:Idle to PTT_SC1_1:Wait_Inc_Dec	319
5.14.6.4 PTT_SC1_1:Wait_Inc_Dec state	319
5.14.6.4.1 State description	319
5.14.6.4.2 Transition PTT_SC1_1:Wait_Inc_Dec to PTT_SC1_0:Idle	319
5.14.6.4.3 Transition PTT_SC1_1:Wait_Inc_Dec to PTT_SC1_2:Set_Coefficient.....	319
5.14.6.5 PTT_SC1_2:Set_Coefficient state	320
5.14.6.5.1 State description	320
5.14.6.5.2 Transition PTT_SC1_2:Set_Coefficient to PTT_SC1_0:Idle	320
5.14.6.5.3 Transition PTT_SC1_2:Set_Coefficient to PTT_SC1_3:Wait_Hold	321
5.14.6.6 PTT_SC1_3:Wait_Hold state	321
5.14.6.6.1 State description	321
5.14.6.6.2 Transition PTT_SC1_3:Wait_Hold to PTT_SC1_0:Idle	321
5.14.6.6.3 Transition PTT_SC1_3:Wait_Hold to PTT_SC1_1:Wait_Inc_Dec	321
5.14.7 PTT_SC2 (phy layer transmitter training set transmitter coefficient 2) state machine	321
5.14.8 PTT_SC3 (phy layer transmitter training set transmitter coefficient 3) state machine	321
5.14.9 PTT_GC (phy layer transmitter training get transmitter coefficient) state machines.....	322
5.14.9.1 PTT_GC (phy layer transmitter training get transmitter coefficient) state machines overview	322
5.14.9.2 PTT_GC1 state machine	323
5.14.9.3 PTT_GC1_0:Idle state.....	323
5.14.9.3.1 State description	323
5.14.9.3.2 Transition PTT_GC1_0:Idle to PTT_GC1_1:Get_Coefficient	324
5.14.9.4 PTT_GC1_1:Get_Coefficient state.....	324
5.14.9.4.1 State description	324
5.14.9.4.2 Transition PTT_GC1_1:Get_Coefficient to PTT_GC1_0:Idle	324
5.14.9.4.3 Transition PTT_GC1_1:Get_Coefficient to PTT_GC1_2:Wait_Restart	324
5.14.9.5 PTT_GC1_2:Wait_Restart state.....	324
5.14.9.5.1 State description	324
5.14.9.5.2 Transition PTT_GC1_2:Wait_Restart to PTT_GC1_0:Idle	325
5.14.10 PTT_GC2 (phy layer transmitter training get transmitter coefficient 2) state machine	325
5.14.11 PTT_GC3 (phy layer transmitter training get transmitter coefficient 3) state machine	325
5.14.12 PTT_PL (phy layer transmitter training pattern lock) state machine	325
5.14.12.1 PTT_PL state machine overview.....	325
5.14.12.2 PTT_PL0:Idle state.....	327
5.14.12.2.1 State description	327
5.14.12.2.2 Transition PTT_PL0:Idle to PTT_PL1:Acquire_Lock	328
5.14.12.3 PTT_PL1:Acquire_Lock state.....	328
5.14.12.3.1 State description	328
5.14.12.3.2 Transition PTT_PL1:Acquire_Lock to PTT_PL2:Valid.....	328

5.14.12.4 PTT_PL2:Valid state	328
5.14.12.4.1 State description	328
5.14.12.4.2 Transition PTT_PL2:Valid to PTT_PL1:Acquire_Lock.....	328
5.14.12.4.3 Transition PTT_PL2:Valid to PTT_PL3:Lock_Acquired.....	328
5.14.12.5 PTT_PL3:Lock_Acquired state.....	328
5.14.12.5.1 State description	328
5.14.12.5.2 Transition PTT_PL3:Lock_Acquired to PTT_PL4:Lost1	328
5.14.12.6 PTT_PL4:Lost1 state.....	328
5.14.12.6.1 State description	328
5.14.12.6.2 Transition PTT_PL4:Lost1 to PTT_PL3:Lock_Acquired	329
5.14.12.6.3 Transition PTT_PL4:Lost1 to PTT_PL5:Lost2	329
5.14.12.7 PTT_PL5:Lost2 state.....	329
5.14.12.7.1 State description	329
5.14.12.7.2 Transition PTT_PL5:Lost2 to PTT_PL3:Lock_Acquired	329
5.14.12.7.3 Transition PTT_PL5:Lost2 to PTT_PL6:Lost3	329
5.14.12.8 PTT_PL6:Lost3 state.....	329
5.14.12.8.1 State description	329
5.14.12.8.2 Transition PTT_PL6:Lost3 to PTT_PL3:Lock_Acquired	329
5.14.12.8.3 Transition PTT_PL6:Lost3 to PTT_PL7:Lost4	329
5.14.12.9 PTT_PL7:Lost4 state.....	329
5.14.12.9.1 State description	329
5.14.12.9.2 Transition PTT_PL7:Lost4 to PTT_PL3:Lock_Acquired	329
5.14.12.9.3 Transition PTT_PL7:Lost4 to PTT_PL1:Acquire_Lock	330
5.15 Multiplexing.....	330
5.16 Spinup	331

iTeh STANDARD PREVIEW

6 Link layer.....	332
6.1 Link layer overview	332
6.2 Primitives	332
6.2.1 Primitives overview	332
6.2.2 Primitive summary	333
6.2.3 Primitive encodings	338
6.2.4 Primitive sequences.....	343
6.2.4.1 Primitive sequences overview	343
6.2.4.2 Single primitive sequence	343
6.2.4.3 Repeated primitive sequence	343
6.2.4.4 Continued primitive sequence	344
6.2.4.5 Extended primitive sequence	344
6.2.4.6 Triple primitive sequence	345
6.2.4.7 Redundant primitive sequence.....	346
6.2.5 Deletable primitives.....	347
6.2.5.1 ALIGN.....	347
6.2.5.2 MUX (Multiplex).....	348
6.2.5.3 NOTIFY	349
6.2.5.3.1 NOTIFY overview	349
6.2.5.3.2 NOTIFY (ENABLE SPINUP).....	349
6.2.5.3.3 NOTIFY (POWER LOSS EXPECTED).....	350
6.2.5.4 OOB_IDLE	351
6.2.6 Primitives not specific to type of connections	351
6.2.6.1 AIP (Arbitration in progress).....	351
6.2.6.2 BREAK	351
6.2.6.3 BREAK_REPLY	351
6.2.6.4 BROADCAST	352
6.2.6.5 CLOSE	352
6.2.6.6 EOAF (End of address frame).....	352
6.2.6.7 ERROR	353
6.2.6.8 HARD_RESET	353
6.2.6.9 OPEN_ACCEPT.....	353

6.2.6.10 OPEN_REJECT	353
6.2.6.11 PS_ACK	356
6.2.6.12 PS_NAK	356
6.2.6.13 PS_REQ	356
6.2.6.14 PWR_ACK	356
6.2.6.15 PWR_DONE	356
6.2.6.16 PWR_GRANT	356
6.2.6.17 PWR_REQ	356
6.2.6.18 SOAF (Start of address frame)	356
6.2.6.19 TRAIN	357
6.2.6.20 TRAIN_DONE	357
6.2.7 Primitives used only inside SSP and SMP connections	357
6.2.7.1 ACK (Acknowledge)	357
6.2.7.2 CREDIT_BLOCKED	357
6.2.7.3 DONE	357
6.2.7.4 EOF (End of frame)	358
6.2.7.5 NAK (Negative acknowledgement)	358
6.2.7.6 RRDY (Receiver ready)	358
6.2.7.7 SOF (Start of frame)	358
6.2.8 Primitives used only inside STP connections and on SATA physical links	358
6.2.8.1 SATA_ERROR	358
6.2.8.2 SATA_PMACK, SATA_PMNAK, SATA_PMREQ_P, and SATA_PMREQ_S (Power management acknowledgements and requests)	359
6.2.8.3 SATA_HOLD and SATA_HOLDA (Hold and hold acknowledge)	359
6.2.8.4 SATA_R_RDY and SATA_X_RDY (Receiver ready and transmitter ready)	359
6.2.8.5 Other primitives used inside STP connections and on SATA physical links	359
6.3 Physical link rate tolerance management	359
6.3.1 Physical link rate tolerance management overview	359
6.3.2 Phys originating dwords	360
6.3.3 Expander phys forwarding dwords	361
6.4 Idle physical links	362
6.5 CRC	362
6.5.1 CRC overview	362
6.5.2 CRC generation	364
6.5.3 CRC checking	366
6.6 Scrambling	367
6.7 Bit order of CRC and scrambler	369
6.8 Address frames	372
6.8.1 Address frames overview	372
6.8.2 IDENTIFY address frame	374
6.8.3 OPEN address frame	378
6.9 Link reset sequence	381
6.9.1 Link reset sequence overview	381
6.9.2 Expander device handling of link reset sequences	384
6.10 SL_IR (link layer identification and hard reset) state machines	384
6.10.1 SL_IR state machines overview	384
6.10.2 SL_IR transmitter and receiver	386
6.10.3 SL_IR_TIR (transmit IDENTIFY or HARD_RESET) state machine	386
6.10.3.1 SL_IR_TIR state machine overview	386
6.10.3.2 SL_IR_TIR1:Idle state	387
6.10.3.2.1 State description	387
6.10.3.2.2 Transition SL_IR_TIR1:Idle to SL_IR_TIR2:Transmit_Identify	387
6.10.3.2.3 Transition SL_IR_TIR1:Idle to SL_IR_TIR3:Transmit_Hard_Reset	387
6.10.3.3 SL_IR_TIR2:Transmit_Identify state	387
6.10.3.3.1 State description	387
6.10.3.3.2 Transition SL_IR_TIR2:Transmit_Identify to SL_IR_TIR4:Completed	387
6.10.3.4 SL_IR_TIR3:Transmit_Hard_Reset state	387
6.10.3.4.1 State description	387

6.10.3.4.2 Transition SL_IR_TIR3:Transmit_Hard_Reset to SL_IR_TIR4:Completed	387
6.10.3.5 SL_IR_TIR4:Completed state	387
6.10.4 SL_IR_RIF (receive IDENTIFY address frame) state machine	388
6.10.4.1 SL_IR_RIF state machine overview	388
6.10.4.2 SL_IR_RIF1:Idle state	388
6.10.4.2.1 State description	388
6.10.4.2.2 Transition SL_IR_RIF1:Idle to SL_IR_RIF2:Receive_Identify_Frame	388
6.10.4.3 SL_IR_RIF2:Receive_Identify_Frame state	388
6.10.4.3.1 State description	388
6.10.4.3.2 Transition SL_IR_RIF2:Receive_Identify_Frame to SL_IR_RIF3:Completed	389
6.10.4.4 SL_IR_RIF3:Completed state	389
6.10.5 SL_IR_IRC (identification and hard reset control) state machine	389
6.10.5.1 SL_IR_IRC state machine overview	389
6.10.5.2 SL_IR_IRC1:Idle state	389
6.10.5.2.1 State description	389
6.10.5.2.2 Transition SL_IR_IRC1:Idle to SL_IR_IRC2:Wait	389
6.10.5.3 SL_IR_IRC2:Wait state	389
6.10.5.3.1 State description	389
6.10.5.3.2 Transition SL_IR_IRC2:Wait to SL_IR_IRC3:Completed	390
6.10.5.4 SL_IR_IRC3:Completed state	390
6.11 Entering a low phy power condition	390
6.12 Power control and SL_P (link layer power control) state machines	391
6.12.1 Power source device	391
6.12.2 Power consumer device	391
6.12.3 NOTIFY (ENABLE SPINUP) usage	392
6.12.4 SL_P_S (link layer power source device) state machine	392
6.12.4.1 SL_P_S state machine overview	392
6.12.4.2 SL_P_S transmitter and SL_P_S receiver	394
6.12.4.3 SL_P_S_1:Idle state	395
6.12.4.3.1 State description	395
6.12.4.3.2 Transition SL_P_S_1:Idle to SL_P_S_2:Wait_Grant	395
6.12.4.4 SL_P_S_2:Wait_Grant state	395
6.12.4.4.1 State description	395
6.12.4.4.2 Transition SL_P_S_2:Wait_Grant to SL_P_S_1:Idle	396
6.12.4.4.3 Transition SL_P_S_2:Wait_Grant to SL_P_S_3:Wait_Done	396
6.12.4.5 SL_P_S_3:Wait_Done state	396
6.12.4.5.1 State description	396
6.12.4.5.2 Transition SL_P_S_3:Wait_Done to SL_P_S_1:Idle	396
6.12.5 SL_P_C (link layer power consumer device) state machine	396
6.12.5.1 SL_P_C state machine overview	396
6.12.5.2 SL_P_C receiver	399
6.12.5.3 SL_P_C_1:Idle state	399
6.12.5.3.1 State description	399
6.12.5.3.2 Transition SL_P_C_1:Idle to SL_P_C_2:Request_Power	399
6.12.5.4 SL_P_C_2:Request_Power state	399
6.12.5.4.1 State description	399
6.12.5.4.2 Transition SL_P_C_2:Request_Power to SL_P_C_1:Idle	400
6.12.5.4.3 Transition SL_P_C_2:Request_Power to SL_P_C_3:Wait_Grant	400
6.12.5.4.4 Transition SL_P_C_2:Request_Power to SL_P_C_4:Wait_Done	400
6.12.5.5 SL_P_C_3:Wait_Grant state	400
6.12.5.5.1 State description	400
6.12.5.5.2 Transition SL_P_C_3:Wait_Grant to SL_P_C_1:Idle	400
6.12.5.5.3 Transition SL_P_C_3:Wait_Grant to SL_P_C_4:Wait_Done	401
6.12.5.6 SL_P_C_4:Wait_Done state	401
6.12.5.6.1 State description	401
6.12.5.6.2 Transition SL_P_C_4:Wait_Done to SL_P_C_1:Idle	401
6.13 SAS domain changes (Broadcast (Change) usage)	401
6.14 Connections	402