

INCITS 512-2015

American National Standard

*for Information Technology –
Fibre Channel –
Physical Interface-6 (FC-PI-6)*

Developed by



Where IT all begins



This is a preview of "INCITS 512-2015 (R20...)". [Click here to purchase the full version from the ANSI store.](#)

INCITS 512-2015

American National Standard
for Information Technology –
**Fibre Channel –
Physical Interface-6 (FC-PI-6)**

Secretariat

Information Technology Industry Council

Approved January 28, 2015

American National Standards Institute, Inc.

Abstract

This standard describes the point-to-point physical interface portions of Fibre Channel serial electrical and optical link variants that support the higher level Fibre Channel protocols. This standard is recommended for new implementations but does not obsolete existing Fibre Channel standards.

American National Standard

Approval of an American National Standard requires review by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by the standards developer.

Consensus is established when, in the judgement of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made towards their resolution.

The use of American National Standards is completely voluntary; their existence does not in any respect preclude anyone, whether he has approved the standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standards.

The American National Standards Institute does not develop standards and will in no circumstances give an interpretation of any American National Standard. Moreover, no person shall have the right or authority to issue an interpretation of an American National Standard in the name of the American National Standards Institute. Requests for interpretations should be addressed to the secretariat or sponsor whose name appears on the title page of this standard.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

CAUTION: The developers of this standard have requested that holders of patents that may be required for the implementation of the standard disclose such patents to the publisher. However, neither the developers nor the publisher have undertaken a patent search in order to identify which, if any, patents may apply to this standard. As of the date of publication of this standard, following calls for the identification of patents that may be required for the implementation of the standard, notice of one or more such claims has been received. By publication of this standard, no position is taken with respect to the validity of this claim or of any rights in connection therewith. The known patent holder(s) has (have), however, filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license. Details may be obtained from the publisher. No further patent search is conducted by the developer or publisher in respect to any standard it processes. No representation is made or implied that this is the only license that may be required to avoid infringement in the use of this standard.

Published by

**American National Standards Institute, Inc.
25 West 43rd Street, New York, NY 10036**

Copyright © 2015 by Information Technology Industry Council (ITI)
All rights reserved.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without prior written permission of ITI, 1101 K Street NW, Suite 610, Washington, DC 20005.

Printed in the United States of America

Contents

1	Scope	1
2	Normative references	1
2.1	General	1
2.2	Normative references	1
2.2.1	Approved references	1
2.3	References under development	2
3	Definitions and conventions	3
3.1	Definitions	3
3.2	Editorial conventions	11
3.2.1	Conventions	11
3.2.2	Keywords	11
3.2.3	Abbreviations, acronyms, and symbols	12
3.2.3.1	Acronyms and other abbreviations	13
3.2.3.2	Signaling rate abbreviations	14
3.2.3.3	Symbols	14
4	FC-PI-6 functional characteristics	15
4.1	General characteristics	15
4.2	FC-0 states	17
4.2.1	Transmitter states	17
4.2.2	Receiver states	17
4.3	Limitations on invalid code	17
4.4	Receiver stabilization time	17
4.5	Loss of signal (Rx_LOS) function	17
4.6	Speed agile ports that support speed negotiation	17
4.7	Transmission codes	18
4.8	Frame scrambling and emission lowering protocol	18
4.9	Speed negotiation and transmitter training	18
4.10	Forward error correction (FEC)	19
4.11	Test patterns	19
4.12	Fibre Channel variants nomenclature	19
4.13	FC-PI-6 variants	21
5	Optical interface specification	23
5.1	TxRx connections	23
5.2	Laser safety issues	23
5.3	SM data links	23
5.3.1	SM general information	23
5.3.2	SM optical output interface	24
5.3.3	SM optical input interface	25
5.4	MM data links	25
5.4.1	MM general information	25
5.4.2	MM optical output interface	26
5.4.3	MM optical input interface	27
6	Electrical interface specification - single lane variants	28
6.1	General electrical characteristics	28
6.2	Compliance test point definitions	28
6.2.1	Test method	28

6.2.2	Host test points	29
6.2.3	Module test points	29
6.2.4	Host input calibration point	30
6.2.5	Module input calibration point	30
6.3	Transmitted signal characteristics	32
6.4	Receive signal characteristics	33
6.5	Receive jitter tracking compliance	34
6.6	Differential return loss and mode conversion requirements	35
6.6.1	Differential return loss	35
6.6.2	Common to differential mode and differential to common mode conversion	35
7	Backplane specification	37
7.1	TxRx Connections	37
7.2	Test fixtures	37
7.3	Transmitter specification	39
7.4	Receiver specification	41
7.4.1	Receiver input return loss	41
7.4.2	Receiver interference tolerance	42
7.4.3	Receiver jitter tolerance	43
7.5	Channel specification	44
7.6	Support for Energy Efficient Fibre Channel	45
7.6.1	Transmitter disable and enable	45
7.6.2	Energy detect	45
	Annex A (informative)	
	Optical cable plant usage	46
	Annex B (informative)	
	Structured cabling environment	48
B.1	Specification of operating distances	48
B.2	Alternate connection loss operating distances	48
	Annex C (informative)	
	Recommended electrical channel	49
C.1	Insertion loss	50

List of Figures

Figure 1. Reclocker location for all 32GFC PMDs	16
Figure 2. Fibre Channel variant nomenclature	20
Figure 3. SM transmitter eye mask for 32GFC	25
Figure 4. MM transmitter eye mask for 32GFC	27
Figure 5. Host Compliance Board	29
Figure 6. Module Compliance Board	30
Figure 7. Host input calibration point C"	30
Figure 8. Module input calibration point B"	31
Figure 9. Receiver jitter tracking template	34
Figure 10. SDD11 and SDD22 for all compliance points	35
Figure 11. SDC11 and SCD11 for receiver input	36
Figure 12. SDC22 and SCD22 for transmitter output	36
Figure 13. Test fixture and test points	37
Figure 14. Test fixture reference insertion loss	38
Figure 15. Test fixture differential return loss	38
Figure 16. Transmitter and receiver differential return loss limit	40
Figure 17. Transmitter common mode return loss	40
Figure 18. Receiver differential to common-mode return loss limit	41
Figure C.1. Typical FC-PI-6 electrical channel construction	49
Figure C.2. FC-PI-6 full channel electrical reference model, high loss channel	49
Figure C.3. Recommended minimum SDD21 of the electrical channel	50

List of Tables

Table 1. ISO convention	11
Table 2. Acronyms and other abbreviations	13
Table 3. Signaling rate abbreviations	14
Table 4. Symbols	14
Table 5. Transmitter training signal frame marker, control, and status field bit sequence	19
Table 6. Fibre Channel variants not in this document	21
Table 7. Fibre Channel Variants in FC-PI-6	22
Table 8. Single-mode link classes (OS1, OS2)	24
Table 9. SM transmitter eye mask parameters for 32GFC	25
Table 10. Multimode link classes	26
Table 11. MM transmitter eye mask values for 32GFC	27
Table 12. General electrical characteristics	28
Table 13. Transmitter compliance requirements	32
Table 14. Receiver compliance requirements	33
Table 15. Minimum jitter tolerance	34
Table 16. Transmitter electrical specifications at A	39
Table 17. Summary of receiver characteristics at test point D	41
Table 18. Receiver interference tolerance parameters	42
Table 19. Receiver jitter tolerance parameters	43
Table 20. Channel Operating Margin (COM) parameters	44
Table A.1. Worst case (nominal bandwidth) multimode cable link power budget	46
Table B.1. 3200-SN max operating distance & loss budget for different connection losses	48
Table C.1. Informative host to module channel characteristics, high loss channel	49
Table C.2. Informative host to module channel characteristics, lower loss channel	50

Foreword (This foreword is not part of American National Standard INCITS 512-2015.)

This standard was developed by Task Group T11.2 of Accredited Standards Committee INCITS during 2011, 2012, and 2013. The standards approval process was started in 2013. This document includes three annexes that are informative and are not considered part of the standard.

Requests for interpretation, suggestions for improvements or addenda, or defect reports are welcomed. They should be sent to the INCITS Secretariat, Information Technology Industry Council, 1101 K Street, NW, Suite 610, Washington, DC 20005.

This standard was processed and approved for submittal to ANSI by the National Committee for Information Technology Standards (INCITS). Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, INCITS had the following members:

Philip Wennblom, Chair
Jennifer Garner, Secretary

<i>Organization Represented</i>	<i>Name of Representative</i>
Adobe Systems, Inc.....	Scott Foshee Steve Zilles (Alt.)
AIM Global, Inc.	Steve Halliday Chuck Evanhoe (Alt.) Dan Kimball (Alt.)
Apple	Helene Workman Marc Braner (Alt.) David Singer (Alt.)
Distributed Management Task Force	John Crandall Jeff Hilland (Alt.) Lawrence Lamers (Alt.)
EMC Corporation	Gary Robinson Stephen Diamond (Alt.)
Farance, Inc.....	Frank Farance Timothy Schoechle (Alt.)
Futurewei Technologies, Inc.....	Yi Zhao Timothy Jeffries (Alt.) Wilbert Adams (Alt.)
GS1GO.....	Frank Sharkey Charles Biss (Alt.)
Hewlett-Packard Company	Karen Higginbottom Paul Jeran (Alt.)
IBM Corporation	Steve Holbrook Alexander Tarpinian (Alt.)
IEEE	Jodie Haasz Terry deCourcelle (Alt.) Bob Labelle(Alt.) Tina Alston (Alt.)
Intel	Philip Wennblom Grace Wei (Alt.) Stephen Balogh (Alt.)
Microsoft Corporation	Laura Lindsay John Calhoon (Alt.)
National Institute of Standards & Technology	Michael Hogan Sal Francomacaro (Alt.) Dan Benigni (Alt.) Fernando Podio (Alt.) Teresa Schwartzhoff (Alt.) Wo Chang (Alt.) Elaine Newton (Alt.)

<i>Organization Represented</i>	<i>Name of Representative</i>
Oracle Corporation	Donald R. Deutsch Jim Melton (Alt.) Michael Kavanaugh (Alt.) Toshihiro Suzuki (Alt.) Jeff Mischkinsky (Alt.) Tony DiCenzo (Alt.) Patrick Curran (Alt.)
Purdue University	Stephen Elliott Kevin O'Connor (Alt.)
Telecommunications Industry Association (TIA)	Herb Congdon, II Cheryl Blum (Alt.) Florence Otieno (Alt.)
US Department of Defense	Jerry Smith Dennis Devera (Alt.) Dave Brown (Alt.) Leonard Levine (Alt.) Matthew Young (Alt.) Thomas D'Agostino (Alt.)
US Department of Homeland Security	Peter Shebell Gregg Piermarini (Alt.) Juan Gonzalez (Alt.)

Technical Committee T11 on Fibre Channel Interfaces, which reviewed this standard, had the following members:

Steven L. Wilson, Chair
 Claudio DeSanti, Vice-Chair
 Richard Johnson, Secretary

<i>Organization Represented</i>	<i>Name of Representative</i>
Agilent Technologies	Joachim Vobis Stephen Didde (Alt.) Steve Sekel (Alt.)
Amphenol Interconnect.....	Gregory McSorley Alex Persaud (Alt.) Michael Wingard (Alt.)
Avago Technologies	Randy Clark David Cunningham (Alt.) Brian Misek (Alt.)
Broadcom Corporation	Ali Ghiasi Pat Thaler (Alt.)
Brocade	Steven L. Wilson David Peterson (Alt.) Scott Kipp (Alt.) John Crandall (Alt.)
Cisco Systems.....	Claudio DeSanti Landon Noll (Alt.) Fabio Maino (Alt.) Joe Pelissier (Alt.)
CommScope.....	G. Mabud Choudhury Richard Case (Alt.) Paul Kolesar (Alt.) Joe Livingston (Alt.) Richard Baca (Alt.)
Corning, Inc.	Doug Coleman Steven E. Swanson (Alt.)
Crossroads Systems	Bill Moody
Data Center Systems	Kevin Ehringer Jack Edwards (Alt.)
Dell	Hien Desai Gaurav Chawla (Alt.) Brad Booth (Alt.)
DSI A*STAR	Khin Mi Aung

<i>Organization Represented</i>	<i>Name of Representative</i>
EMC Corporation	Gary S. Robinson David Black (Alt.) Erik Smith (Alt.) Louis Ricci (Alt.)
Emulex	Gautam Shiroor Hossein Hashemi (Alt.) David Baldwin (Alt.)
FCI	Miguel Conde David Sideck (Alt.)
Finisar Corporation.....	Chris Yien Richard Johnson (Alt.)
Fujitsu America, Inc.....	Sandy Wilson Eugene Owens (Alt.) Jim DeCaires (Alt.) Kun Katsumata (Alt.) Mark Malcolm (Alt.) Osamu Kimura (Alt.)
Futurewei	Serge Manning Xiaoyan Ge (Alt.) Xiaoyan He (Alt.) Jincheng Li (Alt.)
Hewlett Packard	Barry Maskas Rupin Mohan (Alt.) Krishna Babu Puttagunta (Alt.) Nadaraha Navaruparajah (Alt.) Siamack Ayandeh (Alt.)
Hitachi DS	Eric Hibbard Vincent Franceschini (Alt.) Michael Hay (Alt.)
IBM Corporation	Scott Carlson Henry May (Alt.) Roger Hathorn (Alt.) Patty Driever (Alt.)
Intel Corporation.....	Prafulla Deuskar Mark Wunderlich (Alt.)
JDS Uniphase Corporation	Dave Lewis Jason Rusch (Alt.) Paul Gentieu (Alt.) Scott Baxter (Alt.)
Juniper	Joseph White
Liberty International.....	Phil Zuniga
LSI Corporation	Adam Healey Harvey Newman (Alt.) John Lohmeyer (Alt.)
Luxtera	Tom Palkert
Mellanox.....	Diego Crupnicoff Trevor Caulder (Alt.) Dror Goldenberg (Alt.)
Microsoft.....	Steve Olsson Calvin Chen (Alt.) James Borden (Alt.) Paul Luber (Alt.)
Molex, Inc.....	Jay Neer Mark Bugg (Alt.)
NetApp	Frederick Knight Heather Lanigan (Alt.) Denise Ridolfo (Alt.)
Octaro	Jon Anderson
Oracle.....	Roger Dickerson Matt Gaffney (Alt.) Michael Roy (Alt.)
Panduit Corporation	Robert Elliott Jose Castro (Alt.) Robert Reid (Alt.) Steve Skiest (Alt.)
Pegatron.....	Michael Hsu

<i>Organization Represented</i>	<i>Name of Representative</i>
QLogic Corporation	Craig W. Carlson Alan Spalding (Alt.) Dean Wallace (Alt.) Ed McGlaughlin (Alt.) Skip Jones (Alt.)
Solution Technology	David Deming David Deming, Jr. (Alt.)
TE Connectivity	Kim Whitman Andrew Nowak (Alt.) Michael Fogg (Alt.)
Teradyne	Eracar Yonet
Texas Instruments	Rajeev Jain Stephen Hubbins (Alt.)
Unisys	Jeffrey Dremann Diep Nguyen (Alt.) Jose Macias (Alt.) Phil Shelton (Alt.)
Virtual Instruments	Skip Bacon
VMware	Neil MacLean Sandeep Uttamchandani (Alt.) Lawrence Lamers

Emeritus Members

Bill Ham
Gary Stephens
Schelto Van Doorn
Robert W. Kembel
Horst Truestedt
James Coomes
Joseph R. Mathis
Bill Martin

Task Group T11.2 on Fibre Channel Protocols, which developed and reviewed this standard, has the following members:

Tom Palkert, Chair
Dean Wallace, Vice-Chair
Richard Johnson, Secretary

<i>Organization Represented</i>	<i>Name of Representative</i>
Agilent.....	Joachim Vobis Stephen Didde (Alt.) Steve Sekel (Alt.)
Amphenol	Gregory McSorley Michael Wingard (Alt.) Alex Persaud (Alt.)
Avago	Randy Clark David Cunningham (Alt.) Brian Misek (Alt.)
Broadcom	Ali Ghiasi Pat Thaler (Alt.)
Brocade	Steven L. Wilson Scott Kipp (Alt.) David Peterson (Alt.)
Cinch	Hecham Elkhatib
Commscope	G. Mabud Choudhury Richard Case (Alt.) Paul Kolesar (Alt.) Joe Livingstone (Alt.) Richard Baca (Alt.) Jack Jewell (Alt.)
Corning.....	Doug Coleman Steven E. Swanson (Alt.)

<i>Organization Represented</i>	<i>Name of Representative</i>
Data Center Systems	Jack Edwards
	Bhavesh Patel (Alt.)
EMC	Gary S. Robinson
	David Black (Alt.)
	Erik Smith (Alt.)
	Louis Ricci (Alt.)
Emulex	Hossein Hashemi
	Gautam Shiroor (Alt.)
Excelight.....	Mark Furumai
	Eddie Tsumura (Alt.)
FCI	Miguel Conde
	David Sideck (Alt.)
Finisar Corporation.....	Chris Yien
	Richard Johnson (Alt.)
Fujitsu.....	Sandy Wilson
	Eugene Owens (Alt.)
	Jim DeCaires (Alt.)
	Kun Katsumata (Alt.)
	Mark Malcolm (Alt.)
Gennum	David Brown
	Ed Friar (Alt.)
	Francois Tremblay (Alt.)
Hewlett Packard	Barry Maskas
	Krishna Babu Puttagunta (Alt.)
	Nadaraha (Nava) Navaruparajah (Alt.)
	Rupin Mohan (Alt.)
Hitachi GST.....	Dan Colegrove
IBM.....	John Ewen
	David Stauffer (Alt.)
	Scott Carlson (Alt.)
	Roger Hathorn (Alt.)
JDS Uniphase Corporation	Dave Lewis
Juniper	Joseph White
LSI.....	Adam Healey
	John Lohmeyer (Alt.)
	Harvey Newman (Alt.)
Luxtera	Tom Palkert
Molex.....	Jay Neer
	Mark Bugg (Alt.)
Oclaro.....	Jon Anderson
Panduit	Jose Castro
	Robert Elliot(Alt.)
	Robert Reid (Alt.)
	Steve Skiest (Alt.)
PMC-Sierra	Rick Hernandez
	Peichen Chang (Alt.)
QLogic.....	Dean Wallace
	Mark Owen (Alt.)
	Mike Dudek (Alt.)
	Craig W. Carlson (Alt.)
Solution Technology.....	Gianfranco Scherini
	Massimo Pozzoni (Alt.)
Texas Instruments.....	Rajeev Jain
	Stephen Hubbins (Alt.)
Tyco Electronics.....	Kim Whitman
	Andrew Nowak (Alt.)
	Michael Fogg (Alt.)
Vitesse	Marty Spadaro
	Gary Paules (Alt.)

Emeritus Members

Bill Ham
Schelto Van Doorn

Acknowledgments

The technical editor would like to thank the following individuals for their special contributions to this standard:

David Cunningham for optical link budget

Hossein Hashemi for early work editing this document

Adam Healey for backplane and copper solutions

Brian Misek for copper link budget studies

Dean Wallace for leadership

In Memoriam

Brian Misek



The FC-PI-6 document is dedicated to the memory of Brian Misek. Brian made significant technical contributions to the FC-PI-6 document. Brian's technical contributions and humor will be missed.

American National Standard
for Information Technology—

Fibre Channel –
Physical Interface-6 (FC-PI-6)

1 Scope

This international standard describes the physical interface portions of high performance electrical and optical link variants that support the higher level Fibre Channel protocols including FC-FS-4 (reference [18]).

FC-PI-6 includes 32GFC. 16GFC, 8GFC and 4GFC are described in FC-PI-5 (reference [1]). Older technologies of 2GFC and 1GFC are listed in FC-PI-2 (reference [3]).

2 Normative references

2.1 General

The following standards contain provisions that, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. Standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the following list of standards. Members of IEC and ISO maintain registers of currently valid International Standards.

Copies of the following documents can be obtained from ANSI: Approved ANSI standards, approved and draft international and regional standards (ISO, IEC), and other approved standards (including JIS and DIN).

2.2 Normative references

2.2.1 Approved references

- [1] **INCITS 479-2011, FC-PI-5, *Fibre Channel - Physical Interfaces - 5***
- [2] **INCITS 460-2011, FC-PI-3, *Fibre Channel - Physical Interfaces - 3***
- [3] **INCITS 404-2006, FC-PI-2, *Fibre Channel - Physical Interfaces - 2***
- [4] **INCITS TR-35-2006, FC-MJSQ, *Fibre Channel - Methodologies for Jitter and Signal Quality specification***
- [5] **INCITS TR-46-2011, FC-MSQS, *Fibre Channel - Methodologies for Signal Quality specification***
- [6] **IEC 60793-1-43, *Optical fibers - Part 1-43: Measurement methods and test procedures - Numerical aperture***
- [7] **IEC 60793-2-10, *Optical fibers - Part 2-10: Product specifications - Sectional specification for category A1 multimode fibers***