



# IEEE Standard for a High-Performance Serial Bus

---

**IEEE Computer Society**

Sponsored by the  
Microprocessor Standards Committee

1394<sup>TM</sup>

---

IEEE  
3 Park Avenue  
New York, NY 10016-5997, USA  
21 October 2008

**IEEE Std 1394<sup>TM</sup>-2008**  
(Revision of  
IEEE Std 1394-1995)

**IEEE Std 1394<sup>TM</sup>-2008**

(Revision of  
IEEE Std 1394-1995)

# **IEEE Standard for a High-Performance Serial Bus**

Sponsor

**Microprocessor Standards Committee**  
of the  
**IEEE Computer Society**

Approved 12 June 2008

**IEEE-SA Standards Board**

The contents of Table 1, Table 3, Table 4, Table 5, and Table 6 reprinted with permission from the 1394 Trade Association, TS2006001, "Enhanced UTP PMD for IEEE 1394b," © 2006.

Figure 4-2 through Figure 4-11 reprinted with permission from the 1394 Trade Association, TS2006002, "1394 Beta Plus PHY-Link Interface," © 2007.

Figure 4-59A, Figure 4-59B, Figure 9-17B, and Figure 14-4B reprinted with permission from the 1394 Trade Association, TS2007010, "S3200 Electrical Specification," © 2008.

Figure 4-11N, Figure 4-11P, Figure 4-11S, Figure 4-11T, Figure 4-11AVA, and Figure 9-3 reprinted with permission from the 1394 Trade Association, TB2002001, "1394 Clarifications and Errata 2.0," © 2006.

Figure 3-1 through Figure 3-5 reprinted with permission from the 1394 Trade Association, TB0002, "1394a-2000 Connector Socket and Plug," © 2001.

**Abstract:** This standard provides specifications for a high-speed serial bus that supports both asynchronous and isochronous communication and integrates well with most IEEE standard 32-bit and 64-bit parallel buses. It is intended to provide a low-cost interconnect between cards on the same backplane, cards on other backplanes, and external peripherals. Interfaces to longer distance transmission media [such as unshielded twisted pair (UTP), optical fiber, and plastic optical fiber (POF)] allow the interconnection to be extended throughout a local network. This standard follows the command and status register (CSR) architecture of IEEE Std 1212™-2001.

**Keywords:** asynchronous, bus, computers, high-speed serial bus, interconnect, isochronous, optical fiber, plastic optical fiber, POF, unshielded twisted pair, UTP

---

The Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2008 by the Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 21 October 2008. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

EUI-64 is a trademark of the Institute of Electrical and Electronics Engineers, Inc.

Futurebus+ is a registered trademark of the Institute of Electrical and Electronics Engineers, Inc.

National Electrical Code and NEC are both registered trademarks of the National Fire Protection Association, Inc.

NuBus is a registered trademark of Texas Instruments, Inc.

PDF: ISBN 978-0-7381-5770-2 STD95807  
Print: ISBN 978-0-7381-5771-9 STDPD95807

*No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.*

**IEEE Standards** documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS.**”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

**Interpretations:** Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal interpretation of the IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be submitted to the following address:

Secretary, IEEE-SA Standards Board  
445 Hoes Lane  
Piscataway, NJ 08854  
USA

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

## Introduction

This introduction is not part of IEEE Std 1394-2008, IEEE Standard for a High-Performance Serial Bus.

The IEEE 1394 base standard was issued in 1995, followed by three amendments: IEEE Std 1394a<sup>TM</sup>-2000, IEEE Std 1394b<sup>TM</sup>-2002, and IEEE Std 1394c<sup>TM</sup>-2006. In December 2002, a project was approved to merge the first two amendments into the base standard. Work on this project did not begin until July 2006. The project authorization was extended for two years and expanded to include IEEE Std 1394c-2006 as well as a large number of errata and corrigenda and several new features that had been developed over the intervening years. Editorial work on the standard was completed in April 2008.

## Notice to users

### Laws and regulations

Users of these documents should consult all applicable laws and regulations. Compliance with the provisions of this standard does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

### Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

### Updating of IEEE documents

Users of IEEE standards should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Standards Association website at <http://ieeexplore.ieee.org/xpl/standards.jsp>, or contact the IEEE at the address listed previously.

For more information about the IEEE Standards Association or the IEEE standards development process, visit the IEEE-SA website at <http://standards.ieee.org>.

### Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/updates/errata/index.html>. Users are encouraged to check this URL for errata periodically.

## Interpretations

Current interpretations can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/interp/index.html>.

## Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. A patent holder or patent applicant has filed a statement of assurance that it will grant licenses under these rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses. Other essential patent claims may exist for which a statement of assurance has not been received. The IEEE is not responsible for identifying essential patent claims for which a license may be required, for conducting inquiries into the legal validity or scope of patents claims, or for determining whether any licensing terms or conditions are reasonable or nondiscriminatory. Further information may be obtained from the IEEE Standards Association.

## Participants

At the time this revision was sent to Sponsor ballot, the IEEE 1394 Working Group had the following membership:

### **Les Baxter, *Chair and Editor***

Eric Anderson  
Max Bassler  
Duncan Beadnell  
Roumen Botev  
Branko Bukal  
Will Harris  
Don Harwood  
Allen Heberling  
David Instone  
Peter Johansson  
Suehiro Kawanishi  
Hyunchin Kim

Todd Krein  
Pascal Levesque  
Stephan Lietz  
Win Maung  
Azim Mohammed  
Richard Mourn  
Jeremy Nelson  
Jalil Oraee  
Steve Powers  
Nanda Rao  
James Refi

Tsuyoshi Sawada  
Michael Scholles  
Chris Thomas  
Dave Thompson  
Koen van den Brande  
Hans van der Ven  
Barry Walker  
Colin Whitby-Stevens  
Blake Witkin  
Ricardo Wong  
Andy Yanowitz  
John Yurtin

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Toru Aihara  
Eric Anderson  
Ali Al Awazi  
Jim S. Baca  
John Barr  
Hugh Barrass  
Les Baxter  
Tomo Bogataj  
James Carlo  
Juan Carreon  
Weijen Chen  
Naveen Cherukuri  
Kai Moon Chow  
Keith Chow  
Tommy Cooper  
James Davis

Russell Dietz  
Thomas Dineen  
Sourav Dutta  
John Fuller  
James Gilb  
Sergiu Goma  
Randall Groves  
Scott A. Gudgel  
C. Guy  
William Harris  
Donald J. Harwood  
Werner Hoelzl  
David Instone  
Peter Johansson  
Piotr Karocki  
Yongbum Kim

Mark Knight  
Daniel Levesque  
William Lumpkins  
G. Luri  
Joseph Marshall  
Gary Michel  
Michael S. Newman  
Chris Osterloh  
Ulrich Pohl  
Robert Robinson  
Fernando Lucas Rodriguez  
William J. Rose  
Michael D. Rush  
Bartien Sayogo  
Michael Scholles  
Thomas Schossig

Gil Shultz  
Amjad Soomro  
Thomas Starai  
Walter Struppler  
Michael Johas Teener

David Thompson  
Michael Thompson  
Timothy B. Thompson  
Leonard Tsai  
Srinivasa Vemuru  
John Vergis

Colin Whitby-Strevens  
Robert Wilkens  
Don Wright  
Oren Yuen  
Janusz Zalewski

The following were members of the Ballot Response Committee.

Eric Anderson  
Les Baxter  
Will Harris

David Instone  
Peter Johansson  
Win Maung  
Richard Mourn

Chris Thomas  
David Thompson  
Colin Whitby-Strevens

The following individuals have contributed to previous versions of the IEEE 1394 standard.

Kazuyuki Abe  
Bill Anderson  
Eric Anderson  
Mark Andresen  
Tatsuya Arai  
John Atwood  
Oleg Awsienko  
Richard Baker  
James Baldwin  
Steven Bard  
David Barnum  
Peter Bartlett  
Max Bassler  
Les Baxter  
Patrick Beauperin  
Bryan Bell  
Bob Bellino  
Joe Bennett  
Vilas Bhade  
Brad Bickford  
Phil Bolton  
Paul L. Borrill  
David Brief  
Charles Brill  
Dave Brown  
Kevin Brown  
Mike Brown  
David Bruncker  
Jim Busse  
Ed Butler  
Ed Cady  
Ramiro Calvo  
Andy Carter  
Don Chambers  
Mike Chastain  
Dao-Long Chen  
Carissa Cheung  
Richard Churchill  
Kim Clohessy  
Dan Colegrove  
Alistair Coles  
Mike Coletta  
John Creigh  
Forrest Crowell  
Claude Cruz  
Wayne Davis

Tom Debiec  
Eric Deliot  
Dhiru Desai  
David Doman  
Chris Dorsey  
Jim Doyle  
Bill Duckwall  
Frank Duffy  
Sam Duncan  
Sagar Edara  
Mike Eneboe  
Dwayne Escola  
W. P. Evertz  
Firooz Farhoomand  
Lou Fasano  
Stephen Finch  
Greg Floryance  
Mike Fogg  
Mike Foster  
Tony Foster  
Bill Frank  
Giles Frazier  
Richard Fryer  
Taka Fujimori  
John Fuller  
Nobuo Furuya  
Dave Gampell  
Bob Gannon  
Edward A. Gardner  
Mike Gardner  
James Gay  
John Gildred  
Sreekanth Godey  
Carmen Gonzalez  
Charles Grant  
John Grant  
Michael Griffin  
David B. Gustavson  
Steffen Hagene  
Emil Hahn  
Ken Hallam  
Bill Ham  
Eric Hannah  
Norm Harris  
Don Harwood  
Yasumasa Hasegawa

Mark Hassel  
Shinichi Hatae  
David Hatch  
Jerry Hauck  
Rick Heidick  
Keith Heilmann  
Burke Henehan  
Joe Herbst  
John Hill  
Dan Hillman  
Daisuke Hiraoka  
Jack Hollins  
Walter Hurwitz  
Derek Imschweiler  
Tatsuo Inoue  
David Instone  
David James  
Mark Jander  
Peter Johansson  
David Johnson  
Tom Jones  
Prashant Kanhere  
Nick Kanzaki  
Marcus Kellerman  
Al Kelley  
Sam Khoo  
Sean Killeen  
Jinhee Kim  
Greg Kite  
Diana Klashman  
Mark Knecht  
Lawence Kopp  
James Kuo  
Akihito Kuwabara  
Ralph Lachenmaier  
David LaFollette  
Pascal Lagrange  
Lawrence J. Lamers  
Steven Larky  
Farrukh Latif  
Michael Lazar  
Thang Le  
Yoonsun Lee  
Wendell Lengefeld  
Fred Leung  
Paul S. Levy

Francesco Liburdi  
Robert Liu  
John Lohmeyer  
John Lopata  
Ivy Lui  
Hirokazu Mamezaki  
Gerald Marazas  
Jun-ichi Matsuda  
Takashi Matsui  
Don May  
Edward McDonnell  
Daniel Meirsman  
Jack Merrow  
Gene Milligan  
Keiji Miura  
Takatoshi Mizoguchi  
Reza Moattar  
Palanisamy Mohanraj  
Cyrus Momeni  
Charles Monia  
Neil Morrow  
Claude Mosley  
Richard Mourn  
Ray Muggli  
Gary Murdock  
Ganesh Murthy  
Karl Nakamura  
James Nave  
Jay Neer  
Jim Nelson  
Richard Nesin  
Michael Nguyen  
Bill Northey  
Takayuki Nyu  
Dan O'Connor  
Erich Oetting  
Ozay Oktay  
Florin Opreescu  
Farrell Ostler  
Kugao Ouchi  
Bijit Patel  
Shiva Patibanda  
Thomas A. Patrick

Scott Petler  
James Piccione  
Kevin Pokorney  
Thomas J. Potyraj  
Bill Prouty  
Dennis Rehm  
Doug Riemer  
Ron Roberts  
Jeffrey M. Rosa  
Bill Russell  
Kyoze Saito  
Tomoki Saito  
Brad Saunders  
Bradley Saunders  
Dick Scheel  
David Scott  
Don Senzig  
D. C. Sessions  
Masood Shariff  
Robbie Shergill  
Hisato Shima  
Mike Shinkarovsky  
James Skidmore  
Jim Skidmore  
David Smith  
Michael Smith  
Patricia Smith  
John Smolka  
Scott Smyers  
Robert N. Snively  
Ron Soderstrom  
Martin Sodos  
Michael Sorna  
Jeff Stai  
Ken Stewart  
Chris Stone  
David Stone  
Paul Sweazey  
John Ta  
Ju-ching Tang  
Ken Taylor  
Michael Johas Teener  
Peter Teng

Victoria Teng  
Tom Thatcher  
Lars Thernsjö  
Barry Thompson  
David Thompson  
Richard Thousand  
C. Brendan Traw  
Tom Trodden  
Tom Truman  
Motoyasu Tsunoda  
Toru Ueda  
Renard Ulrey  
Joel Urban  
Roger Van Brunt  
Sushant Verman  
Hirosha Wakai  
Hans H. Wang  
Kenji Watanabe  
Yuji Watanabe  
Harvey Watersdorf  
Kent Waterson  
Mike Wenzel  
Alan Wetzel  
Lee Whetsel  
Colin Whitby-Strevens  
Bob Whiteman  
Dave Wickliff  
Paul Wiener  
Doug Williams  
Lee Wilson  
Michael Wingard  
Calto Wong  
David Wooten  
Shuntaro Yamazaki  
Yoshihiko Yano  
Roy Yasoshima  
Takao Yasuda  
Niwa Yoshikatsu  
Len Young  
Phil Young  
Patrick Yu  
Michael Zarreii  
Peng Zhang  
Johann Zipperer

When the IEEE-SA Standards Board approved this revision on 12 June 2008, it had the following membership:

**Robert M. Grow**, *Chair*  
**Thomas A. Prevost**, *Vice Chair*  
**Steve M. Mills**, *Past Chair*  
**Judith Gorman**, *Secretary*

Victor Berman  
Richard DeBlasio  
Andy Drozd  
Mark Epstein  
Alexander Gelman  
William R. Goldbach  
Arnold M. Greenspan  
Kenneth S. Hanus

Jim Hughes  
Richard H. Hulett  
Young Kyun Kim  
Joseph L. Koepfinger\*  
John Kulick  
David J. Law  
Glenn Parsons  
Ronald C. Petersen

Chuck Powers  
Narayanan Ramachandran  
Jon Walter Rosdahl  
Robby Robson  
Anne-Marie Sahazizia  
Malcolm V. Thaden  
Howard L. Wolfman  
Don Wright

\*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*  
Michael H. Kelly, *NIST Representative*

Jennie Steinhaggen  
IEEE Standards Program Manager, Document Development

Malia Zaman  
IEEE Standards Program Manager, Technical Program Development

## Contents

1.	Overview .....	1
1.1	Scope and purpose .....	1
1.1.1	Scope .....	1
1.1.2	Purpose .....	2
1.2	Document organization .....	2
1.3	Serial bus applications .....	2
1.3.1	Alternate bus .....	2
1.3.2	Low-cost peripheral bus .....	2
1.3.3	Bus bridge .....	3
1.4	Service model .....	3
1.5	Document notation .....	4
1.5.1	Mechanical notation .....	4
1.5.2	Signal naming .....	4
1.5.3	Size notation .....	4
1.5.4	Numerical values .....	5
1.5.5	Packet formats .....	6
1.5.6	Register formats .....	6
1.5.7	C code notation .....	6
1.5.8	State machine notation .....	8
1.5.9	CSR, ROM, and field notation .....	8
1.5.10	Register specification format .....	9
1.5.11	Reserved registers and fields .....	10
1.5.12	Operation description priorities .....	11
1.6	Compliance .....	11
1.6.1	CSR architecture compliance .....	11
1.6.2	Serial bus PHYs .....	12
2.	Normative references .....	13
3.	Definitions, acronyms, and abbreviations .....	17
3.1	Definitions .....	17
3.2	Acronyms and abbreviations .....	25
4.	Short-haul copper connector and cable specification .....	29
4.1	Introduction .....	29
4.2	6-circuit Alpha connectors and cables .....	29
4.2.1	6-circuit connectors .....	30
4.2.1.1	Connector plug .....	30
4.2.1.2	Connector plug terminations .....	32
4.2.1.3	Connector socket .....	32
4.2.1.4	Positive retention .....	35
4.2.1.5	Contact finish on plug and socket contacts .....	36
4.2.1.6	Termination finish on plug and contact socket terminals .....	37
4.2.1.7	Shell finish on plugs and sockets .....	37
4.2.1.8	Connector durability .....	37
4.2.2	Cables .....	37
4.2.2.1	Cable material .....	37
4.2.2.2	Cable assemblies .....	37
4.2.3	Connector and cable assembly performance criteria .....	37

4.2.3.1	Performance group A: Basic mechanical dimensional conformance and electrical functionality when subjected to mechanical shock and vibration .....	40
4.2.3.2	Performance group B: Low-level contact resistance when subjected to thermal shock and humidity stress.....	41
4.2.3.3	Performance group C: Insulator integrity when subjected to thermal shock and humidity stress .....	42
4.2.3.4	Performance group D: Contact life and durability when subjected to mechanical cycling and corrosive gas exposure.....	43
4.2.3.5	Performance group E: Contact resistance and unmating force when subjected to temperature life stress.....	45
4.2.3.6	Performance group F: Mechanical retention and durability .....	46
4.2.3.7	Performance group G: General tests.....	47
4.2.4	Signal propagation performance.....	48
4.2.4.1	Signal impedance.....	48
4.2.4.2	Signal pairs attenuation .....	48
4.2.4.3	Signal pairs velocity of propagation .....	49
4.2.4.4	Signal pairs relative propagation skew .....	49
4.2.4.5	Power pair characteristic impedance .....	49
4.2.4.6	Power pair dc resistance .....	49
4.2.4.7	Crosstalk .....	50
4.3	4-circuit Alpha connectors and cables .....	50
4.3.1	Connectors.....	50
4.3.1.1	Connector plug .....	50
4.3.1.2	Connector plug terminations .....	50
4.3.1.3	Connector socket .....	52
4.3.1.4	Contact finish on plug and socket contacts .....	54
4.3.1.5	Termination finish on plug and contact socket terminals.....	54
4.3.1.6	Shell finish on plugs and sockets.....	54
4.3.1.7	Connector durability .....	54
4.3.1.8	PCB footprints .....	55
4.3.2	Cables.....	56
4.3.2.1	Cable material.....	56
4.3.2.2	Cable assemblies.....	56
4.3.3	Connector and cable assembly performance criteria.....	57
4.3.3.1	Performance group A: Basic mechanical dimensional conformance and electrical functionality when subjected to mechanical shock and vibration .....	58
4.3.3.2	Performance group B: Low-level contact resistance when subjected to thermal shock and humidity stress.....	59
4.3.3.3	Performance group C: Insulator integrity when subjected to thermal shock and humidity stress .....	60
4.3.3.4	Performance group D: Contact life and durability when subjected to mechanical cycling and corrosive gas exposure.....	61
4.3.3.5	Performance group E: Contact resistance and unmating force when subjected to temperature life stress.....	63
4.3.3.6	Performance group F: Mechanical retention and durability .....	64
4.3.3.7	Performance group G: General tests.....	65
4.3.4	Signal propagation performance criteria .....	67
4.3.4.1	Signal impedance.....	67
4.3.4.2	Signal pairs attenuation .....	67
4.3.4.3	Signal pairs propagation delay .....	67
4.3.4.4	Signal pairs relative propagation skew .....	68
4.3.4.5	Crosstalk .....	68

4.4	9-circuit Beta and bilingual connectors and cables .....	68
4.4.1	9-circuit Beta and bilingual connectors .....	68
4.4.1.1	Plug cable termination method .....	70
4.4.1.2	Socket .....	70
4.4.1.3	Mating area finish on plug and socket contacts .....	79
4.4.1.4	Termination area finish on plug and socket contacts .....	79
4.4.1.5	Shell finish on plugs and sockets .....	79
4.4.1.6	Durability .....	79
4.4.1.7	Socket PCB termination footprints and PHY trace routing .....	80
4.4.1.8	Plug overmold .....	82
4.4.1.9	Socket orientation preference .....	82
4.4.2	Cables .....	82
4.4.2.1	Reference cable material for Beta-to-Beta cable assemblies .....	83
4.4.2.2	Reference cable material for bilingual-to-Alpha cable assemblies .....	84
4.4.2.3	Cable assemblies .....	84
4.4.3	Connector and cable assembly performance criteria .....	88
4.4.3.1	Performance group A: Basic mechanical dimensional conformance and electrical functionality when subjected to mechanical shock and vibration .....	89
4.4.3.2	Performance group B: Low-level contact resistance when subjected to thermal shock and humidity stress .....	90
4.4.3.3	Performance group C: Insulator integrity when subjected to thermal shock and humidity stress .....	91
4.4.3.4	Performance group D: Contact life and durability when subjected to mechanical cycling and corrosive gas exposure .....	92
4.4.3.5	Performance group E: Contact resistance and unmating force when subjected to temperature life stress .....	94
4.4.3.6	Performance group F: Mechanical retention and durability .....	95
4.4.3.7	Performance group G: General tests .....	95
4.4.4	Signal propagation performance criteria .....	97
4.4.4.1	Test hardware .....	97
4.4.4.2	Signal impedance .....	100
4.4.4.3	Signal pairs attenuation .....	101
4.4.4.4	Signal pairs velocity of propagation .....	102
4.4.4.5	Signal pairs intrapair propagation skew .....	103
4.4.4.6	Crosstalk .....	104
4.4.4.7	Power .....	104
5.	Backplane PHY specification .....	105
5.1	Backplane PHY services .....	105
5.1.1	Backplane PHY bus management services for the management layer .....	106
5.1.1.1	PHY control request (PH_CONTROL.request) .....	106
5.1.1.2	PHY control confirmation (PH_CONTROL.confirmation) .....	106
5.1.1.3	PHY event indication (PH_EVENT.indication) .....	107
5.1.2	PHY layer arbitration services for the link layer .....	107
5.1.2.1	PHY arbitration request (PH_ARB.request) .....	107
5.1.2.2	PHY arbitration confirmation (PH_ARB.confirmation) .....	108
5.1.3	PHY layer data services for the link layer .....	108
5.1.3.1	PHY clock indication (PH_CLOCK.indication) .....	108
5.1.3.2	PHY data request (PH_DATA.request) .....	108
5.1.3.3	PHY data indication (PH_DATA.indication) .....	109
5.2	Backplane physical connection specification .....	109
5.2.1	Media attachment .....	110

5.2.1.1	Distribution of nodes .....	110
5.2.1.2	Fault detection and isolation .....	110
5.2.1.3	Live insertion .....	111
5.2.2	Media signal interface .....	111
5.2.2.1	Definition of logic states .....	111
5.2.2.2	Bit rates .....	112
5.2.2.3	Transition times .....	112
5.2.2.4	Noise rejection .....	112
5.2.3	Media signal timing .....	112
5.2.3.1	Backplane transmit data timing .....	112
5.2.3.2	Backplane receive data timing .....	113
5.2.3.3	Backplane and transceiver skew .....	114
5.2.4	Backplane PHY timing .....	114
5.2.4.1	Arbitration clock rate .....	115
5.2.4.2	Bus synchronization and propagation delay .....	115
5.2.4.3	Arbitration bit timing .....	116
5.3	Backplane PHY facilities .....	118
5.3.1	Coding .....	118
5.3.2	Backplane PHY signals .....	118
5.3.3	Gap timing .....	119
5.3.4	Arbitration sequence .....	120
5.3.4.1	Arbitration number .....	120
5.3.4.2	Priority .....	120
5.3.4.3	Format of arbitration sequence .....	121
5.4	Backplane PHY operation .....	121
5.4.1	Arbitration .....	122
5.4.1.1	Fairness intervals .....	122
5.4.1.2	Fair arbitration .....	123
5.4.1.3	Urgent arbitration .....	124
5.4.1.4	Arbitration by the cycle master .....	125
5.4.1.5	Isochronous arbitration .....	125
5.4.1.6	Immediate arbitration .....	125
5.4.2	Backplane environment packet transmission and reception .....	125
5.4.2.1	Backplane environment packet transmission .....	126
5.4.2.2	Backplane environment packet reception .....	127
5.5	Backplane initialization and reset .....	128
5.5.1	Backplane PHY reset .....	128
5.5.1.1	Command reset .....	128
5.5.1.2	Bus reset .....	128
5.5.2	Backplane PHY initialization .....	128
6.	Link layer specification .....	129
6.1	Link layer services .....	129
6.1.1	Link layer bus management services for the node controller .....	130
6.1.1.1	Link control request (LK_CONTROL.request) .....	130
6.1.1.2	Link control confirmation (LK_CONTROL.confirmation) .....	131
6.1.1.3	Link event indication (LK_EVENT.indication) .....	131
6.1.1.4	Link remote configuration request (LK_CONFIG.request) (cable environment only) .....	131
6.1.1.5	Link remote configuration indication (LK_CONFIG.indication) (cable environment only) .....	132
6.1.2	Link layer asynchronous data services for the transaction layer .....	132
6.1.2.1	Link data request (LK_DATA.request) .....	132

6.1.2.2	Link data confirmation (LK_DATA.confirmation)	133
6.1.2.3	Link data indication (LK_DATA.indication)	133
6.1.2.4	Link data response (LK_DATA.response)	134
6.1.2.5	Link bus indication (LK_BUS.indication)	134
6.1.3	Link layer isochronous data services for application layers	134
6.1.3.1	Link isochronous control request (LK_ISO_CONTROL.request)	134
6.1.3.2	Link cycle sync indication (LK_CYCLE.indication)	135
6.1.3.3	Link isochronous request (LK_ISO.request)	135
6.1.3.4	Link isochronous indication (LK_ISO.indication)	135
6.2	Link layer facilities	136
6.2.1	Primary packets	136
6.2.2	Asynchronous packets	137
6.2.2.1	Asynchronous packets with no-data payload	138
6.2.2.2	Asynchronous packet formats with data quadlet payload	139
6.2.2.3	Asynchronous packet formats with data block payload	142
6.2.3	Isochronous packets	145
6.2.3.1	Isochronous packet components	145
6.2.3.2	Isochronous data block packet format	146
6.2.4	Asynchronous streams	147
6.2.4.1	Asynchronous stream packet format	147
6.2.4.2	Global asynchronous stream packet (GASP) format	148
6.2.4.3	Loose vs. strict isochronous packet reception	149
6.2.5	Primary packet components	149
6.2.5.1	Reserved fields, codes, and values	149
6.2.5.2	Destination address	149
6.2.5.3	Transaction label (tl)	150
6.2.5.4	Retry code (rt)	150
6.2.5.5	Transaction code (tcode)	150
6.2.5.6	Priority (pri)	152
6.2.5.7	Source ID (source_ID)	152
6.2.5.8	Data length (data_length)	152
6.2.5.9	Extended transaction code (extended_tcode)	152
6.2.5.10	Response code (rcode)	153
6.2.5.11	Data field	153
6.2.5.12	Tag (isochronous stream packets)	153
6.2.5.13	Channel	153
6.2.5.14	Synchronization code (sy)	154
6.2.5.15	CRCs	154
6.2.6	Acknowledge packets	155
6.2.6.1	Acknowledge packet format	156
6.2.6.2	ACK packet components	156
6.3	Link layer operation	158
6.3.1	Overview of link layer operation	158
6.3.1.1	Communication with the PHY layer	158
6.3.1.2	Priority arbitration for PHY packets and response packets	159
6.3.1.3	Sending an asynchronous packet	159
6.3.1.4	Receiving an asynchronous packet	159
6.3.1.5	Sending an acknowledge concatenated to an asynchronous packet	160
6.3.1.6	Isochronous cycles	160
6.3.1.7	Sending isochronous packets	160
6.3.1.8	Receiving an isochronous packet	160
6.3.2	Cycle sync event	161
6.3.3	Details of link layer operation	162
6.3.3.1	Link initialization	163

6.3.3.2	Asynchronous operation .....	163
6.3.3.3	Isochronous operation.....	166
6.4	Link layer reference code .....	168
7.	Transaction layer specification .....	171
7.1	Transaction layer services .....	171
7.1.1	Transaction layer bus management services for SBM .....	171
7.1.1.1	Transaction control request (TR_CONTROL.request) .....	172
7.1.1.2	Transaction control confirmation (TR_CONTROL.confirmation) .....	172
7.1.1.3	Transaction event indication (TR_EVENT.indication).....	172
7.1.2	Transaction layer data services for applications and bus management .....	172
7.1.2.1	Transaction data request (TR_DATA.request).....	173
7.1.2.2	Transaction data confirmation (TR_DATA.confirmation) .....	173
7.1.2.3	Transaction data indication (TR_DATA.indication).....	174
7.1.2.4	Transaction data response (TR_DATA.response).....	174
7.2	Transaction facilities .....	175
7.2.1	Split transaction timer.....	175
7.2.2	Transaction retry limit .....	175
7.3	Transaction operation.....	175
7.3.1	Overview of transaction layer operations.....	175
7.3.1.1	Read transactions .....	176
7.3.1.2	Write transactions .....	176
7.3.1.3	Lock transactions .....	177
7.3.1.4	Response codes (rcode) .....	177
7.3.1.5	Error handling.....	179
7.3.2	Transaction completion definitions .....	179
7.3.2.1	Unified transaction .....	180
7.3.2.2	Split transaction .....	180
7.3.2.3	Concatenated transaction .....	180
7.3.2.4	Broadcast transaction.....	180
7.3.2.5	Pending transaction.....	180
7.3.3	Details of transaction layer operation.....	180
7.3.3.1	Outbound transaction state machine .....	181
7.3.3.2	Inbound transaction state machine .....	184
7.3.4	Transaction types.....	188
7.3.4.1	Read transactions .....	188
7.3.4.2	Write transactions .....	188
7.3.4.3	Lock transactions .....	188
7.3.5	Retry protocols .....	189
7.3.5.1	Outbound subaction retry protocol .....	190
7.3.5.2	Inbound subaction single-phase retry protocol.....	191
7.3.5.3	Inbound subaction dual-phase retry protocol .....	191
7.4	CSR architecture transactions mapped to serial bus .....	194
8.	Serial bus management (SBM) specification .....	197
8.1	SBM summary.....	197
8.1.1	Node control .....	197
8.1.2	IRM (cable environment) .....	197
8.1.3	IRM (backplane environment) .....	197
8.1.4	Bus manager (cable environment).....	197
8.2	SBM services.....	198
8.2.1	Serial bus control request (SB_CONTROL.request) .....	198

8.2.2	Serial bus control confirmation (SB_CONTROL.confirmation)	199
8.2.3	Serial bus event indication (SB_EVENT.indication)	199
8.3	SBM facilities	201
8.3.1	Node capabilities taxonomy	201
8.3.1.1	Repeater (cable environment)	201
8.3.1.2	Transaction capable	201
8.3.1.3	Isochronous capable	202
8.3.1.4	Cycle master capable	202
8.3.1.5	IRM capable	202
8.3.1.6	Bus manager capable (cable environment)	202
8.3.2	Command and status registers	203
8.3.2.1	Reset conditions	203
8.3.2.2	CSR architecture core registers	204
8.3.2.3	Serial-Bus-dependent registers	209
8.3.2.4	Unit registers	221
8.3.2.5	TOPOLOGY_MAP registers (cable environment)	222
8.3.2.6	Configuration ROM	223
8.3.3	SBM variables	229
8.4	SBM operations	229
8.4.1	Bus configuration procedures (backplane environment)	229
8.4.1.1	Unmanaged bus (backplane environment)	230
8.4.1.2	Determination of the IRM (backplane environment)	230
8.4.1.3	Determination of the cycle master (backplane environment)	230
8.4.2	Bus configuration procedures (cable environment)	230
8.4.2.1	Unmanaged bus (cable environment)	230
8.4.2.2	Prior isochronous traffic (cable environment)	231
8.4.2.3	Determination of the IRM (cable environment)	231
8.4.2.4	Reallocation of prior isochronous resources (cable environment)	232
8.4.2.5	Determination of the bus manager (cable environment)	232
8.4.2.6	Determination of the cycle master (cable environment)	232
8.4.2.7	Determination of the root (cable environment)	233
8.4.2.8	Power management by the IRM (cable environment)	234
8.4.2.9	Allocation of new isochronous resources (cable environment)	234
8.4.3	Isochronous resource allocation (cable environment)	234
8.4.3.1	Bandwidth allocation	234
8.4.3.2	Channel allocation	235
8.4.3.3	Bandwidth set-aside	236
8.4.3.4	Isochronous requests with no cycle master	236
8.4.4	Power management (cable environment)	236
8.4.4.1	PHY power management	237
8.4.4.2	Link power management	237
8.4.4.3	Unit power management	237
8.4.4.4	Power management by the bus manager	237
8.4.4.5	Power management by the IRM	238
8.4.5	Topology management (cable environment)	238
8.4.5.1	Accessing the topology map	238
8.4.5.2	Gap count optimization	239
8.4.6	Filtered packets on an asynchronous-only B_bus	239
8.5	Bus configuration state machines (cable environment)	239
8.5.1	Candidate cycle master states	240
8.5.2	Candidate IRM states	241
8.5.3	Candidate bus manager states	242
8.5.4	Abdication by the bus manager	244

9.	Short-haul copper PMD electrical specification .....	245
9.1	Introduction .....	245
9.1.1	Short-haul copper PHY operation .....	245
9.1.2	Short-haul copper physical connection specification .....	247
9.1.3	Interfaces .....	248
9.1.4	Modes of operation .....	248
9.2	Data-strobe (DS) mode specification .....	248
9.2.1	Port interface .....	248
9.2.1.1	Signal amplitude .....	250
9.2.1.2	Common mode voltage .....	251
9.2.1.3	Speed signaling .....	252
9.2.1.4	Arbitration signal voltages .....	253
9.2.1.5	Input impedance .....	254
9.2.1.6	Noise .....	254
9.2.1.7	Driver and receiver fault protection .....	255
9.2.2	Media signal timing .....	255
9.2.2.1	Data rate .....	255
9.2.2.2	Data signal rise and fall times .....	255
9.2.2.3	Jitter and skew .....	256
9.2.3	Coding .....	256
9.2.4	DS PHY signals .....	256
9.2.5	DS PHY line states .....	257
9.2.6	Cable PHY timing constants .....	259
9.2.7	Gap timing .....	264
9.2.8	Speed signal sampling and filtering .....	265
9.2.9	Data transmission and reception .....	266
9.2.9.1	Data transmission .....	266
9.2.9.2	Data reception and repeat .....	267
9.3	Beta mode specification .....	267
9.3.1	Transmitter electrical specifications .....	267
9.3.2	Receiver electrical specifications .....	271
9.3.2.1	S3200 equalization .....	275
9.3.3	Electrical measurements .....	275
9.3.3.1	Transmit rise and fall time .....	275
9.3.3.2	Transmit skew .....	275
9.3.3.3	Transmit eye (normalized and absolute) .....	276
9.3.3.4	Rise and fall time setting for receiver jitter tolerance test .....	276
9.3.3.5	Skew setting for receiver jitter tolerance test .....	276
9.3.3.6	Receiver jitter tolerance .....	277
9.3.3.7	Minimum amplitude for receiver jitter tolerance test .....	277
9.3.3.8	S3200 BER .....	278
9.3.3.9	S3200 electrical test configuration .....	278
9.3.4	DC biasing .....	278
9.3.5	Toning and signal detect .....	279
9.3.5.1	Connection tone .....	279
9.3.5.2	PMD signal detect function .....	280
9.3.5.3	Application note .....	281
9.3.6	Jitter specifications .....	281
9.3.7	Intrapair skew .....	285
9.3.8	Termination and isolation .....	285
9.3.8.1	Bilingual port termination and isolation .....	285
9.3.8.2	Beta-only port termination and isolation .....	286
9.3.8.3	PIL-FOP termination and isolation .....	287

9.4	Cable power and ground .....	288
9.4.1	Node power classes .....	288
9.4.2	Ground isolation .....	290
9.4.2.1	Primary power providers .....	291
9.4.2.2	Secondary power provider.....	291
9.4.3	Protection against late VG.....	291
10.	Glass optical fiber (GOF) PMD specification.....	295
10.1	PMD block diagram .....	296
10.2	PMD-to-MDI optical specifications.....	296
10.3	Transmitter optical specifications .....	297
10.4	Receiver optical specifications.....	297
10.5	Worst-case connection optical power budget and penalties.....	298
10.6	Optical jitter specifications.....	299
10.7	Optical measurement requirements.....	301
10.7.1	Center wavelength and spectral width measurements.....	301
10.7.2	Optical power measurements .....	301
10.7.3	Extinction ratio measurements .....	301
10.7.4	Relative intensity noise (RIN).....	301
10.7.5	Transmitter optical waveform (transmit eye).....	301
10.7.6	Transmit rise and fall characteristics.....	302
10.7.7	Receiver sensitivity measurements.....	303
10.7.8	Jitter measurements .....	303
10.8	CPR measurement.....	303
10.9	Optical connection cabling model.....	303
10.9.1	Characteristics of the fiber optic medium .....	303
10.9.2	Optical fiber and cable.....	304
10.9.3	Multimode connector insertion loss .....	304
10.9.4	Optical connection return loss.....	304
10.10	Optical connection .....	304
10.11	Fiber launch conditions: OFL .....	305
11.	PMD specification of fiber media with PN connector.....	307
11.1	Scope .....	307
11.2	PMD block diagram .....	308
11.3	Cables .....	308
11.4	Connector .....	309
11.5	Connector and cable assembly performance criteria.....	310
11.6	Optical fiber interface.....	310
11.7	Optical jitter specifications.....	310
11.8	Permitted number of segments.....	310
12.	Unshielded twisted pair (UTP) PMD specification .....	315
12.1	Overview .....	316
12.2	PMD block diagram .....	316
12.3	Operation of UTP connections.....	316
12.4	Media specification .....	317
12.4.1	100 Ohm UTP connection segment specification .....	317
12.4.2	100 Ohm UTP cable specification.....	317
12.4.3	Connecting hardware.....	317
12.4.4	Media interface connector .....	318

12.4.5	Autocrossover.....	319
12.5	PMD electrical specifications.....	319
12.5.1	Galvanic isolation.....	319
12.5.2	Transmitter specifications.....	320
12.5.3	Receiver specifications.....	323
12.5.3.1	Receiver input signals.....	323
12.5.3.2	PMD signal detect function.....	323
12.6	PMD implementation.....	325
13.	Beta mode port specification.....	327
13.1	Overview.....	327
13.2	Port functions.....	328
13.2.1	Overview.....	328
13.2.2	Naming conventions.....	329
13.2.3	Control mapping.....	329
13.2.4	Request types.....	330
13.2.4.1	BOSS arbitration request mapping.....	330
13.2.4.2	Configuration requests.....	332
13.2.5	Scrambling.....	332
13.2.5.1	Data scrambling.....	333
13.2.5.2	Request symbol scrambling.....	334
13.2.5.3	Control symbol scrambling.....	335
13.2.6	Coding.....	336
13.2.6.1	8B/10B character coding for data and request types.....	336
13.2.6.2	Control coding.....	346
13.2.7	Character transmission.....	348
13.2.8	Decoding.....	348
13.2.8.1	Bit and character synchronization.....	348
13.2.8.2	Data and control character decoding and error detection.....	348
13.2.8.3	Special character decoding.....	348
13.2.9	Receiver running disparity.....	348
13.2.10	Descrambling.....	349
13.3	Beta mode port operation.....	349
13.3.1	Transmit operations.....	349
13.3.1.1	Control transmission.....	349
13.3.1.2	Request transmission.....	350
13.3.1.3	Packet transmission.....	350
13.3.1.4	Speed signaling.....	351
13.3.1.5	Payload transmission.....	352
13.3.2	Receive operations.....	353
13.3.2.1	Port training.....	353
13.3.2.2	Control reception.....	354
13.3.2.3	Request type reception.....	354
13.3.2.4	DATA_PREFIX reception.....	355
13.3.2.5	Speed code determination.....	355
13.3.2.6	Payload reception.....	356
13.3.2.7	Error reporting.....	357
13.4	Beta port state machines.....	357
13.4.1	Port transmit state machine.....	358
13.4.2	Port receive state machine.....	359
14.	Connection management.....	361

14.1	Overview .....	361
14.2	Port characteristics .....	362
14.2.1	Requirements .....	362
14.2.2	Properties .....	363
14.3	Functions, variables, and constants .....	363
14.4	Node-level port controller .....	366
14.5	Port connection manager state machine .....	366
14.6	Standby .....	371
14.6.1	Nephew node characteristics .....	372
14.6.2	Uncle node characteristics .....	372
14.7	Loop prevention .....	373
14.7.1	Test port .....	373
14.7.2	Loop test data (LTD) .....	374
14.7.2.1	M bit .....	374
14.7.2.2	G bit .....	374
14.7.2.3	test_value number .....	375
14.7.3	Holding register (HR) .....	375
14.7.4	Maximum occupancy timer .....	375
14.7.5	Loop test symbol (LTS) .....	375
14.7.6	Loop test packet (LTP) .....	376
14.7.7	Test port selection .....	376
14.7.8	Loop test .....	376
14.7.9	Completing the attach .....	377
14.7.10	Received ATTACH_REQUEST or bus reset .....	378
14.7.11	Loop Disabled state .....	378
14.7.12	Connections to Alpha nodes .....	378
14.7.13	Loop detection during bus initialization .....	378
14.7.14	Minimal LTP support .....	379
14.7.15	Isolated node behavior .....	379
14.8	Connection management .....	379
14.8.1	Connection detection .....	379
14.8.2	Connection detection and mode determination algorithm .....	379
14.8.3	Beta-mode speed negotiation .....	380
14.8.4	Disabled ports .....	382
14.9	T-mode connectivity and operation .....	383
14.10	Simultaneous support for Beta mode and T-mode .....	383
14.11	Negotiation .....	383
14.11.1	Overview .....	383
14.11.2	S100 Beta mode parallel negotiation .....	384
14.11.2.1	Clause 22 in IEEE Std 802.3-2005 .....	384
14.11.3	Differences between T-mode and IEEE 802.3 negotiation .....	384
14.11.3.1	Clause 28 in IEEE Std 802.3-2005 .....	385
14.11.3.2	Annex 28A in IEEE Std 802.3-2005 .....	387
14.11.3.3	Annex 28B in IEEE Std 802.3-2005 .....	387
14.11.3.4	Annex 28C in IEEE Std 802.3-2005 .....	387
14.11.3.5	Subclause 40.5 in IEEE Std 802.3-2005 .....	388
15.	PHY register map .....	389
15.1	Arbitration compliance levels .....	389
15.1.1	Arbitration Compliance Level A .....	389
15.1.2	Arbitration Compliance Level B .....	389
15.2	PHY register map for the cable environment .....	389
15.2.1	Port Status page .....	394

15.2.2	Vendor Identification page.....	398
15.3	PHY register map for the backplane environment.....	399
15.4	Integrated link and PHY.....	400
16.	Data routing, arbitration, and control.....	401
16.1	Overview.....	401
16.2	PHY services.....	402
16.2.1	Cable PHY bus management services for the management layer.....	403
16.2.1.1	PHY control request (PH_CONTROL.request).....	403
16.2.1.2	PHY control confirmation (PH_CONTROL.confirmation).....	403
16.2.1.3	PHY event indication (PH_EVENT.indication).....	403
16.2.1.4	PHY event response (PH_EVENT.response).....	404
16.2.1.5	PHY link type inquiry indication (PH_LINK_TYPE.indication) and response (PH_LINK_TYPE.response).....	404
16.2.2	PHY arbitration services for the link layer.....	405
16.2.2.1	PHY arbitration request (PH_ARB.request).....	405
16.2.2.2	PHY arbitration confirmation (PH_ARB.conf).....	407
16.2.3	PHY data services for the link layer.....	407
16.2.3.1	PHY clock indication (PH_CLOCK.indication).....	408
16.2.3.2	PHY data request (PH_DATA.request).....	408
16.2.3.3	PHY data indication (PH_DATA.indication).....	409
16.2.4	PHY-link interface block.....	409
16.2.5	PMD services for the PHY.....	410
16.2.5.1	PMD control request (PMD_CONTROL.request).....	410
16.2.5.2	PMD status request (PMD_STATUS.request) and confirmation (PMD_STATUS.confirmation).....	410
16.2.5.3	PMD Beta port data indication (PMD_DATA.indication).....	411
16.2.5.4	PMD Beta port transmit data request (PMD_DATA.request).....	411
16.2.5.5	PMD DS port receive signal request (PMD_DSPORT_SIGNAL.request) and confirmation (PMD_DSPORT_SIGNAL.confirmation).....	411
16.2.5.6	PMD DS port receive speed request (PMD_DSPORT_RXSPEED.request) and confirmation (PMD_DSPORT_RXSPEED.confirmation).....	412
16.2.5.7	PMD DS port transmit data request (PMD_DSPORT_DATA.request) ..	412
16.2.5.8	PMD DS port transmit arbitration state request (PMD_DSPORT_ARB.request).....	412
16.2.5.9	PMD DS port transmit speed request (PMD_DSPORT_TXSPEED.request).....	412
16.2.5.10	PMD DS port TpBias request (PMD_DSPORT_TPBIAS.request).....	413
16.2.5.11	PMD cable power status request (PMD_PS.request) and confirmation (PMD_PS.confirmation).....	413
16.2.5.12	PMD cable speed request (PMD_CABLE_SPEED.request) and confirmation (PMD_CABLE_SPEED.confirmation).....	413
16.3	PHY facilities.....	413
16.3.1	PHY packet overview.....	413
16.3.1.1	PHY packet transmission and reception.....	413
16.3.1.2	PHY packet identifier bits.....	414
16.3.2	Alpha packet formats.....	414
16.3.2.1	Alpha self-ID packets.....	415
16.3.2.2	Alpha Link-on packet.....	417
16.3.2.3	Alpha PHY configuration packet.....	417
16.3.2.4	Alpha extended PHY packets.....	418
16.3.3	Beta PHY packet formats.....	422
16.3.3.1	Beta self-ID packets.....	422

16.3.3.2	Beta Remote command packet .....	424
16.3.3.3	Beta Remote confirmation packet .....	425
16.3.3.4	Beta PHY configuration packet .....	426
16.3.3.5	Loop test packet (LTP) .....	427
16.3.4	Data packet formats .....	428
16.3.4.1	Alpha and Beta packet formats .....	428
16.3.4.2	General packet format .....	428
16.3.4.3	Alpha format with speed code .....	429
16.3.4.4	Alpha format for S100 packets without speed code .....	430
16.3.4.5	Beta format for all packet speeds .....	431
16.3.4.6	Minimum packet spacing .....	431
16.3.4.7	Deletable symbols .....	431
16.3.4.8	Packet transmission examples .....	432
16.3.5	Packet forwarding .....	433
16.3.5.1	Packets at speeds greater than the port operating speed .....	433
16.3.5.2	Packet forwarding: DS port to Beta port .....	433
16.3.5.3	Packet forwarding: Beta port to DS port .....	433
16.4	Cable PHY operation .....	434
16.4.1	C code functions and variables .....	434
16.4.2	Arbitration .....	436
16.4.2.1	DS-mode arbitration .....	436
16.4.2.2	Beta-mode arbitration .....	436
16.4.3	Hybrid bus operation .....	439
16.4.3.1	Hybrid bus initialization .....	439
16.4.3.2	Border node functions .....	440
16.4.3.3	BORDER request mapping .....	442
16.4.3.4	Discussion of root outside the Beta cloud .....	442
16.4.4	Isochronous intervals .....	443
16.4.5	Bus reset state machine .....	446
16.4.6	Tree identification state machine .....	448
16.4.7	Self-identification state machine .....	450
16.4.8	Arbitration state machine .....	453
16.4.9	Large diameter networks .....	456
16.4.9.1	BOSS_RESTART_TIME .....	456
16.4.9.2	TEST_INTERVAL .....	457
17.	Parallel PHY-link interface .....	459
17.1	Introduction .....	459
17.2	Alpha (A) PHY-link interface specification .....	460
17.2.1	Initialization and reset .....	463
17.2.2	Link-on and interrupt indications .....	466
17.2.3	Link requests .....	466
17.2.3.1	LReq rules .....	471
17.2.3.2	Acceleration control .....	474
17.2.4	Status .....	474
17.2.5	Transmit .....	476
17.2.6	Cancel .....	478
17.2.7	Receive .....	479
17.2.8	Electrical characteristics (cable environment) .....	479
17.2.8.1	DC signal levels and waveforms .....	479
17.2.8.2	AC timing .....	481
17.2.8.3	AC timing .....	483
17.3	Beta (B) and Beta Plus (B Plus) PHY-link interface specification .....	484

17.3.1	Beta (B) and Beta Plus (B Plus) PHY-link interface characteristics.....	485
17.3.2	PHY-link interface signals .....	485
17.3.2.1	PHY signals .....	485
17.3.2.2	Link signals.....	485
17.3.2.3	PHY-Link signal descriptions .....	486
17.3.2.4	Detailed signal descriptions.....	487
17.3.2.5	Differentiated signals.....	488
17.3.3	Interface initialization, reset, and disable .....	489
17.3.3.1	LPS signal characteristics.....	489
17.3.3.2	Interface reset .....	490
17.3.3.3	Interface disable.....	491
17.3.3.4	Restoration and initialization.....	492
17.3.3.5	Initialization completion sequence .....	492
17.3.4	LinkOn signal characteristics .....	493
17.3.5	Link requests and notifications.....	494
17.3.5.1	Link request characteristics .....	495
17.3.5.2	Link notifications.....	498
17.3.5.3	Link request and notification format .....	499
17.3.6	Interface data transfers .....	502
17.3.6.1	Interface phases .....	502
17.3.6.2	Packet reception.....	502
17.3.6.3	Packet transmission .....	505
17.3.7	Format of received and transmitted data .....	512
17.3.7.1	S100 data .....	513
17.3.7.2	S200 data .....	514
17.3.7.3	S400 data .....	514
17.3.7.4	S800 data .....	515
17.3.7.5	S1600 Data .....	516
17.3.7.6	S3200 Data .....	516
17.3.8	Status transfers and notifications from the PHY .....	516
17.3.8.1	Bus Status Transfers .....	517
17.3.8.2	PHY Status Transfers .....	518
17.3.9	Delays affecting interoperability of PHYs and links.....	521
17.3.10	Alpha link support .....	521
17.3.11	Electrical characteristics.....	522
17.3.11.1	DC signal levels and waveforms .....	522
17.3.11.2	AC timing .....	524
17.4	Isolation barrier .....	527
17.4.1	Introduction .....	527
17.4.2	Capacitive isolation barrier.....	527
17.4.3	Alternative isolation barrier.....	530
18.	PIL-FOP serial interface .....	533
18.1	Operating model.....	533
18.2	PIL-FOP connection management .....	534
18.2.1	Power-on.....	534
18.2.2	PIL-FOP negotiation .....	534
18.2.3	PIL-FOP restore.....	535
18.2.4	Port restore.....	535
18.2.5	Loss of synchronization.....	535
18.2.6	Loss of power .....	535
18.2.7	LPS .....	536
18.2.8	Serial bus reset.....	536

18.3	Serial bus configuration request types not carried over the PIL-FOP interface.....	536
18.4	P2P packet protocol.....	536
19.	PHY C code .....	539
19.1	Common declarations and functions .....	539
19.2	Connection management routines .....	558
19.2.1	Node-level connection monitor .....	558
19.2.2	Port connection manager actions and conditions .....	567
19.3	Port state machine actions .....	587
19.3.1	DS port.....	588
19.3.2	Beta port .....	595
19.3.3	T-mode port .....	611
19.4	Border arbitration actions and conditions .....	630
19.4.1	Border arbitration functions .....	630
19.4.2	Request processing .....	654
19.4.3	Bus reset .....	664
19.4.4	Tree identification .....	667
19.4.5	Self-identification .....	668
19.5	Border arbitration .....	673
20.	T-mode port specification .....	689
20.1	Overview .....	689
20.2	Port functions .....	690
20.2.1	Port functions overview.....	690
20.2.2	Adaptation .....	690
20.2.2.1	Rate adaptation .....	691
20.2.2.2	Clause 40 in IEEE Std 802.3-2005 .....	691
20.2.3	Coding .....	692
20.2.3.1	Main properties.....	692
20.2.4	Symbol types .....	693
20.2.5	Data symbols .....	693
20.2.6	Arbitration requests .....	693
20.2.7	Configuration requests.....	695
20.2.8	Control symbols in symbol positions A and B .....	695
20.2.9	Control symbols in symbol positions C and D .....	695
20.3	T-mode port operation.....	696
20.3.1	Transmit operations .....	696
20.3.1.1	Control transmission .....	696
20.3.1.2	Request transmission .....	697
20.3.1.3	Packet transmission .....	697
20.3.1.4	Speed signaling.....	697
20.3.1.5	Payload transmission .....	697
20.3.2	Receive operations.....	699
20.3.2.1	Symbol decode rules.....	699
20.3.2.2	Control reception .....	702
20.3.2.3	Request type reception.....	702
20.3.2.4	Speed code determination.....	702
20.3.2.5	Payload reception .....	703
20.3.2.6	Further robustness measures .....	703
20.3.2.7	Error reporting .....	704

21.	S800 UTP (T-mode) PMD electrical specification.....	705
21.1	T-mode PMD specification .....	706
21.2	T-mode PMD initialization .....	706
21.3	Gigabit media independent interface (GMII).....	706
21.4	T-mode suspend and resume .....	707
21.4.1	Alternative link pulse (ALP) .....	707
21.4.2	Suspend.....	707
21.4.3	Resume .....	707
21.5	UTP cable power .....	708
	Annex A (normative) Cable environment electrical isolation .....	709
A.1	Grounding characteristics of ac-powered devices .....	709
A.2	Electrical isolation .....	709
A.3	Agency requirements .....	710
	Annex B (normative) External connector positive retention .....	713
	Annex C (normative) Internal device physical interface .....	715
C.1	Overview.....	715
C.2	Electrical interface for internal devices .....	715
C.2.1	Power requirements.....	715
C.2.2	Bus signal requirements .....	716
C.2.3	Miscellaneous signals.....	717
C.2.4	Signal descriptions .....	717
C.3	Internal unitized device connectors .....	719
C.3.1	Internal unitized plug .....	721
C.3.2	Internal unitized receptacles .....	727
C.3.3	Connector cable receptacles .....	731
C.3.4	Cable receptacle termination .....	734
C.3.5	Cable.....	734
C.3.5.1	Flat ribbon cable.....	734
C.3.5.2	Discrete wire .....	735
C.3.6	Contact finish on mating surfaces of plug and receptacle contacts.....	735
C.3.7	Termination finish on plug and receptacle contact .....	735
C.3.8	Connector performance criteria.....	735
C.3.8.1	Test sample preparation .....	736
C.3.8.2	Performance group A: Basic mechanical conformance and electrical functionality when subjected to mechanical shock and vibration.....	736
C.3.8.3	Performance group B: Low-level contact resistance when subjected to thermal shock and humidity stress .....	738
C.3.8.4	Performance group C: Insulator integrity when subjected to thermal shock and humidity stress .....	739
C.3.8.5	Performance group D: Contact life and durability when subjected to mechanical cycling and corrosive gas exposure .....	740
C.3.8.6	Performance group E: Contact resistance and mating and unmating force when subjected to temperature life stress .....	741
C.3.8.7	Performance group F: Mechanical retention and durability .....	741
C.3.8.8	Performance group G: General tests .....	742

Annex D (normative) Backplane PHY timing formulas .....	743
D.1 Backplane propagation delay .....	743
D.2 Backplane arbitration timing .....	744
D.2.1 Synchronization timing .....	744
D.2.2 Arbitration sample timing .....	745
D.2.3 Arbitration hold timing .....	745
D.2.4 Arbitration bit timing .....	746
D.3 Backplane gap timing .....	746
D.3.1 Acknowledge gap .....	747
D.3.1.1 Occurrence of acknowledge gap .....	747
D.3.1.2 Acknowledge gap timing .....	747
D.3.2 Subaction gap and arbitration reset gap .....	748
D.3.2.1 Occurrence of subaction and arbitration reset gaps .....	748
D.3.2.2 Subaction gap and arbitration reset gap timing .....	748
D.3.3 Arbitration gap scenarios .....	749
D.3.3.1 Scenario 1: acknowledge gap .....	750
D.3.3.2 Scenario 2: subaction gap .....	750
D.3.3.3 Scenario 3: arbitration reset gap .....	751
D.4 Backplane environment skew .....	752
Annex E (normative) Cable operation and implementation examples .....	753
E.1 Performance optimization .....	753
E.2 Cable environment jitter budget .....	757
E.3 Cable PHY configuration example .....	759
E.3.1 Bus initialization process .....	759
E.3.2 Tree identify process .....	759
E.3.3 Self identify process .....	763
E.3.4 Topology construction .....	769
Annex F (normative) Backplane physical implementation example .....	773
F.1 Standardized parallel bus implementations .....	773
F.2 PHY implementation .....	775
F.2.1 PHY layer overview .....	775
F.2.1.1 Serial bus PHY logic .....	775
F.2.1.2 Serial bus link logic .....	775
F.2.1.3 Backplane transceivers .....	775
F.2.1.4 Local clock .....	776
F.2.2 High-level PHY logic description .....	776
F.2.2.1 LINK/PHY interface controller .....	776
F.2.2.2 Arbitration controller .....	777
F.2.2.3 Data encode .....	778
F.2.2.4 Arb/data multiplexer .....	778
F.2.2.5 Data resync/decode .....	778
Annex G (normative) Backplane IRM selection .....	779
G.1 Backplane configuration management .....	779
G.2 IRM selection process .....	779
G.3 Example of an IRM selection process .....	779
G.3.1 IRM-capable node environment .....	779
G.3.2 Non-IRM environment .....	780

Annex H (normative) Serial bus configuration in the cable environment .....	781
H.1 Bus configuration timeline.....	781
H.2 Bus configuration scenarios.....	782
H.2.1 Bus configuration with a bus manager and an IRM.....	782
H.2.2 Bus configuration with only an IRM.....	786
H.3 Combined bus manager and IRM .....	787
H.4 Abdication by the bus manager .....	788
Annex I (normative) Socket PCB terminal patterns and mounting .....	789
I.1 Socket orientation .....	789
I.2 PCB mounting 0.....	789
Annex J (normative) Transaction integrity safeguards.....	795
Annex K (normative) Serial bus cable assembly test procedures.....	797
K.1 Scope.....	797
K.2 Test fixtures .....	797
K.2.1 Cable test fixture .....	797
K.2.2 Differential test fixture .....	799
K.3 Signal pairs characteristic and discrete impedance.....	801
K.3.1 Signal pairs impedance setup calibration—short and load .....	802
K.3.2 Signal pairs impedance test procedure (connector).....	802
K.3.3 Signal pairs impedance limits (connector) .....	803
K.3.4 IEEE 1394 bulk serial bus cable test methodology .....	803
K.3.4.1 Equipment .....	803
K.3.4.2 Sample.....	803
K.3.4.3 Method .....	803
K.3.4.4 Results .....	803
K.4 Signal pairs attenuation.....	804
K.4.1 Signal pairs attenuation setup calibration.....	804
K.4.2 ATPA .....	805
K.4.3 ATPB.....	806
K.4.4 Signal pairs attenuation limits .....	807
K.4.5 IEEE 1394 bulk serial bus cable test methodology .....	807
K.4.5.1 Equipment .....	807
K.4.5.2 Sample.....	807
K.4.5.3 Method .....	807
K.4.5.4 Results .....	807
K.5 Signal pairs velocity of propagation .....	807
K.5.1 Signal pairs velocity of propagation setup calibration .....	808
K.5.2 VTPA .....	808
K.5.3 VTPB.....	809
K.5.4 Signal pairs velocity of propagation limits .....	809
K.5.5 IEEE 1394 bulk serial bus cable test methodology (TDR) .....	809
K.5.5.1 Equipment .....	809
K.5.5.2 Sample.....	809
K.5.5.3 Method .....	809
K.5.5.4 Results .....	809
K.5.6 IEEE 1394 bulk serial bus cable test methodology (frequency sweep) .....	810
K.5.6.1 Equipment .....	810
K.5.6.2 Sample.....	810

	K.5.6.3	Method .....	810
	K.5.6.4	Results .....	810
	K.5.7	Rise and fall time .....	810
	K.5.7.1	Equipment .....	810
	K.5.7.2	Sample .....	810
	K.5.7.3	Method .....	810
	K.5.7.4	Results .....	811
	K.5.8	Static shield isolation (insulation resistance) .....	811
	K.5.8.1	Equipment .....	811
	K.5.8.2	Sample .....	811
	K.5.8.3	Method .....	811
	K.5.8.4	Results .....	811
	K.6	Signal pairs relative propagation skew .....	811
	K.6.1	Signal pairs skew setup calibration .....	812
	K.6.2	Signal pairs skew test procedure .....	813
	K.6.3	Signal pairs skew limits .....	813
	K.7	Power pair characteristic impedance .....	814
	K.7.1	Power pair impedance setup calibration—short and load .....	815
	K.7.2	Power pair impedance test procedure .....	815
	K.7.3	Power pair dc resistance .....	815
	K.7.4	DC resistance setup calibration .....	816
	K.7.5	DC resistance test procedure .....	817
	K.7.6	DC resistance limits .....	817
	K.8	Crosstalk .....	818
	K.8.1	Crosstalk setup calibration .....	818
	K.8.2	Crosstalk test procedure (between power and signal pairs) .....	819
	K.8.3	Crosstalk test procedure (between signal pairs) .....	820
	K.8.4	Crosstalk limits .....	820
	K.8.5	Crosstalk limits (between signal pairs) .....	821
Annex L (normative) Shielding effectiveness and transfer impedance testing .....			823
	L.1	Content .....	823
	L.2	Definitions .....	823
	L.3	Test equipment .....	823
	L.4	Theory .....	824
	L.4.1	Reference measurement .....	824
	L.4.2	Sample measurement .....	824
	L.4.3	Calculations .....	825
	L.5	Sample preparation .....	825
	L.5.1	Panel-mounted connector sample .....	825
	L.5.2	Measure sample $Z_0$ with TDR .....	826
	L.5.3	Cable-mounted connector sample .....	826
	L.6	Procedure .....	826
	L.7	“Noise floor” plot .....	827
	L.8	Documentation .....	827
	L.8.1	Plots and magnetic files .....	827
	L.8.2	Test report .....	828
	L.9	Performance .....	828
Annex M (informative) Serial bus topology considerations for power distribution (cable environment) ..			829

Annex N (normative) Jitter measurements .....	833
N.1 Test patterns .....	833
N.2 Random pattern (SB_RPAT) .....	833
N.3 Receive jitter tolerance pattern (SB_JTPAT) .....	833
N.4 Supply noise test sequence (SB_SPAT) .....	834
Annex O (informative) Connection status change .....	835
Annex P (informative) Deriving bus topology from self-ID packets .....	837
P.1 Bus topology analysis .....	837
P.2 Topology analysis after power reset .....	838
P.3 Topology analysis when the root changes .....	842
P.4 Topology analysis when a node is inserted .....	844
Annex Q (informative) Summary description .....	847
Q.1 Node and module architectures .....	847
Q.2 Topology .....	848
Q.2.1 Cable environment .....	848
Q.2.2 Backplane environment .....	849
Q.3 Addressing .....	849
Q.4 Protocol architecture and data transfer services .....	850
Q.4.1 SBP architecture .....	850
Q.4.2 Data transfer services .....	850
Q.5 Transaction layer .....	851
Q.5.1 Transaction layer services .....	852
Q.5.2 Lock subcommands .....	852
Q.5.3 Subaction queue independence .....	853
Q.6 Link layer .....	854
Q.6.1 Link layer services .....	855
Q.6.2 Link and transaction layer interactions .....	856
Q.6.2.1 Unified transactions .....	856
Q.6.2.2 Split transactions .....	857
Q.6.2.3 Subaction concatenation .....	857
Q.6.2.4 Retries .....	859
Q.6.3 Asynchronous arbitration .....	859
Q.6.4 Isochronous arbitration .....	860
Q.7 Physical layer (PHY) .....	861
Q.7.1 Data bit transmission and reception .....	861
Q.7.2 Fair arbitration .....	862
Q.7.3 Cable PHY .....	863
Q.7.3.1 Cable configuration .....	864
Q.7.3.2 Normal arbitration .....	867
Q.7.3.3 Speed signaling .....	870
Q.7.3.4 Cable media interface .....	870
Q.7.4 Backplane PHY .....	871
Q.7.4.1 Backplane arbitration .....	871
Q.7.4.2 Urgent arbitration .....	872
Q.7.4.3 Backplane media interface .....	873
Q.8 Bus management .....	874
Q.9 New features of IEEE Std 1394a-2000 .....	874
Q.9.1 Connection debounce .....	875

Q.9.2	Cable arbitration enhancements .....	875
Q.9.2.1	Arbitrated (short) bus reset.....	875
Q.9.2.2	Ack-accelerated arbitration .....	876
Q.9.2.3	Fly-by concatenation.....	877
Q.9.2.4	Multi-speed packet concatenation.....	878
Q.9.2.5	Arbitration enhancements and cycle start .....	878
Q.9.3	Performance optimization via PHY “pinging”.....	879
Q.9.4	Priority arbitration .....	879
Q.9.5	Port disable, suspend, and resume.....	880
Q.9.5.1	Connection detect circuit.....	880
Q.9.5.2	Suspended connection.....	880
Q.9.5.3	Suspended domain .....	881
Q.9.5.4	Resumption .....	882
Q.9.5.5	Boundary nodes.....	882
Q.10	New features of IEEE Std 1394b-2002.....	883
Q.10.1	The relationship to IEEE Std 1394a-2000.....	883
Q.10.2	Faster and further .....	883
Q.10.3	Nomenclature .....	884
Q.10.4	Media—common properties.....	885
Q.10.4.1	Short-haul shielded twisted pair (STP) cabling .....	885
Q.10.4.2	CAT-5 UTP cable (see Chapter 7 of ISO/IEC 11801:2002).....	885
Q.10.4.3	Plastic optic fiber (POF) and hard polymer clad fiber (HPCF) .....	885
Q.10.4.4	Glass fiber .....	886
Q.10.4.5	Media summary for Beta-mode operation .....	886
Q.10.5	Arbitration improvements .....	886
Q.10.5.1	Legacy arbitration .....	886
Q.10.5.2	New arbitration method—bus owner/supervisor/selector (BOSS).....	887
Q.10.6	PHY-link interface .....	892
Q.10.6.1	Evolutionary PHY-link interface .....	892
Q.10.6.2	Serial PHY-link interface.....	893
Q.10.7	Miscellaneous features .....	893
Q.10.7.1	Autonegotiation.....	893
Q.10.7.2	Loop breaking .....	894
Q.10.7.3	Power conservation improvements .....	894
Q.11	New features of IEEE Std 1394c-2006.....	894
Q.11.1	Scope .....	894
Q.11.2	Purpose .....	895
Q.11.3	T-mode features.....	895
Q.11.4	The relationship of T-mode to Beta mode .....	895
Q.11.5	The relationship to IEEE Std 802.3-2005 .....	895
Q.11.6	S800 over UTP .....	895
Q.11.7	Twin-mode ports .....	896
Q.12	New features of IEEE Std 1394-2008.....	896
Q.12.1	Errata .....	896
Q.12.2	Enhanced UTP PMD .....	896
Q.12.3	Beta PMD electrical specification .....	897
Q.12.4	Beta Plus PHY-link interface .....	897
Q.12.5	Bus topology determination .....	897
Q.12.6	Document organization .....	897

Annex R (informative) Glossary.....	899
R.1 Conformance.....	899
R.2 Definitions .....	899
Annex S (informative) Bibliography .....	905

## List of figures

Figure 1-1—Example hierarchical bus topology.....	3
Figure 1-2—Service model.....	4
Figure 1-3—Bit and byte ordering.....	5
Figure 1-4—Sample packet format.....	6
Figure 1-5—State machine example.....	8
Figure 1-6—Example of CSR format specification .....	9
Figure 1-7—Reserved CSR field behavior .....	11
Figure 4-1—6-circuit plug body .....	31
Figure 4-2—6-circuit plug section details .....	32
Figure 4-3—6-circuit socket shell .....	33
Figure 4-4—6-circuit socket shell detail .....	34
Figure 4-5—6-circuit socket insertion wafer.....	35
Figure 4-6—6-circuit socket insertion wafer details .....	36
Figure 4-7—6-circuit cable material construction example (for reference only).....	38
Figure 4-8—Example 6-circuit cable assembly and schematic.....	39
Figure 4-9—Shock and vibration fixturing diagram .....	41
Figure 4-10—Shield and contact resistance measuring points.....	45
Figure 4-11—4-circuit plug body .....	51
Figure 4-12—4-circuit plug section details .....	51
Figure 4-13—4-circuit connector socket interface .....	52
Figure 4-14—4-circuit socket cross-section A-A .....	53
Figure 4-15—Cross-section of 4-circuit plug and socket contacts.....	53
Figure 4-16—4-circuit socket position when mounted on a PCB.....	54
Figure 4-17—Flat SMT PCB 4-circuit socket footprint.....	55
Figure 4-18—Flat through-hole mount PCB 4-circuit socket footprint .....	55
Figure 4-19—4-circuit cable material construction example (for reference only).....	56
Figure 4-20—Cable assembly and schematic (6-pin to 4-pin connector).....	57
Figure 4-21—Cable assembly and schematic (4-pin connectors).....	57
Figure 4-22—Shield and contact resistance measuring points.....	63
Figure 4-23—Fixture for cable flex test .....	66
Figure 4-24—Beta plug body with overmold.....	69
Figure 4-25—Bilingual plug body with overmold .....	70
Figure 4-26—Beta and bilingual plug interface: Detail A .....	71
Figure 4-27—Beta and bilingual plug section Z-Z (unmated).....	71
Figure 4-28—Beta and bilingual detent cross-section S-S.....	72
Figure 4-29—Beta socket body.....	73
Figure 4-30—Beta socket outer shell profile.....	73
Figure 4-31—Bilingual socket body.....	74
Figure 4-32—Bilingual socket outer shell profile .....	74
Figure 4-33—Beta and bilingual socket section X-X.....	75
Figure 4-34—Beta and bilingual socket section Y-Y.....	75
Figure 4-35—Beta and bilingual socket section V-V.....	76
Figure 4-36—Beta and bilingual socket section Z-Z.....	76
Figure 4-37—Beta and bilingual socket section W-W .....	77
Figure 4-38—Beta and bilingual socket interface .....	77
Figure 4-39—Beta and bilingual plug and socket detent feature cross-section.....	78
Figure 4-40—Socket positions when mounted on a PCB .....	78
Figure 4-41—Beta PCB socket footprint.....	80
Figure 4-42—Bilingual PCB socket footprint .....	81
Figure 4-43—Beta and bilingual PHY trace routing.....	82
Figure 4-44—Example of Beta cable construction—4.5 m maximum (for reference only).....	83
Figure 4-45—Example of Beta cable construction—2 m maximum (for reference only).....	84

Figure 4-46—Interface mating chart .....	85
Figure 4-47—Type 1 cable assembly and schematic (Beta plug to Beta plug).....	86
Figure 4-48—Type 2 cable assembly and schematic (6-circuit plug to bilingual plug).....	87
Figure 4-49—Type 3 cable assembly and schematic (4-circuit plug to bilingual plug).....	88
Figure 4-50—Shield and contact resistance measurement points .....	93
Figure 4-51—Fixture for cable flex test .....	96
Figure 4-52—PCB stack-up for connector-only differential test fixture.....	97
Figure 4-53—PCB top layer for connector-only differential test fixture .....	97
Figure 4-54—PCB ground layer for connector-only differential test fixture.....	98
Figure 4-55—PCB stack-up for cable assembly differential test fixture.....	98
Figure 4-56—PCB top layer for cable assembly differential test fixture .....	98
Figure 4-57—PCB ground layer for cable assembly differential test fixture.....	99
Figure 4-58—Test fixture schematic .....	99
Figure 4-59—Connector impedance exception window mask.....	101
Figure 4-60—S3200 cable insertion loss example .....	102
Figure 4-61—S3200 cable SCD21-SDD21 .....	103
Figure 5-1—Backplane topology.....	110
Figure 5-2—Backplane transmit data timing.....	112
Figure 5-3—Backplane receive data timing .....	113
Figure 5-4—Arbitration bit timing .....	117
Figure 5-5—DS coding.....	118
Figure 5-6—Arbitration sequence .....	121
Figure 5-7—Backplane PHY architecture .....	121
Figure 5-8—Fairness interval .....	123
Figure 5-9—Fair arbitration.....	123
Figure 5-10—Urgent arbitration.....	125
Figure 6-1—Serial bus packets.....	136
Figure 6-2—Primary packet format.....	136
Figure 6-3—Asynchronous packet format .....	137
Figure 6-4—No-data payload primary packet format .....	138
Figure 6-5—Read request for data quadlet packet format.....	139
Figure 6-6—Write response packet format .....	139
Figure 6-7—Data quadlet payload packet format.....	139
Figure 6-8—Read request for data block packet format.....	140
Figure 6-9—Write request for data quadlet packet format.....	140
Figure 6-10—Cycle start packet format .....	141
Figure 6-11—Read response for data quadlet packet format .....	141
Figure 6-12—Data block payload packet format .....	142
Figure 6-13—Write request for data block packet format.....	143
Figure 6-14—Lock-request packet format .....	143
Figure 6-15—Read response for data block packet format .....	144
Figure 6-16—Lock-response packet format .....	145
Figure 6-17—Isochronous data block packet format .....	146
Figure 6-18—Asynchronous stream packet format.....	147
Figure 6-19—Global asynchronous stream packet (GASP) format .....	148
Figure 6-20—Acknowledge packet format .....	156
Figure 6-21—Link layer packet transmit/receive state machine .....	162
Figure 7-1—Outbound transaction state machine .....	181
Figure 7-2—Inbound transaction state machine.....	185
Figure 7-3—Inbound subaction dual-phase retry state machine .....	192
Figure 8-1—STATE_CLEAR format .....	205
Figure 8-2—STATE_CLEAR.bus_depend field.....	205
Figure 8-3—NODE_IDS format .....	207
Figure 8-4—SPLIT_TIMEOUT format .....	208

Figure 8-5—CYCLE_TIME format .....	210
Figure 8-6—BUS_TIME format .....	211
Figure 8-7—POWER_FAIL_IMMINENT format.....	212
Figure 8-8—POWER_SOURCE format .....	213
Figure 8-9—BUSY_TIMEOUT format .....	213
Figure 8-10—PRIORITY_BUDGET format .....	214
Figure 8-11—BUS_MANAGER_ID format.....	216
Figure 8-12—BANDWIDTH_AVAILABLE format .....	216
Figure 8-13—CHANNELS_AVAILABLE format.....	218
Figure 8-14—MAINT_CONTROL format.....	219
Figure 8-15—MAINT_UTILITY format .....	220
Figure 8-16—BROADCAST_CHANNEL format.....	221
Figure 8-17—TOPOLOGY_MAP format.....	222
Figure 8-18—Configuration ROM hierarchy .....	223
Figure 8-19—Minimal ROM format .....	224
Figure 8-20—General ROM format .....	225
Figure 8-21—Bus_Info_Block format.....	225
Figure 8-22—Module_Vendor_Id entry format .....	228
Figure 8-23—Node_Capabilities entry format .....	228
Figure 8-24—Unit_Power_Requirements entry format .....	229
Figure 8-25—Candidate cycle master state machine .....	240
Figure 8-26—Candidate IRM state machine.....	241
Figure 8-27—Candidate bus manager state machine .....	243
Figure 9-1—PHY master architecture (short-haul copper electrical PMD in context) .....	245
Figure 9-2—Short-haul copper PHY architecture .....	246
Figure 9-3—Cable topology .....	247
Figure 9-4—Measurement points (half connection is shown).....	248
Figure 9-5—Port interface .....	249
Figure 9-6—Differential output test loads.....	250
Figure 9-7—Common mode current test loads.....	253
Figure 9-8—Common mode output noise test loads .....	254
Figure 9-9—DS coding.....	257
Figure 9-10—Start of packet transmission .....	263
Figure 9-11—Concatenated packet transmission .....	263
Figure 9-12—End of packet transmission .....	264
Figure 9-13—Subaction response.....	264
Figure 9-14—Example of S1600 and S3200 de-emphasis .....	269
Figure 9-15—Balanced transmitter test circuit.....	269
Figure 9-16—Normalized eye diagram mask at TP2 .....	270
Figure 9-17—Absolute eye diagram mask at TP2.....	270
Figure 9-18—TP3 test load.....	272
Figure 9-19—Eye diagram mask at point TP3 .....	273
Figure 9-20—Example S3200 fixed equalizer function .....	275
Figure 9-21—SIGNAL_DETECT timing parameters.....	281
Figure 9-22—Example of bilingual port termination .....	286
Figure 9-23—Beta-only connection to copper cable.....	287
Figure 9-24—Termination for PIL-FOP interface.....	288
Figure 9-25—Node power interface for POWER_CLASS one, two, or three.....	289
Figure 9-26—Node power interface for POWER_CLASS four (three or more ports) .....	289
Figure 9-27—Providing power to a floating PHY or FOP, power class 1, 2, or 3 .....	291
Figure 9-28—Providing power to a floating PHY or FOP, power class 1, 2, or 3 (alternative) .....	292
Figure 9-29—Providing power to a floating PHY or FOP, power class 4 .....	292
Figure 10-1—PHY master architecture (GOF PMD in context).....	295
Figure 10-2—PMD block diagram .....	296

Figure 10-3—Transmitter eye mask definition .....	302
Figure 10-4—Optical fiber cabling model.....	304
Figure 10-5—Duplex receptacle interface.....	305
Figure 10-6—Duplex connection interface .....	305
Figure 11-1—PHY master architecture .....	307
Figure 11-2—PMD block diagram .....	308
Figure 11-3—Plug connector interface.....	309
Figure 11-4—Receptacle connector interface .....	309
Figure 12-1—PHY master architecture (UTP PMD in context) .....	315
Figure 12-2—UTP PMD interfaces .....	316
Figure 12-3—Media interface connector socket.....	318
Figure 12-4—S100 signal mask for transmitted signal .....	321
Figure 12-5—S200/S400 normalized eye diagram mask at TP2 .....	322
Figure 12-6—S200/S400 absolute eye diagram mask at TP2 .....	322
Figure 12-7—signal_detect timing parameters.....	324
Figure 13-1—PHY master architecture (data routing, arbitration, and control interfaces in context) .....	327
Figure 13-2—Scrambling and coding functions.....	328
Figure 13-3—Representation of the scrambler as a serial bit-shift register with parallel output .....	333
Figure 13-4—Scrambler schematic (data).....	334
Figure 13-5—Scrambler schematic (request symbol) .....	335
Figure 13-6—Scrambler schematic (control) .....	336
Figure 13-7—Structure of packet, packet delimiters, and request types, with examples of coding process .....	351
Figure 13-8—Port transmit state machine .....	358
Figure 13-9—Port receive state machine.....	359
Figure 14-1—PHY master architecture (connection management in context).....	361
Figure 14-2—Port connection manager state machine.....	367
Figure 14-3—Example of dominant subnets .....	374
Figure 14-4—Speed code timing diagram .....	381
Figure 14-5—Example of speed negotiation .....	382
Figure 14-6—Message Code 5 sequence.....	388
Figure 15-1—Extended PHY register map for the cable environment.....	390
Figure 15-2—PHY register page 0: Port Status page .....	394
Figure 15-3—PHY register page 1: Vendor Identification page .....	398
Figure 15-4—PHY register map for the backplane environment.....	399
Figure 16-1—PHY master architecture (data routing, arbitration, and control interfaces in context) .....	401
Figure 16-2—Alpha self-ID packet formats .....	415
Figure 16-3—Alpha Link-on packet format.....	417
Figure 16-4—Alpha PHY configuration packet format .....	417
Figure 16-5—Alpha ping packet format.....	418
Figure 16-6—Alpha remote access packet format.....	419
Figure 16-7—Alpha remote reply packet format .....	419
Figure 16-8—Alpha remote command packet format .....	420
Figure 16-9—Alpha remote confirmation packet format .....	421
Figure 16-10—Alpha resume packet format .....	422
Figure 16-11—Beta self-ID packet formats .....	422
Figure 16-12—Beta Remote command packet format .....	424
Figure 16-13—Beta Remote confirmation packet format .....	425
Figure 16-14—Beta PHY configuration packet format.....	426
Figure 16-15—LTP format .....	427
Figure 16-16—Bus reset state machine .....	446
Figure 16-17—Tree identification state machine .....	448
Figure 16-18—Self-identification state machine.....	450
Figure 16-19—Border arbitration state machine .....	453

Figure 17-1—Alpha PHY-link interface logical signaling .....	461
Figure 17-2—Digital differentiator signal transformation .....	462
Figure 17-3—LPS waveform when differentiated .....	463
Figure 17-4—Alpha PHY-link interface reset via LPS .....	464
Figure 17-5—Alpha PHY-link interface disable via LPS .....	464
Figure 17-6—LReq and Ctl timings .....	467
Figure 17-7—Alpha PHY-link interface status timing .....	475
Figure 17-8—Alpha PHY-link interface transmit timing.....	477
Figure 17-9—Link cancel timing (after Grant) .....	478
Figure 17-10—Link cancel timing (after Hold) .....	478
Figure 17-11—Receive timing .....	479
Figure 17-12—Signal levels for rise and fall times.....	481
Figure 17-13—PHY to link transfer waveform at the PHY .....	481
Figure 17-14—Link to PHY transfer waveform at the PHY .....	482
Figure 17-15—PHY to link transfer waveform at the link .....	482
Figure 17-16—Link to PHY transfer waveform at the link.....	482
Figure 17-17—Alpha link to PHY delay timing .....	484
Figure 17-18—Beta and Beta Plus PHY-link interface logical signalling .....	486
Figure 17-19—Digital differentiator signal transformation .....	489
Figure 17-20—LPS waveform when differentiated .....	489
Figure 17-21—Beta and Beta Plus PHY-link interface reset .....	491
Figure 17-22—Beta and Beta Plus PHY-link interface disable .....	491
Figure 17-23—LinkOn waveform .....	493
Figure 17-24—Link request format .....	499
Figure 17-25—Beta interface PHY-link packet receive operation.....	503
Figure 17-26—Beta Plus PHY-Link packet receive operation in S3200 mode .....	504
Figure 17-27—Beta Plus PHY-Link packet receive operation in S1600 mode .....	504
Figure 17-28—Beta and Beta Plus PHY-link packet transmit operation, including optional HOLD cycles .....	507
Figure 17-29—Beta Plus PHY-Link packet transmit operation in S3200 mode.....	508
Figure 17-30—Beta Plus PHY-Link packet transmit operation in S1600 mode.....	509
Figure 17-31—Format of Beta interface data transfers in S100 mode.....	513
Figure 17-32—Format of Beta Plus interface data transfers in S100 mode.....	513
Figure 17-33—Format of Beta interface data transfers in S200 mode.....	514
Figure 17-34—Format of Beta Plus interface data transfers in S200 mode.....	514
Figure 17-35—Format of Beta interface data transfers in S400 mode.....	514
Figure 17-36—Format of Beta Plus interface data transfers in S400 mode.....	515
Figure 17-37—Format of Beta interface data transfers in S800 mode.....	515
Figure 17-38—Format of Beta Plus interface data transfers in S800 mode.....	515
Figure 17-39—Format of Beta Plus interface data transfers in S1600 mode.....	516
Figure 17-40—Format of Beta Plus interface data transfers in S3200 mode.....	516
Figure 17-41—Bus Status Transfer format .....	518
Figure 17-42—Beta and Beta Plus PHY Status Transfer format .....	520
Figure 17-43—Signal levels for rise and fall times.....	524
Figure 17-44—Transfer waveform at the source.....	526
Figure 17-45—Transfer waveform at the destination.....	526
Figure 17-46—Example of ground coupling circuit.....	527
Figure 17-47—Example of capacitive isolation barrier circuit for Ctl[0:1] and D[0:n].....	528
Figure 17-48—Example of capacitive isolation barrier circuit for LinkOn .....	528
Figure 17-49—Example of capacitive isolation barrier circuit for LPS.....	529
Figure 17-50—Example of capacitive isolation barrier circuit for LReq and PInt .....	529
Figure 17-51—Example of capacitive isolation barrier circuit for LClk and PClk.....	530
Figure 17-52—Example of bus holder isolation circuit for LReq, PInt, PClk, and LClk .....	530
Figure 17-53—Example of bus holder isolation circuit for Ctl[0:1] and D[0:n].....	531

Figure 18-1—Possible system configuration using a FOP device .....	533
Figure 18-2—P2P packet format .....	537
Figure 20-1—PHY master architecture (T-mode functions in context) .....	689
Figure 20-2—T-mode coding functions .....	690
Figure 20-3—T-mode adaptation .....	691
Figure 20-4—T-mode symbol type encoding .....	693
Figure 20-5—Arbitration request encoding .....	693
Figure 20-6—Control symbol encoding in positions A and B .....	695
Figure 20-7—Control symbol encoding in positions C and D .....	695
Figure 20-8—Structure of packet, packet delimiters, and request types with examples of coding process .....	698
Figure 21-1—PHY master architecture (S800 cat-5 UTP PMD in context) .....	705
Figure A.1—AC power supply with ground .....	709
Figure B.1—Exclusion zone for positive retention mechanism .....	713
Figure B.2—Three views of plug with shuttle type latch .....	714
Figure B.3—Cutouts in a typical personal computer option panel .....	714
Figure C.1—Recommended SMT PCB layout (connector mounting to the PC board in the device) .....	720
Figure C.2—Recommended PCB layout (connector mounting side) .....	720
Figure C.3—Internal unitized plug features .....	721
Figure C.4—Internal unitized plug .....	722
Figure C.5—Internal unitized plug retention (detent detail) .....	723
Figure C.6—Internal unitized plug header .....	723
Figure C.7—Internal unitized plug bus (bay detail) .....	724
Figure C.8—Internal unitized plug options (bay detail) .....	724
Figure C.9—Internal unitized plug power (bay detail) .....	725
Figure C.10—Internal unitized plug dual bus (bay detail) .....	726
Figure C.11—Internal unitized plug discrete power (bay detail) .....	727
Figure C.12—Internal unitized receptacle features .....	727
Figure C.13—Internal unitized receptacle .....	728
Figure C.14—Internal unitized receptacle contact detail .....	729
Figure C.15—Internal unitized receptacle bus (bay detail) .....	729
Figure C.16—Internal unitized receptacle option (bay detail) .....	730
Figure C.17—Internal unitized receptacle power (bay detail) .....	730
Figure C.18—Internal unitized device connector contact (wipe detail) .....	731
Figure C.19—Internal cable receptacle bus (bay detail) .....	732
Figure C.20—Internal cable receptacle option and power (bay detail) .....	733
Figure C.21—Overall terminated size of a power cable receptacle .....	734
Figure C.22—Shock and vibration fixturing diagram .....	737
Figure C.23—Contact resistance measuring points .....	738
Figure E.1—PHY pinging and round-trip times .....	755
Figure E.2—Example cable state after bus initialization process .....	759
Figure E.3—Tree identify process start, beginning of child handshake .....	760
Figure E.4—End of child handshake .....	760
Figure E.5—Parent handshake and start of root contention .....	761
Figure E.6—End of root contention, and new child handshake start .....	761
Figure E.7—End of final child handshake and root selection .....	762
Figure E.8—Final parent handshake .....	762
Figure E.9—Tree identify process complete .....	763
Figure E.10—Start of self-identify process .....	764
Figure E.11—First node sends self-ID information .....	764
Figure E.12—First node finishes self-identify .....	765
Figure E.13—Start of bus grant for second node self-identify .....	766
Figure E.14—Finish of bus grant for second node self-identify .....	766
Figure E.15—Second node self-identify .....	767
Figure E.16—Second node finishes self-identify .....	767

Figure E.17—Start of grant for third self-identify .....	768
Figure E.18—Completion of grant for third self-identify .....	768
Figure E.19—Example cable state after self-identify phase .....	769
Figure E.20—Topology information after identification of leaf nodes .....	770
Figure E.21—Topology information after identification of first branch node .....	770
Figure E.22—Topology information after identification of root node .....	771
Figure F.1—Typical application of serial bus in the backplane environment .....	773
Figure F.2—Link/PHY interface .....	775
Figure F.3—PHY logic block diagram .....	776
Figure H.1—Bus configuration timeline .....	781
Figure H.2—Bus configuration example (after power-on) .....	783
Figure H.3—Bus configuration example (after force root and reset) .....	784
Figure H.4—Bus configuration example (after new node insertion and reset) .....	785
Figure H.5—IRM-only bus configuration example (after power-on) .....	786
Figure H.6—IRM-only bus configuration example (after link-on to node 0) .....	787
Figure I.1—Socket orientations .....	789
Figure I.2—Right-angle upright through-hole mount .....	791
Figure I.3—Right-angle upright through-hole mount (inverted) .....	792
Figure I.4—Right-angle flat surface mount .....	793
Figure I.5—Right-angle flat surface mount (inverted) .....	794
Figure K.1—Cable test fixture schematic .....	798
Figure K.2—Test fixture graphic symbol .....	798
Figure K.3—100 W to 110 W matching pad .....	799
Figure K.4—Differential test fixture schematic .....	800
Figure K.5—Differential test fixture graphic symbol .....	801
Figure K.6—Signal pairs impedance measurement configuration (connector) .....	802
Figure K.7—Signal pairs impedance measurement configuration (connector) .....	803
Figure K.8—Signal pairs attenuation and velocity setup calibration .....	805
Figure K.9—Signal pair attenuation and velocity measurement .....	806
Figure K.10—Skew setup calibration .....	812
Figure K.11—Skew measurement .....	814
Figure K.12—Power pair dc resistance setup calibration .....	816
Figure K.13—Power pair resistance measurement .....	817
Figure K.14—Crosstalk setup calibration .....	818
Figure K.15—Crosstalk measurement .....	819
Figure L.1—Equipment block diagram .....	823
Figure L.2—Reference measurement fixturing .....	824
Figure L.3—Sample measurement fixturing .....	825
Figure L.4—Noise floor check fixturing .....	827
Figure M.1—Power distribution example .....	831
Figure P.1—Reference topology (with self-ID packets) .....	837
Figure P.2—Node data structure for normalized topology .....	838
Figure P.3—Self-ID packet topology analysis (nodes zero and one) .....	838
Figure P.4—Self-ID packet topology analysis (node two) .....	839
Figure P.5—Self-ID packet topology analysis (node three) .....	839
Figure P.6—Self-ID packet topology analysis (node four) .....	839
Figure P.7—Self-ID packet topology analysis (node five) .....	840
Figure P.8—Normalized topology (relative to node four) .....	840
Figure P.9—Normalized topology with EUI-64 information .....	841
Figure P.10—Reference topology (changed root) .....	842
Figure P.11—Normalized topology (relative to node five) .....	843
Figure P.12—Normalized topology with EUI-64 information (changed root) .....	844
Figure P.13—Reference topology (inserted node) .....	845
Figure P.14—Normalized topology with EUI-64 information (inserted node) .....	845

Figure Q.1—Module architecture.....	847
Figure Q.2—Serial bus physical topology.....	848
Figure Q.3—Serial bus addressing.....	849
Figure Q.4—SBP stack.....	851
Figure Q.5—Transaction services.....	852
Figure Q.6—Simplified lock model.....	853
Figure Q.7—Transaction request and response subaction queues.....	854
Figure Q.8—Example asynchronous subactions.....	855
Figure Q.9—Example isochronous subactions.....	855
Figure Q.10—Link layer services.....	856
Figure Q.11—Unified transaction example.....	856
Figure Q.12—Split transaction example.....	857
Figure Q.13—Split transaction using concatenated subactions.....	858
Figure Q.14—Example of concatenated asynchronous subactions.....	858
Figure Q.15—Example of concatenated isochronous subactions.....	858
Figure Q.16—Cycle structure.....	860
Figure Q.17—DS encoding.....	861
Figure Q.18—DS encoder and decoder example.....	862
Figure Q.19—Fairness interval.....	862
Figure Q.20—Fair arbitration.....	863
Figure Q.21—Cable PHY.....	864
Figure Q.22—Example cable state after bus initialization process.....	865
Figure Q.23—Tree identify process complete.....	865
Figure Q.24—Example cable state after self-identify phase.....	867
Figure Q.25—Arbitration request.....	867
Figure Q.26—Arbitration request (continued).....	868
Figure Q.27—Arbitration grant.....	868
Figure Q.28—Data prefix.....	869
Figure Q.29—Start of data transmission.....	869
Figure Q.30—Cable interface.....	871
Figure Q.31—Fair/urgent arbitration example.....	873
Figure Q.32—Fly-by concatenation.....	878
Figure Q.33—Master architecture.....	884
Figure Q.34—BOSS pipelined, overlapping arbitration.....	888
Figure Q.35—T-mode coding functions.....	896

## List of tables

Table 1-1—Size notation examples .....	5
Table 1-2—C code operators summary .....	6
Table 1-3—Additional C data types .....	7
Table 1-4—Sample CSR addressing conventions .....	9
Table 1-5—Register definition fields .....	10
Table 1-6—Read value fields .....	10
Table 1-7—Write-effect fields.....	10
Table 4-1—Short-haul copper cables and connectors .....	29
Table 4-2—6-circuit connector socket signal assignment .....	34
Table 4-3—Performance group A .....	40
Table 4-4—Performance group B.....	42
Table 4-5—Performance group C.....	42
Table 4-6—Performance group D .....	43
Table 4-7—Performance group E.....	45
Table 4-8—Performance group F .....	46
Table 4-9—Performance group G .....	47
Table 4-10—6-circuit cable attenuation .....	49
Table 4-11—4-circuit connector socket signal assignment.....	52
Table 4-12—Performance group A .....	59
Table 4-13—Performance group B.....	60
Table 4-14—Performance group C.....	60
Table 4-15—Performance group D .....	61
Table 4-16—Performance group E.....	63
Table 4-17—Performance group F .....	65
Table 4-18—Performance group G .....	65
Table 4-19—4-circuit signal pairs attenuation .....	67
Table 4-20—Beta and bilingual socket contact assignment.....	72
Table 4-21—Cable assembly components .....	85
Table 4-22—Interface speed matrix .....	85
Table 4-23—Type 1 cable assembly .....	86
Table 4-24—Type 2 cable assembly .....	87
Table 4-25—Type 3 cable assembly .....	88
Table 4-26—Performance group A .....	89
Table 4-27—Performance group B.....	90
Table 4-28—Performance group C.....	91
Table 4-29—Performance group D .....	92
Table 4-30—Performance group E.....	94
Table 4-31—Performance group F .....	95
Table 4-32—Performance group G .....	95
Table 4-33—Text fixture pad position to PHY function map .....	100
Table 4-34—Signal pairs attenuation .....	101
Table 5-1—Summary of backplane PHY layer services .....	105
Table 5-2—Backplane transmit data timing.....	113
Table 5-3—Backplane receive data timing .....	114
Table 5-4—Maximum transceiver package and bus skew .....	114
Table 5-5—Backplane PHY timing requirements.....	115
Table 5-6—Arbitration bit timing.....	117
Table 5-7—DATA_PREFIX signal transitions after packet transmission .....	127
Table 5-8—DATA_END signal transitions after packet transmission .....	127
Table 6-1—Summary of link layer services .....	129
Table 6-2—Summary of link control request actions and parameters .....	131
Table 6-3—Summary of asynchronous packet components .....	138

Table 6-4—Maximum payload size for asynchronous data packets .....	142
Table 6-5—Data_length values for lock requests.....	144
Table 6-6—Summary of isochronous packet components .....	146
Table 6-7—Maximum payload size for isochronous stream packets.....	147
Table 6-8—Destination ID encoding.....	150
Table 6-9—Retry code encoding.....	151
Table 6-10—Transaction code encoding.....	151
Table 6-11—Extended transaction code encoding .....	152
Table 6-12—Response code encoding .....	153
Table 6-13—Tag field encoding.....	154
Table 6-14—Acknowledge codes.....	156
Table 6-15—Busy acknowledgments.....	157
Table 6-16—Cycle sync event code .....	161
Table 6-17—CRC generation and checking.....	168
Table 7-1—Summary of transaction layer services.....	171
Table 7-2—Summary of transaction data confirmation during transition TX1:TX0b .....	183
Table 7-3—Summary of transaction event indication during transition TX2:TX0a.....	184
Table 7-4—Acknowledge value in link data response during transition RX1:RX0b .....	186
Table 7-5—Summary of lock transaction functions.....	189
Table 7-6—Outbound subaction retry code decision table .....	190
Table 7-7—Saturated arithmetic procedures .....	191
Table 7-8—CSR architecture/serial bus transaction mapping.....	195
Table 8-1—Reset types.....	203
Table 8-2—Core CSR locations .....	204
Table 8-3—Serial-Bus-dependent registers.....	209
Table 8-4—Request subactions eligible for priority asynchronous arbitration .....	215
Table 8-5—Lock (compare_swap) algorithm for BANDWIDTH_AVAILABLE .....	217
Table 8-6—Lock (compare_swap) algorithm for CHANNELS_AVAILABLE.....	219
Table 8-7—Serial-bus-dependent registers in initial units space .....	222
Table 8-8—Encoding of max_rec field .....	226
Table 8-9—Encoding of max_ROM field .....	227
Table 8-10—SBM variables .....	229
Table 9-1—Short-haul copper PMD modes of operation.....	248
Table 9-2—Differential output signal amplitude.....	250
Table 9-3—Differential receive signal amplitude .....	251
Table 9-4—TPA common mode output voltage.....	251
Table 9-5—TPB common mode input voltage.....	252
Table 9-6—Port_Status signal condition.....	252
Table 9-7—TPB common mode output current and TPA common mode input current .....	253
Table 9-8—Arbitration signaling levels .....	253
Table 9-9—Differential input impedance.....	254
Table 9-10—DS media data rates.....	255
Table 9-11—Output rise and fall times .....	255
Table 9-12—Input slope .....	256
Table 9-13—DS jitter and skew (in ns).....	256
Table 9-14—Arbitration signal generation rules .....	257
Table 9-15—Arbitration signal decoding rules .....	258
Table 9-16—DS PHY transmitted arbitration line states .....	258
Table 9-17—DS PHY received arbitration line states.....	259
Table 9-18—Cable interface timing constants .....	260
Table 9-19—Gap detection times .....	265
Table 9-20—Gap times at originating node .....	265
Table 9-21—Beta mode short-haul copper transmitter characteristics.....	267
Table 9-22—Normalized time intervals for TP2 .....	271

Table 9-23—Eye values for Figure 9-19 .....	273
Table 9-24—Short-haul copper receiver characteristics when using Beta mode .....	274
Table 9-25—Minimum amplitude for receiver jitter tolerance test.....	277
Table 9-26—S3200 electrical test selection .....	278
Table 9-27—Electrical signal assignments.....	279
Table 9-28—Connection tone.....	279
Table 9-29—SIGNAL_DETECT value definition.....	280
Table 9-30—signal_detect timing .....	280
Table 9-31—No Signal budget .....	281
Table 9-32—High-frequency jitter corner frequency .....	282
Table 9-33—S400b short-haul copper jitter output.....	282
Table 9-34—S400b short-haul copper jitter tolerance .....	282
Table 9-35—S800b short-haul copper jitter output.....	283
Table 9-36—S800b short-haul copper jitter tolerance .....	283
Table 9-37—S1600b short-haul copper jitter output.....	283
Table 9-38—S1600b short-haul copper jitter tolerance .....	284
Table 9-39—S3200b short-haul copper jitter output.....	284
Table 9-40—S3200b short-haul copper jitter tolerance .....	284
Table 9-41—Intrapair skew .....	285
Table 9-42—Cable power source requirements .....	290
Table 10-1—Operating range for 50 $\mu$ m MMF.....	296
Table 10-2—Optical transmit characteristics .....	297
Table 10-3—Optical receive characteristics.....	298
Table 10-4—Optical signal_detect thresholds .....	298
Table 10-5—Worst-case connection optical power budget and penalties.....	298
Table 10-6—High-frequency jitter corner frequency .....	299
Table 10-7—S400 $\beta$ MMF jitter output.....	299
Table 10-8—S400 $\beta$ MMF jitter tolerance .....	299
Table 10-9—S800 $\beta$ MMF jitter output.....	300
Table 10-10—S800 $\beta$ MMF jitter tolerance .....	300
Table 10-11—S1600 $\beta$ MMF jitter output.....	300
Table 10-12—S1600 $\beta$ MMF jitter tolerance .....	301
Table 10-13—50 $\mu$ m MMF connection insertion loss at 850 nm wavelength.....	303
Table 10-14—50 $\mu$ m MMF characteristics .....	304
Table 11-1—Worst-case loss increments for 50m POF cable and 100m HPCF cable .....	309
Table 11-2—Optical parameters for POF-HPCF interface at S100 $\beta$ and S200 $\beta$ .....	311
Table 11-3—Optical signal_detect thresholds .....	311
Table 11-4—High-frequency jitter corner frequency .....	311
Table 11-5—S100 $\beta$ POF and HPCF jitter output.....	312
Table 11-6—S100 $\beta$ POF and HPCF jitter tolerance .....	312
Table 11-7—S200 $\beta$ POF and HPCF jitter output.....	312
Table 11-8—S200 $\beta$ POF and HPCF jitter tolerance .....	313
Table 11-9—Trade-off for the number of connections and transmission length.....	313
Table 11-10—Optical parameters in case of POF and HPCF connection.....	313
Table 12-1—UTP transmission distances.....	317
Table 12-2—Standard media interface connector pin assignments.....	318
Table 12-3—Alternate media interface connector pin assignments .....	319
Table 12-4—UTP transmitter electrical specifications .....	320
Table 12-5—Coordinates for S100 signal mask.....	321
Table 12-6—S200/S400 normalized time intervals for TP2 .....	322
Table 12-7—UTP receiver electrical specifications .....	323
Table 12-8—SIGNAL_DETECT value definition .....	324
Table 12-9—signal_detect timing .....	324
Table 13-1—Control mapping.....	330

Table 13-2—Asynchronous request mapping .....	331
Table 13-3—Isochronous request mapping .....	331
Table 13-4—Request and phase mapping .....	332
Table 13-5—Configuration request mapping .....	332
Table 13-6—5B/6B coding .....	338
Table 13-7—3B/4B coding .....	338
Table 13-8—Valid data characters .....	339
Table 13-9—K28.x special characters .....	346
Table 13-10—Control coding .....	347
Table 13-11—Special character decoding .....	348
Table 13-12—Control stretching formats .....	350
Table 13-13—Speed code formats .....	352
Table 13-14—Data padding formats .....	353
Table 13-15—Speed code decoding .....	355
Table 13-16—C code variables used in Beta port state machines .....	357
Table 14-1—Media-dependent Beta mode speed requirements .....	363
Table 14-2—Variables and functions used in port connection manager state machine .....	363
Table 14-3—Connection management constants .....	364
Table 14-4—Connect_status value in various connection scenarios .....	380
Table 14-5—Serial bus Message Code 5, bit a .....	388
Table 15-1—PHY register fields for the cable environment .....	390
Table 15-2—PH_EVENT.indication(INTERRUPT) sources .....	393
Table 15-3—PHY register Port Status page fields .....	395
Table 15-4—PHY register Vendor Identification page fields .....	399
Table 15-5—PHY register fields for the backplane environment .....	400
Table 16-1—Summary of PHY services .....	402
Table 16-2—Cable PHY speed codes .....	406
Table 16-3—PHY packet identifier bits .....	414
Table 16-4—Alpha self-ID packet fields .....	415
Table 16-5—Alpha Link-on packet fields .....	417
Table 16-6—Alpha PHY configuration packet fields .....	418
Table 16-7—Alpha ping packet fields .....	418
Table 16-8—Alpha remote access packet fields .....	419
Table 16-9—Alpha remote reply packet fields .....	420
Table 16-10—Alpha remote command packet fields .....	420
Table 16-11—Alpha remote confirmation packet fields .....	421
Table 16-12—Alpha resume packet fields .....	422
Table 16-13—Beta self-ID packet fields .....	423
Table 16-14—Beta Remote command packet fields .....	424
Table 16-15—Beta Remote confirmation packet fields .....	425
Table 16-16—Beta PHY configuration packet fields .....	426
Table 16-17—LTP fields .....	428
Table 16-18—Maximum payload size for Beta data packets .....	428
Table 16-19—C code functions and variables .....	434
Table 16-20—Asynchronous requests .....	437
Table 16-21—Isochronous requests .....	438
Table 17-1—Comparison of Alpha, Beta, and Beta Plus PHY-link interfaces .....	459
Table 17-2—Summary of PHY-link interface signals .....	459
Table 17-3—Alpha PHY-link interface signal descriptions .....	461
Table 17-4—Ctl[0:1] when PHY is driving .....	462
Table 17-5—Ctl[0:1] when the link is driving (upon a grant from the PHY) .....	462
Table 17-6—LPS timing parameters .....	463
Table 17-7—Initialization of the Alpha PHY-link interface .....	465
Table 17-8—LinkOn timing parameters .....	466

Table 17-9—Bus request format for cable environment .....	467
Table 17-10—Bus request format for backplane environment.....	467
Table 17-11—Register read request format.....	468
Table 17-12—Register write request format .....	468
Table 17-13—Acceleration control request format .....	468
Table 17-14—Request type field.....	469
Table 17-15—Request speed field.....	469
Table 17-16—Link request effects on PHY variables .....	469
Table 17-17—Link rules to initiate a request on LReq .....	471
Table 17-18—PHY disposition of link request .....	472
Table 17-19—Alpha PHY-link interface timing constants .....	473
Table 17-20—Alpha PHY-link interface status bits.....	475
Table 17-21—Speed code signaling .....	476
Table 17-22—DC specifications for the Alpha PHY-link interface.....	480
Table 17-23—AC timing parameters for the Alpha PHY-link interface.....	481
Table 17-24—AC timing parameters at the PHY .....	482
Table 17-25—AC timing parameters at the link .....	483
Table 17-26—Alpha link to PHY delay timing parameters .....	484
Table 17-27—Beta and Beta Plus PHY-link interface signal descriptions .....	486
Table 17-28—Beta Plus PHY-link interface operating modes.....	488
Table 17-29—Timing parameters specified in terms of absolute time .....	489
Table 17-30—Timing parameters specified in terms of number of PClk or LClk .....	490
Table 17-31—Initialization of the Beta and Beta Plus PHY-link interface .....	492
Table 17-32—LinkOn timing parameters.....	494
Table 17-33—Link request types to PHY .....	494
Table 17-34—RT[0:3] field encoding .....	499
Table 17-35—Request format values .....	501
Table 17-36—Beta and Beta Plus speed encodings .....	501
Table 17-37—Ctl[0:1] state encoding when the PHY controls the PHY-link interface.....	502
Table 17-38—Receive packet SPD interval encoding .....	505
Table 17-39—Ctl[0:1] state encoding when the link controls the PHY-link interface .....	506
Table 17-40—Format type during GRANT cycle.....	510
Table 17-41—Grant Type values during GRANT cycle.....	510
Table 17-42—Speed types during GRANT cycle .....	511
Table 17-43—Subaction end notification during the MORE_INFO cycle .....	511
Table 17-44—Link request type during MORE_INFO cycle .....	512
Table 17-45—Link request speed during MORE_INFO cycle .....	512
Table 17-46—Link request format during MORE_INFO cycle .....	512
Table 17-47—Bit encoding for Bus Status Transfers.....	518
Table 17-48—Beta and Beta Plus PHY Status Transfer encoding.....	520
Table 17-49—Beta and Beta Plus PHY-link critical delays.....	521
Table 17-50—Mapping of Beta PHY-link signals to Alpha signals .....	522
Table 17-51—DC specifications for the Beta PHY-link interface .....	523
Table 17-52—DC specifications for the Beta Plus PHY-link interface .....	524
Table 17-53—Beta interface ac timing parameters .....	525
Table 17-54—Beta Plus interface ac timing parameters .....	525
Table 18-1—Packet prefix Data Byte 1 encoding .....	537
Table 18-2—Data Byte 1 encoding .....	537
Table 18-3—Interrupt encoding .....	538
Table 19-1—C code definitions.....	539
Table 19-2—Data structures and enumerated types .....	539
Table 19-3—PHY services .....	545
Table 19-4—Arbitration state machine internal variables.....	548
Table 19-5—Variables shared between architectural elements.....	550

Table 19-6—Node-level connection monitor functions and routines .....	558
Table 19-7—Port connection manager actions and conditions .....	567
Table 19-8—DS receive port .....	588
Table 19-9—DS transmit port .....	591
Table 19-10—DS speed signaling filter .....	593
Table 19-11—Beta port receive actions and conditions .....	595
Table 19-12—Beta port transmit actions and conditions .....	606
Table 19-13—T port receive actions .....	611
Table 19-14—T port transmit actions .....	624
Table 19-15—Border transmit functions .....	631
Table 19-16—Border receive functions .....	636
Table 19-17—PHY packet processing .....	641
Table 19-18—Legacy arbitration functions .....	645
Table 19-19—Border arbitration functions .....	647
Table 19-20—Background request processing .....	654
Table 19-21—Bus reset actions .....	664
Table 19-22—Tree identify actions .....	667
Table 19-23—Self-identify actions .....	668
Table 19-24—Idle actions .....	673
Table 19-25—Grant actions .....	680
Table 19-26—Transmit actions .....	681
Table 19-27—Receive actions .....	685
Table 20-1—Asynchronous request mapping .....	694
Table 20-2—Isochronous request mapping .....	694
Table 20-3—Legacy request and phase mapping .....	694
Table 20-4—Configuration request mapping .....	695
Table 20-5—Control token mapping .....	696
Table 20-6—Control stretching formats .....	697
Table 20-7—Speed code formats .....	698
Table 20-8—Data padding formats .....	699
Table 20-9—Symbol decode rules for nonerrored symbols .....	699
Table 20-10—Symbol decode rules for errored symbols .....	700
Table 20-11—Speed code decoding .....	702
Table 21-1—GMII signal usage .....	706
Table C.1—Internal device power connector pin allocation .....	716
Table C.2—Internal device power connector configurations .....	716
Table C.3—Internal device primary and secondary port pin allocation .....	717
Table C.4—Internal device option connector pin allocation .....	717
Table C.5—Internal device signal description .....	717
Table C.6—Electrical interface specifications .....	718
Table C.7—Options pin comparison .....	719
Table C.8—Performance group A .....	736
Table C.9—Performance group B .....	738
Table C.10—Performance group C .....	739
Table C.11—Performance group D .....	740
Table C.12—Performance group E .....	741
Table C.13—Performance group F .....	742
Table C.14—Performance group G .....	742
Table D-1—Backplane propagation delay .....	744
Table D-2—Gap types .....	747
Table D-3—Acknowledge gap sample time .....	747
Table D-4—Acknowledge gap hold time .....	748
Table D-5—Difference in gap times .....	749
Table D-6—Gap timing .....	749

Table D-7—Backplane environment skew analysis .....	752
Table E.1—Gap count as a function of hops .....	756
Table E.2—S100 jitter budget (ns) .....	757
Table E.3—S200 jitter budget (ns) .....	758
Table E.4—S400 jitter budget (ns) .....	758
Table E.5—Port status encoding .....	769
Table E.6—Example self-ID packet port status values .....	770
Table F.1—Serial bus signal mapping and pin assignment.....	774
Table I.1—Table of socket PCB mounting styles and footprint figures .....	790
Table K.1—Connection matrix for signal pairs impedance tests (connector).....	802
Table K-2—Connection matrix for power pair impedance tests .....	815
Table K-3—Connection matrix for power pair resistance tests.....	817
Table K-4—Connection matrix for crosstalk tests between power and signal pairs.....	819
Table K-5—Connection matrix for crosstalk tests between signal pairs.....	820
Table L.1—Transfer impedance performance requirements .....	828
Table M.1—Power provider ranges by POWER_CLASS and launch voltage .....	830
Table P.1—Topology analysis of self-ID packets .....	841
Table P.2—Normalized topology comparison .....	843
Table Q.1—Beta-mode media summary .....	886

# IEEE Standard for a High-Performance Serial Bus

*IMPORTANT NOTICE: This standard is not intended to assure safety, security, health, or environmental protection in all circumstances. Implementers of the standard are responsible for determining appropriate safety, security, environmental, and health practices or regulatory requirements.*

*This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Documents." They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/disclaimers>.*

## 1. Overview

### 1.1 Scope and purpose

#### 1.1.1 Scope

This standard describes a high-speed, low-cost serial bus suitable for use as a peripheral bus, a backup to parallel backplane buses, or a local area network. Highlights of the serial bus include the following:

- a) Bus transactions that include both block and single quadlet reads and writes, as well as an “isochronous” mode that provides a low-overhead guaranteed bandwidth service.
- b) A fair bus access mechanism that guarantees all nodes equal access. The backplane environment adds a priority mechanism, but one that ensures that nodes using the fair protocol are still guaranteed at least partial access.
- c) Automatic assignment of node addresses—no need for address switches.
- d) A physical layer (PHY) supporting both long-haul and short-haul cable media and backplane buses.
- e) Variable speed data transmission based on ISDN-compatible<sup>1</sup> bit rates from 24.576 Mbit/s for transistor-transistor logic (TTL) backplanes to 49.152 Mbit/s for backplane transceiver logic (BTL) backplanes. For the cable medium, data transmission rates of 98.304 Mbit/s (known as S100), S200, S400, S800, S1600, and S3200 are supported.
- f) A short-haul cable medium that allows up to 16 physical connections (cable hops), each up to 4.5 m, giving a total cable distance of 72 m between any two devices. Bus management recognizes smaller configurations to optimize performance.

---

<sup>1</sup>The lowest data rate of 24.576 Mbit/s is exactly 18 times the 1.536 Mbit/s and 12 times the 2.048 Mbit/s Integrated Services Digital Network (ISDN) primary rates. It is also an integer multiple of the ISDN basic rate and numerous other communication rates.

- g) A long-haul cable medium that permits connections up to 100 m in length over unshielded twisted pair (UTP) cable and glass optical fiber (GOF) and up to 50 m over plastic optical fiber (POF).
- h) Consistency with ISO/IEC 13213:1994 (IEEE Std 1212<sup>TM</sup>, 1994 Edition).<sup>2</sup>

### 1.1.2 Purpose

This standard incorporates the contents of IEEE Std 1394<sup>TM</sup>-1995 as revised by IEEE Std 1394a<sup>TM</sup>-2000, IEEE Std 1394b<sup>TM</sup>-2002, and IEEE Std 1394c<sup>TM</sup>-2006. In addition, over 100 errata have been corrected, and several new features have been added per Q.12.

## 1.2 Document organization

This standard contains this overview, a list of definitions, an informative summary description, chapters of technical specification, and application annexes. The new reader should read the document in order. The actual specification follows the summary and is organized from the bottom up; that is, the specification starts at the PHY (cable and backplane), works up to the link layer, the transaction layer, and the bus management layer.

## 1.3 Serial bus applications

Three primary applications have driven the design and architecture of the serial bus: an alternate for a parallel backplane bus, a low-cost peripheral bus, and a bus bridge between architecturally compatible 32-bit buses.

### 1.3.1 Alternate bus

There are five main reasons for providing a serial bus on a system that already has a parallel bus:

- a) The many modules that make up a system might operate on different backplane bus standards, yet they need to work together.
- b) Although located within the same enclosure, a system is too large or physically disperse to use a single backplane, yet modules in the different backplanes have to communicate.
- c) One or more modules of a system are located neither on the same backplane nor within the same enclosure.
- d) A redundant data path increases fault tolerance. A system can use the serial bus to isolate and diagnose errors without depending on the failed parallel bus.
- e) Many system modules are price-sensitive and do not need the full bandwidth of a parallel bus.

### 1.3.2 Low-cost peripheral bus

The serial bus can also be used as a powerful and low-cost peripheral interconnect. The compact serial bus cable and connector allow bandwidths comparable with existing input/output (I/O) interconnect standards. The serial bus has the added advantage of architectural compatibility with parallel computer buses; this compatibility leads to lower communications overhead than with limited, function-dedicated I/O interconnects.

---

<sup>2</sup>Information on references can be found in Clause 2.

### 1.3.3 Bus bridge

The serial bus architecture limits the number of nodes on any bus to 63, but supports multiple bus systems via bus bridges. The command and status register (CSR) architecture defines the serial bus addressing structure, which allows almost  $2^{16}$  nodes.

A bus bridge normally eavesdrops on the bus, ignoring all transactions between local addresses but listening carefully for remote transactions. When the bridge receives a packet for a remote address, it forwards the packet to an adjacent bus.

Although the serial bus may be used in many bus configurations, when used to bridge CSR-architecture-compliant buses, it is expected to be used mostly in a hierarchical bus fashion, as illustrated in Figure 1-1 (where bus #5 is a serial bus and bridges together other CSR-architecture-compliant bus #1 through bus #4, bus #1 could be IEEE 896 Futurebus+<sup>®</sup> ([B23], [B24], [B26]),<sup>3,4</sup> bus #2 could be IEEE 1596 scalable coherent interface (SCI) ([B25]), and so on).

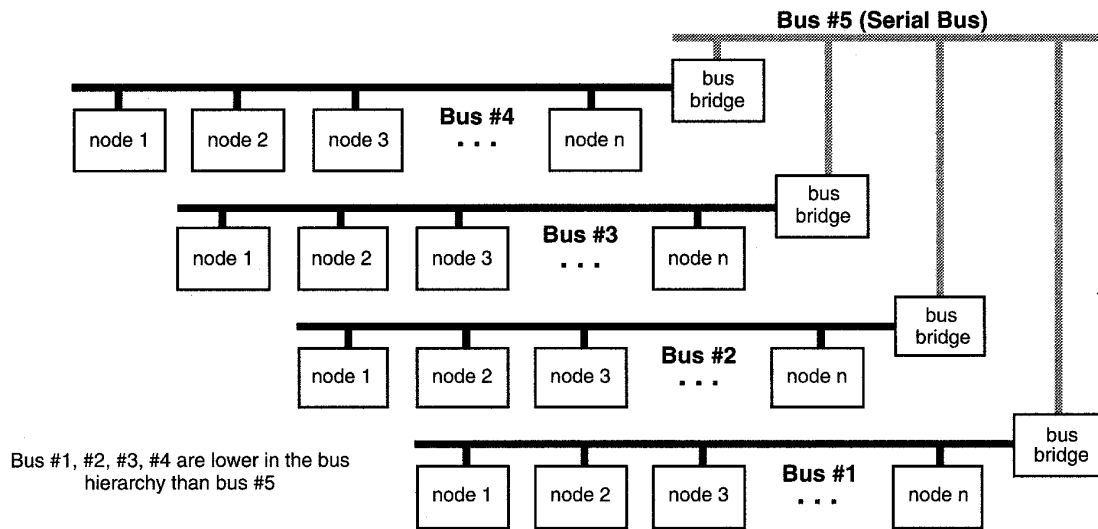


Figure 1-1—Example hierarchical bus topology

### 1.4 Service model

This standard uses a protocol model with multiple layers. Each layer provides services to the next higher layer and to serial bus management (SBM). These services are abstractions of a possible implementation; an actual implementation may be significantly different and still meet all the requirements. The method by which these services are communicated between the layers is not defined by this standard. Four types of service are defined by this standard as follows:

- a) *Request service.* A request service is a communication from a layer to a lower or adjacent layer to request some action. A request may also communicate parameters that may or may not be associated with an action. A request may or may not be confirmed. A data transfer request usually triggers a corresponding indication on peer node(s). (Because broadcast addressing is supported on a serial bus, it is possible for the request to trigger a corresponding indication on multiple nodes.)

<sup>3</sup>Futurebus+ is a registered trademark of the Institute of Electrical and Electronics Engineers, Inc.

<sup>4</sup>The numbers in brackets correspond to the numbers of the bibliography in Annex S.