

IEEE Standard for Ethernet

Amendment 4: Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

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

IEEE Std 802.3bp™-2016
(Amendment to
IEEE Std 802.3™-2015
as amended by
IEEE Std 802.3bw™-2015,
IEEE Std 802.3by™-2016, and
IEEE Std 802.3bq™-2016)

IEEE Std 802.3bp™-2016

(Amendment to
IEEE Std 802.3™-2015
as amended by
IEEE Std 802.3bw™-2015,
IEEE Std 802.3by™-2016, and
IEEE Std 802.3bq™-2016)

IEEE Standard for Ethernet

Amendment 4: Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable

Sponsor

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 30 June 2016

IEEE-SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2015 adds point-to-point 1 Gb/s Physical Layer (PHY) specifications and management parameters for operation on a single twisted-pair copper cable in an automotive application.

Keywords: 1000BASE-T1, Ethernet, IEEE 802[®], IEEE 802.3[™], IEEE 802.3bp[™]

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

Copyright © 2016 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 9 September 2016. Printed in the United States of America.

IEEE and 802 are registered trademarks in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

Print: ISBN 978-1-5044-2288-8 STD21091
PDF: ISBN 978-1-5044-2289-5 STDPD21091

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

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.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, 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.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. 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.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of 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 of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive 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 comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

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

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document 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

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted 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 these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, 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.

Updating of IEEE Standards documents

Users of IEEE Standards documents 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.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, 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 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-SA Website at <http://ieeexplore.ieee.org/Xplore/home.jsp> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

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 by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent 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.

Essential Patent Claims may exist for which a Letter 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 determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

The following individuals were officers and members of the IEEE 802.3 Working Group at the beginning of the IEEE P802.3bp Working Group ballot. Individuals may have not voted, voted for approval, disapproval, or abstained on this standard.

David J. Law, *IEEE 802.3 Working Group Chair*
Adam Healey, *IEEE 802.3 Working Group Vice-Chair*
Peter Anslow, *IEEE 802.3 Working Group Secretary*
Steven B. Carlson, *IEEE 802.3 Working Group Executive Secretary*
Valerie Maguire, *IEEE 802.3 Working Group Treasurer*

Steven B. Carlson, *IEEE P802.3bp 1000BASE-T1 Task Force Chair*
Marek Hajduczenia, *IEEE P802.3bp 1000BASE-T1 Task Force Editor-in-Chief*
Curtis Donahue, *IEEE P802.3bp 1000BASE-T1 Task Force PICS Editor*

John Abbott	Christopher R. Cole	Thomas Hogenmueller
David Abramson	Keith Conroy	Brian Holden
Shadi Abughazaleh	Eugene Dai	Rita Horner
Faisal Ahmad	Shaoan Dai	Bernd Horrmeier
Dale Amason	John D'Ambrosia	Victor Hou
J. Michael Andrewartha	Mike Darling	Liang-wei Huang
Oleksandr Babenko	Yair Darshan	Yasuhiro Hyakutake
Kwang-Hyun Baek	Piers Dawe	Scott Irwin
Amrik Bains	Fred Dawson	Kazuhiko Ishibe
Koussalya Balasubramanian	Ian Dedic	Hideki Isono
Thananya Baldwin	Chris Diminico	Tom Issenhuth
Denis Beaudoin	Thuyen Dinh	Kenneth Jackson
Christian Beia	Dan Dove	Andrew Jimenez
Yakov Belopolsky	Mike Dudek	Chad Jones
Michael Bennett	Nick Duer	Peter Jones
Vipul Bhatt	David Dwelley	Antony Joseph
William Bliss	Frank Effenberger	Manabu Kagami
Brad Booth	Hesham Elbakoury	Upen Kareti
Martin Bouda	David Estes	Keisuke Kawahara
David Brandt	John Ewen	Yasuaki Kawatsu
Ralf-Peter Braun	Josef Faller	Michael Kelsen
Theodore Brillhart	Shahar Feldman	Yongbum Kim
Paul Brooks	German Feyh	Jonathan King
David Brown	Alan Flatman	Scott Kipp
Matthew Brown	Howard Frazier	Michael Klempa
Thomas Brown	Richard Frosch	Curtis Knittle
Phillip Brownlee	Andrew Gardner	Shigeru Kobayashi
Juan-Carlos Calderon	Mike Gardner	Keisuke Kojima
J. Martin Carroll	Ali Ghiasi	Paul Kolesar
Clark Carty	Joel Goergen	Tom Kolze
Mandeep Chadha	Zhigang Gong	Glen Kramer
David Chalupsky	Steven Gorshe	Hans Lackner
Jacky Chang	James Graba	Brett Lane
Xin Chang	Robert Grow	Jeff Lapak
David Chen	Mark Gustlin	Efstathios Larios
Wheling Cheng	Bernie Hammond	Mark Laubach
Ahmad Chini	Takehiro Hayashi	Greg Le Cheminant
Golam Choudhury	David Hess	Arthur Lee
Keng Hua Chuang	Yasuo Hidaka	David Lewis
Peter Cibula	Riu Hirai	Jon Lewis

Lei Li
Mike Peng Li
Shaohua Li
Thomas Lichtenegger
Ru Jian Lin
Robert Lingle
James Liu
Zhenyu Liu
William Lo
Miklos Lukacs
Kent Lusted
Jeffery Maki
James Malkemus
Yonatan Malkiman
Edwin Mallette
Arthur Marris
Chris Mash
Kirsten Matheus
Erdem Matoglu
Laurence Matola
Brett McClellan
Thomas McDermott
John McDonough
Richard Mei
Richard Mellitz
Bryan Moffitt
Leo Montreuil
Paul Mooney
Andy Moorwood
Thomas Mueller
Ron Muir
Dale Murray
Henry Muyshondt
Edward Nakamoto
Gary Nicholl
Paul Nikolich
Kevin Noll
Ronald Nordin
Mark Nowell
David Ofelt
Ichiro Ogura
Tom Palkert
Hui Pan
Sujan Pandey
Sesha Panguluri
Carlos Pardo
Moon Park
Petar Pepeljugin
Gerald Pepper
Ruben Perez De Aranda Alonso
Michael Peters

John Petrilla
Rick Pimpinella
Neven Pischl
Rainer Poehmerer
William Powell
Richard Prodan
Rick Rabinovich
Saifur Rahman
Adee Ran
Ram Rao
Alon Regev
Duane Remein
Victor Renteria
Michael Ressler
Poldi (Pavlick) Rimboim
Martin Rossbach
Christopher Roth
Salvatore Rotolo
Hisaya Sakamoto
Vineet Salunke
Sam Sambasivan
Yasuo Sasaki
Fred Schindler
Stefan Schneelee
Peter Scruton
Alexander Seiger
Naoshi Serizawa
Megha Shanbhag
Masood Shariff
Stephen Shellhammer
Bazhong Shen
Mizuki Shirao
Kapil Shrikhande
Jeff Slavick
Scott Sommers
Yoshiaki Sone
Xiaolu Song
Tom Souvignier
Bryan Sparrowhawk
Edward Sprague
Peter Stassar
Leonard Stencil
Robert Stone
Steve Swanson
Andre Szczepanek
William Szeto
Bharat Tailor
Akio Tajima
Takayuki Tajima
Tomoo Takahara
Satoshi Takahashi

Kiyoto Takahata
Alexander Tan
Toshiki Tanaka
Mehmet Tazebay
Brian Teipen
Geoffrey Thompson
Alan Tipper
Pirooz Tooyserkani
Nathan Tracy
David Tremblay
Albert Tretter
Stephen Trowbridge
Wen-Cheng Tseng
Yoshihiro Tsukamoto
Mike Tu
Alan Ugolini
Ed Ulrichs
Sterling A. Vaden
Stefano Valle
Paul Vanderlaan
Robert Wagner
Robert Wang
Roy Wang
Tongtong Wang
Xiaofeng Wang
Xinyuan Wang
Zhong Feng Wang
Markus Weber
Brian Welch
Yang Wen
Matthias Wendt
Oded Wertheim
Martin White
Natalie Wienckowski
Ludwig Winkel
Peter Wu
Yu Xu
Lennart Yseboodt
Ting-Fa Yu
Liquan Yuan
Hayato Yuki
Garold Yurko
Andrew Zambell
Jin Zhang
Yan Zhuang
George Zimmerman
Helge Zinner
Pavel Zivny
Gaoling Zou

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

Shadi Abughazaleh	Adam Healey	Arumugam Paventhan
Thomas Alexander	Marco Hernandez	Ruben Perez De Aranda Alonso
Richard Alfvin	David Hess	Michael Peters
Dale Amason	Guido Hiertz	Adee Ran
Peter Anslow	Werner Hoelzl	Alon Regev
Butch Anton	Rita Horner	Duane Remein
Stefan Aust	Tetsushi Ikegami	Maximilian Riegel
Saman Behtash	Noriyuki Ikeuchi	Robert Robinson
Jacob Ben Ary	Sergiu Iordanescu	Benjamin Rolfe
Michael Bennett	Atsushi Ito	Nicola Scantamburlo
Gennaro Boggia	Michael Johas Teener	Frank Schewe
Christian Boiger	Vincent Jones	Dieter Schicketanz
Ralf-Peter Braun	Adri Jovin	Stefan Schnee
Nancy Bravin	Shinkyō Kaku	Shusaku Shimada
Theodore Brillhart	Piotr Karocki	Kapil Shrikhande
William Bush	John Kay	Ju-Hyung Son
Jairo Bustos Heredia	Stuart Kerry	Thomas Starai
William Byrd	Yongbum Kim	Peter Stassar
Steven B. Carlson	Scott Kipp	Eugene Stoudenmire
Juan Carreon	Bruce Kraemer	Walter Struppler
Mandeep Chadha	Mark Laubach	Mitsutoshi Sugawara
Minho Cheong	David J. Law	Patricia Thaler
Ahmad Chini	David Lewis	David Thompson
Keng Hua Chuang	Jon Lewis	Geoffrey Thompson
Peter Cibula	Arthur H. Light	Michael Thompson
Charles Cook	William Lo	Sterling A. Vaden
Rodney Cummings	Michael Lynch	Dmitri Varsanofiev
Shaoan Dai	Elvis Maculuba	Prabodh Varshney
John D'Ambrosia	Valerie Maguire	George Vlantis
Christopher Diminico	Jeffery Maki	Stephen Webb
Daniel Dove	Arthur Marris	Hung-Yu Wei
Sourav Dutta	Michael Maytum	Natalie Wienckowski
Liu Fangfang	Brett McClellan	Andreas Wolf
German Feyh	Richard Mellitz	Peter Wu
Matthias Fritsche	Bryan Moffitt	Oren Yuen
Yukihiro Fujimoto	Charles Moorwood	Andrew Zambell
James Graba	Henry Muyschondt	Zhen Zhou
Randall Groves	Michael Newman	George Zimmerman
Robert Grow	Nick S. A. Nikjoo	
Marek Hajduczenia	Satoshi Obara	

When the IEEE-SA Standards Board approved this standard on 30 June 2016, it had the following membership:

Jean-Philippe Faure, *Chair*
Ted Burse, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams
Masayuki Ariyoshi
Stephen Dukes
Jianbin Fan
Ronald W. Hotchkiss
J. Travis Griffith

Gary Hoffman
Michael Janezic
Joseph L. Koepfinger*
Hung Ling
Kevin Lu
Gary Robinson
Annette D. Reilly

Mehmet Ulema
Yingli Wen
Howard Wolfman
Don Wright
Yu Yuan
Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.3bp™-2016, IEEE Standard for Ethernet—Amendment 4: Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable.

IEEE Std 802.3 was first published in 1985. Since the initial publication, many projects have added functionality or provided maintenance updates to the specifications and text included in the standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba™-2010).

The half-duplex Media Access Control (MAC) protocol specified in IEEE Std 802.3-1985 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was key to the experimental Ethernet developed at Xerox Palo Alto Research Center, which had a 2.94 Mb/s data rate. Ethernet at 10 Mb/s was jointly released as a public specification by Digital Equipment Corporation (DEC), Intel, and Xerox in 1980. Ethernet at 10 Mb/s was approved as an IEEE standard by the IEEE Standards Board in 1983 and subsequently published in 1985 as IEEE Std 802.3-1985. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3. A full duplex MAC protocol was added in 1997.

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3z™ added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae™ added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile), and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2015 and are not maintained as separate documents.

At the date of IEEE Std 802.3bp-2016 publication, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2015

Section One—Includes Clause 1 through Clause 20 and Annex A through Annex H and Annex 4A. Section One includes the specifications for 10 Mb/s operation and the MAC, frame formats, and service interfaces used for all speeds of operation.

Section Two—Includes Clause 21 through Clause 33 and Annex 22A through Annex 33E. Section Two includes management attributes for multiple protocols and speed of operation as well as specifications for providing power over twisted-pair cabling for multiple operational speeds. It also includes general information on 100 Mb/s operation as well as most of the 100 Mb/s Physical Layer specifications.

Section Three—Includes Clause 34 through Clause 43 and Annex 36A through Annex 43C. Section Three includes general information on 1000 Mb/s operation as well as most of the 1000 Mb/s Physical Layer specifications.

Section Four—Includes Clause 44 through Clause 55 and Annex 44A through Annex 55B. Section Four includes general information on 10 Gb/s operation as well as most of the 10 Gb/s Physical Layer specifications.

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines services and protocol elements that enable the exchange of IEEE 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification. Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

Section Six—Includes Clause 78 through Clause 95 and Annex 83A through Annex 93C. Clause 78 specifies Energy-Efficient Ethernet. Clause 79 specifies IEEE 802.3 Organizationally Specific Link Layer Discovery Protocol (LLDP) type, length, and value (TLV) information elements. Clause 80 through Clause 95 and associated annexes include general information on 40 Gb/s and 100 Gb/s operation as well the 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

IEEE Std 802.3bw-2015

Amendment 1—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 96. This amendment adds 100 Mb/s Physical Layer (PHY) specifications and management parameters for operation on a single balanced twisted-pair copper cable.

IEEE Std 802.3by-2016

Amendment 2—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 105 through Clause 112, Annex 109A, Annex 109B, Annex 109C, Annex 110A, Annex 110B, and Annex 110C. This amendment adds MAC parameters, Physical Layers, and management parameters for the transfer of IEEE 802.3 format frames at 25 Gb/s.

IEEE Std 802.3bq-2016

Amendment 3—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 113 and Annex 113A. This amendment adds new Physical Layers for 25 Gb/s and 40 Gb/s operation over balanced twisted-pair structured cabling systems.

IEEE Std 802.3bp-2016

Amendment 4—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 97 and Clause 98. This amendment adds point-to-point 1 Gb/s Physical Layer (PHY) specifications and management parameters for operation on a single balanced twisted-pair copper cable in automotive and other applications not utilizing the structured wiring plant.

A companion document IEEE Std 802.3.1 describes Ethernet management information base (MIB) modules for use with the Simple Network Management Protocol (SNMP). IEEE Std 802.3.1 is updated to add management capability for enhancements to IEEE Std 802.3 after approval of the enhancements.

IEEE Std 802.3 will continue to evolve. New Ethernet capabilities are anticipated to be added within the next few years as amendments to this standard.

Contents

1.	Introduction.....	24
1.3	Normative references.....	24
1.4	Definitions.....	24
1.5	Abbreviations.....	24
30.	Management.....	25
30.3	Layer management for DTEs.....	25
30.3.2	PHY device managed object class.....	25
30.3.2.1	PHY device attributes.....	25
30.3.2.1.2	aPhyType.....	25
30.3.2.1.3	aPhyTypeList.....	25
30.5	Layer management for medium attachment units (MAUs).....	25
30.5.1	MAU managed object class.....	25
30.5.1.1	MAU attributes.....	25
30.5.1.1.2	aMAUType.....	25
30.5.1.1.4	aMediaAvailable.....	25
30.6	Management for link Auto-Negotiation.....	26
30.6.1	Auto-Negotiation managed object class.....	26
30.6.1.1	Auto-Negotiation attributes.....	26
30.6.1.1.3	aAutoNegRemoteSignaling.....	26
30.6.1.1.5	aAutoNegLocalTechnologyAbility.....	26
30.6.1.1.6	aAutoNegAdvertisedTechnologyAbility.....	26
30.6.1.1.7	aAutoNegReceivedTechnologyAbility.....	26
30.6.1.1.8	aAutoNegLocalSelectorAbility.....	27
30.6.1.1.9	aAutoNegAdvertisedSelectorAbility.....	27
30.6.1.1.10	aAutoNegReceivedSelectorAbility.....	27
34.	Introduction to 1000 Mb/s baseband network.....	28
34.1	Overview.....	28
34.1.5a	Auto-Negotiation, type 1000BASE-T1.....	28
45.	Management Data Input/Output (MDIO) Interface.....	29
45.2	MDIO Interface Registers.....	29
45.2.1	PMA/PMD registers.....	29
45.2.1.6	PMA/PMD control 2 register (Register 1.7).....	29
45.2.1.6.3	PMA/PMD type selection (1.7.5:0).....	29
45.2.1.14a	BASE-T1 PMA/PMD extended ability register (1.18).....	30
45.2.1.131	BASE-T1 PMA/PMD control register (Register 1.2100).....	30
45.2.1.131.1	BASE-T1 MASTER-SLAVE manual config enable (1.2100.15).....	30
45.2.1.131.1	BASE-T1 MASTER-SLAVE config value (1.2100.14).....	31
45.2.1.131.2	BASE-T1 Type selection (1.2100.3:0).....	31
45.2.1.133	1000BASE-T1 PMA control register (Register 1.2304).....	31
45.2.1.133.1	PMA/PMD reset (1.2304.15).....	31
45.2.1.133.2	Transmit disable (1.2304.14).....	32
45.2.1.133.3	Low power (1.2304.11).....	32

45.2.1.134	1000BASE-T1 PMA status register (Register 1.2305)	32
45.2.1.134.1	1000BASE-T1 OAM ability (1.2305.11)	32
45.2.1.134.2	EEE ability (1.2305.10)	32
45.2.1.134.3	Receive fault ability (1.2305.9)	32
45.2.1.134.4	Low-power ability (1.2305.8)	33
45.2.1.134.5	Receive polarity (1.2305.2)	33
45.2.1.134.6	Receive fault (1.2305.1)	33
45.2.1.134.7	Receive link status (1.2305.0)	34
45.2.1.135	1000BASE-T1 training register (Register 1.2306)	34
45.2.1.135.1	User field (1.2306.10:4)	34
45.2.1.135.2	1000BASE-T1 OAM advertisement (1.2306.1)	34
45.2.1.135.3	EEE advertisement (1.2306.0)	34
45.2.1.136	1000BASE-T1 link partner training register (Register 1.2307)	34
45.2.1.136.1	Link partner user field (1.2307.10:4)	35
45.2.1.136.2	Link partner 1000BASE-T1 OAM advertisement (1.2307.1)	35
45.2.1.136.3	Link partner EEE advertisement (1.2307.0)	35
45.2.1.137	1000BASE-T1 test mode control register (Register 1.2308)	35
45.2.1.137.1	Test mode control (1.2308.15:13)	35
45.2.3	PCS Registers	36
45.2.3.51	1000BASE-T1 PCS control register (Register 3.2304)	36
45.2.3.51.1	PCS reset (3.2304.15)	37
45.2.3.51.2	Loopback (3.2304.14)	37
45.2.3.52	1000BASE-T1 PCS status 1 register (Register 3.2305)	37
45.2.3.52.1	Tx LPI received (3.2305.11)	38
45.2.3.52.2	Rx LPI received (3.2305.10)	38
45.2.3.52.3	Tx LPI indication (3.2305.9)	38
45.2.3.52.4	Rx LPI indication (3.2305.8)	38
45.2.3.52.5	Fault (3.2305.7)	39
45.2.3.52.6	PCS receive link status (3.2305.2)	39
45.2.3.53	1000BASE-T1 PCS status 2 register (Register 3.2306)	39
45.2.3.53.1	Receive link status (3.2306.10)	39
45.2.3.53.2	PCS high BER (3.2306.9)	39
45.2.3.53.3	PCS block lock (3.2306.8)	40
45.2.3.53.4	Latched high BER (3.2306.7)	40
45.2.3.53.5	Latched block lock (3.2306.6)	40
45.2.3.53.6	BER count (3.2306.5:0)	40
45.2.3.54	1000BASE-T1 OAM transmit register (Register 3.2308)	40
45.2.3.54.1	1000BASE-T1 OAM message valid (3.2308.15)	41
45.2.3.54.2	Toggle value (3.2308.14)	41
45.2.3.54.3	1000BASE-T1 OAM message received (3.2308.13)	41
45.2.3.54.4	Received message toggle value (3.2308.12)	41
45.2.3.54.5	Message number (3.2308.11:8)	41
45.2.3.54.6	Ping received (3.2308.3)	42
45.2.3.54.7	Ping transmit (3.2308.2)	42
45.2.3.54.8	Local SNR (3.2308.1:0)	42
45.2.3.55	1000BASE-T1 OAM message register (Registers 3.2309 to 3.2312)	42
45.2.3.56	1000BASE-T1 OAM receive register (Register 3.2313)	42
45.2.3.56.1	Link partner 1000BASE-T1 OAM message valid (3.2313.15)	42
45.2.3.56.2	Link partner toggle value (3.2313.14)	42
45.2.3.56.3	Link partner message number (3.2313.11:8)	43
45.2.3.56.4	Link partner SNR (3.2313.1:0)	43

45.2.3.57	Link partner 1000BASE-T1 OAM message register (Registers 3.2314 to 3.2317)	43
45.2.7	Auto-Negotiation registers	44
45.2.7.14c	BASE-T1 AN control register (Register 7.512)	45
45.2.7.14c.1	AN reset (7.512.15)	45
45.2.7.14c.2	Auto-Negotiation enable (7.512.12)	45
45.2.7.14c.3	Restart Auto-Negotiation (7.512.9)	46
45.2.7.14d	BASE-T1 AN status (Register 7.513)	46
45.2.7.14d.1	Page received (7.513.6)	46
45.2.7.14d.2	Auto-Negotiation complete (7.513.5)	47
45.2.7.14d.3	Remote fault (7.513.4)	47
45.2.7.14d.4	Auto-Negotiation ability (7.513.3)	47
45.2.7.14d.5	Link status (7.513.2)	47
45.2.7.14e	BASE-T1 AN advertisement register (Registers 7.514, 7.515, and 7.516)	47
45.2.7.14f	BASE-T1 AN LP Base Page ability register (Registers 7.517, 7.518, and 7.519)	48
45.2.7.14g	BASE-T1 AN Next Page transmit register (Registers 7.520, 7.521, and 7.522)	48
45.2.7.14h	BASE-T1 AN LP Next Page ability register (Registers 7.523, 7.524, and 7.525)	49
45.5	Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) interface	51
45.5.3	PICS proforma tables for the Management Data Input Output (MDIO) interface	51
45.5.3.3	PMA/PMD management functions	51
45.5.3.7	PCS management functions	53
45.5.3.9	Auto-Negotiation management functions	55
78.	Energy-Efficient Ethernet (EEE)	57
78.1	Overview	57
78.1.3	Reconciliation sublayer operation	57
78.1.3.3	PHY LPI operation	57
78.1.3.3.1	PHY LPI transmit operation	57
78.2	LPI mode timing parameters description	57
78.5	Communication link access latency	58
97.	Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 1000BASE-T1	59
97.1	Overview	59
97.1.1	Relationship of 1000BASE-T1 to other standards	59
97.1.2	Operation of 1000BASE-T1	59
97.1.2.1	Physical Coding Sublayer (PCS)	61
97.1.2.2	Physical Medium Attachment (PMA) sublayer	61
97.1.2.3	EEE capability	62
97.1.2.4	Link Synchronization	62
97.1.3	Signaling	64
97.1.4	Interfaces	64
97.1.5	Conventions in this clause	64
97.2	1000BASE-T1 Service Primitives and Interfaces	64
97.2.1	Technology Dependent Interface	65
97.2.1.1	PMA_LINK.request	65

	97.2.1.1.1	Semantics of the primitive	65
	97.2.1.1.2	When generated	65
	97.2.1.1.3	Effect of receipt	65
97.2.1.2	PMA_LINK.indication.....		65
	97.2.1.2.1	Semantics of the primitive	65
	97.2.1.2.2	When generated	66
	97.2.1.2.3	Effect of receipt	66
97.2.2	PMA service interface		66
97.2.2.1	PMA_TXMODE.indication		66
	97.2.2.1.1	Semantics of the primitive	66
	97.2.2.1.2	When generated	67
	97.2.2.1.3	Effect of receipt	67
97.2.2.2	PMA_CONFIG.indication		68
	97.2.2.2.1	Semantics of the primitive	68
	97.2.2.2.2	When generated	68
	97.2.2.2.3	Effect of receipt	68
97.2.2.3	PMA_UNITDATA.request		68
	97.2.2.3.1	Semantics of the primitive	68
	97.2.2.3.2	When generated	68
	97.2.2.3.3	Effect of receipt	68
97.2.2.4	PMA_UNITDATA.indication.....		69
	97.2.2.4.1	Semantics of the primitive	69
	97.2.2.4.2	When generated	69
	97.2.2.4.3	Effect of receipt	69
97.2.2.5	PMA_SCRSTATUS.request		69
	97.2.2.5.1	Semantics of the primitive	69
	97.2.2.5.2	When generated	69
	97.2.2.5.3	Effect of receipt	69
97.2.2.6	PMA_PCSSTATUS.request		69
	97.2.2.6.1	Semantics of the primitive	69
	97.2.2.6.2	When generated	70
	97.2.2.6.3	Effect of receipt	70
97.2.2.7	PMA_RXSTATUS.indication.....		70
	97.2.2.7.1	Semantics of the primitive	70
	97.2.2.7.2	When generated	70
	97.2.2.7.3	Effect of receipt	70
97.2.2.8	PMA_PHYREADY.indication		70
	97.2.2.8.1	Semantics of the primitive	70
	97.2.2.8.2	When generated	71
	97.2.2.8.3	Effect of receipt	71
97.2.2.9	PMA_REMRXSTATUS.request		71
	97.2.2.9.1	Semantics of the primitive	71
	97.2.2.9.2	When generated	71
	97.2.2.9.3	Effect of receipt	71
97.2.2.10	PMA_REMPHYREADY.request		71
	97.2.2.10.1	Semantics of the primitive	71
	97.2.2.10.2	When generated	72
	97.2.2.10.3	Effect of receipt	72
97.2.2.11	PMA_PCS_RX_LPI_STATUS.request		72
	97.2.2.11.1	Semantics of the primitive	72
	97.2.2.11.2	When generated	72
	97.2.2.11.3	Effect of receipt	72
97.2.2.12	PMA_PCS_TX_LPI_STATUS.request		72
	97.2.2.12.1	Semantics of the primitive	72

	97.2.2.12.2	When generated	72
	97.2.2.12.3	Effect of receipt	73
97.3	Physical Coding Sublayer (PCS)		73
97.3.1	PCS service interface (GMII)		73
97.3.2	PCS functions		73
97.3.2.1	PCS Reset function		73
97.3.2.2	PCS Transmit function		73
	97.3.2.2.1	Use of blocks	75
	97.3.2.2.2	81B-RS transmission code	75
	97.3.2.2.3	Notation conventions	75
	97.3.2.2.4	Transmission order	75
	97.3.2.2.5	Block structure	75
	97.3.2.2.6	Control codes	78
	97.3.2.2.7	Idle	79
	97.3.2.2.8	LP_IDLE	79
	97.3.2.2.9	Error	79
	97.3.2.2.10	Transmit process	79
	97.3.2.2.11	RS-FEC encoder	80
	97.3.2.2.12	PCS scrambler	81
	97.3.2.2.13	3B2T to PAM3	81
	97.3.2.2.14	81B-RS framer	82
	97.3.2.2.15	EEE capability	82
97.3.2.3	PCS Receive function		83
	97.3.2.3.1	Frame and block synchronization	84
	97.3.2.3.2	PCS descrambler	84
	97.3.2.3.3	Valid and invalid blocks	84
97.3.3	Test-pattern generators		84
97.3.4	PMA training side-stream scrambler polynomials		84
	97.3.4.1	Generation of S_n	85
	97.3.4.2	Generation of symbol T_n	85
	97.3.4.3	PMA training mode descrambler polynomials	85
97.3.5	LPI signaling		86
	97.3.5.1	LPI Synchronization	86
	97.3.5.2	Quiet period signaling	87
	97.3.5.3	Refresh period signaling	87
97.3.6	Detailed functions and state diagrams		87
	97.3.6.1	State diagram conventions	87
	97.3.6.2	State diagram parameters	88
	97.3.6.2.1	Constants	88
	97.3.6.2.2	Variables	88
	97.3.6.2.3	Functions	90
	97.3.6.2.4	Counters	90
	97.3.6.3	Messages	90
	97.3.6.4	State diagrams	91
97.3.7	PCS management		95
	97.3.7.1	Status	95
	97.3.7.2	Counter	95
	97.3.7.3	Loopback	95
97.3.8	100BASE-T1 Operations, Administration, and Maintenance (OAM)		96
	97.3.8.1	Definitions	96
	97.3.8.2	Functional specifications	96
	97.3.8.2.1	100BASE-T1 OAM Frame Structure	96
	97.3.8.2.2	100BASE-T1 OAM Frame Data	97
	97.3.8.2.3	Ping RX	97

	97.3.8.2.4	Ping TX.....	97
	97.3.8.2.5	PHY Health.....	98
	97.3.8.2.6	1000BASE-T1 OAM Message Valid	98
	97.3.8.2.7	1000BASE-T1 OAM Message Toggle.....	98
	97.3.8.2.8	1000BASE-T1 OAM Message Acknowledge.....	98
	97.3.8.2.9	1000BASE-T1 OAM Message Toggle Acknowledge ...	98
	97.3.8.2.10	1000BASE-T1 OAM Message Number.....	99
	97.3.8.2.11	1000BASE-T1 OAM Message Data	99
	97.3.8.2.12	CRC16	99
	97.3.8.2.13	1000BASE-T1 OAM Frame Acceptance Criteria	99
	97.3.8.2.14	PHY Health Indicator	100
	97.3.8.2.15	Ping.....	100
	97.3.8.2.16	1000BASE-T1 OAM Message Exchange	100
	97.3.8.3	State diagram variable to 1000BASE-T1 OAM register mapping ...	101
	97.3.8.4	Detailed functions and State Diagrams	103
	97.3.8.4.1	State diagram conventions.....	103
	97.3.8.4.2	State diagram parameters.....	103
	97.3.8.4.3	Variables.....	103
	97.3.8.4.4	Counters.....	107
	97.3.8.4.5	Functions	108
	97.3.8.4.6	State Diagrams.....	109
97.4		Physical Medium Attachment (PMA) sublayer.....	111
	97.4.1	PMA functional specifications	111
	97.4.2	PMA functions.....	111
	97.4.2.1	PMA Reset function	112
	97.4.2.2	PMA Transmit function	112
	97.4.2.2.1	Global PMA transmit disable	112
	97.4.2.3	PMA Receive function.....	112
	97.4.2.4	PHY Control function	113
	97.4.2.4.1	InfoField notation	114
	97.4.2.4.2	Start of Frame Delimiter.....	114
	97.4.2.4.3	Partial PHY frame Count (PFC24).....	114
	97.4.2.4.4	Message Field.....	114
	97.4.2.4.5	PHY Capability Bits, User Configurable Register, and Data Mode Scrambler Seed	115
	97.4.2.4.6	Data Switch partial PHY frame Count	115
	97.4.2.4.7	Reserved Fields.....	115
	97.4.2.4.8	CRC16	115
	97.4.2.4.9	PMA MDIO function mapping.....	116
	97.4.2.4.10	Start-up sequence.....	116
	97.4.2.4.11	PHY Control Registers	118
	97.4.2.5	Link Monitor function.....	118
	97.4.2.6	PHY Link Synchronization	119
	97.4.2.6.1	State diagram variables.....	120
	97.4.2.6.2	State diagram timers	121
	97.4.2.6.3	Messages.....	121
	97.4.2.6.4	State diagrams.....	122
	97.4.2.7	Refresh Monitor function	123
	97.4.2.8	Clock Recovery function.....	123
97.4.3		MDI	123
	97.4.3.1	MDI signals transmitted by the PHY	123
	97.4.3.2	Signals received at the MDI.....	123
97.4.4		State variables.....	123
	97.4.4.1	State diagram variables	123

	97.4.4.2	Timers.....	126
	97.4.5	State diagrams	127
97.5		PMA electrical specifications	128
	97.5.1	EMC Requirements	128
	97.5.1.1	Immunity—DPI test	128
	97.5.1.2	Emission—150 W conducted emission test	128
	97.5.2	Test modes.....	128
	97.5.2.1	Test fixtures.....	131
	97.5.3	Transmitter electrical specifications	132
	97.5.3.1	Maximum output droop.....	133
	97.5.3.2	Transmitter distortion.....	133
	97.5.3.3	Transmitter timing jitter	134
	97.5.3.4	Transmitter Power Spectral Density (PSD) and power level.....	135
	97.5.3.5	Transmitter peak differential output.....	136
	97.5.3.6	Transmitter clock frequency.....	136
	97.5.4	Receiver electrical specifications	136
	97.5.4.1	Receiver differential input signals.....	136
	97.5.4.2	Alien crosstalk noise rejection	136
97.6		Link segment characteristics.....	136
	97.6.1	Link transmission parameters for link segment type A.....	137
	97.6.1.1	Insertion loss	137
	97.6.1.2	Differential characteristic impedance.....	138
	97.6.1.3	Return loss.....	138
	97.6.1.4	Differential to common mode conversion.....	138
	97.6.1.5	Maximum link delay	139
	97.6.2	Link transmission parameters for link segment type B.....	140
	97.6.2.1	Insertion loss	140
	97.6.2.2	Differential characteristic impedance.....	140
	97.6.2.3	Return loss.....	140
	97.6.2.4	Maximum link delay	141
	97.6.2.5	Coupling attenuation	141
	97.6.3	Coupling parameters between type A link segments	142
	97.6.3.1	Multiple disturber alien near-end crosstalk (MDANEXT) loss	142
	97.6.3.2	Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss	142
	97.6.3.3	Multiple disturber alien far-end crosstalk (MDAFEXT) loss	143
	97.6.3.4	Multiple disturber power sum alien attenuation crosstalk ratio far-end (PSAACRF).....	143
	97.6.4	Coupling parameters between type B link segments.....	144
	97.6.4.1	Multiple disturber alien near-end crosstalk (MDANEXT) loss	144
	97.6.4.2	Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss	145
	97.6.4.3	Multiple disturber alien far-end crosstalk (MDAFEXT) loss	145
	97.6.4.4	Multiple disturber power sum alien attenuation crosstalk ratio far-end (PSAACRF).....	145
97.7		Media Dependent Interface (MDI)	146
	97.7.1	MDI connectors	146
	97.7.2	MDI electrical specification	146
	97.7.2.1	MDI return loss	146
	97.7.2.2	MDI mode conversion loss	147
	97.7.3	MDI fault tolerance	147
97.8		Management Interfaces	147
	97.8.1	Optional Support for Auto-Negotiation.....	147
97.9		Environmental specifications.....	148

97.9.1	General safety	148
97.9.2	Network safety.....	148
97.9.2.1	Environmental safety.....	148
97.9.2.2	Electromagnetic compatibility	148
97.10	Delay constraints.....	148
97.11	Protocol implementation conformance statement (PICS) proforma for Clause 97, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 1000BASE-T1	150
97.11.1	Introduction	150
97.11.2	Identification.....	150
97.11.2.1	Implementation identification	150
97.11.2.2	Protocol summary	150
97.11.3	Major capabilities/options	151
97.11.4	General	151
97.11.5	Physical Coding Sublayer (PCS).....	152
97.11.6	PCS Receive functions	153
97.11.7	PCS loopback	154
97.11.8	Physical Medium Attachment (PMA).....	155
97.11.9	PMA electrical specifications.....	157
97.11.10	MDI electrical requirements.....	160
97.11.10.1	Characteristics of the link segment	160
97.11.11	MDI Requirements	162
97.11.12	EEE capability requirements	162
97.11.13	Environmental specifications	163
98.	Auto-Negotiation for single differential-pair media.....	164
98.1	Overview.....	164
98.1.1	Scope	164
98.1.2	Relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model	164
98.2	Functional specifications	164
98.2.1	Transmit function requirements	165
98.2.1.1	DME transmission.....	165
98.2.1.1.1	DME page encoding	165
98.2.1.1.2	DME page timing	167
98.2.1.1.3	DME page Delimiters	168
98.2.1.1.4	Transmitter peak differential output.....	169
98.2.1.2	Link codeword encoding	169
98.2.1.2.1	Selector Field	169
98.2.1.2.2	Echoed Nonce Field.....	169
98.2.1.2.3	Transmitted Nonce Field	170
98.2.1.2.4	Technology Ability Field.....	170
98.2.1.2.5	Force MASTER-SLAVE.....	170
98.2.1.2.6	Pause Ability.....	171
98.2.1.2.7	Remote Fault.....	171
98.2.1.2.8	Acknowledge	171
98.2.1.2.9	Next Page.....	171
98.2.1.3	Transmit Switch function	172
98.2.2	Receive function requirements.....	172
98.2.2.1	DME page reception.....	172
98.2.2.2	Receive Switch function.....	172
98.2.2.3	Link codeword matching.....	172
98.2.3	AN half-duplex function requirements.....	172

98.2.4	Arbitration function requirements	172
98.2.4.1	Renegotiation function	173
98.2.4.2	Priority Resolution function	173
98.2.4.3	Next Page function	173
98.2.4.3.1	Next page encodings	174
98.2.4.3.2	Use of Next Pages	174
98.3	State diagram variable to Auto-Negotiation register mapping	175
98.4	Technology-Dependent Interface	175
98.4.1	PMA_LINK.indication	175
98.4.1.1	Semantics of the service primitive	175
98.4.1.2	When generated	176
98.4.1.3	Effect of receipt	176
98.4.2	PMA_LINK.request	176
98.4.2.1	Semantics of the service primitive	176
98.4.2.2	When generated	176
98.4.2.3	Effect of receipt	176
98.5	Detailed functions and state diagrams	176
98.5.1	State diagram variables	176
98.5.2	State diagram timers	183
98.5.3	State diagram counters	184
98.5.4	Function	185
98.5.5	State diagrams	185
98.6	Protocol implementation conformance statement (PICS) proforma for Clause 98, Auto-Negotiation for Single Differential-Pair Media	189
98.6.1	Introduction	189
98.6.2	Identification	189
98.6.2.1	Implementation identification	189
98.6.2.2	Protocol summary	189
98.6.3	General	190
98.6.4	DME transmission	190
98.6.5	Link codeword encoding	191
98.6.6	Arbitration function requirements	193
98.6.7	Service primitives	194
98.6.8	State diagram and variable definitions	194
Annex 97A (normative) Common mode conversion test methodology		196
97A.1	Introduction	196
97A.2	Test configuration and measurement	196
97A.3	Protocol implementation conformance statement (PICS) proforma for Annex 97A, Common mode conversion test methodology	198
97A.3.1	Introduction	198
97A.3.2	Identification	198
97A.3.2.1	Implementation identification	198
97A.3.2.2	Protocol summary	198
97A.3.3	Major capabilities/options	199
Annex 97B (normative) Alien Crosstalk Test Procedure		200
97B.1	Introduction	200
97B.1.1	Alien crosstalk test configurations	200
97B.2	Alien crosstalk coupled between type A link segments	200
97B.3	Cable bundling	201

97B.4	Protocol implementation conformance statement (PICS) proforma for Annex 97B, Alien Crosstalk Test Procedure	203
97B.4.1	Introduction	203
97B.4.2	Identification.....	203
97B.4.2.1	Implementation identification	203
97B.4.2.2	Protocol summary.....	203
97B.4.3	Major capabilities/options	204
Annex 98A (normative) Selector Field definitions.....		205
98A.1	Introduction.....	205
Annex 98B (normative) IEEE 802.3 Selector Base Page definition		206
98B.1	Introduction.....	206
98B.2	Selector field value	206
98B.3	Technology Ability Field bit assignments	206
98B.4	Priority Resolution.....	206
98B.5	Message Page transmission convention.....	207
Annex 98C (normative) Next Page Message Code Field definitions.....		208
98C.1	Introduction.....	208
98C.2	Message code 1—Null Message code	208
98C.3	Message code 5—Organizationally Unique Identifier (OUI) tag code	208
98C.4	Message code 6—AN device identifier tag code.....	209

IEEE Standard for Ethernet

Amendment 4: Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

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/IPR/disclaimers.html>.

(This amendment is based on IEEE Std 802.3™-2015 as amended by IEEE Std 802.3bw™-2015, IEEE Std 802.3by™-2016, and IEEE Std 802.3bq™-2016.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strike through~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.¹

Cross references that refer to clauses, tables, equations, or figures not covered by this amendment are highlighted in green.

¹Notes in text, tables, and figures are given for information only, and do not contain requirements needed to implement the standard.