

IEEE P802.3bj™/D1.2

Draft Standard for Ethernet Amendment X: Physical Layer Specifications and Management Parameters for 100 Gb/s Operation Over Backplanes and Copper Cables

Prepared by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

This draft is an amendment of IEEE Std 802.3-2012. This amendment adds 100 Gb/s Physical Layer (PHY) specifications and management parameters for operation on electrical backplanes and twinaxial copper cables. This amendment also specifies optional Energy Efficient Ethernet (EEE) for 40 Gb/s and 100 Gb/s operation over electrical backplanes and copper cables. Draft D1.2 is prepared for Task Force review. This draft expires 6 months after the date of publication or when the next version is published, whichever comes first.

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Abstract: This amendment to IEEE Std 802.3-2012 adds 100 Gb/s Physical Layer (PHY) specifications and management parameters for operation on electrical backplanes and twinaxial copper cables. This amendment also specifies optional Energy Efficient Ethernet (EEE) for 40 Gb/s and 100 Gb/s operation over electrical backplanes and copper cables.

Keywords: 100 Gb/s Ethernet; 100GBASE-CR10; 100GBASE-CR4; 100GBASE-KR4; 100GBASE-KP4; 40 Gb/s Ethernet; 40GBASE-CR4; 40GBASE-KR4; 802.3bj; Auto-Negotiation (AN); Backplane Ethernet; Energy Efficient Ethernet (EEE); Ethernet; Forward Error Correction (FEC); physical medium attachment (PMA) sublayer; physical medium dependent (PMD) sublayer.

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Introduction

Editor's Note (to be removed prior to publication):

This front matter is provided for comment only. Front matter is not part of a published standard and is therefore, not part of the draft standard. You are invited to review and comment on it as it will be included in the published standard after approval.

One exception to IEEE style that is consciously used to simplify the balloting process is the numbering of the front matter. Instead of the front matter being lower case Roman numeral page numbers, with the draft restarting at 1 with arabic page numbers, balloted front matter and draft are numbered consecutively with arabic page numbers.

This introduction is not part of IEEE P802.3bj, IEEE Draft Standard for Ethernet. Amendment 1: Physical Layer Specifications and Management Parameters for 100 Gb/s Operation Over Backplanes and Copper Cables.

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 Media Access Control (MAC) protocol specified in IEEE Std 802.3 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was included in the experimental Ethernet developed at Xerox Palo Alto Research Center. While the experimental Ethernet had a 2.94 Mb/s data rate, IEEE Std 802.3-1985 specified operation at 10 Mb/s. Since 1985 new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3.

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 802.3x specified full duplex operation and a flow control protocol, 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 802.3-2012 and are not maintained as separate documents.

At the date of IEEE Std 802.3bj-201X publication, IEEE Std 802.3 is comprised of the following documents:

IEEE Std 802.3-2012

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 Std 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 90 and Annex 83A through Annex 86A. 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 89 and associated annexes includes 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 802.3bj™-201X

This amendment includes changes to IEEE Std 802.3-2012 and adds Clause 91 through Clause 94 as well as associated annexes. This amendment adds 100 Gb/s Physical Layer (PHY) specifications and management parameters for operation on electrical backplanes and twinaxial copper cables. This amendment also specifies optional Energy Efficient Ethernet (EEE) for 40 Gb/s and 100 Gb/s operation over electrical backplanes and copper cables."

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.

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Draft Standard for Ethernet Amendment X: Physical Layer Specifications and Management Parameters for 100 Gb/s Operation Over Backplanes and Copper Cables

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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 ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. 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. Introduction

1.4 Definitions

Insert the following definition after 1.4.51:

1.4.51a 100GBASE-CR4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding and Clause 91 RS-FEC over four lanes of shielded balanced copper cabling, with reach up to at least 5 m. (See IEEE Std 802.3, Clause 92.)

Insert the following definitions after 1.4.53:

1.4.53a 100GBASE-KP4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding, Clause 91 RS-FEC, and 4-level pulse amplitude modulation over four lanes of an electrical back-plane, with a total insertion loss up to 33 dB at 7.0 GHz. (See IEEE Std 802.3, Clause 94.)

1.4.53b 100GBASE-KR4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding, Clause 91 RS-FEC, and 2-level pulse amplitude modulation over four lanes of an electrical back-plane, with a total insertion loss up to 35 dB at 12.9 GHz. (See IEEE Std 802.3, Clause 93.)

30. Management

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

30.3.2.1.2 aPhyType

Change entry in *APPROPRIATE SYNTAX* and insert a new entry below that as shown:

APPROPRIATE SYNTAX:

...	
<u>100GBASE-R</u>	Clause 82 100 Gb/s multi-PCS lane 64B/66B using 2-level PAM
<u>100GBASE-P</u>	Clause 82 100 Gb/s multi-PCS lane using more than 2-level PAM

30.3.2.1.3 aPhyTypeList

Change entry in *APPROPRIATE SYNTAX* and insert a new entry below that as shown:

APPROPRIATE SYNTAX:

...	
<u>100GBASE-R</u>	Clause 82 100 Gb/s multi-PCS lane 64B/66B using 2-level PAM
<u>100GBASE-P</u>	Clause 82 100 Gb/s multi-PCS lane using more than 2-level PAM

30.5.1.1.2 aMAUType

Change entry in *APPROPRIATE SYNTAX* and insert new entries below that as shown:

APPROPRIATE SYNTAX:

...	
100GBASE-R	Multi-lane PCS as specified in Clause 82 over undefined PMA/PMD
<u>100GBASE-R</u>	Multi-lane Clause 82 PCS over undefined PMA/PMD using 2-level PAM
<u>100GBASE-P</u>	Multi-lane Clause 82 PCS over undefined PMA/PMD using >2-level PAM
<u>100GBASE-KP4</u>	100GBASE-P PCS/PMA over an electrical backplane PMD as specified in Clause 94
<u>100GBASE-KR4</u>	100GBASE-R PCS/PMA over an electrical backplane PMD as specified in Clause 93
<u>100GBASE-CR4</u>	100GBASE-R PCS/PMA over 4 lane shielded copper balanced cable PMD as specified in Clause 92

Change final paragraph in *BEHAVIOUR DEFINED AS* section as shown:

BEHAVIOUR DEFINED AS:

...

The enumerations 1000BASE-X, 1000BASE-XHD, 1000BASE-XFD, 10GBASE-X, 10GBASE-R, 10GBASE-W, 40GBASE-R, ~~and 100GBASE-R, and 100GBASE-P~~ shall only be returned if the underlying PMD type is unknown.;

Change 30.5.1.1.15, 16, 17, 18 for RS-FEC:

30.5.1.1.15 aFECability

ATTRIBUTE

APPROPRIATE SYNTAX:

~~A ENUMERATION~~ An ENUMERATED VALUE that meets the requirement of the description below

unknown	initializing, true state not yet known
supported	FEC supported
not supported	FEC not supported

BEHAVIOUR DEFINED AS:

A read-only value that indicates if the PHY supports an optional FEC sublayer for forward error correction (see 65.2, ~~and~~ Clause 74, and Clause 91).

If a Clause 45 MDIO Interface to the PCSPHY is present, then this attribute will map to the FEC capability register (see 45.2.8.2).;

30.5.1.1.16 aFECmode

ATTRIBUTE

APPROPRIATE SYNTAX:

~~A ENUMERATION~~ An ENUMERATED VALUE that meets the requirement of the description below

unknown	initializing, true state not yet known
disabled	FEC disabled
enabled	FEC enabled

BEHAVIOUR DEFINED AS:

A read-write value that indicates the mode of operation of the optional FEC sublayer for forward error correction (see 65.2, ~~and~~ Clause 74, and Clause 91).

A GET operation returns the current mode of operation of the PHY. A SET operation changes the mode of operation of the PHY to the indicated value. When Clause 73 Auto-Negotiation is enabled for a PHY supporting Clause 74 FEC a SET operation is not allowed and a GET operation maps to the variable FEC_enabled in Clause 74.

If a Clause 45 MDIO Interface to the PCSPHY is present, then this attribute will map to the FEC control register (see 45.2.8.3) for 1000BASE-PX or FEC enable bit in BASE-R FEC control register (see 45.2.1.90) or FEC enable bit in RS-FEC control register (see 45.2.1.93a).;

30.5.1.1.17 aFECCorrectedBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of generalized nonresetable counters. Each counter has a maximum increment rate of 1 200 000 counts per second for 1000 Mb/s implementations, 5 000 000 counts per second for

10 Gb/s and 40 Gb/s implementations, and 2 500 000 counts per second for 100 Gb/s implementations.

BEHAVIOUR DEFINED AS:

For 1000BASE-PX PHYs or 10/40/100GBASE-R PHYs, ~~a count~~ an array of corrected FEC blocks counters. The counters will not increment for other PHY types. The indices of this array (0 to N - 1) denote the PCS lane number where N is the number of PCS lanes in use. The number of PCS lanes in use is set to one for PHYs that do not use PCS lanes. Each element of this array contains a count of corrected FEC blocks for that PCS lane.

Increment the counter by one for each received block that is corrected by the FEC function in the PHY for the corresponding lane.

If a Clause 45 MDIO Interface to the PCSPHY is present, then this attribute will map to the FEC corrected blocks counter(s) (see [45.2.8.5](#), [45.2.1.91](#) and [45.2.1.93](#), or [45.2.1.93c](#));

30.5.1.1.18 aFECUncorrectableBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of generalized nonresetable counters. Each counter has a maximum increment rate of 1 200 000 counts per second for 1000 Mb/s implementations, and 5 000 000 counts per second for 10 Gb/s and 40 Gb/s implementations, and 2 500 000 counts per second for 100 Gb/s implementations.

BEHAVIOUR DEFINED AS:

For 1000BASE-PX PHYs or 10/40/100GBASE-R PHYs, an array of uncorrectable FEC blocks counters. The counters will not increment for other PHY types. The indices of this array (0 to N - 1) denote the PCS lane number where N is the number of PCS lanes in use. The number of PCS lanes in use is set to one for PHYs that do not use PCS lanes. Each element of this array contains a count of uncorrectable FEC blocks for that PCS lane.

Increment the counter by one for each FEC block that is determined to be uncorrectable by the FEC function in the PHY for the corresponding lane.

If a Clause 45 MDIO Interface to the PCSPHY is present, then this attribute will map to the FEC uncorrectable blocks counter(s) (see [45.2.8.6](#), [45.2.1.92](#) and [45.2.1.94](#), or [45.2.1.93d](#));

30.6.1.1.5 aAutoNegLocalTechnologyAbility

Insert 100GBASE-CR4, 100GBASE-KR4, and 100GBASE-KP4 after 100GBASE-CR10 as shown:

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

global	Reserved for future use
other	See 30.2.5
unknown	Initializing, true state or type not yet known
10BASE-T	10BASE-T half duplex as defined in Clause 14
10BASE-TFD	Full duplex 10BASE-T as defined in Clause 14 and Clause 31
100BASE-T4	100BASE-T4 half duplex as defined in Clause 23
100BASE-TX	100BASE-TX half duplex as defined in Clause 25
100BASE-TXFD	Full duplex 100BASE-TX as defined in Clause 25 and Clause 31
FDX PAUSE	PAUSE operation for full duplex links as defined in Annex 31B

FDX APAUSE	Asymmetric PAUSE operation for full duplex links as defined in Clause 37 , Annex 28B , and Annex 31B	1
FDX SPAUSE	Symmetric PAUSE operation for full duplex links as defined in Clause 37 , Annex 28B , and Annex 31B	2
FDX BPAUSE	Asymmetric and Symmetric PAUSE operation for full duplex links as defined in Clause 37 , Annex 28B , and Annex 31B	3
100BASE-T2	100BASE-T2 half duplex as defined in Clause 32	4
100BASE-T2FD	Full duplex 100BASE-T2 as defined in Clause 31 and Clause 32	5
1000BASE-X	1000BASE-X half duplex as specified in Clause 36	6
1000BASE-XFD	Full duplex 1000BASE-X as specified in Clause 31 and Clause 36	7
1000BASE-T	1000BASE-T half duplex PHY as specified in Clause 40	8
1000BASE-TFD	Full duplex 1000BASE-T PHY as specified in Clause 31 and as specified in Clause 40	9
Rem Fault1	Remote fault bit 1 (RF1) as specified in Clause 37	10
Rem Fault2	Remote fault bit 2 (RF2) as specified in Clause 37	11
10GBASE-T	10GBASE-T PHY as specified in Clause 55	12
1000BASE-KXFD	Full duplex 1000BASE-KX as specified in Clause 70	13
10GBASE-KX4FD	Full duplex 10GBASE-KX4 as specified in Clause 71	14
10GBASE-KRFD	Full duplex 10GBASE-KR as specified in Clause 72	15
40GBASE-KR4	40GBASE-KR4 as specified in Clause 84	16
40GBASE-CR4	40GBASE-CR4 as specified in Clause 85	17
100GBASE-CR10	100GBASE-CR10 as specified in Clause 85	18
<u>100GBASE-CR4</u>	<u>100GBASE-CR4 as specified in Clause 92</u>	19
<u>100GBASE-KR4</u>	<u>100GBASE-KR4 as specified in Clause 93</u>	20
<u>100GBASE-KP4</u>	<u>100GBASE-KP4 as specified in Clause 94</u>	21
Rem Fault	Remote fault bit (RF) as specified in Clause 73	22
FEC Capable	FEC ability as specified in Clause 73 (see 73.7) and Clause 74	23
FEC Requested	FEC requested as specified in Clause 73 (see 73.7) and Clause 74	24
isoethernet	IEEE Std 802.9 ISLAN-16T	25
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45. Management Data Input/Output (MDIO) Interface

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

45.2.1 PMA/PMD registers

Replace the identified reserved row in Table 45-3 with the rows shown:

Table 45-3—PMA/PMD registers

Register address	Register name	Clause
1.176 through 1.299	Reserved	
1.176 through 1.199	Reserved	
1.200	RS-FEC control register	45.2.1.93a
1.201	RS-FEC status register	45.2.1.93b
1.202, 1.203	RS-FEC corrected codewords counter	45.2.1.93c
1.204, 1.205	RS-FEC uncorrected codewords counter	45.2.1.93d
1.206 through 1.209	Reserved	
1.210 through 1.217	RS-FEC symbol error counter, FEC lanes 0 to 3	45.2.1.93e
1.218 through 1.229	Reserved	
1.230 through 1.249	RS-FEC BIP error counter, PCS lanes 0 to 19	45.2.1.93g
1.250 through 1.299	Reserved	

45.2.1.2 PMA/PMD status 1 register (Register 1.1)

Change the first row of Table 45-5 and insert the following rows below that row:

Insert the following subclauses before 45.2.1.2.1:

45.2.1.2.a PMA ingress AUI stop ability (1.1.9)

If bit 1.1.9 is set to one, then the PMA is indicating that the PMA sublayer attached by the ingress AUI is permitted to stop signaling during LPI. If the bit is set to zero then the PMA is indicating that the PMA sublayer attached by the ingress AUI is not permitted to stop signaling during LPI. If the PMA sublayer

Table 45–5—PMA/PMD status 1 register bit definitions

Bit(s)	Name	Description	R/W ^a
1.1.15:810	Reserved	Value always 0, writes ignored	R/W
1.1.9	PIASA	PMA ingress AUI stop ability	R/W
1.1.8	PEASA	PMA egress AUI stop ability	R/W

^aR/W = Read/Write

attached by the ingress AUI does not support EEE capability or is not capable to stop signaling then this bit has no effect.

45.2.1.2.b PMA egress AUI stop ability (1.1.8)

If bit 1.1.8 is set to one, then the PMA is indicating that the PMA sublayer attached by the egress AUI is permitted to stop signaling during LPI. If the bit is set to zero then the PMA is indicating that the PMA sublayer attached by the egress AUI is not permitted to stop signaling during LPI. If the PMA sublayer attached by the egress AUI does not support EEE capability or is not capable to stop signaling then this bit has no effect.

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Change Table 45-7 as follows:

Insert the following subclauses before 45.2.1.6.1:

45.2.1.6.a PMA ingress AUI stop enable (1.7.9)

If bit 1.7.9 is set to 1 then the PMA may stop the ingress direction AUI signaling during LPI otherwise it shall keep active signaling on that AUI. If the PMA does not support EEE capability or is not able to stop the ingress direction AUI signaling then this bit has no effect.

45.2.1.6.b PMA egress AUI stop enable (1.7.8)

If bit 1.7.8 is set to 1 then the PMA may stop the egress direction AUI signaling during LPI otherwise it shall keep active signaling on that AUI. If the PMA does not support EEE capability or is not able to stop the egress direction AUI signaling then this bit has no effect.

Table 45–7—PMA/PMD control 2 register bit definitions

Bit(s)	Name	Description	R/W ^a
1.7.15:6	Reserved	Value always 0, writes ignored	R/W
1.7.9	PIASE	PMA ingress AUI stop enable	R/W
1.7.8	PEASE	PMA egress AUI stop enable	R/W
1.7.7:6	Reserved	Value always 0, writes ignored	R/W
1.7.5:0	PMA/PMD type selection	5 4 3 2 1 0 1 1 x x x = reserved for future use 1 0 1 1 x x = reserved for future use 1 0 1 1 1 = reserved for future use 1 0 1 1 1 0 = 100GBASE-CR4 PMA/PMD type 1 0 1 1 0 1 = 100GBASE-KP4 PMA/PMD type 1 0 1 1 0 0 = 100GBASE-KR4 PMA/PMD type 1 0 1 0 1 1 = 100GBASE-ER4 PMA/PMD type 1 0 1 0 1 0 = 100GBASE-LR4 PMA/PMD type 1 0 1 0 0 1 = 100GBASE-SR10 PMA/PMD type 1 0 1 0 0 0 = 100GBASE-CR10 PMA/PMD type 1 0 0 1 1 x = reserved for future use 1 0 0 1 0 1 = reserved for future use 1 0 0 1 0 0 = 40GBASE-FR PMA/PMD type 1 0 0 0 1 1 = 40GBASE-LR4 PMA/PMD type 1 0 0 0 1 0 = 40GBASE-SR4 PMA/PMD type 1 0 0 0 0 1 = 40GBASE-CR4 PMA/PMD type 1 0 0 0 0 0 = 40GBASE-KR4 PMA/PMD type 0 1 1 1 x x = reserved 0 1 1 0 1 1 = reserved 0 1 1 0 1 0 = 10GBASE-PR-U3 0 1 1 0 0 1 = 10GBASE-PR-U1 0 1 1 0 0 0 = 10/1GBASE-PRX-U3 0 1 0 1 1 1 = 10/1GBASE-PRX-U2 0 1 0 1 1 0 = 10/1GBASE-PRX-U1 0 1 0 1 0 1 = 10GBASE-PR-D3 0 1 0 1 0 0 = 10GBASE-PR-D2 0 1 0 0 1 1 = 10GBASE-PR-D1 0 1 0 0 1 0 = 10/1GBASE-PRX-D3 0 1 0 0 0 1 = 10/1GBASE-PRX-D2 0 1 0 0 0 0 = 10/1GBASE-PRX-D1 0 0 1 1 1 1 = 10BASE-T PMA/PMD type 0 0 1 1 1 0 = 100BASE-TX PMA/PMD type 0 0 1 1 0 1 = 1000BASE-KX PMA/PMD type 0 0 1 1 0 0 = 1000BASE-T PMA/PMD type 0 0 1 0 1 1 = 10GBASE-KR PMA/PMD type 0 0 1 0 1 0 = 10GBASE-KX4 PMA/PMD type 0 0 1 0 0 1 = 10GBASE-T PMA type 0 0 1 0 0 0 = 10GBASE-LRM PMA/PMD type 0 0 0 1 1 1 = 10GBASE-SR PMA/PMD type 0 0 0 1 1 0 = 10GBASE-LR PMA/PMD type 0 0 0 1 0 1 = 10GBASE-ER PMA/PMD type 0 0 0 1 0 0 = 10GBASE-LX4 PMA/PMD type 0 0 0 0 1 1 = 10GBASE-SW PMA/PMD type 0 0 0 0 1 0 = 10GBASE-LW PMA/PMD type 0 0 0 0 0 1 = 10GBASE-EW PMA/PMD type 0 0 0 0 0 0 = 10GBASE-CX4 PMA/PMD type	R/W

^aR/W = Read/Write

45.2.1.7.4 Transmit fault (1.8.11)

Add the following rows to the bottom of Table 45-9:

Table 45-9—Transmit fault description location

PMA/PMD	Description location
100GBASE-CR4	92.7.10
100GBASE-KR4	93.7.10
100GBASE-KP4	94.3.8

45.2.1.7.5 Receive fault (1.8.10)

Add the following rows to the bottom of Table 45-10:

Table 45-10—Receive fault description location

PMA/PMD	Description location
100GBASE-CR4	92.7.11
100GBASE-KR4	93.7.11
100GBASE-KP4	94.3.9

Change 45.2.1.8 for transmit disable:

45.2.1.8 PMD transmit disable register (Register 1.9)

The assignment of bits in the PMD transmit disable register is shown in [Table 45-11](#). The transmit disable functionality is optional and a PMD's ability to perform the transmit disable functionality is advertised in the PMD transmit disable ability bit 1.8.8. A PMD that does not implement the transmit disable functionality shall ignore writes to the PMD transmit disable register and may return a value of zero for all bits. A PMD device that operates using a single lane and has implemented the transmit disable function shall use bit 1.9.0 to control the function. Such devices shall ignore writes to bits 1.9.10:1 and return a value of zero for those bits when they are read. The transmit disable function for the 10GBASE-KR PMD is described in [72.6.5](#), for 10GBASE-LRM serial PMDs in [68.4.7](#), and for other serial PMDs in [52.4.7](#). The transmit disable function for the 10GBASE-LX4 PMD is described in [53.4.7](#). The transmit disable function for the 10GBASE-CX4 PMD is described in [54.5.6](#). The transmit disable function for 10GBASE-KX4 is described in [71.6.6](#). The transmit disable function for the 10GBASE-T PMA is described in [55.4.2.3](#). The transmit disable function for 40GBASE-KR4 is described in [84.7.6](#). The transmit disable function for 40GBASE-CR4 and 100GBASE-CR10 is described in [85.7.6](#). The transmit disable function for 40GBASE-SR4 and 100GBASE-SR10 is described in [86.5.7](#). The transmit disable function for 40GBASE-FR is described in [89.5.6](#). The transmit disable function for 40GBASE-LR4 is described in [87.5.7](#). The transmit disable function for 100GBASE-LR4 and 100GBASE-ER4 is described in [88.5.7](#). The transmit disable function for 100GBASE-CR4 is described in [92.7.6](#). The transmit disable function for 100GBASE-KR4 is described in

93.7.6. The transmit disable function for 100GBASE-KP4 is described in 94.3.6.6.

45.2.1.12 40G/100G PMA/PMD extended ability register (Register 1.13)

Insert the following rows into Table 45–15 in place of the row currently reserved:

Table 45–15—40G/100G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W ^a
1.13.14	100GBASE-CR4 ability	1 = PMA/PMD is able to perform 100GBASE-CR4 0 = PMA/PMD is not able to perform 100GBASE-CR4	RO
1.13.13	100GBASE-KR4 ability	1 = PMA/PMD is able to perform 100GBASE-KR4 0 = PMA/PMD is not able to perform 100GBASE-KR4	RO
1.13.12	100GBASE-KP4 ability	1 = PMA/PMD is able to perform 100GBASE-KP4 0 = PMA/PMD is not able to perform 100GBASE-KP4	RO

^aRO = Read only

Insert the following subclauses after 45.2.1.12.1:

45.2.1.12.1a 100GBASE-CR4 ability (1.13.14)

When read as a one, bit 1.13.14 indicates that the PMA/PMD is able to operate as a 100GBASE-CR4 PMA/PMD type. When read as a zero, bit 1.13.14 indicates that the PMA/PMD is not able to operate as a 100GBASE-CR4 PMA/PMD type.

45.2.1.12.1b 100GBASE-KR4 ability (1.13.13)

When read as a one, bit 1.13.13 indicates that the PMA/PMD is able to operate as a 100GBASE-KR4 PMA/PMD type. When read as a zero, bit 1.13.13 indicates that the PMA/PMD is not able to operate as a 100GBASE-KR4 PMA/PMD type.

45.2.1.12.1c 100GBASE-KP4 ability (1.13.12)

When read as a one, bit 1.13.12 indicates that the PMA/PMD is able to operate as a 100GBASE-KP4 PMA/PMD type. When read as a zero, bit 1.13.12 indicates that the PMA/PMD is not able to operate as a 100GBASE-KP4 PMA/PMD type.

Change 45.2.1.80 as follows:

45.2.1.80 BASE-R PMD status register (Register 1.151)

The BASE-R PMD status register is used for 10GBASE-KR and other PHY types using the PMDs described in [Clause 72](#), [Clause 84](#), ~~or~~ [Clause 85](#), [Clause 92](#) or [Clause 93](#). The assignment of bits in the BASE-R PMD status register is shown in [Table 45–59](#).

Change the first paragraph of 45.2.1.81 as follows:

45.2.1.81 BASE-R LP coefficient update, lane 0 register (Register 1.152)

The BASE-R LP coefficient update, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in [Clause 72](#), Clause 84, ~~or Clause 85~~, [Clause 92 or Clause 93](#). The BASE-R LP coefficient update, lane 0 register reflects the contents of the first 16-bit word of the training frame most recently received from the control channel for lane 0 or for a single lane PHY.

Change the first paragraph of 45.2.1.82 as follows:

45.2.1.82 BASE-R LP status report, lane 0 register (Register 1.153)

The BASE-R LP status report, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in [Clause 72](#), Clause 84, ~~or Clause 85~~, [Clause 92 or Clause 93](#). The BASE-R LP status report, lane 0 register reflects the contents of the second 16-bit word of the training frame most recently received from the control channel for lane 0 or for a single lane PHY.

Change the first paragraph of 45.2.1.83 as follows:

45.2.1.83 BASE-R LD coefficient update, lane 0 register (Register 1.154)

The BASE-R LD coefficient update, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in [Clause 72](#), Clause 84, ~~or Clause 85~~, [Clause 92 or Clause 93](#). The BASE-R LD coefficient update, lane 0 register reflects the contents of the first 16-bit word of the outgoing training frame as defined by the LD receiver adaptation process in [72.6.10.2.5](#) for lane 0 or for a single lane PHY.

Change the first paragraph of 45.2.1.84 as follows:

45.2.1.84 BASE-R LD status report, lane 0 register (Register 1.155)

The BASE-R LD status report, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in [Clause 72](#), Clause 84, ~~or Clause 85~~, [Clause 92 or Clause 93](#). The BASE-R LD status report, lane 0 register reflects the contents of the second 16-bit word of the current outgoing training frame, as defined in the training state diagram in [Figure 72–5](#) for lane 0 or for a single lane PHY.

Insert 45.2.1.93a through 45.2.1.93f before 45.2.1.93 for RS-FEC registers:

45.2.1.93a RS-FEC control register (Register 1.200)

The assignment of bits in the RS-FEC control register is shown in Table 45–72a.

Table 45–72a—RS-FEC control register bit definitions

Bit(s)	Name	Description	R/W ^a
1.200.15:2	Reserved	Value always zero, writes ignored	RO
1.200.1	FEC enable error indication	1 = FEC decoder indicates errors to the PCS layer 0 = FEC decoder does not indicate errors	R/W
1.200.0	FEC bypass correction enable	1 = FEC decoder performs detection without correction 0 = FEC decoder performs detection and correction	R/W

^aR/W = Read/Write, RO Read only

45.2.1.93a.1 FEC bypass correction enable (1.200.0)

When this variable is set to one the Reed-Solomon decoder performs error detection without error correction (see 91.5.3.3). When this variable is set to zero, the decoder also performs error correction.

45.2.1.93a.2 FEC enable error indication (1.200.1)

This bit enables the RS-FEC decoder to indicate decoding errors to the upper layers (PCS) through the sync bits for the BASE-R PHY in the Local Device. When written as a one, this bit enables indication of decoding errors through the sync bits to the PCS layer. When written as zero the error indication function is disabled. Writes to this bit are ignored and reads return a zero if the RS-FEC does not have the ability to indicate decoding errors to the PCS layer (see 91.5.3.3).

45.2.1.93b RS-FEC status register (Register 1.201)

The assignment of bits in the RS-FEC status register is shown in Table 45–72b.

Table 45–72b—RS-FEC status register bit definitions

Bit(s)	Name	Description	R/W ^a
1.201.15:2	Reserved	Value always zero, writes ignored	RO
1.201.2	FEC error indication ability	1 = FEC decoder has ability to indicate errors 0 = FEC decoder does not have ability to indicate errors	RO
1.201.1	FEC bypass correction ability	1 = FEC decoder has ability to bypass error correction 0 = FEC decoder does not have correction bypass ability	RO
1.201.0	RS-FEC ability	1 = Sublayer has RS-FEC ability 0 = Sublayer does not have RS-FEC ability	RO

^aR/W = Read/Write, RO Read only

45.2.1.93b.1 RS-FEC ability (1.201.0)

When read as a one, this bit indicates that the sublayer supports Reed-Solomon forward error correction (RS-FEC). When read as a zero, the sublayer does not support RS-FEC.

45.2.1.93b.2 FEC bypass correction ability (1.201.1)

The Reed-Solomon decoder may have the option to perform error detection without error correction (see 91.5.3.3) to reduce the delay contributed by the RS-FEC sublayer. This variable is set to one to indicate that the decoder has this ability to bypass error correction. The variable is set to zero if this ability is not supported.

45.2.1.93b.3 FEC error indication ability (1.201.2)

The RS-FEC sublayer may have the option to indicate decoding errors to the PCS sublayer by intentionally corrupting 66-bit block synchronization headers as defined in 91.5.3.3. This variable is set to one to indicate

that the RS-FEC sublayer has the ability to indicate decoding errors to the PCS sublayer. The variable is set to zero if this ability is not supported.

45.2.1.93c RS-FEC corrected codewords counter (Register 1.202, 1.203)

The assignment of bits in the RS-FEC corrected codewords counter register is shown in Table 45–72c. See 91.6.5 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.202, 1.203 are used to read the value of a 32-bit counter. When registers 1.202 and 1.203 are used to read the 32-bit counter value, the register 1.202 is read first, the value of the register 1.203 is latched when (and only when) register 1.202 is read and reads of register 1.203 returns the latched value rather than the current value of the counter.

Table 45–72c—RS-FEC corrected codewords counter register bit definitions

Bit(s)	Name	Description	R/W ^a
1.202.15:0	FEC corrected codewords lower	FEC_corrected_cw_counter[15:0]	RO, NR
1.203.15:0	FEC corrected codewords upper	FEC_corrected_cw_counter[31:16]	RO, NR

^aRO = Read only, NR = Non Roll-over

45.2.1.93d RS-FEC uncorrected codewords counter (Register 1.204, 1.205)

The assignment of bits in the RS-FEC uncorrected codewords counter register is shown in Table 45–72d. See 91.6.6 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.204, 1.205 are used to read the value of a 32-bit counter. When registers 1.204 and 1.205 are used to read the 32-bit counter value, the register 1.204 is read first, the value of the register 1.205 is latched when (and only when) register 1.204 is read and reads of register 1.205 returns the latched value rather than the current value of the counter.

Table 45–72d—RS-FEC uncorrected codewords counter register bit definitions

Bit(s)	Name	Description	R/W ^a
1.204.15:0	FEC uncorrected codewords lower	FEC_uncorrected_cw_counter[15:0]	RO, NR
1.205.15:0	FEC uncorrected codewords upper	FEC_uncorrected_cw_counter[31:16]	RO, NR

^aRO = Read only, NR = Non Roll-over

45.2.1.93e RS-FEC symbol errors counter lane 0 (Register 1.210, 1.211)

The assignment of bits in the RS-FEC symbol errors counter lane 0 register is shown in Table 45–72e. Symbol errors detected in FEC lane 0 are counted and shown in register 1.210.15:0 and 1.211.15:0. See 91.6.7 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.210, 1.211 are used to read the value of a 32-bit counter. When registers 1.210 and 1.211 are used to read

the 32-bit counter value, the register 1.210 is read first, the value of the register 1.211 is latched when (and only when) register 1.210 is read and reads of register 1.211 returns the latched value rather than the current value of the counter.

Table 45–72e—RS-FEC symbol errors counter register bit definitions

Bit(s)	Name	Description	R/W ^a
1.210.15:0	FEC symbol errors, lane 0 lower	FEC_symbol_error_counter_0[15:0]	RO, NR
1.211.15:0	FEC symbol errors, lane 0 upper	FEC_symbol_error_counter_0[31:16]	RO, NR

^aRO = Read only, NR = Non Roll-over

45.2.1.93f RS-FEC symbol errors counter lanes 1 through 3 (Register 1.212, 1.213, 1.214, 1.215, 1.216, 1.217)

The behavior of the RS-FEC symbol errors counters, lanes 1 through 3 is identical to that described for FEC lane 0 in 45.2.1.93e. Errors detected in each FEC lane are counted and shown in register bits 15:0 in the corresponding register. FEC lane 1, lower 16 bits are shown in register 1.212; FEC lane 1, upper 16 bits are shown in register 1.213; FEC lane 2, lower 16 bits are shown in register 1.213; through register 1.217 for FEC lane 1, upper 16 bits.

45.2.1.93g RS-FEC BIP error counter lane 0 (Register 1.230)

The assignment of bits in the RS-FEC BIP error counter lane 0 is shown in Table 45–72f. The RS-FEC described in Clause 91 calculates a BIP value for each PCS lane (see 91.5.2.4, 91.6.8). Errors detected in PCS lane 0 are counted and shown in register 1.230.15:0. The 16-bit counter shall be reset to all zeros when register 1.230 is read or upon PMA/PMD reset. The 16-bit counter shall be held at all ones in the case of overflow.

Table 45–72f—RS-FEC BIP error counter, lane 0 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.200.15:0	BIP error counter, lane 0	Errors detected by BIP in PCS lane 0	RO

^aRO = Read only

45.2.1.93h RS-FEC BIP error counter, lanes 1 through 19 (Registers 1.231 through 1.249)

The behavior of the RS-FEC BIP error counters, lanes 1 through 19 is identical to that described for PCS lane 0 in 45.2.1.93g. Errors detected in each PCS lane are counted and shown in register bits 15:0 in the corresponding register. PCS lane 1 is shown in register 1.231; PCS lane 2 is shown in register 1.232; through register 1.249 for PCS lane 19.

45.2.3 PCS registers*Change row of Table 45-99 as follows:***Table 45-3—PMA/PMD registers**

Register address	Register name	Subclause
3.20	EEE <u>control and</u> capability register	45.2.3.9

*Change title of subclause 45.2.3.9 as follows:***45.2.3.9 EEE control and capability (Register 3.20)***Change title and reserved rows of Table 45-105 and add the indicated rows below the first (reserved) row:***Table 45-105—EEE capability register (Register 3.20) bit definitions**

Bit(s)	Name	Description	R/W ^a
3.20.15-7 14	Reserved	Ignore on read	RO
<u>3.20.13</u>	<u>100GBASE-CR4 EEE</u>	<u>1 = EEE is supported for 100GBASE-CR4</u> <u>0 = EEE is not supported for 100GBASE-CR4</u>	<u>RO</u>
<u>3.20.12</u>	<u>100GBASE-KR4 EEE</u>	<u>1 = EEE is supported for 100GBASE-KR4</u> <u>0 = EEE is not supported for 100GBASE-KR4</u>	<u>RO</u>
<u>3.20.11</u>	<u>100GBASE-KP4 EEE</u>	<u>1 = EEE is supported for 100GBASE-KP4</u> <u>0 = EEE is not supported for 100GBASE-KP4</u>	<u>RO</u>
<u>3.20.10</u>	<u>100GBASE-CR10 EEE</u>	<u>1 = EEE is supported for 100GBASE-CR10</u> <u>0 = EEE is not supported for 100GBASE-CR10</u>	<u>RO</u>
<u>3.20.9</u>	<u>Reserved</u>	<u>Ignore on read</u>	<u>RO</u>
<u>3.20.8</u>	<u>40GBASE-CR4 EEE</u>	<u>1 = EEE is supported for 40GBASE-CR4</u> <u>0 = EEE is not supported for 40GBASE-CR4</u>	<u>RO</u>
<u>3.20.7</u>	<u>40GBASE-KR4 EEE</u>	<u>1 = EEE is supported for 40GBASE-KR4</u> <u>0 = EEE is not supported for 40GBASE-KR4</u>	<u>RO</u>
3.20.0	Reserved <u>LPI FW</u>	Ignore on read <u>1 = Fast wake mode is used for LPI function</u> <u>0 = Normal wake is used for LPI function</u>	RO <u>R/W</u>

^a R/W = Read/Write, RO = Read only*Insert the following subclauses before 45.2.1.9.1:***45.2.3.9.a 100GBASE-CR4 EEE supported (3.20.13)**

If the device supports EEE operation for 100GBASE-CR4 as defined in 92.1, this bit shall be set to one.

45.2.3.9.b 100GBASE-KR4 EEE supported (3.20.12)

If the device supports EEE operation for 100GBASE-KR4 as defined in 93.1, this bit shall be set to one.

45.2.3.9.c 100GBASE-KP4 EEE supported (3.20.11)

If the device supports EEE operation for 100GBASE-KP4 as defined in 94.1, this bit shall be set to one.

45.2.3.9.d 100GBASE-CR10 EEE supported (3.20.10)

If the device supports EEE operation for 100GBASE-CR10 as defined in 85.1, this bit shall be set to one.

45.2.3.9.e 40GBASE-CR4 EEE supported (3.20.8)

If the device supports EEE operation for 40GBASE-CR4 as defined in 85.1, this bit shall be set to one.

45.2.3.9.f 40GBASE-CR4 EEE supported (3.20.7)

If the device supports EEE operation for 40GBASE-KR4 as defined in 84.1, this bit shall be set to one.

Insert the following subclause after 45.2.1.9.5:

45.2.3.9.6 LPI_FW (3.20.0)

If the device supports Fast Wake as defined in 78.5, this bit selects Fast Wake or normal wake operation. Setting 3.20.0 to one selects Fast Wake, setting to zero selects normal wake. This bit is ignored by devices that do not support Fast Wake and this bit defaults to one for devices that support Fast Wake.

45.2.7 Auto-Negotiation registers**45.2.7.12 Backplane Ethernet, BASE-R copper status (Register 7.48)***Change Table 45–189 as shown:***Table 45–189—Backplane Ethernet, BASE-R copper status register (Register 7.48)
bit definitions**

Bit(s)	Name	Description	RO ^a
7.48.15:9 12	Reserved	Ignore on read	RO
<u>7.48.11</u>	<u>100GBASE-CR4</u>	<u>1 = PMA/PMD is negotiated to perform 100GBASE-CR4</u> <u>0 = PMA/PMD is not negotiated to perform 100GBASE-CR4</u>	<u>RO</u>
<u>7.48.10</u>	<u>100GBASE-KR4</u>	<u>1 = PMA/PMD is negotiated to perform 100GBASE-KR4</u> <u>0 = PMA/PMD is not negotiated to perform 100GBASE-KR4</u>	<u>RO</u>
<u>7.48.9</u>	<u>100GBASE-KP4</u>	<u>1 = PMA/PMD is negotiated to perform 100GBASE-KP4</u> <u>0 = PMA/PMD is not negotiated to perform 100GBASE-KP4</u>	<u>RO</u>
7.48.8	100GBASE-CR10	1 = PMA/PMD is negotiated to perform 100GBASE-CR10 0 = PMA/PMD is not negotiated to perform 100GBASE-CR10	RO
7.48.7	Reserved	Ignore on read	RO
7.48.6	40GBASE-CR4	1 = PMA/PMD is negotiated to perform 40GBASE-CR4 0 = PMA/PMD is not negotiated to perform 40GBASE-CR4	RO
7.48.5	40GBASE-KR4	1 = PMA/PMD is negotiated to perform 40GBASE-KR4 0 = PMA/PMD is not negotiated to perform 40GBASE-KR4	RO
7.48.4	BASE-R FEC negotiated	1 = PMA/PMD is negotiated to perform BASE-R FEC 0 = PMA/PMD is not negotiated to perform BASE-R FEC	RO
7.48.3	10GBASE-KR	1 = PMA/PMD is negotiated to perform 10GBASE-KR 0 = PMA/PMD is not negotiated to perform 10GBASE-KR	RO
7.48.2	10GBASE-KX4	1 = PMA/PMD is negotiated to perform 10GBASE-KX4 or CX4 0 = PMA/PMD is not negotiated to perform 10GBASE-KX4/CX4	RO
7.48.1	1000BASE-KX	1 = PMA/PMD is negotiated to perform 1000BASE-KX 0 = PMA/PMD is not negotiated to perform 1000BASE-KX	RO
7.48.0	BP AN ability	If a Backplane, BASE-R copper PHY type is implemented, this bit is set to 1	RO

^aRO = Read only*Change 45.2.7.12.2 as shown:***45.2.7.12.2 Negotiated Port Type (7.48.1, 7.48.2, 7.48.3, 7.48.5, 7.48.6, 7.48.8, 7.48.9, 7.48.10, 7.48.11)**

When the AN process has been completed as indicated by the AN complete bit, these bits (1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, 100GBASE-CR10, 100GBASE-KP4, 100GBASE-KR4, 100GBASE-CR4) indicate the negotiated port type. Only one of these bits is set depending on the priority resolution function. System developers need to distinguish between parallel detection of 10GBASE-KX4 and 10GBASE-CX4 based on the MDI and media type present.

45.2.7.13 EEE advertisement (Register 7.60)

Change Table 45–190 as shown:

Table 45–190—EEE advertisement register (Register 7.60) bit definitions

Bit(s)	Name	Description	Clause reference; Next Page bit number	R/W ^a
7.60.15:7	Reserved	Ignore on read		RO
<u>7.60.14</u>	<u>Both EEE modes</u>	<u>1 = Advertise that the PHY supports both EEE modes</u> <u>0 = Do not advertise that the PHY supports both EEE modes (the PHY supports only Fast Wake)</u>	<u>TBD</u>	R/W
<u>7.60.13</u>	<u>100GBASE-CR4 EEE</u>	<u>1 = Advertise that the 100GBASE-CR4 has EEE capability</u> <u>0 = Do not advertise that the 100GBASE-CR4 has EEE capability</u>	<u>TBD</u>	R/W
<u>7.60.12</u>	<u>100GBASE-KR4 EEE</u>	<u>1 = Advertise that the 100GBASE-KR4 has EEE capability</u> <u>0 = Do not advertise that the 100GBASE-KR4 has EEE capability</u>	<u>TBD</u>	R/W
<u>7.60.11</u>	<u>100GBASE-KP4 EEE</u>	<u>1 = Advertise that the 100GBASE-KP4 has EEE capability</u> <u>0 = Do not advertise that the 100GBASE-KP4 has EEE capability</u>	<u>TBD</u>	R/W
<u>7.60.10</u>	<u>100GBASE-CR10 EEE</u>	<u>1 = Advertise that the 100GBASE-CR10 has EEE capability</u> <u>0 = Do not advertise that the 100GBASE-CR10 has EEE capability</u>	<u>TBD</u>	R/W

Table 45–190—EEE advertisement register (Register 7.60) bit definitions

<u>7.60.9</u>	<u>Reserved</u>	<u>Ignore on read</u>		<u>RO</u>
<u>7.60.8</u>	<u>40GBASE-CR4 EEE</u>	<u>1 = Advertise that the 40GBASE-CR4 has EEE capability</u> <u>0 = Do not advertise that the 40GBASE-CR4 has EEE capability</u>	<u>TBD</u>	R/W
<u>7.60.7</u>	<u>40GBASE-KR4 EEE</u>	<u>1 = Advertise that the 40GBASE-KR4 has EEE capability</u> <u>0 = Do not advertise that the 40GBASE-KR4 has EEE capability</u>	<u>TBD</u>	R/W
7.60.6	10GBASE-KR EEE	1 = Advertise that the 10GBASE-KR has EEE capability 0 = Do not advertise that the 10GBASE-KR has EEE capability	73.7.7.1; U6	R/W
7.60.5	10GBASE-KX4 EEE	1 = Advertise that the 10GBASE-KX4 has EEE capability 0 = Do not advertise that the 10GBASE-KX4 has EEE capability	73.7.7.1; U5	R/W
7.60.4	1000BASE-KX EEE	1 = Advertise that the 1000BASE-KX has EEE capability 0 = Do not advertise that the 1000BASE-KX has EEE capability	73.7.7.1; U4	R/W
7.60.3	10GBASE-T EEE	1 = Advertise that the 10GBASE-T has EEE capability 0 = Do not advertise that the 10GBASE-T has EEE capability	28.2.3.4.1; U3 / 55.6.1; U24	R/W
7.60.2	1000BASE-T EEE	1 = Advertise that the 1000BASE-T has EEE capability 0 = Do not advertise that the 1000BASE-T has EEE capability	28.2.3.4.1; U2 / 55.6.1; U23	R/W
7.60.1	100BASE-TX EEE	1 = Advertise that the 100BASE-TX has EEE capability 0 = Do not advertise that the 100BASE-TX has EEE capability	28.2.3.4.1; U1 / 55.6.1; U22	R/W
7.60.0	Reserved	Ignore on read		RO

^aR/W = Read/Write, RO = Read only*Insert 45.2.7.13.a through 45.2.7.13.g before 45.2.7.13.1 as follows:***45.2.7.13.a Both EEE modes (7.60.14)**

Support for both EEE modes, as defined in 82.2.18.2.2, shall be advertised if this bit is set to one. This bit is not set for PHYs less than 40 Gb/s and for PHYs that support only Fast Wake mode.

45.2.7.13.b 100GBASE-CR4 EEE supported (7.60.13)

Support for EEE operation for 100GBASE-CR4, as defined in 92.1, shall be advertised if this bit is set to one.

45.2.7.13.c 100GBASE-KR4 EEE supported (7.60.12)

Support for EEE operation for 100GBASE-KR4, as defined in 93.1, shall be advertised if this bit is set to one.

45.2.7.13.d 100GBASE-KP4 EEE supported (7.60.11)

Support for EEE operation for 100GBASE-KP4, as defined in 94.1, shall be advertised if this bit is set to one.

45.2.7.13.e 100GBASE-CR10 EEE supported (7.60.10)

Support for EEE operation for 100GBASE-CR10, as defined in 85.1, shall be advertised if this bit is set to one.

45.2.7.13.f 40GBASE-CR4 EEE supported (7.60.8)

Support for EEE operation for 40GBASE-CR4, as defined in 85.1, shall be advertised if this bit is set to one.

45.2.7.13.g 40GBASE-KR4 EEE supported (7.60.7)

Support for EEE operation for 40GBASE-KR4, as defined in 84.1, shall be advertised if this bit is set to one.

45.2.7.14 EEE link partner ability (Register 7.61)

Change Table 45–191 as shown:

Table 45–191—EEE link partner ability (Register 7.61) bit definitions

Bit(s)	Name	Description	Clause reference; Next Page bit number	R/W ^a
7.61.15–7	Reserved	Ignore on read		RO
<u>7.61.14</u>	<u>Both EEE modes</u>	<u>1 = Link partner is advertising both EEE modes</u> <u>0 = Link partner is not advertising both EEE modes</u>	<u>TBD</u>	R/W
<u>7.61.13</u>	<u>100GBASE-CR4 EEE</u>	<u>1 = Link partner is advertising EEE capability for 100GBASE-CR4</u> <u>0 = Link partner is not advertising EEE capability for 100GBASE-CR4</u>	<u>TBD</u>	<u>RO</u>
<u>7.61.12</u>	<u>100GBASE-KR4 EEE</u>	<u>1 = Link partner is advertising EEE capability for 100GBASE-KR4</u> <u>0 = Link partner is not advertising EEE capability for 100GBASE-KR4</u>	<u>TBD</u>	<u>RO</u>
<u>7.61.11</u>	<u>100GBASE-KP4 EEE</u>	<u>1 = Link partner is advertising EEE capability for 100GBASE-KP4</u> <u>0 = Link partner is not advertising EEE capability for 100GBASE-KP4</u>	<u>TBD</u>	<u>RO</u>
<u>7.61.10</u>	<u>100GBASE-CR10 EEE</u>	<u>1 = Link partner is advertising EEE capability for 100GBASE-CR10</u> <u>0 = Link partner is not advertising EEE capability for 100GBASE-CR10</u>	<u>TBD</u>	<u>RO</u>

Table 45–191—EEE link partner ability (Register 7.61) bit definitions (*continued*)

<u>7.61.9</u>	<u>Reserved</u>	<u>Ignore on read</u>		<u>RO</u>
<u>7.61.8</u>	<u>40GBASE-CR4</u> <u>EEE</u>	<u>1 = Link partner is advertising EEE</u> <u>capability for 40GBASE-CR4</u> <u>0 = Link partner is not advertising EEE</u> <u>capability for 40GBASE-CR4</u>	<u>TBD</u>	<u>RO</u>
<u>7.61.7</u>	<u>40GBASE-KR4</u> <u>EEE</u>	<u>1 = Link partner is advertising EEE</u> <u>capability for 40GBASE-KR4</u> <u>0 = Link partner is not advertising EEE</u> <u>capability for 40GBASE-KR4</u>	<u>TBD</u>	<u>RO</u>
7.61.6	10GBASE-KR EEE	1 = Link partner is advertising EEE capability for 10GBASE-KR 0 = Link partner is not advertising EEE capability for 10GBASE-KR	73.7.7.1; U6	RO
7.61.5	10GBASE-KX4 EEE	1 = Link partner is advertising EEE capability for 10GBASE-KX4 0 = Link partner is not advertising EEE capability for 10GBASE-KX4	73.7.7.1; U5	RO
7.61.4	1000BASE-KX EEE	1 = Link partner is advertising EEE capability for 1000BASE-KX 0 = Link partner is not advertising EEE capability for 1000BASE-KX	73.7.7.1; U4	RO
7.61.3	10GBASE-T EEE	1 = Link partner is advertising EEE capability for 10GBASE-T 0 = Link partner is not advertising EEE capability for 10GBASE-T	28.2.3.4.1; U3 / 55.6.1; U24	RO
7.61.2	1000BASE-T EEE	1 = Link partner is advertising EEE capability for 1000BASE-T 0 = Link partner is not advertising EEE capability for 1000BASE-T	28.2.3.4.1; U2 / 55.6.1; U23	RO
7.61.1	100BASE-TX EEE	1 = Link partner is advertising EEE capability for 100BASE-TX 0 = Link partner is not advertising EEE capability for 100BASE-TX	28.2.3.4.1; U1 / 55.6.1; U22	RO
7.61.0	Reserved	Ignore on read		RO

^aR/W = Read/Write, RO = Read only

45.5 Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) Interface¹

45.5.3.2 PMA/PMD MMD options

Add the following row below FEC-R in the table in 45.5.3.2 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
*RS-FEC	Implementation of RS-FEC	45.2.1.93b		PMA:O	Yes [] No []

45.5.3.3 PMA/PMD management functions

Add the following row above MM117 in the table in 45.5.3.3 as follows, unchanged rows are not shown:

Item	Feature	Subclause	Value/Comment	Status	Support
MM117a	RS-FEC counters are reset when read or upon PHY reset.	45.2.1.93c, 45.2.1.93d, 45.2.1.93e, 45.2.1.93f, 45.2.1.93g, 45.2.1.93h		RS-FEC:M	Yes [] N/A []
MM117b	RS-FEC counters are held at all ones in the case of overflow	45.2.1.93c, 45.2.1.93d, 45.2.1.93e, 45.2.1.93f, 45.2.1.93g, 45.2.1.93h		RS-FEC:M	Yes [] N/A []

¹*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

69. Introduction to Ethernet operation over electrical backplanes

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

69.1.1 Scope

Change the second paragraph of 69.1.1 as shown:

Backplane Ethernet supports the IEEE 802.3 MAC operating at 1000 Mb/s, 10 Gb/s, ~~or 40 Gb/s, or~~ 100 Gb/s. For 1000 Mb/s operation, the family of 1000BASE-X Physical Layer signaling systems is extended to include 1000BASE-KX. For 10 Gb/s operation, two Physical Layer signaling systems are defined. For operation over four logical lanes, the 10GBASE-X family is extended to include 10GBASE-KX4. For serial operation, the 10GBASE-R family is extended to include 10GBASE-KR. For 40 Gb/s operation, there is 40GBASE-KR4 that operates over four lanes. For 100 Gb/s operation, the 100GBASE-R family is extended to include 100GBASE-KR4 and 100GBASE-KP4.

Change 69.1.2 as shown.

69.1.2 BER objective~~Objectives~~

It is an objective of Backplane Ethernet to provide a bit error ratio (BER) better than or equal to 10^{-12} at the MAC/PLS service interface.

The following are the objectives of Backplane Ethernet:

- a) ~~Support full duplex operation only.~~
- b) ~~Provide for Auto Negotiation among Backplane Ethernet Physical Layer signaling systems.~~
- e) ~~Not preclude compliance to CISPR/FCC Class A for RF emission and noise immunity.~~
- d) ~~Support operation of the following PHY over differential, controlled impedance traces on a printed circuit board with two connectors and total length up to at least 1 m consistent with the guidelines of Annex 69B.~~
 - i) ~~a 1 Gb/s PHY~~
 - ii) ~~a 4 lane 10 Gb/s PHY~~
 - iii) ~~a single lane 10 Gb/s PHY~~
 - iv) ~~a 4 lane 40 Gb/s PHY~~
- e) ~~Support a BER of 10^{-12} or better.~~
- f) ~~Optionally support IEEE for 10 Gb/s rates or lower.~~

69.1.3 Relationship of Backplane Ethernet to the ISO OSI reference model

Change the first paragraph as shown:

Backplane Ethernet couples the IEEE 802.3 (CSMA/CD) MAC to a family of Physical Layers defined for operation over electrical backplanes. The relationships among Backplane Ethernet, the IEEE 802.3 MAC, and the ISO Open System Interconnection (OSI) reference model are shown in Figure 69–1 and Figure 69–1a.

Replace Figure 69–1 and insert Figure 69–1a as shown:

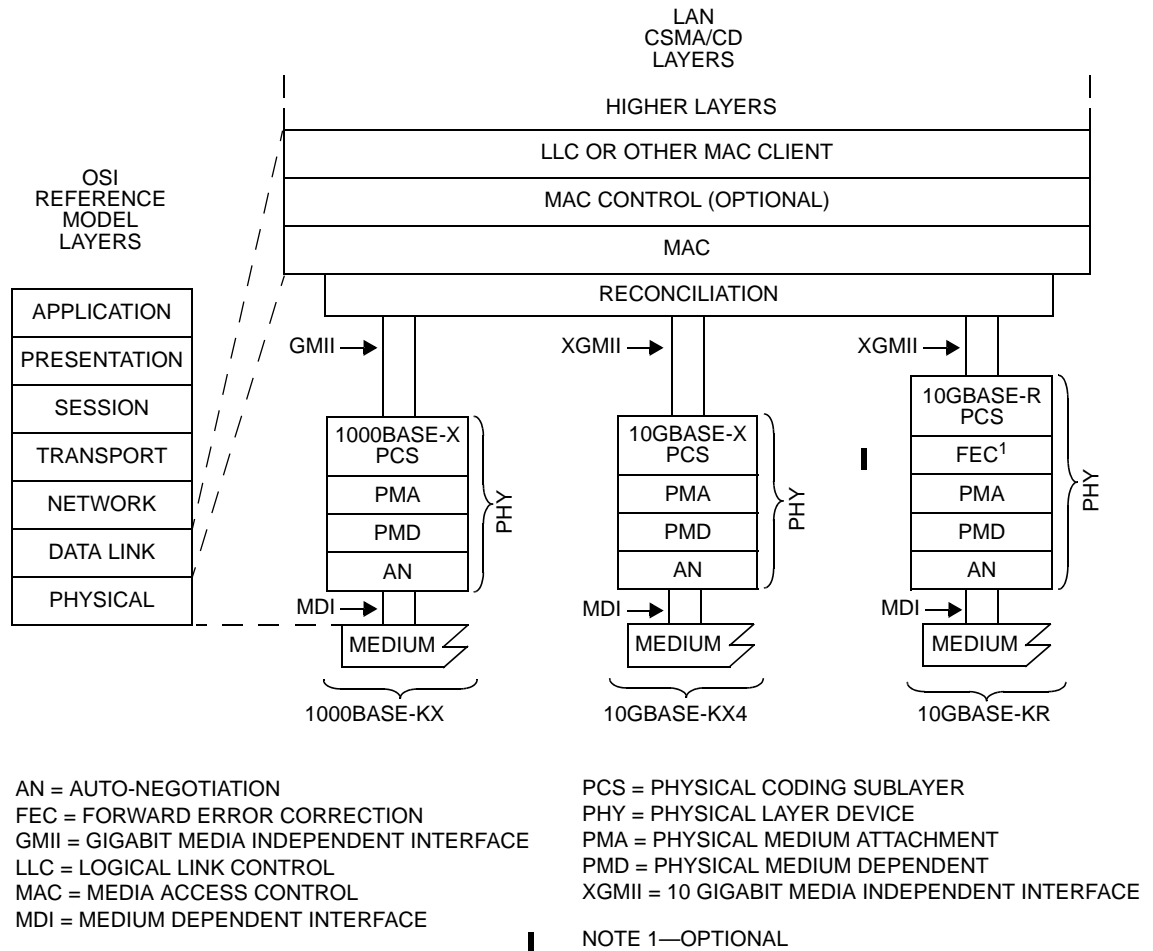


Figure 69–1—Architectural positioning of 1 Gb/s and 10 Gb/s Backplane Ethernet

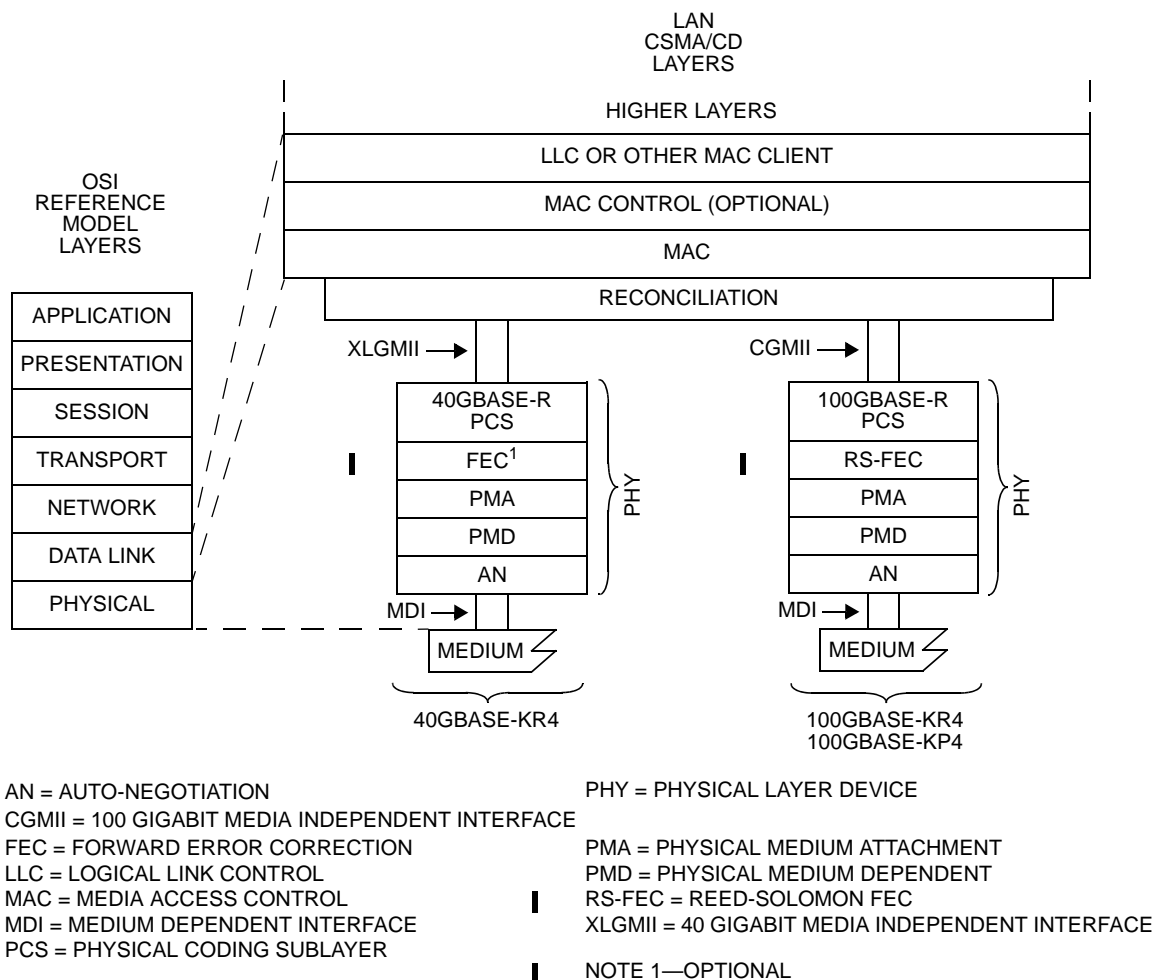


Figure 69-1a—Architectural positioning of 40 Gb/s and 100 Gb/s Backplane Ethernet

Change item f) and add item g) as shown:

- f) ~~The MDI as specified in Clause 70 for 1000BASE-KX, Clause 71 for 10GBASE-KX4, Clause 72 for 10GBASE-KR, or Clause 84 for 40GBASE-KR4. The PMA service interface, which, when physically implemented as XLAUI (40 Gigabit Attachment Unit Interface) at an observable interconnection port, uses a 4 lane data path as specified in Annex 83A or Annex 83B.~~
- g) The MDI for 1000BASE-KX and 10GBASE-KR use a serial data path while the MDI for 10GBASE-KX4, 40GBASE-KR4, 100GBASE-KR4, and 100GBASE-KP4 use a four lane data path.

69.2.1 Reconciliation sublayer and media independent interfaces

Change the first paragraph as shown:

The [Clause 35](#) RS and GMII, the [Clause 46](#) RS and XGMII, and the [Clause 81](#) RS ~~and~~, XLGMII, and CGMII are employed for the same purpose in Backplane Ethernet, that being the interconnection between the MAC sublayer and the PHY.

69.2.4 Physical Layer signaling systems

Insert the following two paragraphs after the fourth paragraph:

Backplane Ethernet also specifies 100GBASE-KR4 for 100 Gb/s operation using 2-level pulse amplitude modulation (PAM) over four differential signal pairs in each direction for a total of eight pairs where the insertion loss of each pair does not exceed 35 dB at 12.9 GHz. The embodiment of 100GBASE-KR4 employs the PCS defined in Clause 82, the RS-FEC defined in Clause 91, the PMA defined in Clause 83, and the PMD defined in Clause 93.

Backplane Ethernet also specifies 100GBASE-KP4 for 100 Gb/s operation using 4-level PAM over four differential signal pairs in each direction for a total of eight pairs where the insertion loss of each pair does not exceed 33 dB at 7.0 GHz. The embodiment of 100GBASE-KP4 employs the PCS defined in Clause 82, the RS-FEC defined in Clause 91, and the PMA and PMD defined in Clause 94.

Change the last paragraph as shown:

Table 69–1 and Table 69–1a ~~specify~~ specifies the correlation between nomenclature and clauses. A complete implementation conforming to one or more nomenclatures meets the requirements of the corresponding clauses.

Replace Table 69–1 and insert Table 69–1a as shown:

Table 69–1—Nomenclature and clause correlation for 1 Gb/s and 10 Gb/s Backplane Ethernet Physical Layers

Nomenclature	Clause													
	35		36	46		48	49	51	70	71	72	73	74	78
	RS	GMII	1000BASE-X PCS/PMA	RS	XGMII	10GBASE-X PCS/PMA	10GBASE-R PCS	Serial PMA	1000BASE-KX PMD	10GBASE-KX4 PMD	10GBASE-KR PMD	Auto-Negotiation	BASE-R FEC	Energy-Efficient Ethernet (EEE)
1000BASE-KX	M ^a	O ^a	M						M			M		O
10GBASE-KX4				M	O	M				M		M		O
10GBASE-KR				M	O		M	M			M	M	O	O

^aO = Optional, M = Mandatory

69.2.6 Low-Power Idle

Change the first sentence as shown:

With the optional EEE feature, described in Clause 78, Backplane Ethernet PHYs for 10Gb/s or lower can achieve lower power consumption during periods of low link utilization.

Table 69–1a—Nomenclature and clause correlation for 40 Gb/s and 100 Gb/s Backplane Ethernet Physical Layers

Nomenclature	Clause															
	73	74	78	81			82		83		83A		84	91	93	94
	Auto-Negotiation	BASE-R FEC	Energy-Efficient Ethernet (EEE)	RS	XLGMII	CGMII	40GBASE-R PCS	100GBASE-R PCS	40GBASE-R PMA	100GBASE-R PMA	XLAUI	CAUI	40GBASE-KR4 PMD	100GBASE-R RS-FEC	100GBASE-KR4 PMD	100GBASE-KP4 PMA/PMD
40GBASE-KR4	M ^a	O ^a	O	M	O		M		M		O		M			
100GBASE-KR4	M		O	M		O		M		M		O		M	M	
100GBASE-KP4	M		O	M		O		M				O		M		M

^aO = Optional, M = Mandatory

69.3 Delay constraints

Insert the following two paragraphs after the last paragraph:

For 100GBASE-KR4, normative delay specifications may be found in 81.1.4, 82.5, 83.5.4, 91.4, and 93.4 and also referenced in 80.4.

For 100GBASE-KP4, normative delay specifications may be found in 81.1.4, 82.5, 91.4, and 94.3.3 and also referenced in 80.4.

69.5 Protocol implementation conformance statement (PICS) proforma

Change the first paragraph as shown:

The supplier of a protocol implementation that is claimed to conform to any part of IEEE Std 802.3, Clause 70 through Clause 74, Clause 91, Clause 93, Clause 94, and related annexes demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

73. Auto-Negotiation for backplane and copper cable assembly

Change the first paragraph of Clause 73 as shown:

Note that although the Auto-Negotiation defined in this clause was originally intended for use with Backplane Ethernet PHYs, it is also specified for use with 40GBASE-CR4, ~~and~~ 100GBASE-CR10, and 100GBASE-CR4 PHYs.

73.3 Functional specifications

Change the last sentence of the third paragraph as shown:

These functions shall comply with the state diagrams from [Figure 73–9](#) through [Figure 73–11](#). The Auto-Negotiation functions shall interact with the technology-dependent PHYs through the Technology-Dependent interface (see 73.9). Technology-Dependent PHYs include 1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, ~~and~~ 100GBASE-CR10, 100GBASE-KR4, 100GBASE-KP4, and 100GBASE-CR4.

73.5.1 DME electrical specifications

Change the last paragraph as shown:

For any multi-lane PHY, DME pages shall be transmitted only on lane 0. The transmitters on other lanes should be disabled as specified in [71.6.7](#), [84.7.7](#), ~~or~~ [85.7.7](#), [92.7.6](#), [93.7.7](#), or [94.3.6.6](#).

73.6.4 Technology Ability Field

Change Table 73–4 as shown:

Table 73–4—Technology Ability Field encoding

Bit	Technology
A0	1000BASE-KX
A1	10GBASE-KX4
A2	10GBASE-KR
A3	40GBASE-KR4
A4	40GBASE-CR4
A5	100GBASE-CR10
<u>A6</u>	<u>100GBASE-KP4</u>
<u>A7</u>	<u>100GBASE-KR4</u>
<u>A8</u>	<u>100GBASE-CR4</u>
A6 <u>A9</u> through A24	Reserved for future technology

Replace the second to last paragraph (“40GBASE-CR4 and...”) with the following:

A PHY for operation over an electrical backplane (e.g. 1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 100GBASE-KR4, 100GBASE-KP4) shall not be advertised simultaneously with a PHY for operation over a copper cable assembly (e.g. 40GBASE-CR4, 100GBASE-CR10, 100GBASE-CR4) as the MDI and physical medium are different.

Change the last paragraph as shown:

The fields A[24:69] are reserved for future use. Reserved fields shall be sent as zero and ignored on receive.

73.6.10 Transmit Switch function

Replace the first two paragraphs of 73.6.10 as shown:

~~The Transmit Switch function shall enable the transmit path from a single technology dependent PHY to the MDI once a highest common denominator choice has been made and Auto-Negotiation has completed.~~

~~During Auto-Negotiation, the Transmit Switch function shall connect only the DME page generator controlled by the Transmit State Diagram to the MDI.~~

Prior to entry into the AN_GOOD_CHECK state, the Transmit Switch function shall connect only the DME page generator controlled by the Transmit State Diagram to the MDI.

Upon entry into the AN_GOOD_CHECK state, the Transmit Switch function shall connect the transmit path from a single technology-dependent (highest common denominator) PHY to the MDI.

When a PHY is connected to the MDI through the Transmit Switch function, the signals at the MDI shall conform to all of the PHY's specifications.

73.7 Receive function requirements

Change the last sentence as shown:

The receive function incorporates a receive switch to control connection to the 1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, ~~or 100GBASE-CR10,~~ 100GBASE-KR4, 100GBASE-KP4, or 100GBASE-CR4 PHYs.

73.7.1 DME page reception

Change the first sentence as shown:

To be able to detect the DME bits, the receiver should have the capability to receive DME signals sent with the electrical specifications of the PHY (1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, ~~or 100GBASE-CR10,~~ 100GBASE-KR4, 100GBASE-KP4, or 100GBASE-CR4). The DME transmit signal level and receive sensitivity are specified in 73.5.1.

73.7.2 Receive Switch function

Replace the contents of 73.7.2 as shown:

~~The Receive Switch function shall enable the receive path from the MDI to a single technology dependent PHY once a highest common denominator choice has been made and Auto-Negotiation has completed.~~

~~During Auto-Negotiation, the Receive Switch function shall connect the DME page receiver controlled by the Receive state diagram to the MDI and the Receive Switch function shall also connect the 1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, and 100GBASE-CR10 PMA receivers to the MDI if the PMAs are present.~~

Prior to entry into the AN_GOOD_CHECK state, the Receive Switch function shall connect the DME page receiver to the MDI. For the Parallel Detection function, the Receive Switch function shall also connect the receive path of the 1000BASE-KX and 10GBASE-KX4 PHY to the MDI when those PHYs are present.

Upon entry into the AN_GOOD_CHECK state, the Receive Switch function shall connect the receive path from a single technology-dependent (highest comment denominator) PHY to the MDI.

73.7.6 Priority Resolution function

Change Table 73–5 as shown:

Table 73–5—Priority Resolution

Priority	Technology	Capability
<u>1</u>	<u>100GBASE-CR4</u>	<u>100 Gb/s 4 lane, highest priority</u>
<u>2</u>	<u>100GBASE-KR4</u>	<u>100 Gb/s 4 lane</u>
<u>3</u>	<u>100GBASE-KP4</u>	<u>100 Gb/s 4 lane</u>
4	100GBASE-CR10	100 Gb/s 10 lane, highest priority
25	40GBASE-CR4	40 Gb/s 4 lane
36	40GBASE-KR4	40 Gb/s 4 lane
47	10GBASE-KR	10 Gb/s 1 lane
58	10GBASE-KX4	10 Gb/s 4 lane
69	1000BASE-KX	1 Gb/s 1 lane, lowest priority

73.10.7 State diagram variables

Insert new values for the variable “x” as shown:

A variable with “_[_x]” appended to the end of the variable name indicates a variable or set of variables as defined by “x”. “x” may be as follows:

- all; represents all specific technology-dependent PMAs supported in the local device.
- 1GKX; represents that the 1000BASE-KX PMA is the signal source.
- 10GKR; represents that the 10GBASE-KR PMA is the signal source.
- 10GKX4; represents that the 10GBASE-KX4 or 10GBASE-CX4 PMA is the signal source.
- 40GKR4; represents that the 40GBASE-KR4 PMD is the signal source.
- 40GCR4; represents that the 40GBASE-CR4 PMD is the signal source.
- 100GCR10; represents that the 100GBASE-CR10 PMD is the signal source.
- 100GKP4; represents that the 100GBASE-KP4 PMD is the signal source.
- 100GKR4; represents that the 100GBASE-KR4 PMD is the signal source.
- 100GCR4; represents that the 100GBASE-CR4 PMD is the signal source.
- HCD; represents the single technology-dependent PMA chosen by Auto-Negotiation as the

- highest common denominator technology through the Priority Resolution or parallel detection function.
- notHCD; represents all technology-dependent PMAs not chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or parallel detection function.
- PD; represents all of the following that are present: 1000BASE-KX PMA, 10GBASE-KX4 PMA or 10GBASE-CX4 PMA, 10GBASE-KR PMA, 40GBASE-KR4 PMD, 40GBASE-CR4 PMD, and 100GBASE-CR10 PMD.

Change the definition of the variable `single_link_ready` as shown:

`single_link_ready`

Status indicating that `an_receive_idle` = true and only one the of the following indications is being received:

- 1) `link_status_[1GKX]` = OK
- 2) `link_status_[10GKX4]` = OK
- 3) `link_status_[10GKR]` = OK
- 4) `link_status_[40GKR4]` = OK
- 5) `link_status_[40GCR4]` = OK
- 6) `link_status_[100GCR10]` = OK
- 7) `link_status_[100GKR4]` = OK
- 8) `link_status_[100GKP4]` = OK
- 9) `link_status_[100GCR4]` = OK

Values: false; either zero or more than one of the above indications are true or `an_receive_idle` = false.
true; Exactly one of the above indications is true and `an_receive_idle` = true.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

73.11 Protocol implementation conformance statement (PICS) proforma for Clause 73, Auto-Negotiation for backplane and copper cable assembly²

73.11.4.3 Link codeword encoding

Change LE14 and LE15 as shown:

Item	Feature	Subclause	Value/Comment	Status	Support
LE14	Transmit switch function after <u>Auto-Negotiation upon entry into the AN_GOOD_CHECK state</u>	73.6.10	Enable transmit path upon completion of Auto-Negotiation <u>Connect the transmit path of HCD PHY to the MDI</u>	M	Yes []
LE15	Transmit switch function during <u>Auto-Negotiation prior to entry into the AN_GOOD_CHECK state</u>	73.6.10	Connect only DME page generator to MDI	M	Yes []

73.11.4.4 Receive function requirements

Change RF1 through RF3 as shown:

Item	Feature	Subclause	Value/Comment	Status	Support
RF1	Receive switch function after <u>Auto-Negotiation upon entry into the AN_GOOD_CHECK state</u>	73.7.2	Enable receive path at completion of Auto-Negotiation <u>Connect the receive path of HCD PHY to the MDI</u>	M	Yes []
RF2	Receive switch function during <u>Auto-Negotiation prior to entry into the AN_GOOD_CHECK state</u>	73.7.2	Connect DME page receiver to MDI	M	Yes []
RF3	Receive switch function during <u>Auto-Negotiation prior to entry into the AN_GOOD_CHECK state</u>	73.7.2	Connect present PMA receivers to MDI receive path of the 1000BASE-KX and 10GBASE-KX4 PHY when present.	M	Yes []

²Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

78. Energy-Efficient Ethernet (EEE)

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

Change 78.1 to add 100 Gb/s Ethernet:

78.1 Overview

The optional EEE capability combines the IEEE 802.3 Media Access Control (MAC) Sublayer with a family of Physical Layers defined to support operation in the Low Power Idle (LPI) mode. When the LPI mode is enabled, systems on both sides of the link can save power during periods of low link utilization.

EEE also provides a protocol to coordinate transitions to or from a lower level of power consumption and does this without changing the link status and without dropping or corrupting frames. The transition time in to and out of the lower level of power consumption is kept small enough to be transparent to upper layer protocols and applications.

For operation over twisted-pair cabling systems, ~~EEE supports~~ may be supported by the 100BASE-TX PHY, the 1000BASE-T PHY, and the 10GBASE-T PHY. For operation over twinax cable, ~~EEE may be supported~~ by the 40GBASE-CR10, the 100GBASE-CR10 and the 100GBASE-CR4 PHY. For operation over electrical backplanes, ~~EEE supports~~ may be supported by the 1000BASE-KX PHY, the 10GBASE-KX4 PHY, and the 10GBASE-KR PHY, the 40GBASE-KR4 PHY, the 100GBASE-KR4 PHY, and the 100GBASE-KP4 PHY. EEE also ~~supports~~ may be supported by XGMII extension using the XGXS for 10 Gb/s PHYs and inter-sub-layer service interfaces using the XLAUI for 40 Gb/s PHYs and CAUI for 100 Gb/s PHYs.

In addition to the above, EEE defines a 10 Mb/s MAU (10BASE-T_e) with reduced transmit amplitude requirements. The 10BASE-T_e MAU is fully interoperable with 10BASE-T MAUs over 100 m of class D (Category 5) or better cabling as specified in ISO/IEC 11801:1995. These requirements can also be met by Category 5 cable and components as specified in ANSI/TIA/EIA-568-B-1995. The definition of 10BASE-T_e allows a reduction in power consumption.

EEE also specifies means to exchange capabilities between link partners to determine whether EEE is supported and to select the best set of parameters common to both devices. Clause 78 provides an overview of EEE operation. PICS for the optional EEE capability for each specific PHY type are specified in the respective PHY clauses. Normative requirements for Data Link Layer capabilities are contained in 78.4.

Editors' Note (to be removed prior to publication):

The PHY list in 78.1.3.3.1 is not changed as this is presented with "e.g." and does not need to be definitive.

78.1.4 PHY types which may support EEE

Change the table title and body as shown in Table 78–1 for 40 Gb/s and 100 Gb/s Ethernet:

Table 78–1—Clauses associated with each PHY or interface type

PHY <u>or</u> interface type	Clause
10BASE-T _e	14
100BASE-TX	24, 25
1000BASE-T	40
XGXS (XAUI)	47, 48
1000BASE-KX	70, 35 36
10GBASE-T	55
10GBASE-KX4	71, 48
10GBASE-KR	72, 51, 49, 74
40GBASE-CR4	82, 83, 85, 74
40GBASE-KR4	82, 83, 84, 74
100GBASE-CR10	82, 83, 85, 74
100GBASE-KP4	82, 91, 94
100GBASE-KR4	82, 83, 91, 93
100GBASE-CR4	82, 83, 91, 92
XLAUI/CAUI	83A

78.2 LPI mode timing parameters description

Change table title and column heading and add rows to Table 78–2 to for 100 Gb/s Ethernet:

78.5 Communication link access latency

Add the following to the end of 78.5

For PHYs with an operating speed of 40 Gb/s and 100 Gb/s (that implement EEE) two modes of LPI operation may be supported. Normal wake refers to the mode for which the transmitter ceases transmission during the quiet state (as shown in Figure 78–3); Fast wake refers to the mode for which the transmitter continues to transmit signals during the fast wake state (between the sleep and wake states) so that the receiver can resume operation with a shorter wake time. Fast wake is mandatory for PHYs that implement EEE; normal wake is an additional option.

Add rows to Table 78-4 to for 100 Gb/s Ethernet:

Add 78.5.2 for PHY extension:

Table 78–2—Summary of the key EEE parameters for supported PHYs or interfaces

Protocol-PHY or interface Type	T_s (μs)		T_q (μs)		T_r (μs)	
	Min	Max	Min	Max	Min	Max
40GBASE-CR4	TBD	TBD	TBD	TBD	TBD	TBD
40GBASE-KR4	TBD	TBD	TBD	TBD	TBD	TBD
100GBASE-CR10	TBD	TBD	TBD	TBD	TBD	TBD
100GBASE-CR4	TBD	TBD	TBD	TBD	TBD	TBD
100GBASE-KR4	TBD	TBD	TBD	TBD	TBD	TBD
100GBASE-KP4	TBD	TBD	TBD	TBD	TBD	TBD
XLAUI/CAUI	TBD	TBD	TBD	TBD	TBD	TBD

Editor's note (to be removed prior to final publication):

If the definitions for FEC allow more than 1 wake scenario for any PHY then multiple cases will be defined (as for 10GBASE-KR) and the text of 78.5 will be altered accordingly.

Table 78–4—Summary of the LPI timing parameters for supported PHYs or interfaces

PHY or interface Type	Case	$T_{w_sys_tx}$ (min) (μs)	T_{w_phy} (min) (μs)	$T_{phy_shrink_tx}$ (max) (μs)	$T_{phy_shrink_rx}$ (max) (μs)	$T_{w_sys_rx}$ (min) (μs)
40GBASE-CR4	Normal	TBD	TBD	TBD	TBD	TBD
	Fast Wake	TBD	TBD	TBD	TBD	TBD
40GBASE-KR4	Normal	TBD	TBD	TBD	TBD	TBD
	Fast Wake	TBD	TBD	TBD	TBD	TBD
100GBASE-CR10	Normal	TBD	TBD	TBD	TBD	TBD
	Fast Wake	TBD	TBD	TBD	TBD	TBD
100GBASE-CR4	Normal	TBD	TBD	TBD	TBD	TBD
	Fast Wake	TBD	TBD	TBD	TBD	TBD
100GBASE-KR4	Normal	TBD	TBD	TBD	TBD	TBD
	Fast Wake	TBD	TBD	TBD	TBD	TBD
100GBASE-KP4	Normal	TBD	TBD	TBD	TBD	TBD
	Fast Wake	TBD	TBD	TBD	TBD	TBD
CAUI		TBD	TBD	TBD	TBD	TBD

78.5.2 40 Gb/s and 100 Gb/s PHY extension using CAUI

40 Gb/s and 100 Gb/s PHYs may be extended using XLAUI and CAUI as a physical instantiation of the inter-sublayer service interface to separate functions between devices. The LPI signaling can operate across XLAUI/CAUI with no change to the PHY timing parameters described in Table 78–4 or the operation of the Data Link Layer Capabilities negotiation described in 78.4.

If PMA Egress AUI Stop Enable (PEASE, see 83.3; MDIO register bit 1.n.n) is asserted for any of the PMA sublayers, the PMA may stop signaling on the XLAUI/CAUI in the transmit direction to conserve energy. If PEASE is asserted, the RS defers sending data following deassertion of LPI by an additional time equal to $T_{w_sys_tx} - T_{w_sys_rx}$ as shown in Table 78–4 for each PMA with PEASE asserted (see 81.3a.2.1).

If PMA Ingress AUI Stop Enable (PIASE, see 83.3; MDIO register bit 1.n.n) is asserted for any of the PMA sublayers, the PMA may stop signaling on the XLAUI/CAUI in the receive direction to conserve energy. The receiver should negotiate an additional time for the remote T_{w_sys} (equal to $T_{w_sys_tx} - T_{w_sys_rx}$ for the XLAUI/CAUI as shown in Table 78–4) for each PMA with PIASE to be asserted before setting the PIASE bits.

78.6 Protocol implementation conformance statement (PICS) proforma for EEE Data Link Layer Capabilities³

Editor's Note (to be removed prior to publication):

No changes to the PICS are required for 100 Gb/s Ethernet.

³*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

80. Introduction to 40 Gb/s and 100 Gb/s networks

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

Change subclause 80.1.2 as shown.

80.1.2 BER Objectives

It is an objective of 40 Gigabit and 100 Gigabit Ethernet to provide a bit error ratio (BER) better than or equal to 10^{-12} at the MAC/PLS service interface.

The following are the objectives of 40 Gigabit and 100 Gigabit Ethernet:

- a) ~~Support the full duplex Ethernet MAC.~~
- b) ~~Preserve the IEEE 802.3 Ethernet frame format utilizing the IEEE 802.3 MAC.~~
- e) ~~Preserve minimum and maximum frame size of IEEE Std 802.3.~~
- d) ~~Support a BER better than or equal to 10^{-12} at the MAC/PLS service interface.~~
- e) ~~Provide appropriate support for Optical Transport Network (OTN).~~
- f) ~~Support a MAC data rate of 40 Gb/s.~~
- g) ~~Provide Physical Layer specifications that support 40 Gb/s operation over up to the following:~~
 - 1) ~~At least 10 km on single-mode fiber (SMF)~~
 - 2) ~~At least 2 km on single-mode fiber (SMF)~~
 - 3) ~~At least 100 m on OM3 multimode fiber (MMF)~~
 - 4) ~~At least 7 m over a copper cable assembly~~
 - 5) ~~At least 1 m over a backplane~~
- h) ~~Support a MAC data rate of 100 Gb/s.~~
- i) ~~Provide Physical Layer specifications that support 100 Gb/s operation over up to the following:~~
 - 1) ~~At least 40 km on single-mode fiber (SMF)~~
 - 2) ~~At least 10 km on single-mode fiber (SMF)~~
 - 3) ~~At least 100 m on OM3 multimode fiber (MMF)~~
 - 4) ~~At least 7 m over a copper cable assembly~~

80.1.3 Relationship of 40 Gigabit and 100 Gigabit Ethernet to the ISO OSI reference model

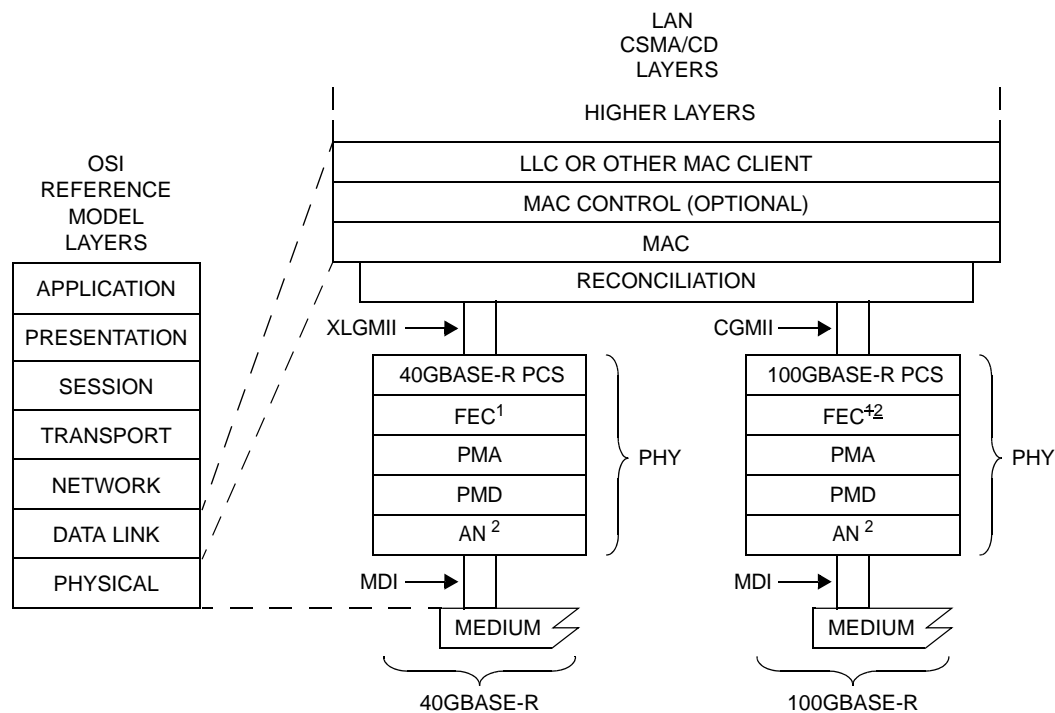
Change item h) as shown.

- h) The MDIs as specified in Clause 84 for 40GBASE-KR4, in Clause 85 for 40GBASE-CR4, in [Clause 86](#) for 40GBASE-SR4, in [Clause 87](#) for 40GBASE-LR4, and in [Clause 88](#) for 100GBASE-LR4 and 100GBASE-ER4, and in Clause 92 for 100GBASE-CR4 all use a 4 lane data path.

Add item j) as shown.

- j) There is no electrical or mechanical specification of the MDI for backplane Physical Layers.

Change figure 80-1 as shown.



AN = AUTO-NEGOTIATION

CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE

FEC = FORWARD ERROR CORRECTION

LLC = LOGICAL LINK CONTROL

MAC = MEDIA ACCESS CONTROL

MDI = MEDIUM DEPENDENT INTERFACE

PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE

PMA = PHYSICAL MEDIUM ATTACHMENT

PMD = PHYSICAL MEDIUM DEPENDENT

XLGMII = 40 Gb/s MEDIA INDEPENDENT INTERFACE

NOTE 1—OPTIONAL OR OMITTED DEPENDING ON PHY TYPE

NOTE 2—CONDITIONAL BASED ON PHY TYPE

Figure 80-1—Architectural positioning of 40 Gigabit and 100 Gigabit Ethernet

Change 80.1.4 as shown.

80.1.4 Nomenclature

The nomenclature employed by the 40 Gigabit and 100 Gigabit Physical Layers is explained as follows.

The alpha-numeric prefix 40GBASE in the port type (e.g., 40GBASE-R) represents a family of Physical Layer devices operating at a speed of 40 Gb/s. The alpha-numeric prefix 100GBASE in the port type (e.g., 100GBASE-R) represents a family of Physical Layer devices operating at a speed of 100 Gb/s.

40GBASE-R or 100GBASE-R represents a family of Physical Layer devices using the Clause 82 Physical Coding Sublayer ~~a physical coding sublayer~~ for 40 Gb/s or 100 Gb/s operation over multiple PCS lanes (see Clause 82) based on 64B/66B block encoding and a PMD implementing 2-level pulse amplitude modulation (PAM). Some 100GBASE-R Physical Layer devices also use the transcoding and FEC of Clause 91.

100GBASE-P represents Physical Layer devices using the Clause 82 Physical Coding Sublayer for 100 Gb/s operation over multiple PCS lanes (see Clause 82) and a PMD implementing more than 2-level pulse amplitude modulation (PAM). Some 100GBASE-P Physical Layer devices also use the transcoding and FEC of Clause 91.

Physical Layer devices listed in Table 80–1 are defined for operation at 40 Gb/s and 100 Gb/s.

Add the following rows between 40GBASE-LR4 and 100GBASE-CR10 to Table 80-1.

Table 80–1—40 Gb/s and 100 Gb/s PHYs

Name	Description
100GBASE-KR4	100 Gb/s PHY using 100GBASE-R encoding, Clause 91 RS-FEC and 2-level pulse amplitude modulation over four lanes of an electrical back-plane, with a total insertion loss up to 35 dB at 12.9 GHz (see Clause 93)
100GBASE-KP4	100 Gb/s PHY using 100GBASE-P encoding, Clause 91 RS-FEC and 4-level pulse amplitude modulation over four lanes of an electrical back-plane, with a total insertion loss up to 33 dB at 7.0 GHz (see Clause 94)
100GBASE-CR4	100 Gb/s PHY using 100GBASE-R encoding and Clause 91 RS-FEC over four lanes of shielded balanced copper cabling, with reach up to at least 5 m (see Clause 92)

Change 80.1.5 as follows

80.1.5 Physical Layer signaling systems

This standard specifies a family of Physical Layer implementations. The generic term 40 Gigabit and 100 Gigabit Ethernet refers to any use of the 40 Gb/s and 100 Gb/s IEEE 802.3 MAC (the 40 Gigabit and 100 Gigabit Ethernet MAC) coupled with any IEEE 802.3 40GBASE or 100GBASE Physical Layer implementations. Table 80–2 and Table 80–2a specify the correlation between nomenclature and clauses. Implementations conforming to one or more nomenclatures must meet the requirements of the corresponding clauses.

Replace Table 80-2 and insert Table 80-2a as shown

Table 80–2—Nomenclature and clause correlation (40GBASE)

Nomenclature	Clause ^a														
	73	74	78	81		82	83	83A	83B	84	85	86	86A	87	89
	Auto-Negotiation	BASE-R FEC	EEE	RS	XLGMII	40GBASE-R PCS	40GBASE-R PMA	XLAUI	XLAUI	40GBASE-KR4 PMD	40GBASE-CR4 PMD	40GBASE-SR4 PMD	XLPI	40GBASE-LR4 PMD	40GBASE-FR PMD
40GBASE-KR4	M	O	O	M	O	M	M	O		M					
40GBASE-CR4	M	O	O	M	O	M	M	O			M				
40GBASE-SR4				M	O	M	M	O	O			M	O		
40GBASE-FR				M	O	M	M	O	O						M
40GBASE-LR4				M	O	M	M	O	O				O	M	

^aO = Optional, M = Mandatory.

Table 80–2a—Nomenclature and clause correlation (100GBASE)

Nomenclature	Clause ^a																	
	73	74	78	81		82	83	83A	83B	85	86	86A	88		91	92	93	94
	Auto-Negotiation	BASE-R FEC	EEE	RS	CGMII	100GBASE-R PCS	100GBASE-R PMA	CAUI	CAUI	100GBASE-CR10 PMD	100GBASE-SR10 PMD	CPPI	100GBASE-LR4 PMD	100GBASE-ER4 PMD	RS FEC	100GBASE-CR4 PMD	100GBASE-KR4 PMD	100GBASE-KP4 PMD
100GBASE-KR4	M		O	M	O	M	M		O						M		M	
100GBASE-KP4	M		O	M	O	M									M			M
100GBASE-CR4	M		O	M	O	M	M		O						M	M		
100GBASE-CR10	M	O	O	M	O	M	M	O		M								
100GBASE-SR10				M	O	M	M	O	O		M	O						
100GBASE-LR4				M	O	M	M	O	O				M					
100GBASE-ER4				M	O	M	M	O	O					M				

^aO = Optional, M = Mandatory.

Change 80.2.2 as shown.

80.2.2 Physical Coding Sublayer (PCS)

The terms 40GBASE-R and 100GBASE-R refer to a specific family of Physical Layer implementations based upon the 64B/66B data coding method specified in Clause 82 and the PMA specifications defined in Clause 83 and Clause 94. The 40GBASE-R and 100GBASE-R PCSs perform encoding (decoding) of data from (to) the XLGMII/CGMII to 64B/66B code blocks, distribute the data to multiple lanes, and transfer the encoded data to the PMA.

Change 80.2.3 as shown.

80.2.3 Forward Error Correction (FEC) sublayers

~~The A~~ Forward Error Correction sublayer is an optional sublayer for most 40GBASE-R and 100GBASE-R copper and backplane PHYs, and is mandatory for certain PHYs. The FEC sublayer can be placed in between the PCS and PMA sublayers or between two PMA sublayers, ~~is instantiated for each PCS lane, and operates autonomously on a per PCS lane basis.~~

The BASE-R FEC sublayer (see Clause 74) is instantiated for each PCS lane, and operates autonomously on a per PCS lane basis specified in Clause 74. The Reed-Solomon FEC (see Clause 91) is instantiated once and requires 20 PCS lanes and 4 PMA lanes for operation.

80.2.4 Physical Medium Attachment (PMA) sublayer

Change the second paragraph of 80.2.4 as shown.

The 40GBASE-R and 100GBASE-R PMAs are specified in Clause 83; the PMA for 100GBASE-KP4 is specified in Clause 94.

80.2.5 Physical Medium Dependent (PMD) sublayer

Change the second paragraph of 80.2.5 as shown.

The 40GBASE-R and 100GBASE-R PMDs and their corresponding media are specified in Clause 84 through Clause 89 and Clause 92 through Clause 94.

80.2.6 Auto-Negotiation

Change the last sentence as shown.

Clause 73 Auto-Negotiation is used by the 40 Gb/s and 100 Gb/s backplane PHYs (40GBASE-KR4, 100GBASE-KR4, and 100GBASE-KP4~~see Clause 84~~) and the 40 Gb/s and 100 Gb/s copper PHYs (40GBASE-CR4, and 100GBASE-CR10, and 100GBASE-CR4~~see Clause 85~~).

80.3.1 Inter-sublayer service interface

Add the following at the end of 80.3.1:

If the optional Energy Efficient Ethernet (EEE) capability is supported (see Clause 78, 78.3) then the inter-sublayer service interface includes two additional primitives defined as follows:

IS_TX_MODE.request
IS_RX_MODE.request

IS_ENERGY_DETECT.indication
IS_RX_LPI_ACTIVE.request

The IS_TX_MODE.request primitive is used to communicate the state of the PCS LPI transmit function to other sublayers in the PHY. The IS_RX_MODE.request primitive is used to communicate the state of the PCS LPI receive function to other sublayers. The IS_RX_LPI_ACTIVE.request primitive is used to communicate to the FEC that the PCS is using its receive LPI function. The IS_ENERGY_DETECT.indication primitive is used to communicate that the PMD has detected the return of energy on the interface following a period of quiescence.

80.3.2 Inter-sublayer service interface

Change the second paragraph of 80.3.2 as shown:

Examples of inter-sublayer service interfaces for 40GBASE-R and 100GBASE-R with their corresponding instance names are illustrated in [Figure 80-2](#), ~~and Figure 80-3~~, [Figure 80-3a](#) and [Figure 80-3b](#). For example, the primitives for one instance of the inter-sublayer service interface, named the PMD service interface, are identified as follows:

Editor's note (to be removed prior to final publication):

Comments 61, 76, 77, 78, 79, 80, 129, (and indirectly, comment 115) against draft 1.1 require the addition of items to figures 80-2, 80-3 and 80-3a. The editor has split the optional EEE items into a separate figure to preserve readability for these figures.

Change note in Figure 80-3 as shown:

NOTE 1—~~OPTIONAL OR OMITTED DEPENDING ON~~ CONDITIONAL BASED ON PHY TYPE

Add Figure 80-3a and Figure 80-3b as shown:

Add 80.3.3.4 and 80.3.3.5 as shown:

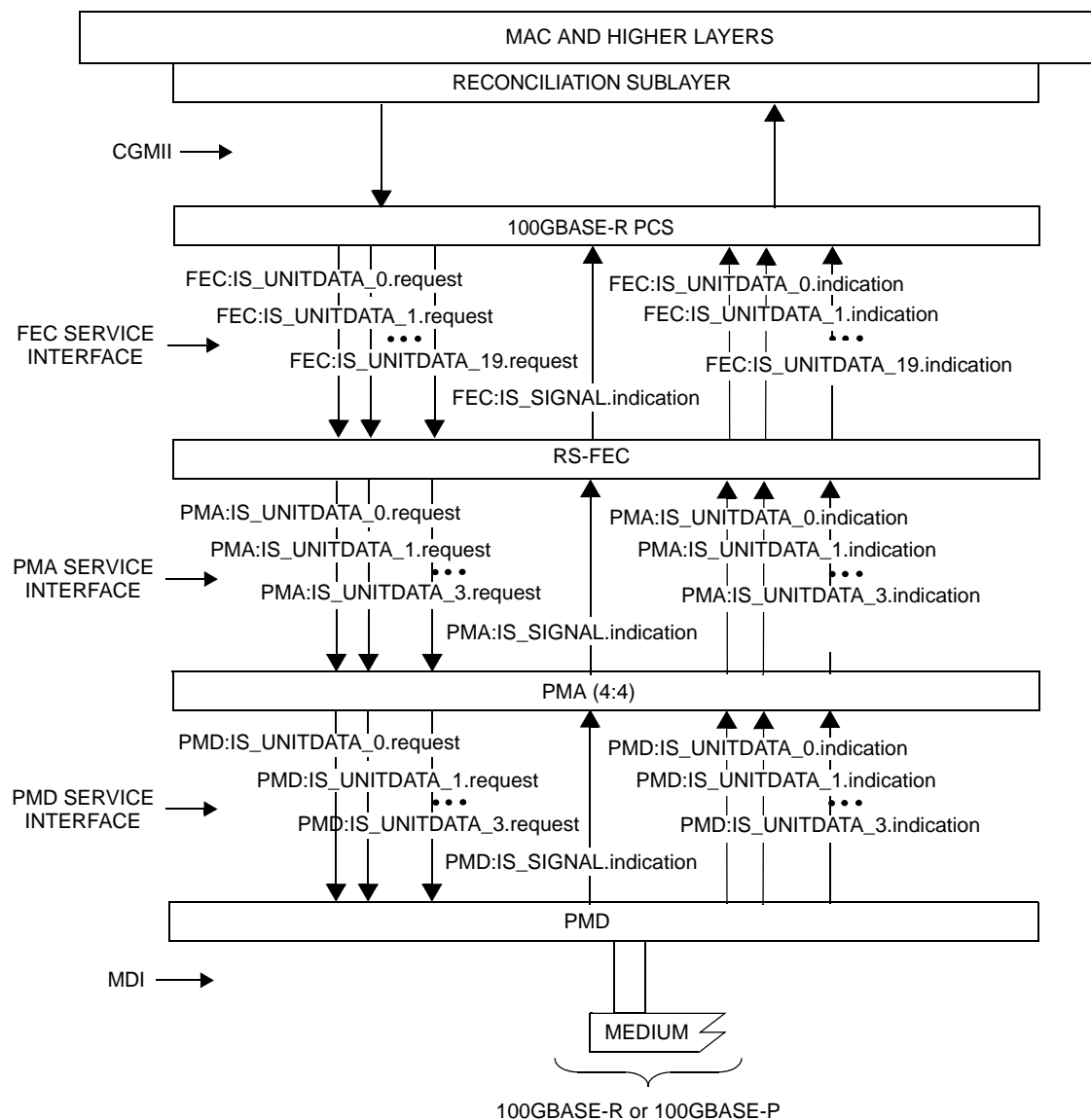
80.3.3.4 IS_TX_MODE.request

The IS_TX_MODE.request primitive communicates the tx_mode parameter generated by the PCS Transmit Process for EEE capability to invoke the appropriate PMA, FEC and PMD transmit EEE states. Without EEE capability, the primitive is never invoked and the sublayers behave as if tx_mode = DATA.

80.3.3.4.1 Semantics of the service primitive

IS_TX_MODE.request(tx_mode)

The tx_mode parameter takes on one of up to eight values: DATA, SLEEP, QUIET, FW, ALERT, RF_ALERT, WAKE or RF_WAKE.



CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
RS-FEC = REED-SOLOMON FORWARD
ERROR CORRECTION
MAC = MEDIA ACCESS CONTROL

MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 80-3a—100GBASE-R inter-sublayer service interfaces with RS-FEC

80.3.3.4.2 When generated

This primitive is generated to indicate the low power mode of the transmit path.

80.3.3.4.3 Effect of receipt

The specific effect of receipt of this primitive is defined by the sublayer that receives this primitive. In general, when tx_mode is DATA the sublayer operates normally and when tx_mode is QUIET, the sublayer may go into a low power mode.

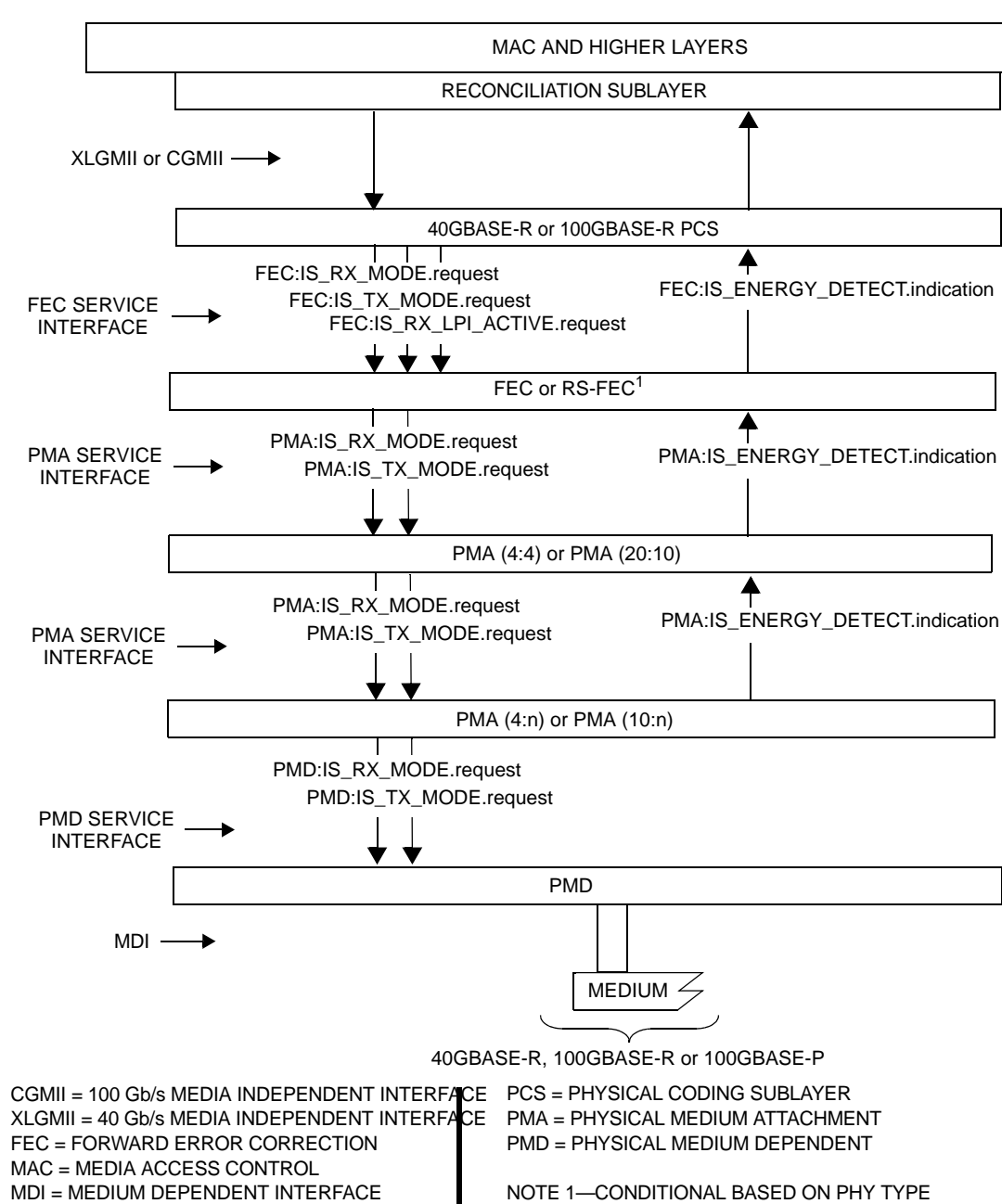


Figure 80-3b—Optional inter-sublayer service interfaces for EEE support

80.3.3.5 IS_RX_MODE.request

The IS_RX_MODE.request primitive communicates the rx_mode parameter generated by the PCS LPI receive function to other sublayers. Without EEE capability, the primitive is never invoked and the sublayers behave as if rx_mode = DATA.

80.3.3.5.1 Semantics of the service primitive

IS_RX_MODE.request(rx_mode)

The rx_mode parameter takes on one of two values: DATA or QUIET.

80.3.3.5.2 When generated

This primitive is generated to indicate the state of the PCS LPI receive function.

80.3.3.5.3 Effect of receipt

The specific effect of receipt of this primitive is defined by the sublayer that receives this primitive. In general, when rx_mode is DATA the sublayer operates normally and when rx_mode is QUIET, the sublayer may go into a low power mode.

80.3.3.6 IS_RX_LPI_ACTIVE.request

The IS_RX_LPI_ACTIVE.request primitive communicates to the FEC that the PCS LPI receive function is active. Without EEE capability, the primitive is never invoked and has no effect.

80.3.3.6.1 Semantics of the service primitive

IS_RX_LPI_ACTIVE.request(rx_lpi_active)

The parameter rx_lpi_active is boolean.

80.3.3.6.2 When generated

This primitive is generated to indicate the state of the PCS LPI receive function.

80.3.3.6.3 Effect of receipt

The specific effect of receipt of this primitive is defined by the FEC sublayer that receives this primitive. In general, when rx_lpi_active is true the FEC sublayer uses rapid block lock to reestablish FEC operation following a period of quiescence.

80.3.3.7 IS_ENERGY_DETECT.indicate

The IS_ENERGY_DETECT.indicate primitive is used to communicate that the PMD has detected the return of energy on the interface following a period of quiescence. Without EEE capability, the primitive is never invoked and has no effect.

80.3.3.7.1 Semantics of the service primitive

IS_ENERGY_DETECT.indicate(energy_detect)

The parameter energy_detect is boolean.

80.3.3.7.2 When generated

This primitive is generated by the PMA, reflecting the state of the signal_detect parameter received from the PMD.

80.3.3.7.3 Effect of receipt

The specific effect of receipt of this primitive is defined by the PCS sublayer that receives this primitive. This parameter is used to indicate that activity has returned on the interface following a period of quiescence.

80.4 Delay constraints

Insert rows in Table 80-3 as shown (insert 100GBASE-R RS-FEC below 100GBASE-R FEC; insert the other 3 rows below 100GBASE-R PMA):

Table 80-3—Sublayer delay constraints

Sublayer	Maximum (bit time) ^a	Maximum (pause_quanta) ^b	Maximum (ns)	Notes ^c
100GBASE-R RS-FEC	40960	80	409.60	See 91.4.
100GBASE-CR4 PMD	TBD	TBD	TBD	Does not include delay of cable medium. See 92.4.
100GBASE-KR4 PMD	1024	2	10.24	See 93.4.
100GBASE-KP4 PMA/PMD	TBD	TBD	TBD	See 94.2.7.

^a For 40GBASE-R, 1 bit time (BT) is equal to 25 ps and for 100GBASE-R, 1 bit time (BT) is equal to 10 ps. (See 1.4.110 for the definition of bit time.)

^b For 40GBASE-R, 1 pause_quantum is equal to 12.8 ns and for 100GBASE-R, 1 pause_quantum is equal to 5.12 ns. (See 31B.2 for the definition of pause_quanta.)

^c Should there be a discrepancy between this table and the delay requirements of the relevant sublayer clause, the sublayer clause prevails.

80.5 Skew constraints

Change NOTE 1 in Figure 80-4 as shown:

NOTE1—~~OPTIONAL OR OMITTED DEPENDING ON PHY TYPE~~

Change NOTE 1 in Figure 80-5 as shown:

NOTE1—~~OPTIONAL OR OMITTED DEPENDING ON PHY TYPE~~

Add Figure 80-5a with introductory text after Figure 80-5:

The skew points are similarly illustrated for a PHY incorporating RS-FEC (see Clause 91) in Figure 80-5a.

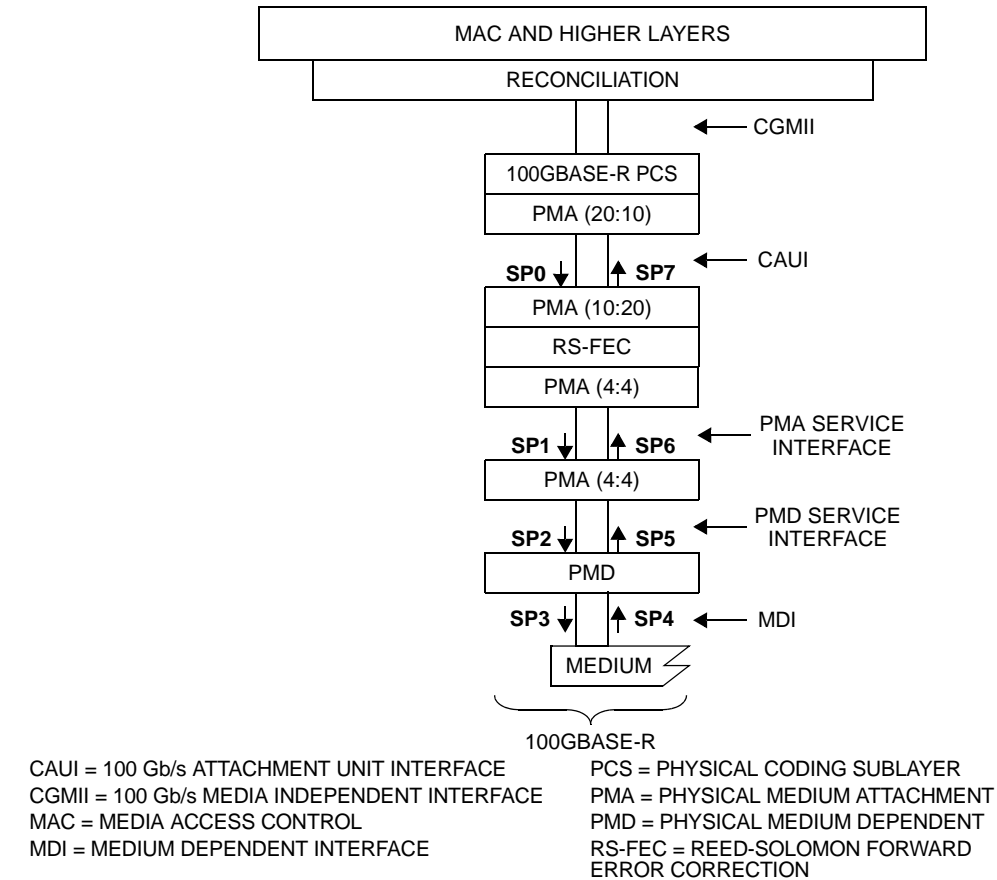


Figure 80-5a—100GBASE-R Skew points with RS-FEC and CAUI

Change Table 80-4 and 80-5 as shown:

Table 80–4—Summary of Skew constraints

Skew points	Maximum Skew (ns) ^a	Maximum Skew for 40GBASE-R PCS lane (UI) ^b	Maximum Skew for 100GBASE-R PCS lane (UI) ^c	Notes ^d
<u>SP0</u>	<u>29</u>	<u>N/A</u>	<u>≈ 150</u>	See TBD
SP1	29	≈ 299	≈ 150	See 83.5.3.1
SP2	43	≈ 443	≈ 222	See 83.5.3.3 or 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP3	54	≈ 557	≈ 278	See 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP4	134	≈ 1382	≈ 691	See 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP5	145	≈ 1495	≈ 748	See 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP6	160	≈ 1649	≈ 824	See 83.5.3.5
<u>SP7</u>	<u>29</u>	<u>N/A</u>	<u>≈ 150</u>	See TBD
At PCS receive	180	≈ 1856	≈ 928	See 82.2.12
<u>At RS-FEC transmit</u>	<u>49</u>	<u>N/A</u>	<u>≈ 258</u>	See TBD
<u>At RS-FEC receive</u>	<u>180</u>	<u>N/A</u>	<u>≈ 928</u>	See TBD
<u>At PCS receive (with RS-FEC)</u>	<u>49</u>	<u>N/A</u>	<u>≈ 258</u>	See 82.2.12

^aThe Skew limit includes 1 ns allowance for PCB traces that are associated with the Skew points.

^bThe symbol ≈ indicates approximate equivalent of maximum Skew in UI for 40GBASE-R, based on 1 UI equals 96.969697 ps at PCS lane signaling rate of 10.3125 GBd.

^cThe symbol ≈ indicates approximate equivalent of maximum Skew in UI for 100GBASE-R, based on 1 UI equals 193.939394 ps at PCS lane signaling rate of 5.15625 GBd.

^dShould there be a discrepancy between this table and the Skew requirements of the relevant sublayer clause, the sublayer clause prevails.

Table 80–5—Summary of Skew Variation constraints

Skew points	Maximum Skew Variation (ns)	Maximum Skew Variation for 10.3125 GBd PMD lane (UI) ^a	Maximum Skew Variation for 25.78125 GBd PMD lane (UI) ^b	Notes ^c
SP0	<u>0.2</u>	<u>≈ 2</u>	<u>N/A</u>	See TBD
SP1	0.2	≈ 2	N/A	See 83.5.3.1
SP2	0.4	≈ 4	≈ 10	See 83.5.3.3 or 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP3	0.6	≈ 6	≈ 15	See 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP4	3.4	≈ 35	≈ 88	See 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP5	3.6	≈ 37	≈ 93	See 83.5.3.4 or 84.5 or 85.5 or 86.3.2 or 87.3.2 or 88.3.2 or 89.3.2 or 92.5 or 93.5
SP6	3.8	≈ 39	N/A	See 83.5.3.5
<u>SP7</u>	<u>0.2</u>	<u>≈ 2</u>	<u>N/A</u>	See TBD
At PCS receive	4	≈ 41	N/A	See 82.2.12
<u>At RS-FEC transmit</u>	<u>0.4</u>	<u>N/A</u>	<u>N/A</u>	See TBD
<u>At RS-FEC receive</u>	<u>4</u>	<u>N/A</u>	<u>N/A</u>	See TBD
<u>At PCS receive (with RS-FEC)</u>	<u>0.4</u>	<u>N/A</u>	<u>N/A</u>	See 82.2.12

^aThe symbol ≈ indicates approximate equivalent of maximum Skew Variation in UI for 40GBASE-R, based on 1 UI equals 96.969697 ps at PMD lane signaling rate of 10.3125 GBd.

^bThe symbol ≈ indicates approximate equivalent of maximum Skew Variation in UI for 100GBASE-R, based on 1 UI equals 38.787879 ps at PMD lane signaling rate of 25.78125 GBd.

^cShould there be a discrepancy between this table and the Skew requirements of the relevant sublayer clause, the sublayer clause prevails.

80.7 Protocol implementation conformance statement (PICS) proforma

Change the first paragraph of 80.7 as shown:

The supplier of a protocol implementation that is claimed to conform to any part of IEEE Std 802.3, Clause 45, Clause 73, [Clause 74](#), Clause 81 through [Clause 89](#), Clause 91 through Clause 94, and related annexes demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

81. Reconciliation Sublayer (RS) and Media Independent Interface for 40 Gb/s and 100 Gb/s operation (XLGMII and CGMII)

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

81.1 Overview

Change NOTE 1 in Figure 81-1 as shown:

NOTE 1—~~OPTIONAL OR OMITTED DEPENDING~~ CONDITIONAL BASED ON PHY TYPE

81.1.1 Summary of major concepts

Insert item g) at the end of the list of major concepts:

- g) The XLGMII and CGMII may also support Low Power Idle (LPI) signaling for PHY types supporting Energy Efficient Ethernet (EEE) (see Clause 78).

81.1.7 Mapping of XLGMII/CGMII signals to PLS service primitives

Change 81.1.7 for LPI operation:

The Reconciliation Sublayer (RS) shall map the signals provided at the XLGMII/CGMII to the PLS service primitives defined in [Clause 6](#). The PLS service primitives provided by the RS and described here behave in exactly the same manner as defined in [Clause 6](#). Full duplex operation only is implemented at 40 Gb/s and 100 Gb/s; therefore, PLS service primitives supporting CSMA/CD operation are not mapped through the RS to the XLGMII/CGMII. This behavior and restrictions are the same as described in [22.7](#), with the details of the signaling described in 81.3. LPI REQUEST shall not be set to ASSERT unless the attached link has been operational for at least one second (i.e. link status = OK, according to the underlying PCS/PMA).

EEE capability requires the use of the MAC defined in [Annex 4A](#) for simplified full duplex operation (with carrier sense deferral). This provides full duplex operation but uses the carrier sense signal to defer transmission when the PHY is in its low power state.

Mappings for the following primitives are defined for 40 Gb/s and 100 Gb/s operation:

- PLS_DATA.request
- PLS_DATA.indication
- PLS_CARRIER.indication
- PLS_SIGNAL.indication
- PLS_DATA_VALID.indication

81.1.7.3 Mapping of PLS_CARRIER.indication*Change 81.1.7.3 for carrier indication definition:*

40 Gb/s and 100 Gb/s operation supports full duplex operation only. The RS never generates this primitive for PHYs that do not support EEE.

For PHYs that support EEE capability, CARRIER STATUS is set in response to LPI REQUEST as shown in Figure 81–10a.

81.3 XLGMII/CGMII functional specifications**81.3.1.2 TXC<7:0> (transmit control)***Insert the following at the end of 81.3.1.2:*

A PHY with EEE capability shall interpret the combination of TXC and TXD as shown in Table 81–3 as an assertion of LPI. Transition into and out of the LPI state is shown in Figure 81–6a.

*Change Table 81–3 as follows:***Table 81–3—Permissible encodings of TXC and TXD**

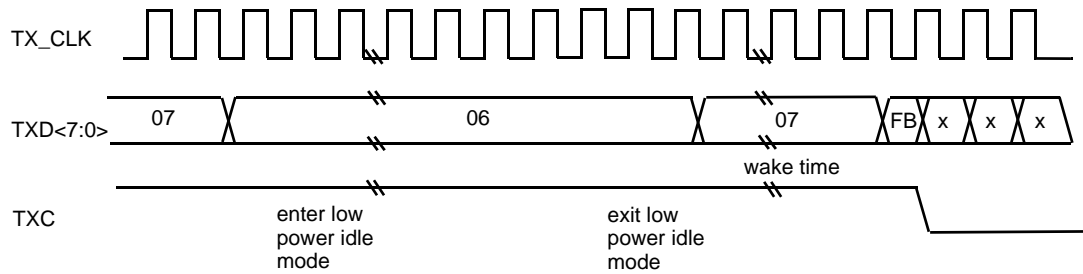
TXC	TXD	Description	PLS_DATA.request parameter
+	00 through 06	Reserved	—
1	00 through 05	Reserved	==
1	06	<u>Only valid on all eight lanes simultaneously to request LPI</u>	<u>No applicable parameter (Normal inter-frame)</u>

*Insert 81.3.1.5 after 81.3.1.4 for transmit LPI transition:***81.3.1.5 Transmit direction LPI transition**

LPI operation and the LPI client are described in 78.1. The RS requests the PHY to transition to the LPI state by asserting TXC and setting TXD to 0x06 (in all lanes). The RS maintains the same state for these signals for the entire time that the PHY is to remain in the LPI state.

The RS asserts TXC and asserts IDLE on lanes 0 to 7 in order to make the PHY transition out of the LPI state. The RS should not present a start code for valid transmit data until after the wake up time specified for the PHY. The wake times are shown in Table 78–4

Figure 81–6a shows the behavior of TXC and TXD<7:0> during the transition into and out of the LPI state.



Note: TXC and TXD are shown for one lane, all 8 lanes behave identically during LPI

Figure 81–6a—LPI transition

Table 81–3 summarizes the permissible encodings of TXD<63:0>, TXC<7:0>.

81.3.2.2 RXC<7:0> (receive control)

Insert new row and change Table 81–4 as follows:

Table 81–4—Permissible lane encodings of RXD and RXC

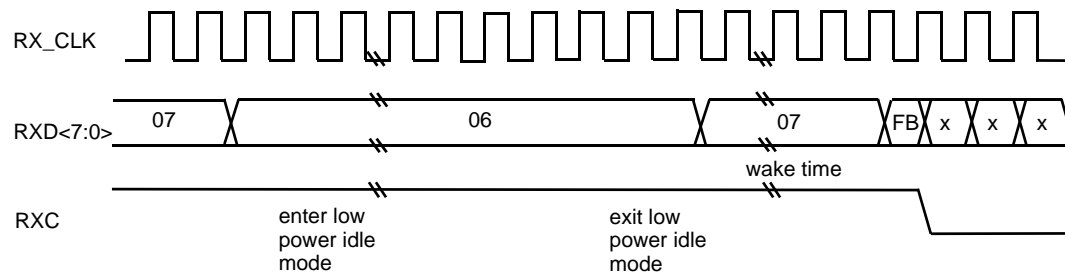
RXC	RXD	Description	PLS_DATA.indication parameter
1	00 through 06	Reserved	—
1	00 through 05	Reserved	—
1	06	Only valid on all eight lanes simultaneously to indicate LP_IDLE is asserted	No applicable parameter (Normal inter-frame)

Insert 81.3.2.4 after 81.3.2.3 for receive LPI transition:

81.3.2.4 Receive direction LPI transition

LPI operation and the LPI client are described in 78.1. When the PHY receives signals from the link partner to indicate transition into the low power state it indicates this to the RS by asserting RXC and setting RXD to 0x06 (in all lanes). The PHY maintains these signals in this state while it remains in the LPI state. When the PHY receives signals from the link partner to indicate transition out of the LPI state it indicates this to the RS by asserting RXC and asserting idle on all lanes 0 to 7 to return to a normal interframe state. The RS shall interpret the LPI coding as shown in Table 81–4.

Figure 81–8a shows the behavior of RXC and RXD<7:0> during LPI transitions.



Note: RXC and RXD are shown for one lane, all 8 lanes behave identically during LPI

Note: In some instances, LPI may be followed by characters other than IDLE during wake time

Figure 81–8a—LPI transition

81.3.4 Link fault signaling

Change 81.3.4 as follows:

Link fault signaling operates between the remote RS and the local RS. Faults detected between the remote RS and the local RS are received by the local RS as Local Fault. Only an RS originates Remote Fault signals. The behavior of the fault signaling is the same as it is for [Clause 46](#) with the exception that the ordered sets are aligned to eight byte boundaries, padding lanes 4 to 7 with 0x00.

[Clause 46](#) uses the term column when describing data transfers on the XGMII. The eight lanes of data and control transferred per clock cycle on XLGMII/CGMII are equivalent to a column in the following description of link fault signaling.

Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. Upon recognition of a fault condition, a PHY sublayer indicates Local Fault status on the data path. When this Local Fault status reaches an RS, the RS stops sending MAC data or LPI, and continuously generates a Remote Fault status on the transmit data path (possibly truncating a MAC frame being transmitted). When Remote Fault status is received by an RS, the RS stops sending MAC data or LPI, and continuously generates Idle control characters. When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data or LPI. Note that this behavior only supports bidirectional operation.

Status is signaled in an eight byte Sequence ordered_set as shown in [Table 81–5](#). The PHY indicates Local Fault with a Sequence control character in lane 0 and data characters of 0x00 in lanes 1, 2, 4, 5, 6, and 7 plus a data character of 0x01 in lane 3. The RS indicates a Remote Fault with a Sequence control character in lane 0 and data characters of 0x00 in lanes 1, 2, 4, 5, 6, and 7 plus a data character of 0x02 in lane 3. Though most fault detection is on the receive data path of a PHY, in some specific sublayers, faults can be detected on the transmit side of the PHY. This is also indicated by the PHY with a Local Fault status. All other values in lanes 1 to 3 not shown in [Table 81–5](#) are reserved. The link fault signaling state diagram allows future standardization of reserved Sequence ordered_sets for functions other than link fault indications.

The RS reports the fault status of the link. Local Fault indicates a fault detected on the receive data path between the remote RS and the local RS. Remote Fault indicates a fault on the transmit path between the local RS and the remote RS. The RS shall implement the link fault signaling state diagram (see [Figure 81–9](#)).

Insert a new section, 81.3a before 81.4:

81.3a LPI Assertion and Detection

Certain PHYs support Energy Efficient Ethernet (see Clause 78). PHYs with EEE capability support LPI assertion and detection. LPI operation and the LPI client are described in 78.1. LPI signaling allows the RS to signal to the PHY and to the link partner that a break in the data stream is expected and components may use this information to enter power saving modes that require additional time to resume normal operation. Similarly, it allows the LPI client to understand that the link partner has sent such an indication.

The LPI assertion and detection mechanism fits conceptually between the PLS Service Primitives and the XLGMII and CGMII signals as shown in Figure 81–9a.

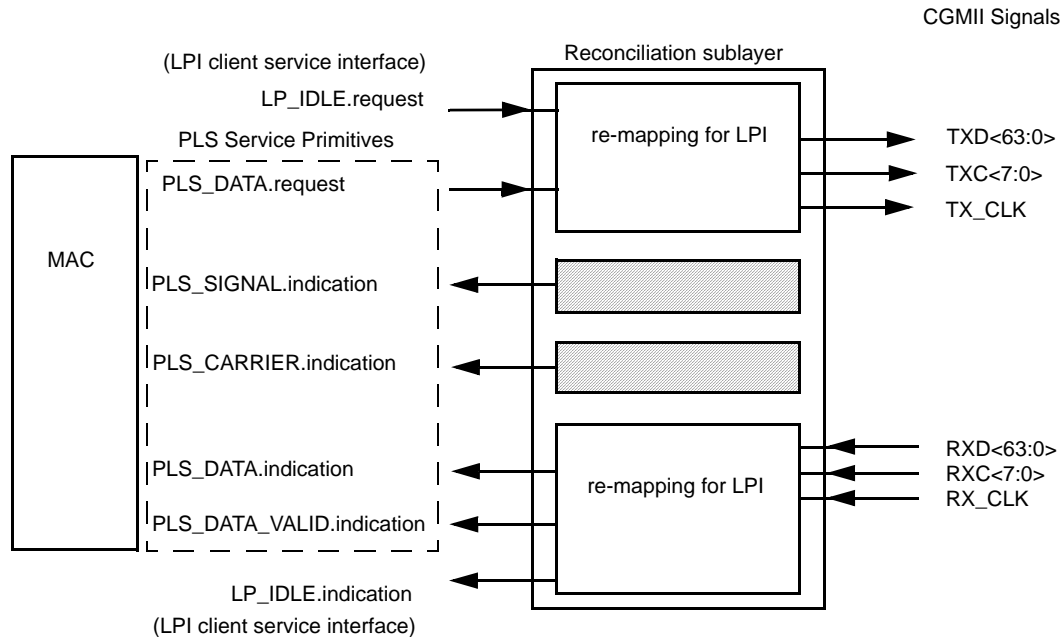


Figure 81–9a—LPI assertion and detection mechanism

The definition of TXC<7:0> and TXD<63:0> is derived from the state of PLS_DATA.request (81.1.7), except when it is overridden by an assertion of LP_IDLE.request.

Similarly, RXC<7:0> and RXD<63:0> are mapped to PLS_DATA.indication except when LP_IDLE is detected.

PLS_CARRIER.indication(CARRIER_STATUS) will be set to CARRIER_ON when the link is in LPI mode. See 81.1.7.3.

The timing of PLS_CARRIER.indication when used for the LPI function is controlled by the LPI transmit state diagram.

81.3a.1 LPI messages

LP_IDLE.indication(LPI_INDICATION)

A primitive that indicates to the LPI client that the PHY has detected the assertion or de-assertion of LPI from the link partner.

Values: DEASSERT: The link partner is operating with normal inter-frame behavior (default).

ASSERT: The link partner has asserted LPI.

LP_IDLE.request(LPI_REQUEST)

The LPI_REQUEST parameter can take one of two values: ASSERT or DE-ASSERT. ASSERT

initiates the signaling of LPI to the link partner. DE-ASSERT stops the signaling of LPI to the link partner. The effect of receipt of this primitive is undefined if link_status is not OK (see 73.9.1.1) or within 1 second of the change of link_status to OK.

81.3a.2 Transmit LPI state diagram

The operation of LPI in the PHY requires that the MAC does not send valid data for a time after LPI has been de-asserted as governed by resolved Transmit T_{w_sys} defined in 78.4.2.3.

This wake up time is enforced by the transmit LPI state diagram using PLS_CARRIER.indication(CARRIER_STATUS). The implementation shall conform to the behavior described by the transmit LPI state diagram shown in Figure 81–10a.

Editor's note (to be removed prior to final publication):

The state diagram conventions described in 80.6 apply to all of the state diagrams in this clause.

81.3a.2.1 Variables and counters

The transmit LPI state diagram uses the following variables and counters:

LPI_CARRIER_STATUS

The LPI_CARRIER_STATUS variable indicates how the CARRIER_STATUS parameter is controlled by the LPI_REQUEST parameter. The LPI_CARRIER_STATUS is either TRUE or FALSE as determined by the Transmit LPI state diagram in Figure 81–10a.

power_on

Condition that is true until such time as the power supply for the device that contains the RS has reached the operating region.

Values: FALSE: The device is completely powered (default).
TRUE: The device has not been completely powered.

reset

Used by management to control the resetting of the RS.

Values: FALSE: Do not reset the RS (default).
TRUE: Reset the RS.

tw_timer

A timer that counts, in microseconds, the time since the de-assertion of LPI. The terminal count of the timer is the value of the resolved $T_{w_sys_tx}$ as defined in 78.2. If PMA Ingress AUI Stop Enable (PIASE) bit (1.TBD) is asserted for any of the PMA sublayers, the terminal count of the timer is the value of the resolved $T_{w_sys_tx}$ as defined in 78.2 plus additional time equal to $T_{w_sys_tx} - T_{w_sys_rx}$ for the XLAUI and CAUI as shown in Table 78–4 for each PMA with PIASE to be asserted. The signal tw_timer_done is asserted when tw_timer reaches its terminal count.

81.3a.2.2 State Diagram

81.3a.3 Considerations for transmit system behavior

The transmit system should expect that egress data flow will be halted for at least resolved $T_{w_sys_tx}$ (see 78.2) time, in microseconds, after it requests the de-assertion of LPI. Buffering and queue management should be designed to accommodate this.

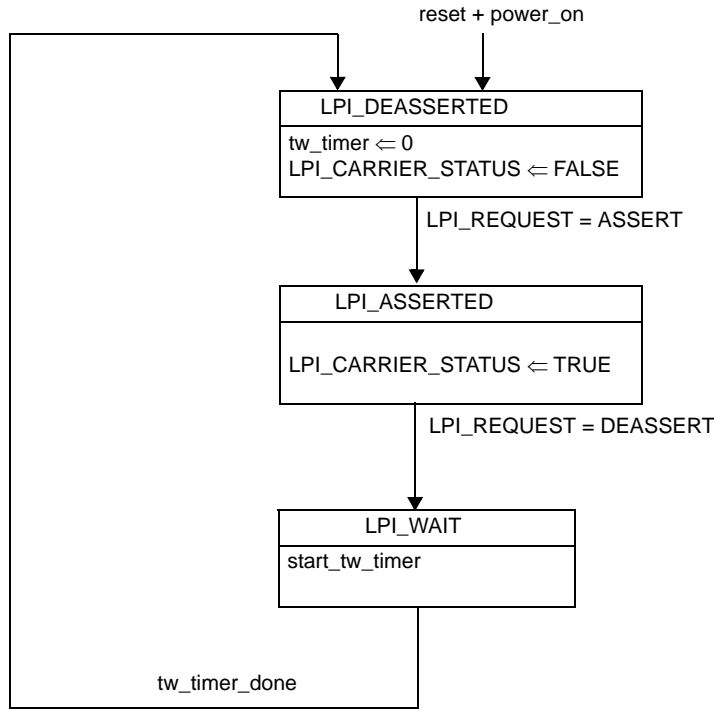


Figure 81-10a—Transmit LPI State Diagram

81.3a.3.1 Considerations for receive system behavior

The mapping function of the Reconciliation Sublayer shall continue to signal DATA_NOT_VALID on PLS_DATA_VALID.indication while it is detecting LP_IDLE on the XLGMII and CGMII. The receive system should be aware that data frames may arrive at the XLGMII and CGMII following the de-assertion of LPI_INDICATION with a delay corresponding to the link partner's resolved $T_{w_sys_rx}$ (as specified in 78.5) time, in microseconds.

If the PMA Ingress AUI Stop Enable (PIASE) bit (1.TBD) is asserted for any of the PMA sublayers, the PMA may stop signaling on the XLAUI and CAUI in the receive direction to conserve energy. The receiver should negotiate an additional time for the remote T_{w_sys} (equal to $T_{w_sys_tx} - T_{w_sys_rx}$ for the XLAUI and CAUI as shown in Table 78-4) for each PMA with PIASE to be asserted before setting the PIASE bits.

81.4 Protocol implementation conformance statement (PICS) proforma for Clause 81, Reconciliation Sublayer (RS) and Media Independent Interface for 40 Gb/s and 100 Gb/s operation⁴**81.4.2.3 Major capabilities/options***Insert the following row into table 81.4.2.3:*

Item	Feature	Subclause	Value/Comment	Status	Support
*LPI	Implementation of LPI	81.1.7		<u>Q</u>	<u>Yes</u> <input type="checkbox"/> <u>No</u> <input type="checkbox"/>

*Insert the new subclause 81.4.3.6 after 81.4.3.5 for LPI functions:***81.4.3.6 LPI functions**

Item	Feature	Subclause	Value/Comment	Status	Support
<u>L1</u>	<u>Assertion of LPI in Tx direction</u>	<u>81.3.1.2</u>	<u>As defined in Table 81–3</u>	<u>LPI:M</u>	<u>Yes</u> <input type="checkbox"/> <u>N/A</u> <input type="checkbox"/>
<u>L2</u>	<u>Assertion of LPI in Rx direction</u>	<u>81.3.2.2</u>	<u>As defined in Table 81–4</u>	<u>LPI:M</u>	<u>Yes</u> <input type="checkbox"/> <u>N/A</u> <input type="checkbox"/>

⁴Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

82. Physical Coding Sublayer (PCS) for 64B/66B, type 40GBASE-R and 100GBASE-R

Editor's note (to be removed prior to final publication):

The state diagram conventions described in 82.2.18.1 apply to all of the state diagrams in this clause.

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

82.1.3 Summary of 40GBASE-R and 100GBASE-R sublayers

Change NOTE 1 in Figure 82-1 as follows:

NOTE 1—~~OPTIONAL OR OMITTED DEPENDING~~ CONDITIONAL BASED ON PHY TYPE

Change 82.1.4 as follows:

82.1.4 Inter-sublayer interfaces

The upper interface of the PCS may connect to the Reconciliation Sublayer through the XLGMII/CGMII. The lower interface of the PCS connects to the PMA sublayer to support a PMD. If the optional FEC sublayer is implemented (see [Clause 74](#)) and an optional physical instantiation, i.e., XLAUI or CAUI, is not implemented directly below the PCS sublayer, then the lower interface connects to the FEC sublayer. For Physical Layers that use Clause 91 RS-FEC, if an optional physical instantiation, i.e. CAUI, is not implemented directly below the PCS sublayer, then the lower interface connects to the FEC sublayer. The 40GBASE-R PCS has a nominal rate at the PMA/FEC service interface of 10.3125 Gtransfers/s per PCS lane, which provides capacity for the MAC data rate of 40 Gb/s. The 100GBASE-R PCS has a nominal rate at the PMA/FEC service interface of 5.15625 Gtransfers/s per PCS lane, which provides capacity for the MAC data rate of 100 Gb/s.

It is important to note that, while this specification defines interfaces in terms of bits, octets, and frames, implementations may choose other data-path widths for implementation convenience.

82.1.4.1 PCS service interface (XLGMII/CGMII)

The PCS service interface allows the 40GBASE-R or 100GBASE-R PCS to transfer information to and from a PCS client. The PCS client is the Reconciliation Sublayer. The PCS Service Interface is precisely defined as the Media Independent Interface (XLGMII/CGMII) in Clause 81.

82.1.4.2 Physical Medium Attachment (PMA) or Forward Error Correction (FEC) service interface

The PMA or FEC service interface for the PCS is described in an abstract manner and does not imply any particular implementation. The PMA/FEC Service Interface supports the exchange of encoded data between the PCS and PMA or FEC sublayer. The PMA or FEC service interface is defined in 83.3 or 94.2.1 and is an instance of the inter-sublayer service interface definition in 80.3 or 91.2.

Change Figure 82-2 in 82.1.5 for the functional block diagram:

82.1.5 Functional block diagram

Figure 82–2 provides a functional block diagram of the 40GBASE-R PCS and 100GBASE-R PCS.

Change 82.2.3.4 for the control codes

82.2.3.4 Control codes

The same set of control characters are supported by the XLGMII/CGMII and the PCS. The representations of the control characters are the control codes. XLGMII/CGMII encodes a control character into an octet (an eight bit value). The 40GBASE-R and 100GBASE-R PCS encode the start and terminate control characters implicitly by the block type field. The 40GBASE-R and 100GBASE-R PCS encode the ordered_set control codes using the block type field. The 40GBASE-R and 100GBASE-R PCS encode each of the other control characters into a 7-bit control code.

The control characters and their mappings to 40GBASE-R and 100GBASE-R control codes and XLGMII/CGMII control codes are specified in Table 82–1. All XLGMII/CGMII, 40GBASE-R, and 100GBASE-R control code values that do not appear in the table shall not be transmitted and shall be considered an error if received. The ability to transmit or receive Low Power Idle (LPI) is required for PHYs that support EEE (see Clause 78). If EEE is not supported LPI shall not be transmitted and shall be treated as an error if received.

Insert row in Table 82-1 for LPI coding:

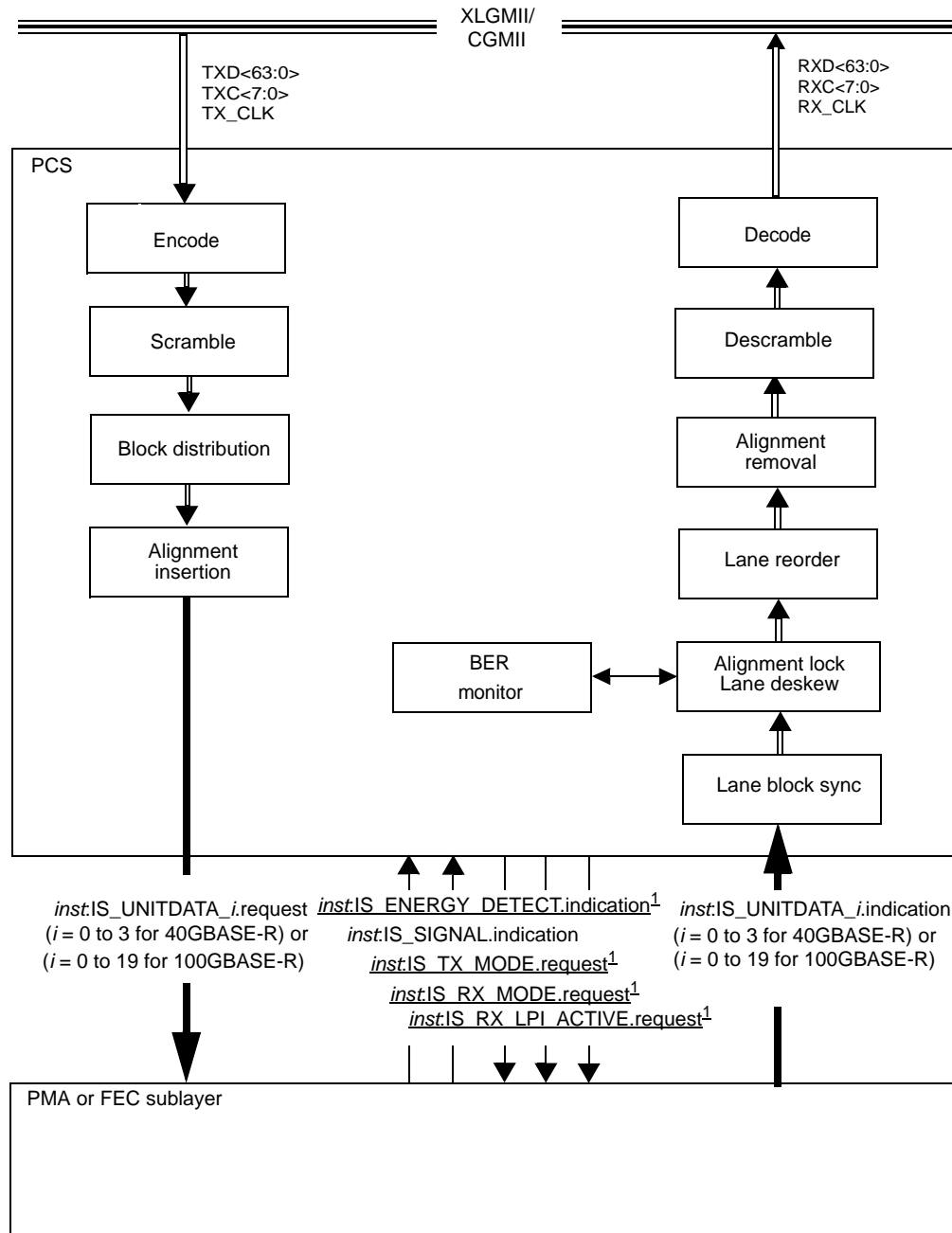
Table 82–1—Control codes

Control character	Notation	XLGMII/ CGMII control code	40/100GBASE-R O code	40GBASE-R and 100GBASE-R control code
idle	/I/	0x07		0x00
<u>LPI</u>	<u>/LI/</u>	<u>0x06</u>		<u>0x06</u>
start	/S/	0xFB		Encoded by block type field

Change 82.2.3.6 for LPI definition:

82.2.3.6 Idle (/I/)

Idle control characters (/I/) are transmitted when idle control characters are received from the XLGMII/CGMII. Idle control characters may be added or deleted by the PCS to adapt between clock rates.



NOTE 1—FOR OPTIONAL FEE SUPPORT

Figure 82-2—Functional block diagram

/I/ insertion and deletion shall occur in groups of 8. /I/s may be added following idle control characters or ordered sets. They shall not be added while data is being received.

To communicate LPI, the LPI control character /LI/ is sent continuously in place of /I/. LPI control characters are transmitted when LPI control characters are received from the XLGMII or CGMII. LPI characters may be added or deleted by the PCS to adapt between clock rates in a similar manner to idle control characters. /LI/ insertion and deletion shall occur in groups of 8. /LI/s may only be inserted following other LPI characters.

Insert 82.2.8a after 82.2.8 for RAM definition:

82.2.8a Rapid alignment marker insertion

For the optional EEE function, an alternate method of alignment is used. Rapid Alignment Markers (RAMs) function in a similar manner to the alignment markers described in 82.2.7. RAMs are sent in the place of normal alignment markers when the transmitter has an LPI transmit state other than TX_ACTIVE and down_count_done = FALSE. Additionally, the BIP component defined for alignment markers is replaced by a count down field (CD) so that the transition from RAMs to normal alignment markers can be indicated. The RAMs shall be inserted after every 7 66-bit blocks on each 100G PCS lane and every 15 66-bit blocks on each 40G PCS lane. RAM insertion is performed in the same manner as shown in Figure 82-7 and Figure 82-9a. The transition from RAMs to normal alignment markers is shown in Figure 82-9a. The count down field is also used to communicate some of the states of the tx_mode when it is not being used to coordinate the transition. After the LPI Transmit state diagram transitions from TX_ACTIVE to TX_SLEEP, the first RAM shall be inserted after at least one block of /LI/ has been transmitted on PCS lane 0. In order to force the RAMs to coincide with the start of an FEC block, the distance between the first RAM and preceding normal alignment marker shall be a multiple of 4 66-bit blocks.

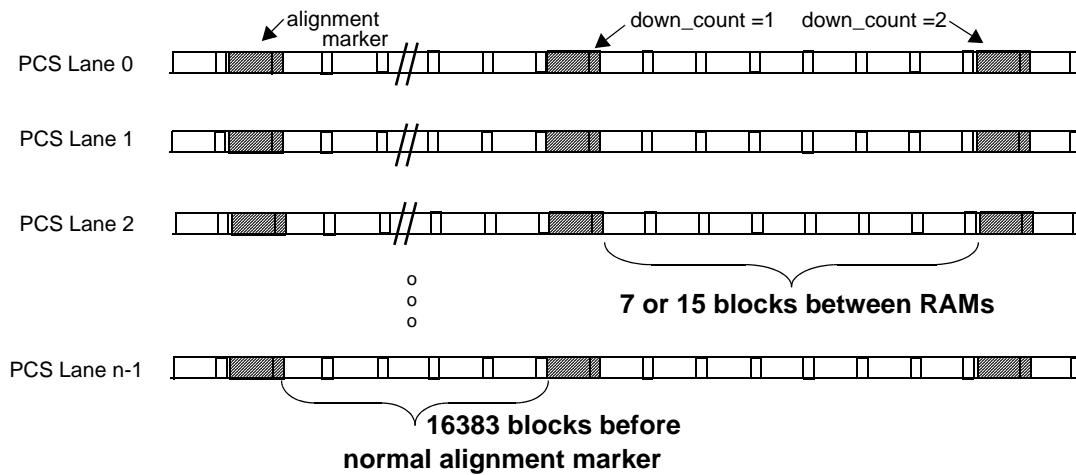


Figure 82-9a—RAM transition

The format of the RAMs is shown in Figure 82-9b.

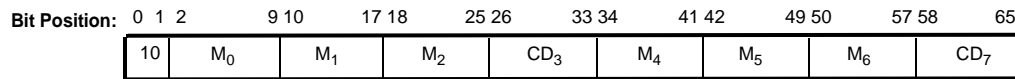


Figure 82-9b—RAM format

The content of the RAMs shall be as shown in Table 82-2 with CD₃ replacing BIP₃ and CD₇ replacing BIP₇. The contents depend on the PCS lane number and the octet number. Note that M₄ through M₆ are the bit-wise inversion of M₀ through M₂, respectively. Also CD₇ is the bit-wise inversion of CD₃. This property allows the alignment markers to be DC balanced. Lane markers 0 to 19 from Table 82-2 are used for the

100GBASE-R PCS and lane markers 0 to 3 from Table 82–3 are used for the 40GBASE-R PCS. As an example, the lane marker for 100GBASE-R lane number 0 is sent as (left most bit sent first):

10 10000011 00010110 10000100 CD₃ 01111100 11101001 01111011 CD₇

After the RAMs are inserted, data is sent to the PMA or FEC sublayer adjacent to the PCS.

The value of the CD₃ field is derived by the bit-wise XOR of the down_count variable with the M₀ value for the lane (therefore the last 5 RAMs sent by a 100GBASE-R PCS on PCS lane 0 would have CD₃ values: 0xC4, 0xC5, 0xC2, 0xC3, 0xC0; for PCS lane 1 these would be: 0x98, 0x99, 0x9E, 0x9F, 0x9C). The CD₇ field is the bit-wise inversion of CD₃. The CD field is used by the link partner to understand the expected transition from RAMs to normal AMs. It may also be used by a device with a detached PMA or FEC sublayer to infer the state of the PCS.

If the EEE capability is supported, BIP statistics are only updated when the receiver is in the RX_ACTIVE state (see Figure 82–17). In all other states, the running parity is not calculated. The BIP statistics will be first updated after transitioning from RAMs to normal AMs on the first received normal AM.

Change 82.2.11 and Figure 82-10 for LPI override of synchronization:

82.2.11 Block synchronization

When the receive channel is operating in normal mode, the block synchronization function receives data via 4 (for 40GBASE-R) or 20 (for 100GBASE-R) IS_UNITDATA_*i*.indication primitives. The PCS forms 4 or 20 bit streams from the primitives by concatenating the bits from the indications of each primitive in order from each *inst*:IS_UNITDATA_0.indication to *inst*:IS_UNITDATA_3.indication or *inst*:IS_UNITDATA_0.indication to *inst*:IS_UNITDATA_19.indication. It obtains lock to the 66-bit blocks in each bit stream using the sync headers and outputs 66-bit blocks. Block lock is obtained as specified in the block lock state diagram shown in Figure 82–10.

If EEE is not supported then block lock is identical to rx block lock. Otherwise the relationship between block lock and rx block lock is given by Figure 82–17 the LPI receive state diagram.

82.2.12 PCS lane deskew

Insert the following at the end of 82.2.12, change Figures 82-11 and 82-12 for LPI override of align status:

If EEE is not supported then align status is identical to rx align status. Otherwise the relationship between align status and rx align status is given by Figure 82–17 the LPI receive state diagram.

Add a row to Table 82-5 as shown:

Table 82–5—Skew tolerance requirements

PCS	Maximum skew	Maximum skew variation
100GBASE-P/R with RS-FEC	49 ns (~258 bits)	0.4ns (~2 bits)

82.2.18.2.2 Variables

Insert a note in 82.2.18.2.2 below the definition for “align_status”:

NOTE: If the EEE capability is supported, then this variable is affected by the LPI receive state diagram. If the EEE capability is not supported then this variable is identical to rx_align_status controlled by the Alignment marker lock state diagram.

Insert a note in 82.2.18.2.2 below the definition for “block_lock”:

NOTE: If the EEE capability is supported, then this variable is affected by the LPI receive state diagram. If the EEE capability is not supported then this variable is identical to rx_block_lock controlled by the Block lock state diagram.

Insert the following new variables at appropriate places in 82.2.18.2.2:

rx_align_status

Variable used by the PCS lane deskew process to reflect the status of the PCS lane-to-lane alignment. This variable is set true when all lanes are synchronized and aligned, set false when the deskew process is not complete.

rx_block_lock<x>

Variable used by the Block lock state diagram to reflect the status of the code-group delineation for each lane. This variable is set true when the receiver acquires block delineation.

Insert the following new text and variables at the end of the existing subclause 82.2.18.2.2:

The following variables are used only for the EEE capability.

down_count_enable

Boolean variable controlling decrement of the counter down_count. This variable is set by the LPI transmit state diagram.

energy_detect

A parameter generated by the PMA/PMD sublayer to reflect the state of the received signal. In the PMD this has the same definition as parameter signal_detect and is passed through without modification by the PMA (and FEC).

LPI_FW

Boolean variable controlling the wake mode for the LPI transmit function. This variable is set true when the transmitter is to use the Fast Wake mechanism, and false when the transmitter is to use the optional normal wake mechanism. This variable defaults true and may only be set to false if the optional normal wake mode is supported.

received_tx_mode

Variable reflecting state of the LPI transmit function for the link partner. The value of this variable is inferred from the coding of the RAMs of the incoming data stream and may take the values defined for tx_mode.

rx_lpi_active

A Boolean variable that is set to true when the receiver is in a low power state and set to false when it is in an active state and capable of receiving data.

Rx LPI indication:

A boolean variable indicating the current state of the receive LPI function. This flag is set to true (register bit set to one) when the LPI receive state diagram is in any state other than RX_ACTIVE. This status is reflected in MDIO register 3.1.8. A latch high view of this status is reflected in MDIO register 3.1.10 (Rx LPI received).

rx_mode

A variable reflecting state of the LPI receive function as described by the LPI receive state diagram (Figure 82–17). The parameter has one of two values : DATA and QUIET.

scrambler_bypass

This Boolean variable is used to bypass the Tx PCS scrambler in order to assist rapid synchronization following low power idle. When set to TRUE, the PCS will pass the unscrambled data from the scrambler input rather than the scrambled data from the scrambler output. The scrambler will continue to operate normally, shifting input data into the delay line. When scrambler_bypass is set to FALSE the PCS will pass scrambled data from the scrambler output.

scr_bypass_enable

A Boolean variable used to indicate to the transmit LPI state diagram that the scrambler bypass option is required. The PHY shall set scr_bypass_enable = TRUE if Clause 74 FEC is in use. The PHY shall set scr_bypass_enable = FALSE if this FEC is not in use.

tx_mode

A variable reflecting state of the LPI transmit function as described by the LPI transmit state diagram (Figure 82–16). When tx_mode is set to QUIET the sublayer may go into a low power state.

82.2.18.2.3 Functions

Change 89.2.18.2.3 function definitions for LPI block types:

AM_SLIP

Causes the next candidate block position to be tested. The precise method for determining the next candidate block position is not specified and is implementation dependent. However, an implementation shall ensure that all possible blocks are evaluated.

DECODE(rx_coded<65:0>)

Decodes the 66-bit vector returning rx_raw<71:0>, which is sent to the XLGMII/CGMII. The DECODE function shall decode the block as specified in 82.2.3.

ENCODE(tx_raw<71:0>)

Encodes the 72-bit vector returning tx_coded<65:0> of which tx_coded<65:2> is sent to the scrambler. The two bits of the sync header bypass the scrambler. The ENCODE function shall encode the block as specified in 82.2.3.

R_TYPE(rx_coded<65:0>)

This function classifies the current rx_coded<65:0> vector as belonging to one of the following ~~five~~ types, depending on its contents. The classification results are returned via the r_block_type variable.

Values: C; The vector contains a sync header of 10 and one of the following:

- a) A block type field of 0x1E and eight valid control characters other than /E/ or /LI/;
- b) A block type field of 0x4B.

LI: For EEE capability, the LI type is supported where the vector contains a sync header of 10, a block type field of 0x1E and eight control characters of 0x06 (/LI/).

S; The vector contains a sync header of 10 and the following:

a) A block type field of 0x78.

T; The vector contains a sync header of 10, a block type field of 0x87, 0x99, 0xAA, 0xB4, 0xCC, 0xD2, 0xE1 or 0xFF and all control characters are valid.

D; The vector contains a sync header of 01.

E; The vector does not meet the criteria for any other value.

Valid control characters are specified in Table 82–1.

Note: A PCS that does not support EEE classifies vectors containing one or more /LI/ control characters as type E.

R_TYPE_NEXT

This function classifies the 66-bit rx_coded vector that immediately follows the current rx_coded<65:0> vector as belonging to one of the five types defined in R_TYPE, depending on its contents. It is intended to perform a prescient end of packet check. The classification results are returned via the r_block_type_next variable.

SLIP

Causes the next candidate block sync position to be tested. The precise method for determining the next candidate block sync position is not specified and is implementation dependent. However, an implementation shall ensure that all possible bit positions are evaluated.

T_TYPE = (tx_raw<71:0>)

This function classifies each 72-bit tx_raw vector as belonging to one of the following five types depending on its contents. The classification results are returned via the t_block_type variable.

Values: C; The vector contains one of the following:

a) Eight valid control characters other than /O/, /S/, /T/, /LI/, and /E/;

b) One valid ordered set.

LI; For EEE capability, this vector contains eight /LI/ characters.

S; The vector contains an /S/ in its first character, and all characters following the /S/ are data characters.

T; The vector contains a /T/ in one of its characters, all characters before the /T/ are data characters, and all characters following the /T/ are valid control characters other than /O/, /S/ and /T/.

D; The vector contains eight data characters.

E; The vector does not meet the criteria for any other value.

A tx_raw character is a control character if its associated TXC bit is asserted. A valid control character is one containing an XLGMII/CGMII control code specified in Table 82–1. A valid ordered_set consists of a valid /O/ character in the first character and data characters in the seven characters following the /O/. A valid /O/ is any character with a value for O code in Table 82–1.

Note: A PCS that does not support EEE, classifies vectors containing one or more /LI/ control characters as type E.

82.2.18.2.4 Counters

Change the definition for am_counter in 82.2.18.2.4 for RAMs:

am_counter

This counter counts 16383 66-bit blocks that separate two consecutive alignment markers for normal alignment markers or 7 66-bit blocks for rapid alignment markers for the optional EEE capability.

Insert new counters into 82.2.18.2.4, and new timers into 82.2.18.2.5 in support of the LPI state diagrams. In each case, insert the new text at the end of the existing subclause:

The following counters are used only for the EEE capability.

down_count

A counter that is used in rapid alignment markers and is decremented each time a RAM is sent while variable down_count_enable = true. The counter initial value is set by the LPI transmit state diagram. When the down_count counter reaches zero it will set the variable down_count_done = true.

wake_error_counter

A counter that is incremented each time that the LPI receive state diagram enters the RX_WTF state indicating that a wake time fault has been detected. The counter is reflected in register 3.22 (see 45.2.3.10)

82.2.18.2.5 Timers

The following timers are used only for the EEE capability.

one_us_timer

A timer used to count approximately 1 μ s intervals. The timer terminal count is set to T_{IU} . When the timer reaches terminal count it will set one_us_timer_done = true.

rx_tq_timer

This timer is started when the PCS receiver enters the RX_SLEEP state. The timer terminal count is set to T_{QR} . When the timer reaches terminal count it will set rx_tq_timer_done = true.

rx_tw_timer

This timer is started when the PCS receiver enters the RX_WAKE state. The timer terminal count shall be set to a value no larger than the maximum value given for T_{WR} in Table 82-5b. When the timer reaches terminal count it will set rx_tw_timer_done = true.

rx_wf_timer

This timer is started when the PCS receiver enters the RX_WTF state, indicating that the receiver has encountered a wake time fault. The rx_wf timer allows the receiver an additional period in which to synchronize or return to the QUIET state before a link failure is indicated. The timer terminal count is set to T_{WTF} . When the timer reaches terminal count it will set the rx_wf_timer_done = true.

tx_ts_timer

This timer is started when the PCS transmitter enters the TX_SLEEP state. The timer terminal count is set to T_{SL} . When the timer reaches terminal count it will set the tx_ts_timer_done = true.

tx_tq_timer

This timer is started when the PCS transmitter enters the TX_QUIET state. The timer terminal count is set to T_{QL} . When the timer reaches terminal count it will set the tx_tq_timer_done = true.

tx_tw_timer

This timer is started when the PCS transmitter enters the TX_WAKE or TX_RF_WAKE state. The timer terminal count is set to T_{WL} . When the timer reaches terminal count it will set the tx_tw_timer_done = true.

82.2.18.3 State diagrams

Insert 82.2.18.3.1 at the end of 82.2.18.3:

82.2.18.3.1 LPI state diagrams

A PCS which supports the EEE capability shall implement the LPI transmit and receive processes as shown in figures 82-16 and 82-17. The transmit LPI state diagram controls tx_mode which disables the transmitter when it is set to QUIET. The receive LPI state diagram controls block_lock during LPI and signals the end of LPI to the receive state diagram.

Following a period of LPI, the receiver is required to achieve block synchronization within the wakeup time specified (See Figure 82–17). The implementation of the block synchronization state diagram should use techniques to ensure that block lock is achieved with minimal numbers of slip attempts. If Fast Wake is selected then the receiver is expected to maintain sufficient state to allow much faster wake up.

The LPI functions shall use timer values for these state diagrams as shown in Table 82–5a for transmit and Table 82–5b for receive.

Table 82–5a—Transmitter LPI timing parameters

Parameter	Description	Min	Max	Units
T _{SL}	Local Sleep Time from entering the TX_SLEEP state to when tx_mode is set to QUIET, LPI_FW = FALSE	0.9	1.1	μs
T _{SL}	Local Sleep Time from entering the TX_SLEEP state to when tx_mode is set to FW, LPI_FW = TRUE	240	260	ns
T _{QL}	Local Quiet Time from when tx_mode is set to QUIET or FW to entry into the TX_RF_ALERT or TX_WAKE states	1.7	1.8	ms
T _{WL}	Time spent in the TX_WAKE or TX_RF_WAKE states, LPI_FW = FALSE	3.9	4.1	μs
T _{WL}	Time spent in the TX_WAKE state, LPI_FW = TRUE	312	332	ns
T _{IU}	Time spent in the TX_ALERT or TX_RF_ALERT states	1.1	1.3	μs

Table 82–5b—Receiver LPI timing parameters

Parameter	Description	Min	Max	Units
T _{QR}	The time the receiver waits for energy_detect to be set to true while in the RX_SLEEP and RX_QUIET or RX_FW states before asserting receive fault	2	3	ms
T _{WR}	Time the receiver waits in the RX_WAKE state before indicating a wake time fault, LPI_FW = FALSE.	—	4.5	μs
T _{WR}	Time the receiver waits in the RX_WAKE state before indicating a wake time fault, LPI_FW = TRUE.	—	300	ns
T _{WTF}	Wake time fault recovery time	—	10	ms

82.3.1 PMD MDIO function mapping

Add the following row to Table 82-6 in 82.3.1:

Table 82–6—MDIO/PMD control variable mapping

MDIO control variable	PCS register name	Register/ bit number	PCS control variable
LPI_FW	LPI fast wake enable	3.20.0	LPI_FW

Add the following rows to Table 82-7 in 82.3.1:

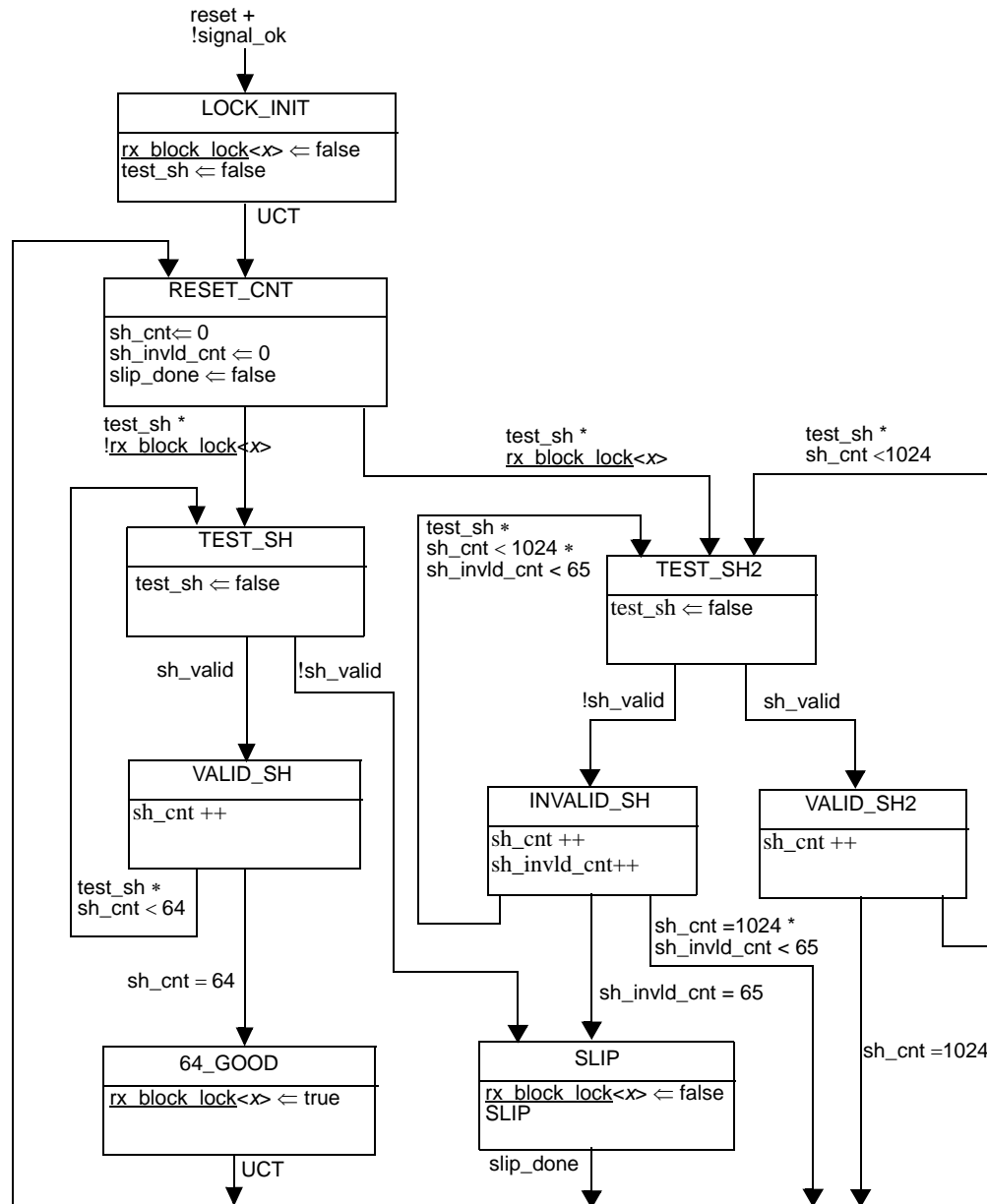
Table 82–7—MDIO/PMD status variable mapping

MDIO status variable	PCS register name	Register/ bit number	PCS status variable
Tx LPI indication	Tx LPI indication	3.1.9	Tx LPI indication
Tx LPI received	Tx LPI received	3.1.11	Tx LPI received
Rx LPI indication	Rx LPI indication	3.1.8	Rx LPI indication
Rx LPI received	Rx LPI received	3.1.10	Rx LPI received
Wake_error_counter	Wake_error_counter	3.22	Wake_error_counter

82.6 Auto-Negotiation

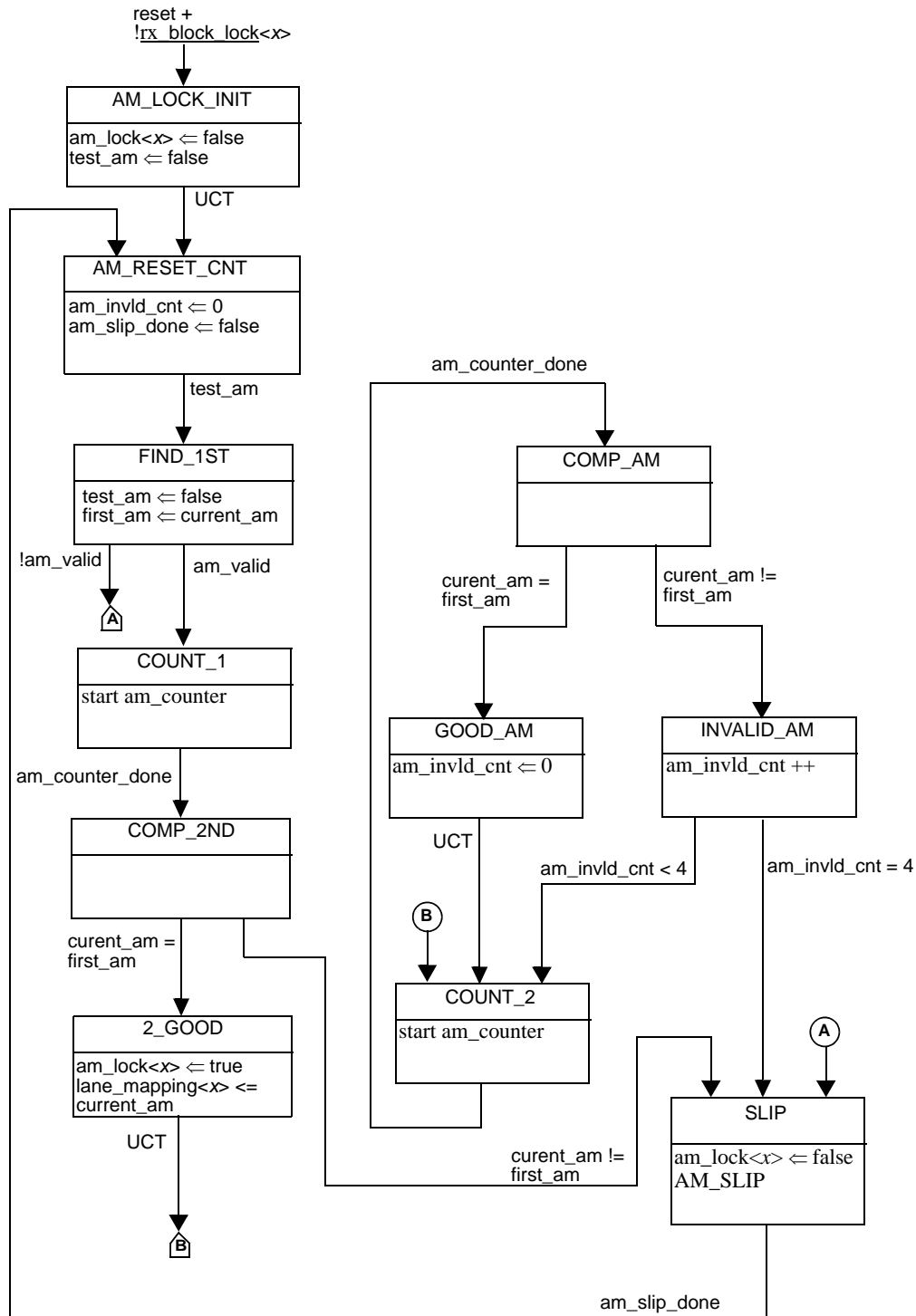
Change 82.6 to add new PHY types

The following requirements apply to a PCS used with a 40GBASE-KR4 PMD, 40GBASE-CR4 PMD, ~~or~~ 100GBASE-CR10, 100GBASE-CR4, 100GBASE-KR4, or 100GBASE-KP4 PMD where support for the Auto-Negotiation process defined in Clause 73 is mandatory. The PCS shall support the primitive AN_LINK.indication(link_status) (see 73.9). The parameter link_status shall take the value FAIL when PCS_status=false and the value OK when PCS_status=true. The primitive shall be generated when the value of link_status changes.



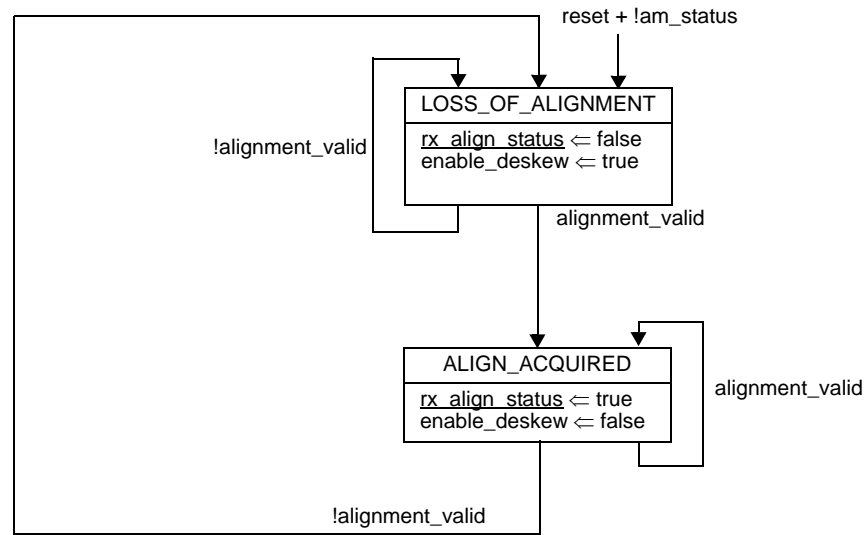
NOTE— $rx_block_lock<x>$ refers to the received lane x of the service interface, where $x = 0:3$ (for 40GBASE-F) or $0:19$ (for 100GBASE-R)

Figure 82–10—Block lock state diagram



NOTE— am_lock<x> refers to the received lane x of the service interface, where x = 0:3 (for 40GBASE-R) or 0:19 (for 100GBASE-R)

Figure 82-11—Alignment marker lock state diagram

**Figure 82–12—PCS deskew state diagram**

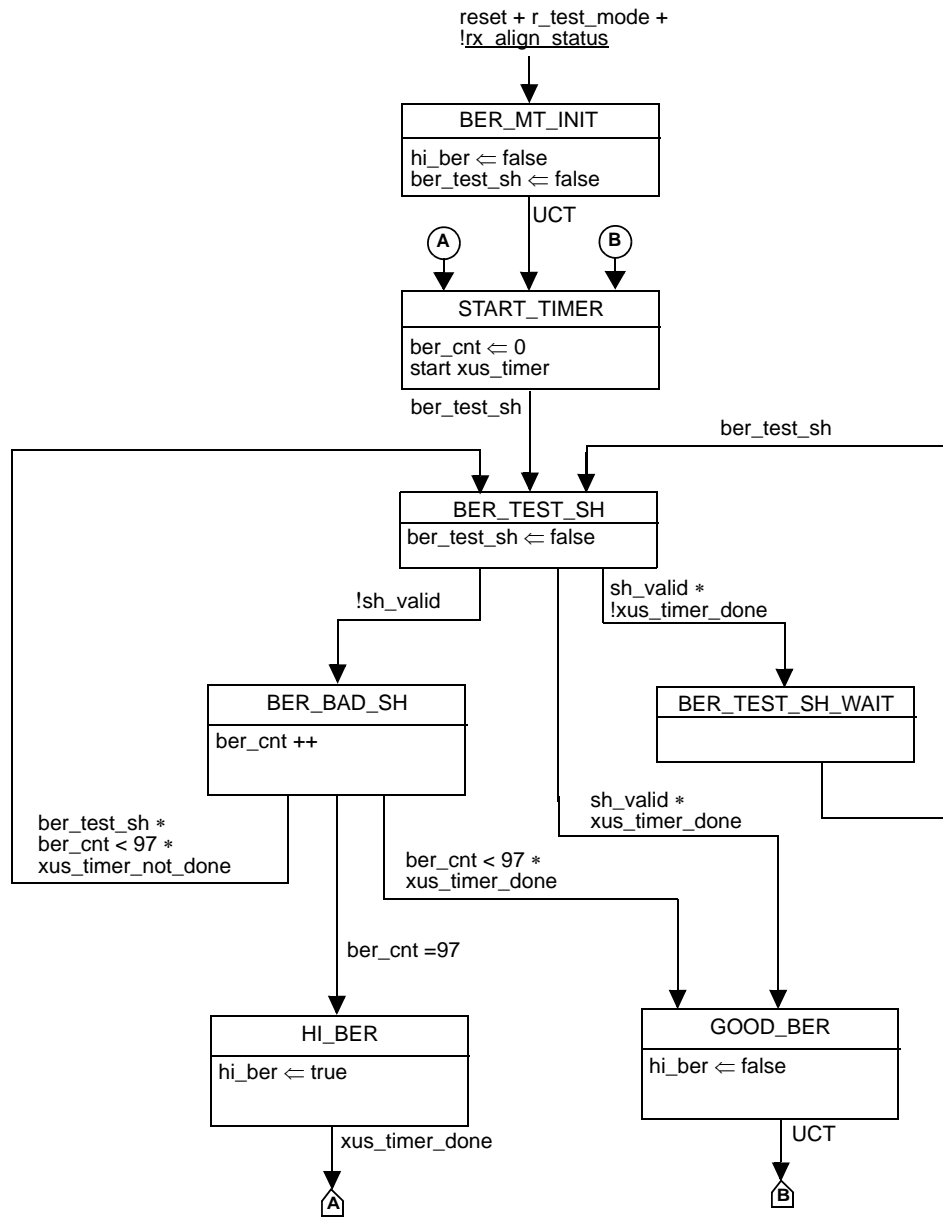


Figure 82–13—BER monitor state diagram

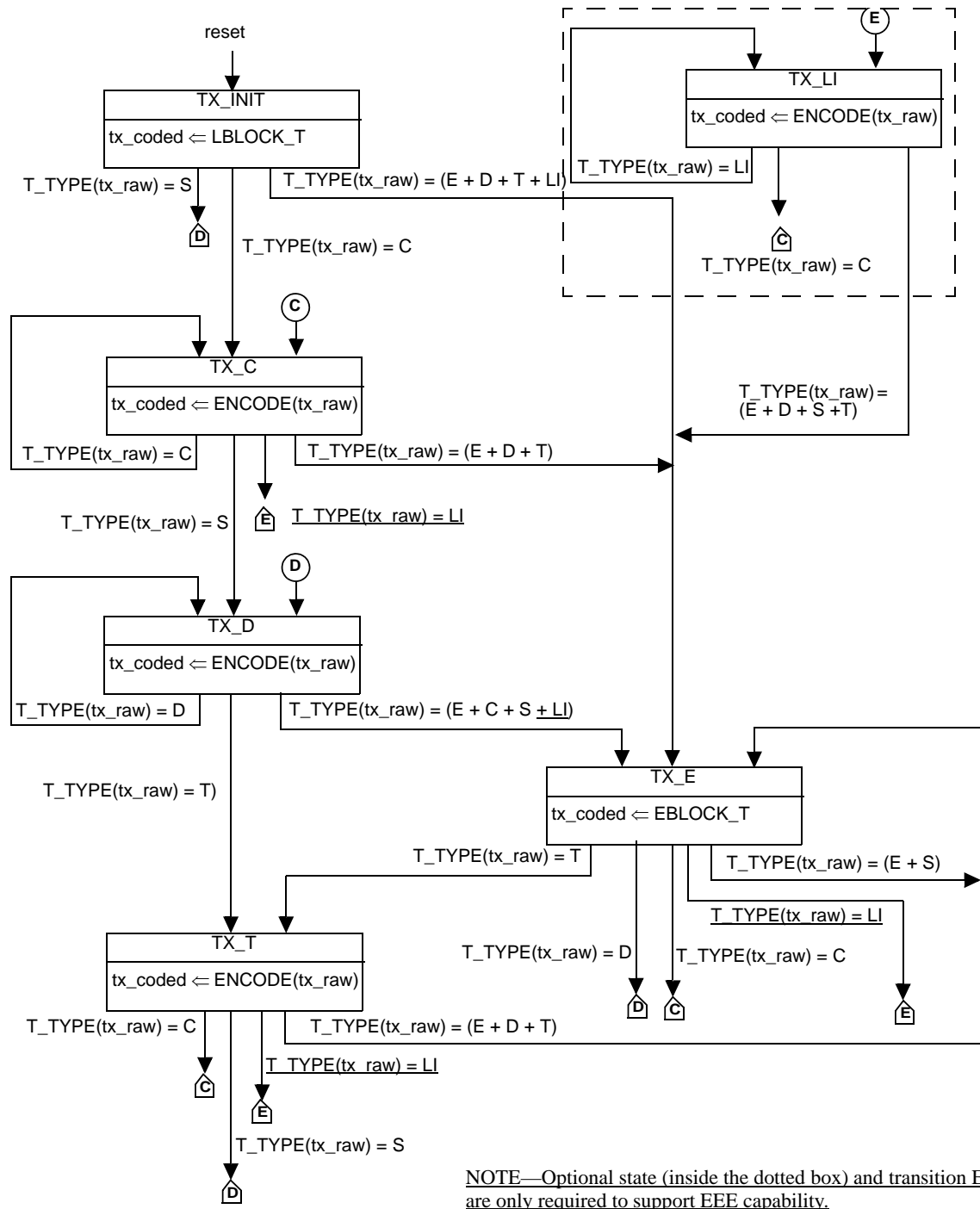
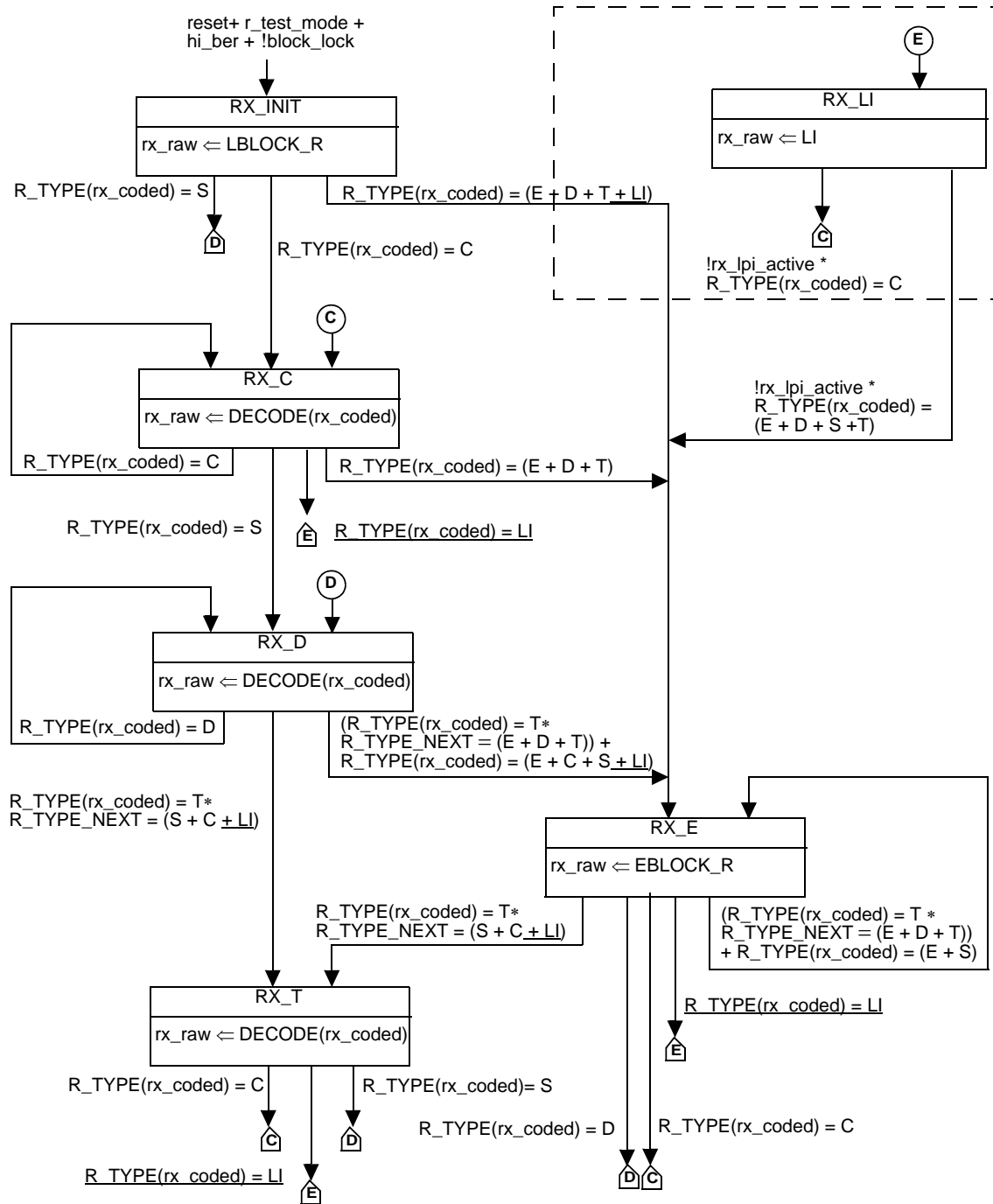


Figure 82–14—Transmit state diagram



NOTE—Optional state (inside the dotted box) and transition E are only required to support EEE capability.

Figure 82–15—Receive state diagram

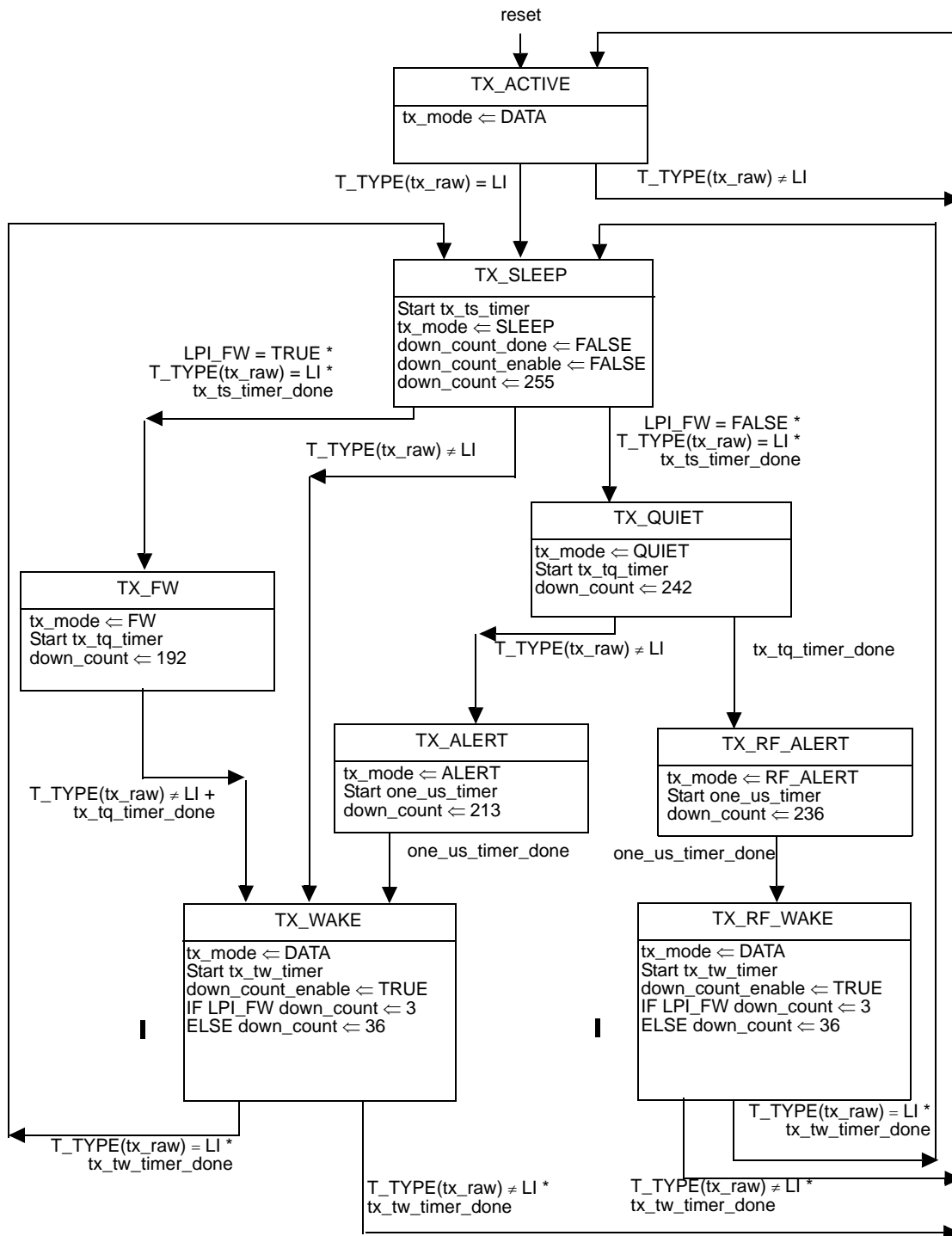


Figure 82-16—LPI Transmit state diagram

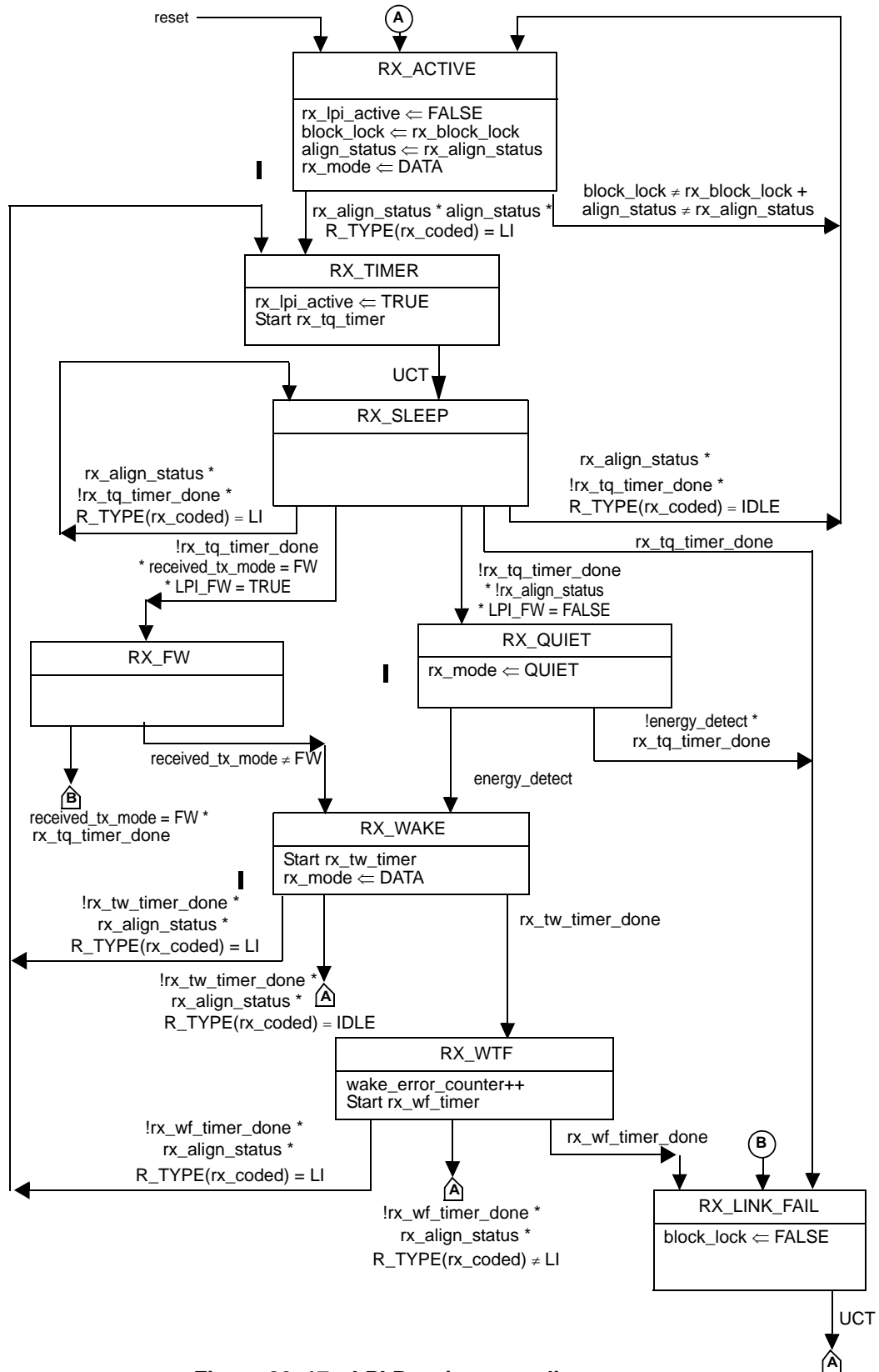


Figure 82-17—LPI Receive state diagram

82.7 Protocol implementation conformance statement (PICS) proforma for Clause 82, Physical Coding Sublayer (PCS) for 64B/66B, type 40GBASE-R and 100GBASE-R⁵*Insert the following row into table 82.7.3:***82.7.3 Major Capabilities/Options**

Item	Feature	Subclause	Value/Comment	Status	Support
<u>*LPI</u>	<u>Implementation of LPI</u>	<u>82.2.3.4</u>		<u>O</u>	<u>Yes []</u> <u>No []</u>

Change rows AN1 and AN2 in 82.7.6.5:***82.7.6.5 Auto-Negotiation for Backplane Ethernet functions**

Item	Feature	Subclause	Value/Comment	Status	Support
AN1*	Support for use with a 40GBASE-KR4, 40GBASE-CR4, or 100GBASE-CR10 PMD, <u>100GBASE-CR4, 100GBASE-KR4, or 100GBASE-KP4</u>	82.6	AN technology dependent interface described in Clause 73	O	Yes []
AN2	AN_LINK.indication primitive	82.6	Support of the primitive AN_LINK.indication(link_status), when the PCS is used with 10GBASE-KR PMD, 40GBASE-KR4, 40GBASE-CR4, 100GBASE-CR10 PMD, <u>100GBASE-CR4, 100GBASE-KR4, or 100GBASE-KP4</u>	AN1:M	Yes []

Insert the new subclause 82.7.6.6 after 82.7.6.5 for LPI functions:

⁵Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

82.7.6.6 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
LP-01	Support for both wake modes	82.2.18.2.2	Variable LPI_FW may be true or false	LPI:O	Yes [] No []
LP-02	Insertion and deletion of LPIs in groups of 8	82.2.3.6		LPI:M	Yes [] No []
LP-03	Transmit state diagrams	82.2.18.3	Support LPI operation in Figure 82–14	LPI:M	Yes [] No []
LP-04	Receive state diagrams	82.2.18.3	Support LPI operation in Figure 82–15	LPI:M	Yes [] No []
LP-05	LPI transmit state diagrams	82.2.18.3.1	Meets the requirements of Figure 82–16	LPI:M	Yes [] No []
LP-06	LPI receive state diagrams	82.2.18.3.1	Meets the requirements of Figure 82–17	LPI:M	Yes [] No []
LP-07	LPI transmit timing	82.2.18.3.1	Meets the requirements of Table 82–5a	LPI:M	Yes [] No []
LP-08	LPI receive timing	82.2.18.3.1	Meets the requirements of Table 82–5b	LPI:M	Yes [] No []

83. Physical Medium Attachment (PMA) sublayer, type 40GBASE-R and 100GBASE-R

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

83.1 Overview

Change NOTE 1 in Figure 83-1 as shown:

NOTE1—~~OPTIONAL OR OMITTED DEPENDING~~ CONDITIONAL BASED ON PHY TYPE

Change the first paragraph of 83.1.1 as follows:

83.1.1 Scope

This clause specifies the Physical Medium Attachment sublayer (PMA) that is common to two families of (40 Gb/s and 100 Gb/s) Physical Layer implementations, known as 40GBASE-R and 100GBASE-R. The PMA allows the PCS (specified in Clause 82) to connect in a media-independent way with a range of physical media. The 40GBASE-R PMA(s) can support any of the 40 Gb/s PMDs in Table 80–2. The 100GBASE-R PMA(s) can support any of the 100 Gb/s PMDs in ~~Table 80–2~~ Table 80–2a, except 100GBASE-KP4 (Clause 94). The terms 40GBASE-R and 100GBASE-R are used when referring generally to Physical Layers using the PMA defined in this clause.

83.3 PMA service interface

Change third paragraph of 83.3 for FEC types:

If the PMA client is the PCS or ~~an~~ a BASE-R FEC sublayer (see Clause 74), the PMA (or PMA client) continuously sends four (for 40GBASE-R) or twenty (for 100GBASE-R) parallel bit streams to the PMA client (or PMA), each at the nominal signaling rate of the PCSL. If the PMA client is the 100GBASE-R FEC sublayer (see Clause 91), the PMA continuously sends four parallel bit streams to the PMA client (or PMA), each at 25.78125 GBd.

Add the following at the end of 83.3 for the EEE service interface:

If the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option is supported (see Clause 78, 78.3) then the inter-sublayer service interface includes two additional primitives defined as follows:

IS_TX_MODE.request
IS_RX_MODE.request
IS_ENERGY_DETECT.indication

The IS_TX_MODE.request primitive is used to communicate the state of the PCS LPI transmit function to other sublayers in the PHY. The IS_RX_MODE.request primitive is used to communicate the state of the PCS LPI receive function to other sublayers. The IS_ENERGY_DETECT.indication primitive is used to communicate that the PMD has detected the return of energy on the interface following a period of quiescence.

A physically instantiated service interface with the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option (see 78.3) may enter a low power state to conserve energy during periods of low link utilization. The ability to support transition to a low power state in the ingress direction is indicated by register 1.1.9 (PMA Ingress AUI Stop Ability, PIASA) and register 1.1.8 for the egress direction (PMA Egress AUI Stop Ability, PEASA). Transition to the low power state is enabled in the ingress direction by register 1.7.9 (PMA Ingress AUI Stop Enable, PIASE) and register 1.7.8 for the egress direction (PMA Egress AUI Stop Enable, PEASE). The system shall not assert the enable bit for an interface unless the corresponding ability bit at the other side of the interface is also asserted. If the PIASE bit is TRUE, then the PMA may disable transmitters on the physical instantiation of the ingress AUI when rx_mode is QUIET. If the PEASE bit is TRUE, then the PMA may disable transmitters on the physical instantiation of the egress AUI when tx_mode is QUIET.

Change the first paragraph of 83.5.8 as follows:

83.5.8 PMA local loopback mode

PMA local loopback shall be provided by the PMA adjacent to the PMD for 40GBASE-KR4, 40GBASE-CR4, and 100BASE-CR10 PMDs, 100GBASE-KR4, and 100GBASE-CR4. PMA local loopback mode is optional for other PMDs or for PMAs not adjacent to the PMD. If it is implemented, it shall be as described in this subclause (83.5.8).

83.6 PMA MDIO function mapping

Add rows to Table 83-2 for fast wake and stop enable:

Table 83–2—MDIO/PMA control variable mapping

MDIO variable	PMA/PMD register name	Register/ bit number	PMA control variable
<u>PIASE</u>	<u>PMA ingress AUI stop enable</u>	<u>1.7.9</u>	<u>PIASE</u>
<u>PEASE</u>	<u>PMA egress AUI stop enable</u>	<u>1.7.8</u>	<u>PEASE</u>

Add rows to Table 83-3 for stop ability:

Table 83–3—MDIO/PMA status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMA status variable
<u>PIASA</u>	<u>PMA ingress AUI stop ability</u>	<u>1.1.9</u>	<u>PIASA</u>
<u>PEASA</u>	<u>PMA egress AUI stop ability</u>	<u>1.1.8</u>	<u>PEASA</u>

**83.7 Protocol implementation conformance statement (PICS) proforma for Clause 83,
Physical Medium Attachment (PMA) sublayer, type 40GBASE-R and 100GBASE-R⁶***Insert the following row into table 82.7.3:***83.7.3 Major Capabilities/Options**

Item	Feature	Subclause	Value/Comment	Status	Support
<u>*LPI</u>	<u>Implementation of LPI with the normal wake mode option</u>	<u>83.3</u>		<u>Q</u>	<u>Yes</u> <input type="checkbox"/> <u>No</u> <input type="checkbox"/>

⁶*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

84. Physical Medium Dependent sublayer and baseband medium, type 40GBASE-KR4

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

Proposals for amendments to this clause that define operation with the optional Energy Efficient Ethernet capability are needed.

84.1 Overview

Add a row in Table 84-1 for EEE:

Table 84-1—Physical Layer clauses associated with the 40GBASE-KR4 PMD

Associated clause	40GBASE-KR4
78—Energy Efficient Ethernet	Optional

Insert the following at the end of 84.1:

40GBASE-KR4 PHYs with the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization (see Clause 78).

84.2 Physical Medium Dependent (PMD) service interface

Add the following at the end of 84.2 for the EEE service interface

If the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option is supported (see Clause 78, 78.3) then the inter-sublayer service interface includes two additional primitives defined as follows:

PMD:IS_TX_MODE.request
PMD:IS_RX_MODE.request

The TX_MODE parameter takes on one of eight values: DATA, SLEEP, QUIET, FW, ALERT, RF_ALERT, WAKE or RF_WAKE. When TX_MODE = QUIET, transmission is disabled; when TX_MODE = ALERT or RF_ALERT, the alert signal is transmitted. Note: if Clause 74 FEC is in use, only the values DATA, QUIET and ALERT may be passed through the FEC to the PMD.

The RX_MODE parameter is used to communicate the state of the PCS LPI receive function and takes the value QUIET or DATA.

84.7.2 PMD Transmit function

Add the following at the end of 84.7.2 for the EEE function:

If the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option is supported (see Clause 78) then when tx_mode is set to ALERT, the adjacent PMA sends a repeating 16-bit pattern, hexadecimal 0xFF00, to the PMD, which the PMD transmits. When tx_mode is ALERT, the transmitter equalizer taps are set to the preset state specified in 72.6.10.2.3.1. When tx_mode is QUIET, the transmitter is disabled as specified in 84.7.6. For all other states of tx_mode, the driver coefficients are restored to their states resolved during training.

84.7.4 Global PMD signal detect function

At the end of the first paragraph add:

When the PHY supports the optional EEE capability, PMD_SIGNAL.indication is also used to indicate when the ALERT signal is detected, which corresponds to the beginning of a refresh or a wake.

At the beginning of the second and third paragraphs add:

When the PHY does not support the EEE capability or if the PHY supports the EEE capability and rx_mode is set to DATA

At the end of the third paragraph add:

When the PHY supports the EEE capability, SIGNAL_DETECT is set to FAIL following a transition from rx_mode = DATA to rx_mode = QUIET. When rx_mode = QUIET, SIGNAL_DETECT shall be set to OK within 500 ns following the application of a signal at the receiver input that is the output of a channel that satisfies the requirements of all the parameters of both interference tolerance test channels defined in 72.7.2.1 when driven by a square wave pattern with a period of 16 unit intervals and peak-to-peak differential output amplitude of 720 mV. While rx_mode = QUIET, SIGNAL_DETECT changes from FAIL to OK only after a valid ALERT signal is applied to the channel.

84.7.6 Global PMD transmit disable function

Change 84.7.6 for the EEE transmit_disable:

The Global_PMD_transmit_disable function is mandatory if EEE with the normal wake mode option is supported and is otherwise optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

- a) When Global_PMD_transmit_disable variable is set to one, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 72-7.
- b) If a PMD_fault (84.7.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
- c) Loopback, as defined in 84.7.8, shall not be affected by Global_PMD_transmit_disable.
- d) For EEE capability, the PMD transmit disable function shall turn off the transmitter after tx_mode is set to QUIET within a time and voltage level specified in 72.7.1.4. The PMD transmit disable

function shall turn on the transmitter after tx_mode is set to DATA or ALERT within the time and voltage level specified in [72.7.1.4](#).

If the MDIO interface is implemented, then this function shall map to the Global_PMD_transmit_disable bit as specified in 45.2.1.8.7.

84.11 Protocol implementation conformance statement (PICS) proforma for Clause 84, Physical Medium Dependent (PMD) sublayer and baseband medium, type 40GBASE-KR4⁷

Insert the following row into table 84.11.3:

84.11.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*LPI	Implementation of LPI with the normal wake mode option	84.2		<u>O</u>	Yes <input type="checkbox"/> No <input type="checkbox"/>

84.11.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 40GBASE-CR4 and 100GBASE-CR10

Insert the following rows into table 84.11.4.1:

84.11.4.1 PMD functional specifications

Item	Feature	Sub clause	Value/Comment	Status	Support
FS13	Signal detect during LPI	84.7.4	Detect signal energy during LPI	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>
FS14	Signal detect for EEE	84.7.4	Transition timing to set SIGNAL_DETECT	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>
FS15	Transmit disable during LPI	84.7.6	Disable transmitter during tx_mode = QUIET	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>

Insert the following rows into table 84.11.4.3:

84.11.4.3 Transmitter electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
TC3	Output Amplitude LPI voltage	84.7.6	Less than 30 mV within 500 ns of tx_quiet	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>
TC4	Output Amplitude ON voltage	84.7.6	Greater than 90% of previous level within 500 ns of tx_quiet de-asserted	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>

⁷Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS

85. Physical Medium Dependent sublayer and baseband medium, type 40GBASE-CR4 and 100GBASE-CR10

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

85.1 Overview

Add a row in Table 85-1 for EEE:

Table 85–1—Physical Layer clauses associated with the 40GBASE-CR4 and 100GBASE-CR10 PMDs

Associated clause	40GBASE-CR4	100GBASE-CR10
<u>78—Energy Efficient Ethernet</u>	<u>Optional</u>	<u>Optional</u>

Insert the following at the end of 85.1:

100GBASE-CR10 and 40GBASE-CR4 PHYs with the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization (see Clause 78).

85.2 Physical Medium Dependent (PMD) service interface

Add the following at the end of 85.2 for the EEE service interface

If the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option is supported (see Clause 78, 78.3) then the inter-sublayer service interface includes two additional primitives defined as follows:

PMD:IS_TX_MODE.request
PMD:IS_RX_MODE.request

The TX_MODE parameter takes on one of eight values: DATA, SLEEP, QUIET, FW, ALERT, RF_ALERT, WAKE or RF_WAKE. When TX_MODE = QUIET, transmission is disabled; when TX_MODE = ALERT or RF_ALERT, the alert signal is transmitted. Note: if Clause 74 FEC is in use, only the values DATA, QUIET and ALERT may be passed through the FEC to the PMD.

The RX_MODE parameter is used to communicate the state of the PCS LPI receive function and takes the value QUIET or DATA.

85.7.2 PMD Transmit function

Add the following at the end of 85.7.2 for the EEE function:

If the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option is supported (see Clause 78) then when tx_mode is set to ALERT, the adjacent PMA sends a repeating 16-bit pattern, hexadecimal 0xFF00, to the PMD, which the PMD transmits. When tx_mode is ALERT, the transmitter equalizer taps are set to the preset state specified in 85.8.3.3.1. When tx_mode is QUIET, the transmitter is disabled as specified in 85.7.6. For all other states of tx_mode, the driver coefficients are restored to their states resolved during training.

85.7.4 Global PMD signal detect function

At the end of the first paragraph add:

When the PHY supports the optional EEE capability, PMD_SIGNAL.indication is also used to indicate when the ALERT signal is detected, which corresponds to the beginning of a refresh or a wake.

At the beginning of the second and third paragraphs add:

When the PHY does not support the EEE capability or if the PHY supports the EEE capability and rx_mode is set to DATA

At the end of the third paragraph add:

When the PHY supports the EEE capability, SIGNAL_DETECT is set to FAIL following a transition from rx_mode = DATA to rx_mode = QUIET. When rx_mode = QUIET, SIGNAL_DETECT shall be set to OK within 500 ns following the application of a signal at the receiver input that is the output of a channel that satisfies the requirements of all the parameters of both interference tolerance test channels defined in 72.7.2.1 when driven by a square wave pattern with a period of 16 unit intervals and peak-to-peak differential output amplitude of 720 mV. While rx_mode = QUIET, SIGNAL_DETECT changes from FAIL to OK only after a valid ALERT signal is applied to the channel.

85.7.6 Global PMD transmit disable function

Change 85.7.6 for the EEE transmit_disable:

The Global_PMD_transmit_disable function is mandatory if EEE with the normal wake mode option is supported and is otherwise optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

- a) When Global_PMD_transmit_disable variable is set to one, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 85–2.
- b) If a PMD_fault (85.7.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
- c) Loopback, as defined in 85.7.8, shall not be affected by Global_PMD_transmit_disable.
- d) For EEE capability, the PMD transmit disable function shall turn off the transmitter after tx_mode is set to QUIET within a time and voltage level specified in 72.7.1.4. The PMD transmit disable function shall turn on the transmitter after tx_mode is set to DATA or ALERT within the time and voltage level specified in 72.7.1.4.

85.8.3 Transmitter characteristics

Add the following row in Table 85-5 in 85.8.3:

Table 85–2—Transmitter characteristics at TP2 summary

Parameter	Subclause reference	Value	Units
Common-mode voltage deviation (max) during LPI	72.7.1.4	150	mV

85.13 Protocol implementation conformance statement (PICS) proforma for Clause 85, Physical Medium Dependent (PMD) sublayer and baseband medium, type 40GBASE-CR4 and 100GBASE-CR10⁸

Insert the following row into table 85.13.3:

85.13.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*LPI	Implementation of LPI with the normal wake mode option	85.2		<u>Q</u>	Yes <input type="checkbox"/> No <input type="checkbox"/>

85.13.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 40GBASE-CR4 and 100GBASE-CR10

Insert the following rows into table 85.13.4.1:

85.13.4.1 PMD functional specifications

Item	Feature	Sub clause	Value/Comment	Status	Support
PF20	Signal detect during LPI	85.7.4	Detect signal energy during LPI	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>
PF21	Signal detect for EEE	85.7.4	Transition timing to set SIGNAL_DETECT	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>
PF22	Transmit disable during LPI	85.7.6	Disable transmitter during tx_mode = QUIET	LPI:M	Yes <input type="checkbox"/> No <input type="checkbox"/>

Insert the following rows into table 85.13.4.3:

⁸Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

85.13.4.3 Transmitter specifications

Item	Feature	Subclause	Value/Comment	Status	Support
DS6	Output Amplitude LPI voltage	85.7.6	Less than 30 mV within 500 ns of tx_quiet	LPI:M	Yes [] No []
DS7	Output Amplitude ON voltage	85.7.6	Greater than 90% of previous level within 500 ns of tx_quiet de-asserted	LPI:M	Yes [] No []

91. Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 100GBASE-R PHYs

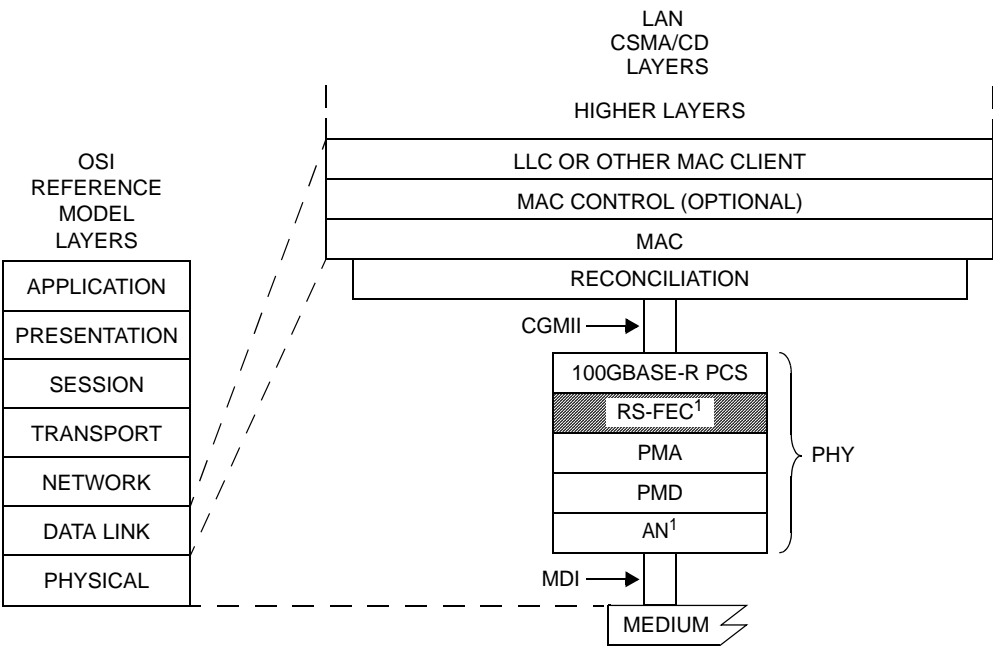
91.1 Overview

91.1.1 Scope

This clause specifies a Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 100GBASE-R PHYs.

91.1.2 Position of RS-FEC in the 100GBASE-R sublayers

Figure 91–1 shows the relationship of the RS-FEC sublayer to the ISO/IEC Open System Interconnection (OSI) reference model.



AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION

NOTE 1—CONDITIONAL BASED ON PHY TYPE

Figure 91–1—RS-FEC relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

91.2 FEC service interface

This subclause specifies the services provided by the RS-FEC sublayer. The service interface is described in an abstract manner and does not imply any particular implementation.

The FEC service interface is provided to allow the PCS to transfer information to and from the RS-FEC. The PCS may be connected to the RS-FEC using an optional instantiation of the PMA service interface (refer to Annex 83A) in which case a PMA will be the client of the FEC service interface.

The FEC service interface is an instance of the inter-sublayer service interface defined in 80.3. The FEC service interface primitives are summarized as follows:

```
FEC:IS_UNITDATA_i.request
FEC:IS_UNITDATA_i.indication
FEC:IS_SIGNAL.indication
```

The RS-FEC operates on twenty parallel bit streams, hence $i = 0$ to 19. The PCS (or PMA) continuously sends twenty parallel bit streams to the RS-FEC, one per lane, each at a nominal signaling rate of 5.15625 GBd. The RS-FEC continuously sends twenty parallel bit streams to the PCS (or PMA), one per lane, each at a nominal signaling rate of 5.15625 GBd

The SIGNAL_OK parameter of the FEC:IS_SIGNAL.indication primitive can take one of two values: OK or FAIL. The value is set to OK when the FEC receive function has identified codeword boundaries as indicated by fec_align_status equal to true. That value is set to FAIL when the FEC receive function is unable to reliably establish codeword boundaries as indicated by fec_align_status equal to false. When SIGNAL_OK is FAIL, the rx_bit parameters of the FEC:IS_UNITDATA_i.indication primitives are undefined.

If the optional EEE capability is supported, then the FEC service interface includes three additional primitives as follows:

```
FEC:IS_TX_MODE.request
FEC:IS_RX_MODE.request
FEC:IS_ENERGY_DETECT.indication
```

91.3 PMA compatibility

The RS-FEC sublayer requires that the PMA service interface consist of exactly four upstream lanes and exactly four downstream lanes. Therefore, the RS-FEC sublayer may be a client of the PMA sublayer defined in Clause 83 when the PMA service interface width, p , is set to 4. The RS-FEC sublayer may also be a client of the PMA sublayer defined in Clause 94.

91.4 Delay constraints

The maximum delay contributed by the RS-FEC sublayer (sum of transmit and receive delays at one end of the link) shall be no more than 40960 bit times (80 pause_quanta or 409.6 ns). A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 80.4 and its references.

91.5 Functions within the RS-FEC sublayer

91.5.1 Functional block diagram

A functional block diagram of the RS-FEC sublayer is shown in Figure 91–2.

91.5.2 Transmit function

91.5.2.1 Lane block synchronization

The RS-FEC transmit function forms 20 bit streams by concatenating the bits from each of the 20 FEC:IS_UNITDATA_*i*.request primitives in the order they are received. It obtains lock to the 66-bit blocks in each bit stream using the sync headers and outputs 66-bit blocks. Block lock is obtained as specified in the block lock state diagram shown in Figure 82–10.

91.5.2.2 Alignment lock and deskew

Once the RS-FEC transmit function achieves block lock on a PCS lane, it then begins obtaining alignment marker lock as specified by the alignment marker lock state diagram shown in Figure 82–11. This process identifies the PCS lane number received on a particular lane of the service interface. After alignment marker lock is achieved on all 20 lanes, all inter-lane Skew is removed as specified by the PCS deskew state diagram shown in Figure 82–12. The RS-FEC transmit function shall support a maximum Skew of 49 ns between PCS lanes and a maximum Skew Variation of 400 ps. Skew and Skew Variation are defined in 80.5.

91.5.2.3 Lane reorder

PCS lanes can be received on different lanes of the service interface from which they were originally transmitted due to Skew between lanes and multiplexing by the PMA. The RS-FEC transmit function shall order the PCS lanes according to the PCS lane number.

91.5.2.4 Alignment marker removal

After all PCS lanes are aligned and deskewed, the PCS lanes are multiplexed together in the proper order to reconstruct the original stream of blocks and the alignment markers are removed from the data stream. Note that an alignment marker is always removed when am_lock is true for a given PCS lane even if it does not match the expected alignment marker value (due to a bit error for example). Repeated alignment marker errors will result in am_lock being set to false for a given PCS lane, but until that happens it is sufficient to remove the block in the alignment marker position.

For the optional EEE capability, transitions between normal alignment markers and Rapid Alignment markers result in changes in relative position and frequency of alignment markers. These transitions are detected by the Transmit LPI state diagram (see Figure 91–10) and this information is used by the alignment marker removal function to determine which 66-bit blocks are to be removed.

As part of the alignment marker removal process, the BIP₃ field is compared to the calculated Bit Interleaved Parity (BIP) value (refer to 82.2.8) for each PCS lane. If a Clause 45 MDIO is implemented, then the appropriate BIP error counter register (registers 1.230 to 1.249) is incremented by one each time the calculated BIP value does not equal the value received in the BIP₃ field. The incoming bit error ratio can be estimated by dividing the BIP block error ratio by a factor of 1081344.

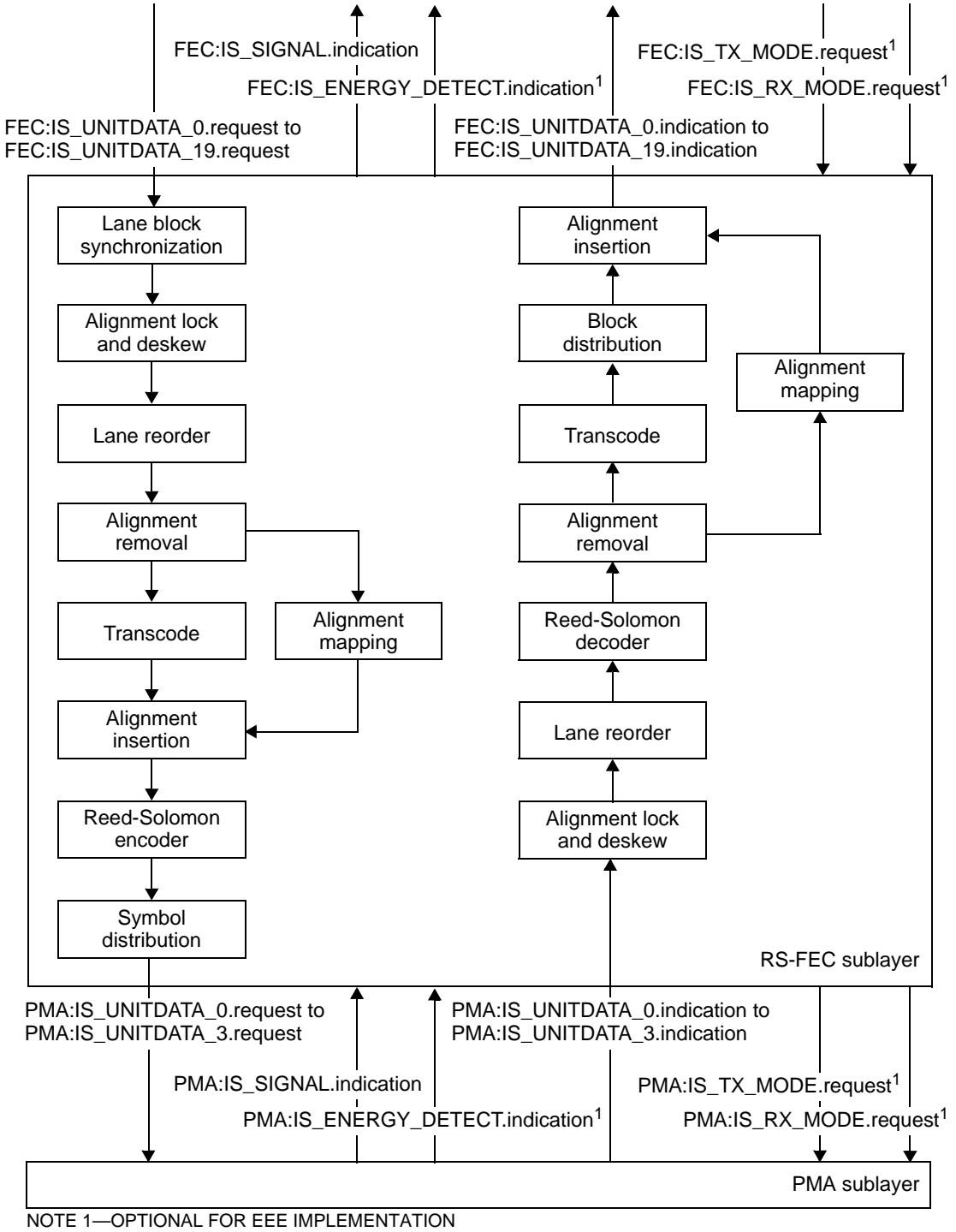


Figure 91-2—Functional block diagram

91.5.2.5 64B/66B to 256B/257B transcoder

The transcoder constructs a 257-bit block, $\text{tx_scrambled}\langle 256:0 \rangle$, from a group of four 66-bit blocks, $\text{tx_coded}_j\langle 65:0 \rangle$ where $j=0$ to 3. For each group of four 66-bit blocks, $j=3$ corresponds to the most recently received block. Bit 0 in each 66-bit block is the first bit received and corresponds to the first bit of the synchronization header.

If for all $j=0$ to 3, $\text{tx_coded}_j\langle 0 \rangle = 0$ and $\text{tx_coded}_j\langle 1 \rangle = 1$, $\text{tx_xcoded}\langle 256:0 \rangle$ shall be constructed as follows.

- a) $\text{tx_xcoded}\langle 0 \rangle = 1$
- b) $\text{tx_xcoded}\langle (64j+64):(64j+1) \rangle = \text{tx_coded}_j\langle 65:2 \rangle$ for $j=0$ to 3

If for all $j=0$ to 3, $\text{tx_coded}_j\langle 0 \rangle \neq \text{tx_coded}_j\langle 1 \rangle$ (valid synchronization header) and for any $j=0$ to 3, $\text{tx_coded}_j\langle 0 \rangle = 1$ and $\text{tx_coded}_j\langle 1 \rangle = 0$, $\text{tx_xcoded}\langle 256:0 \rangle$ shall be constructed as follows.

- a) $\text{tx_xcoded}\langle 0 \rangle = 0$
- b) $\text{tx_xcoded}\langle j+1 \rangle = \text{tx_coded}_j\langle 1 \rangle$ for $j=0$ to 3
- c) Let c be the smallest value of j such that $\text{tx_coded}_c\langle 0 \rangle = 1$ and $\text{tx_coded}_c\langle 1 \rangle = 0$. In other words, tx_coded_c is the first 66-bit control block that was received in the current group of four blocks.
- d) Let $\text{tx_payloads}\langle (64j+63):64j \rangle = \text{tx_coded}_j\langle 65:2 \rangle$ for $j=0$ to 3
- e) Omit $\text{tx_coded}_c\langle 9:6 \rangle$, which is the second nibble (based on transmission order) of the block type field for tx_coded_c , from tx_xcoded per the following expressions.
 $\text{tx_xcoded}\langle (64c+8):5 \rangle = \text{tx_payloads}\langle (64c+3):0 \rangle$
 $\text{tx_xcoded}\langle 256:(64c+9) \rangle = \text{tx_payloads}\langle 255:(64c+8) \rangle$

If for any $j=0$ to 3, $\text{tx_coded}_j\langle 0 \rangle = \text{tx_coded}_j\langle 1 \rangle$ (invalid synchronization header), $\text{tx_xcoded}\langle 256:0 \rangle$ shall be constructed as follows.

- a) $\text{tx_xcoded}\langle 0 \rangle = 0$
- b) $\text{tx_xcoded}\langle j+1 \rangle = 1$ for $j=0$ to 3
- c) Let $\text{tx_payloads}\langle (64j+63):64j \rangle = \text{tx_coded}_j\langle 65:2 \rangle$ for $j=0$ to 3
- d) Omit the second nibble (based on transmission order) of tx_coded_0 per the following expressions.
 $\text{tx_xcoded}\langle 8:5 \rangle = \text{tx_payloads}\langle 3:0 \rangle$
 $\text{tx_xcoded}\langle 256:9 \rangle = \text{tx_payloads}\langle 255:8 \rangle$

Several examples of the construction of $\text{tx_xcoded}\langle 256:0 \rangle$ are shown in Figure 91–3.

Finally, scramble the first 5 bits, based on transmission order, of $\text{tx_xcoded}\langle 256:0 \rangle$ to yield $\text{tx_scrambled}\langle 256:0 \rangle$ as follows.

- a) Set $\text{tx_scrambled}\langle 4:0 \rangle$ to the result of the bit-wise exclusive-OR of the $\text{tx_xcoded}\langle 4:0 \rangle$ and $\text{tx_xcoded}\langle 12:8 \rangle$.
- b) Set $\text{tx_scrambled}\langle 256:5 \rangle$ to $\text{tx_xcoded}\langle 256:5 \rangle$

For each 257-bit block, bit 0 shall be the first bit transmitted.

91.5.2.6 Alignment marker mapping and insertion

The alignment markers that were removed per 91.5.2.4 are re-inserted after being processed by the alignment marker mapping function. The alignment marker mapping function compensates for the operation of the symbol distribution function defined in 91.5.2.8 and rearranges the alignment marker bits so that they appear on the FEC lanes intact and in the desired sequence. This preserves the properties of the alignment

markers (e.g. DC balance, transition density) and provides a deterministic pattern for the purpose of synchronization.

The alignment marker mapping function operates on a group of twenty aligned and reordered alignment markers. Let $am_tx_x<65:0>$ be the alignment marker for PCS lane x , $x=0$ to 19, where bit 0 is the first bit transmitted. The alignment markers shall be mapped to $am_txmapped<1284:0>$ in a manner that yields the same result as the process defined below.

Discard the synchronization headers, $am_tx_x<1:0>$, and construct a matrix of 4 rows and 320 columns, $am_txpayloads$, from the 64-bit payloads as shown in Figure 91–4. Given $i=0$ to 3, $j=0$ to 4, and $x=i+4j$, the matrix is defined by the following expression.

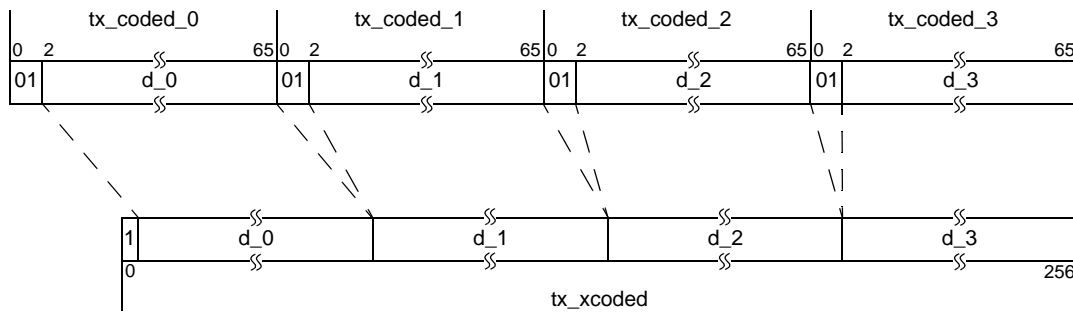
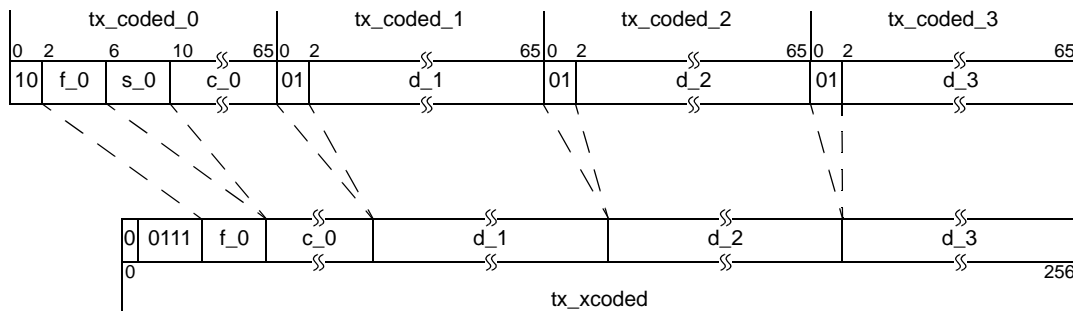
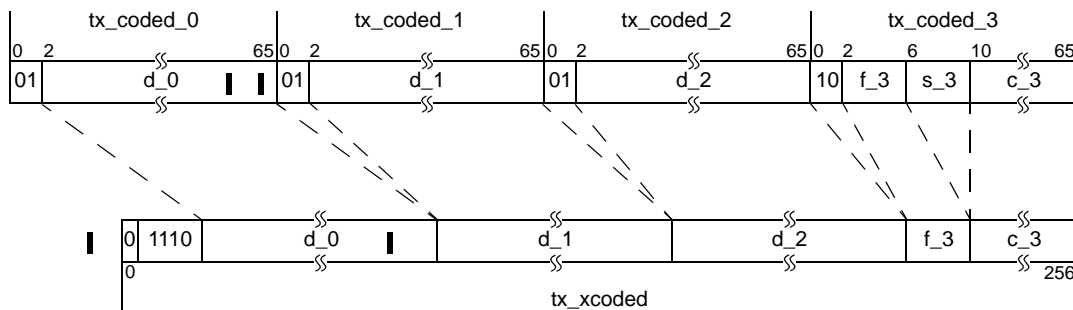
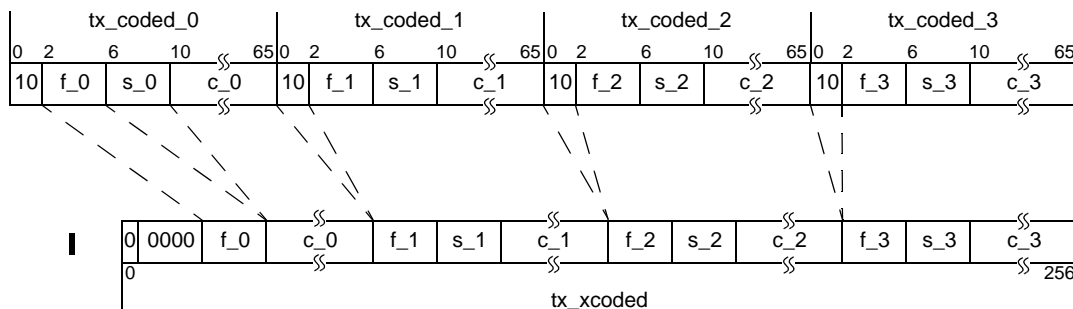
$$am_txpayloads<i, (64j+63):64j> = am_tx_x<65:2>$$


Given $i=0$ to 3, $k=0$ to 31, and $y=i+4k$, $am_txmapped$ may then be derived from $am_txpayloads$ per the following expression.


$$am_txmapped<(10y+9):10y> = am_txpayloads<i, (10k+9):10k>$$

A 5-bit pad is appended to the mapped alignment markers to yield the equivalent of five 257-bit blocks. The pad bits, $am_txmapped<1284:1280>$, shall be set to the binary values 00101 and 11010 (the leftmost bit is assigned to the highest bit index) in an alternating pattern. In other words, if a pad value of 00101 is used for the current iteration of the mapping function, a value of 11010 will be used in the next iteration and vice versa.

The result of the alignment marker mapping function is a deterministic mapping between alignment marker payloads and FEC lanes. The alignment marker payloads corresponding to PCS lanes 0, 4, 8, 12, and 16 are transmitted on FEC lane 0, the alignment marker payloads corresponding to PCS lanes 1, 5, 6, 13, and 17 are transmitted to FEC lane 1, and so on (see Figure 91–4). The RS-FEC receive function uses knowledge of this mapping to determine the FEC lane that is received on a given lane of the PMA service interface.

**Example 1: All data blocks****Example 2: Control block followed by three data blocks****Example 3: Three data blocks followed by a control block****Example 4: All control blocks****Figure 91-3—Examples of the construction of tx_xcoded**

FEC lane, <i>i</i>	Reed-Solomon symbol index, <i>k</i> (10-bit symbols)																																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33			
0	2	am_tx_0					65	2	am_tx_4					65	2	am_tx_8					65	2	am_tx_12					65	2	am_tx_16					65		
1	2	am_tx_1					65	2	am_tx_5					65	2	am_tx_9					65	2	am_tx_13					65	2	am_tx_17					65		
2	2	am_tx_2					65	2	am_tx_6					65	2	am_tx_10					65	2	am_tx_14					65	2	am_tx_18					65		
3	2	am_tx_3					65	2	am_tx_7					65	2	am_tx_11					65	2	am_tx_15					65	2	am_tx_19					65		

 = 5-bit pad


tx_scrambled

Figure 91-4—Alignment marker mapping to FEC lanes

As a result of this process, the BIP₃ and BIP₇ fields from normal alignment markers are carried across the link protected by FEC. It should be noted that these fields cannot be used to monitor errors on the link protected by FEC as 64B/66B to 256B/257B transcoding and Reed-Solomon encoding alters the bit sequence. However, these fields may again be used to monitor errors after the original bit sequence is restored, i.e. following Reed-Solomon decoding and 256B/257B to 64B/66B transcoding.

One group of aligned and reordered alignment markers are mapped every 20 × 16384 66-bit blocks. This corresponds to 4096 Reed-Solomon codewords (refer to 91.5.2.7). The mapped alignment markers, am_txmapped<1284:0> shall be inserted as the first 1285 message bits to be transmitted from every 4096th codeword.

For the optional EEE capability, when tx_lpi_active is true, one group of Rapid Alignment Markers (see 82.2.7a) are mapped every 20 × 8 66-bit blocks. This corresponds to 2 Reed-Solomon codewords. The mapped Rapid Alignment Markers, am_txmapped<1284:0> shall be inserted as the first 1285 message bits to be transmitted from every other codeword.

91.5.2.7 Reed-Solomon encoder

The RS-FEC sublayer employs a Reed-Solomon code operating over the Galois Field GF(2¹⁰) where the symbol size is 10 bits. The encoder processes *k* message symbols to generate 2*t* parity symbols which are then appended to the message to produce a codeword of *n*=*k*+2*t* symbols. For the purposes of this clause, a particular Reed-Solomon code is denoted RS(*n*, *k*).

When used to form a 100GBASE-CR4 or 100GBASE-KR4 PHY, the RS-FEC sublayer shall implement RS(528, 514). When used to form a 100GBASE-KP4 PHY, the RS-FEC sublayer shall implement RS(544, 514). Each *k*-symbol message corresponds to twenty 257-bit blocks produced by the transcoder. Each code is based on the generating polynomial given by Equation (91-1).

$$g(x) = \prod_{j=0}^{2t-1} (x - \alpha^j) = g_{2t}x^{2t} + g_{2t-1}x^{2t-1} + \dots + g_1x + g_0 \quad (91-1)$$

In Equation (91-1), α is a primitive element of the finite field defined by the polynomial $x^{10} + x^3 + 1$.

Equation (91-2) defines the message polynomial $m(x)$ whose coefficients are the message symbols m_{k-1} to m_0 .

$$m(x) = m_{k-1}x^{n-1} + m_{k-2}x^{n-2} + \dots + m_1x^{2t+1} + m_0x^{2t} \quad (91-2)$$

Each message symbol m_i is the bit vector $(m_{i,9}, m_{i,8}, \dots, m_{i,1}, m_{i,0})$ which is identified with the element $m_{i,9}\alpha^9 + m_{i,8}\alpha^8 + \dots + m_{i,1}\alpha + m_{i,0}$ of the finite field. The message symbols are composed of the bits of the transcoded blocks tx_scrambled (including a mapped group of alignment markers when appropriate) such that bit 0 of the first transcoded block in the message (or am_txmapped<0>) is bit 0 of m_{k-1} and bit 256 of the last transcoded block in the message is bit 9 of m_0 . The first symbol input to the encoder is m_{k-1} .

Equation (91–3) defines the parity polynomial $p(x)$ whose coefficients are the parity symbols p_{2t-1} to p_0 .

$$p(x) = p_{2t-1}x^{2t-1} + p_{2t-2}x^{2t-2} + \dots + p_1x + p_0 \quad (91-3)$$

The parity polynomial is the remainder from the division of $m(x)$ by $g(x)$. This may be computed using the shift register implementation illustrated in Figure 91–5. The outputs of the delay elements are initialized to zero prior to the computation of the parity for a given message. After the last message symbol, m_0 , is processed by the encoder, the outputs of the delay elements are the parity symbols for that message.

The codeword polynomial $c(x)$ is then the sum of $m(x)$ and $p(x)$ where the coefficient of the highest power of x , $c_{n-1} = m_{k-1}$, is transmitted first and the coefficient of the lowest power of x , $c_0 = p_0$, is transmitted last. The first bit transmitted from each symbol is bit 0.

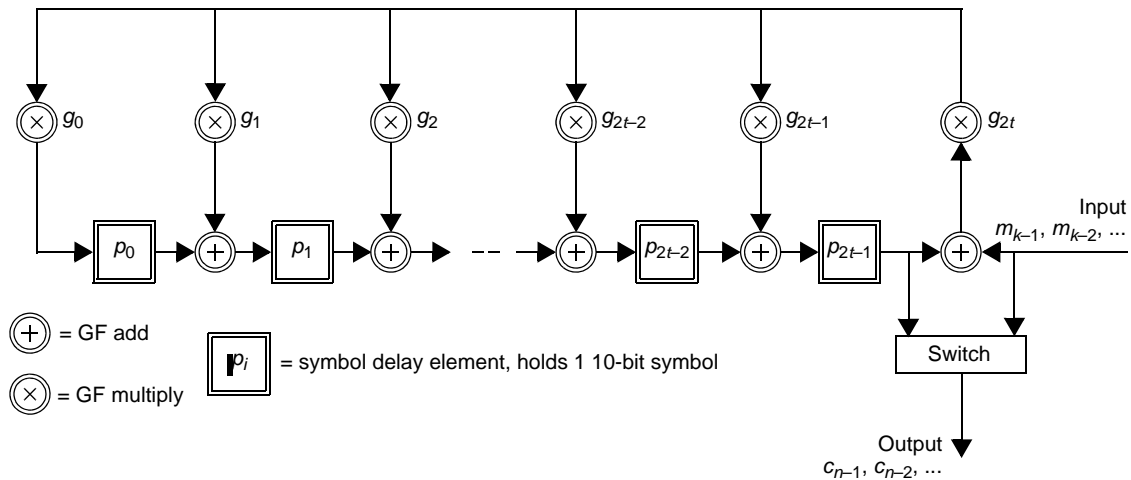


Figure 91–5—Reed-Solomon encoder functional model

The coefficients of the generator polynomial for each code are presented in Table 91–1. Example codewords for each code are provided in Annex 91A.

91.5.2.8 Symbol distribution

Once the data has been Reed-Solomon encoded, it shall be distributed to 4 FEC lanes, one 10-bit symbol at a time in a round robin distribution from the lowest to the highest numbered FEC lane. The distribution process is shown in Figure 91–6.

When used to form a 100GBASE-KP4 PHY, the PMA:IS_UNITDATA_i.request primitive is defined to include an additional parameter (refer to 94.2.1.1). At the beginning of an FEC codeword, the parameter start=TRUE is asserted for the first bit of the first four symbols of the codeword transferred across the four primitives. Otherwise the parameter start is set to FALSE.

Table 91–1—Coefficients of the generator polynomial g_i (decimal)

i	RS(528,514)	RS(544,514)	i	RS(528,514)	RS(544,514)	i	RS(528,514)	RS(544,514)
0	432	523	11	701	883	22		565
1	290	834	12	6	503	23		108
2	945	128	13	904	942	24		1
3	265	158	14	1	385	25		552
4	592	185	15		495	26		230
5	391	127	16		720	27		187
6	614	392	17		94	28		552
7	900	193	18		132	29		575
8	925	610	19		593	30		1
9	656	788	20		249			
10	32	361	21		282			

91.5.2.9 Transmit bit ordering

The transmit bit ordering is illustrated in Figure 91–6.

91.5.3 Receive function**91.5.3.1 Alignment lock and deskew**

The RS-FEC receive function forms 4 bit streams by concatenating the bits from each of the 4 PMA:IS_UNITDATA_ i .indication primitives in the order they are received. It obtains lock to the alignment markers as specified by the FEC synchronization state diagram shown in Figure 91–8.

After alignment marker lock is achieved on all 4 lanes, all inter-lane Skew is removed as specified by the FEC alignment state diagram shown in Figure 91–9. The FEC receive function shall support a maximum Skew of 180 ns between FEC lanes and a maximum Skew Variation of 4 ns.

The 100GBASE-KP4 PMA transmit function (refer to 94.2.2) inserts PMA-specific overhead that is aligned with the start of a Reed-Solomon codeword. The 100GBASE-KP4 PMA receive function (refer to 94.2.4) synchronizes to this overhead and indicates the first bit of each of the first four symbols in a codeword by setting the PMA:IS_UNITDATA_ i .indication parameter start=TRUE (see 94.2.1.2).

91.5.3.2 Lane reorder

FEC lanes can be received on different lanes of the service interface from which they were originally transmitted. The FEC receive function shall order the FEC lanes according to the FEC lane number (see 91.5.2.6). The FEC lane number is defined by the sequence of alignment markers that are mapped to each FEC lane.

After all FEC lanes are aligned, deskewed, and reordered, the FEC lanes are multiplexed together in the proper order to reconstruct the original stream of FEC codewords.

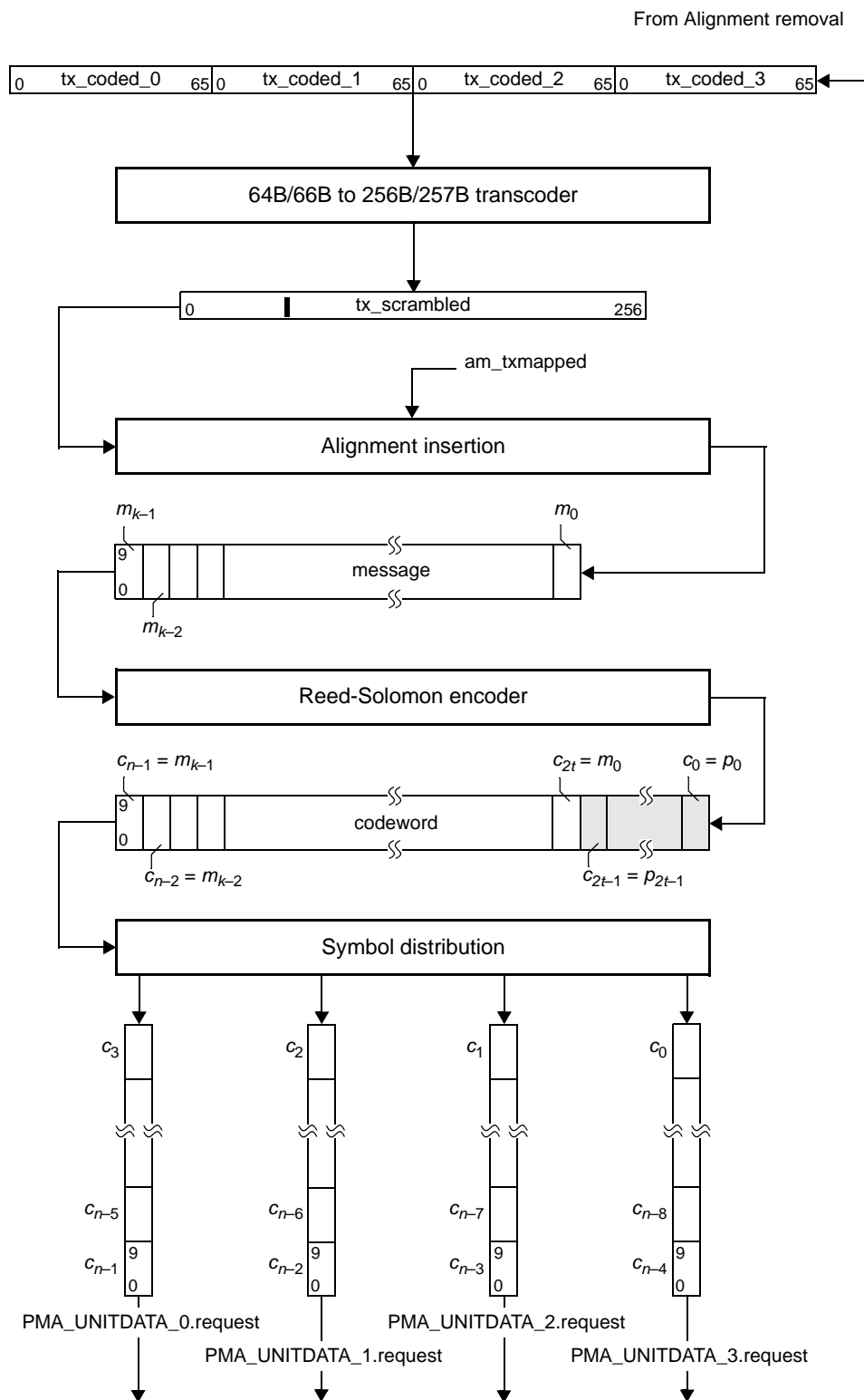


Figure 91-6—Transmit bit ordering

91.5.3.3 Reed-Solomon decoder

The Reed-Solomon decoder extracts the message symbols from the codeword, correcting them as necessary, and discards the parity symbols. The message symbols correspond to 20 transcoded blocks rx_scrambled.

When used to form a 100GBASE-CR4 or 100GBASE-KR4 PHY, the RS-FEC sublayer shall be capable of correcting any combination of up to $t=7$ symbol errors in a codeword. When used to form a 100GBASE-KP4 PHY, the RS-FEC sublayer shall be capable of correcting any combination of up to $t=15$ symbol errors in a codeword. The RS-FEC sublayer shall also be capable of detecting uncorrectable codewords.

The Reed-Solomon decoder may provide the option to perform error detection without error correction to reduce the delay contributed by the RS-FEC sublayer. The presence of this option is indicated by the assertion of the FEC_bypass_correction_ability variable (see 91.6.3). When the option is provided, it is enabled by the assertion of the FEC_bypass_correction_enable variable (see 91.6.1).

The Reed-Solomon decoder may optionally provide the option to indicate errors to the PCS sublayer by intentionally corrupting 66-bit block synchronization headers. The presence of this option is indicated by the assertion of the FEC_error_indication_ability variable (see 91.6.4). When the option is provided, it is enabled by the assertion of the FEC_error_indication_enable variable (see 91.6.2).

When the error indication function is enabled and the decoder determines that a codeword contains errors (when the bypass correction feature is enabled) or is uncorrectable (when the bypass correction feature is not supported or enabled), it shall ensure that, for every other 257-bit block within the codeword starting with the first (1st, 3rd, 5th, etc.), the synchronization header for the first 66-bit block at the output of the 256B/267B to 64B/66B transcoder, rx_coded_0<1:0>, is set to 11. In addition, it shall ensure rx_coded_3<1:0> corresponding to the last (20th) 257-bit block in the codeword is set to 11. This will cause the PCS to discard all frames 64 bytes and larger that are fully or partially within the codeword.

91.5.3.4 Alignment marker removal

The first 1285 message bits in every 4096th codeword is the vector am_rxmapped<1284:0> where bit 0 is the first bit received. The specific codewords that include this vector are indicated by the alignment lock and deskew function (refer to 91.5.3.1).

For the optional EEE capability, transitions between normal alignment markers and Rapid Alignment markers result in changes in relative position and frequency of am_rxmapped<1284:0>. These transitions are detected by the Receive LPI state diagram (see Figure 91-11) and this information is used by the alignment marker removal function to determine which bits are to be removed. The rx_lpi_active is true, the first 1285 message bits in every other codeword is the vector am_rxmapped<1284:0>.

The vector am_rxmapped shall be removed prior to transcoding.

91.5.3.5 256B/257B to 64B/66B transcoder

The transcoder extracts a group of four 66-bit blocks, rx_coded_j<65:0> where $j=0$ to 3, from each 257-bit block rx_scrambled<256:0>. Bit 0 of the 257-bit block is the first bit received.

First, descramble the first 5 bits, based on reception order, of rx_scrambled<256:0> to yield rx_xcoded<256:0> as follows.

- a) Set rx_xcoded<4:0> to the result of the bit-wise exclusive-OR of the rx_scrambled<4:0> and rx_scrambled<12:8>.
- b) Set rx_xcoded<256:5> to rx_scrambled<256:5>.

If $\text{rx_xcoded}_{<0>}$ is 1, $\text{rx_coded}_j_{<65:0>}$ for $j=0$ to 3 shall be derived as follows.

- a) $\text{rx_coded}_j_{<65:2>} = \text{rx_xcoded}_{<(64j+64):(64j+1)>}$ for $j=0$ to 3
- b) $\text{rx_coded}_j_{<0>}=0$ and $\text{rx_coded}_j_{<1>}=1$ for all $j=0$ to 3

If $\text{rx_xcoded}_{<0>}$ is 0 and any $\text{rx_coded}_{<j+1>}=1$ for $j=0$ to 3, $\text{rx_coded}_j_{<65:0>}$ for $j=0$ to 3 shall be derived as follows.

- a) Let c be the smallest value of j such that $\text{rx_xcoded}_{<j+1>}=0$. In other words, rx_coded_c will be the first 66-bit control block in the resulting group of four blocks.
- b) Let rx_payloads be a vector representing the payloads of the four 66-bit blocks. It is derived using the following expressions.
 $\text{rx_payloads}_{<(64c+3):0>} = \text{rx_xcoded}_{<(64c+8):5>}$
 $\text{rx_payloads}_{<(64c+7):(64c+4)>} = 0000$ (an arbitrary value that is later replaced by s_c)
 $\text{rx_payloads}_{<255:(64c+8)>} = \text{rx_xcoded}_{<256:(64c+9)>}$
- c) $\text{rx_coded}_j_{<65:2>} = \text{rx_payloads}_{<(64j+63):64j>}$ for $j=0$ to 3
- d) Let $f_{<c:3:0>} = \text{rx_coded}_c_{<5:2>}$ be the scrambled first nibble (based on transmission order) of the block type field for rx_coded_c .
- e) Descramble $f_{<c:3:0>}$ to yield $g_{<3:0>}$ per the following expression where “^” denotes the exclusive-OR operation. When $c=0$, $\text{rx_coded}_{(c-1)}$ corresponds to rx_coded_3 from the previous 257-bit block.
 $g_{<i>} = f_{<c:i>} \wedge \text{rx_coded}_{(c-1)}_{<i+8>} \wedge \text{rx_coded}_{(c-1)}_{<i+27>}$ for $i=0$ to 3
- f) The block type field may be uniquely identified by either its most or least significant nibble. Since $g_{<3:0>}$ is the least significant nibble of the block type field (per the transmission order), derive $h_{<3:0>}$ by cross-referencing to $g_{<3:0>}$ using Figure 82-5. For example, if $g_{<3:0>}$ is 0xE then $h_{<3:0>}$ is 0x1. If no match to $g_{<3:0>}$ is found, $h_{<3:0>}$ is set to 0000.
- g) if $\text{rx_xcoded}_{<j+1>}=0$, $\text{rx_coded}_j_{<0>}=1$ and $\text{rx_coded}_j_{<1>}=0$ for $j=0$ to 3
- h) if $\text{rx_xcoded}_{<j+1>}=1$, $\text{rx_coded}_j_{<0>}=0$ and $\text{rx_coded}_j_{<1>}=1$ for $j=0$ to 3
- i) if $h_{<3:0>} = 0000$, $\text{rx_coded}_c_{<1>}=1$ (invalidate synchronization header)

If $\text{rx_xcoded}_{<0>}$ is 0 and all $\text{rx_coded}_{<j+1>}=1$ for $j=0$ to 3, $\text{rx_coded}_j_{<65:0>}$ for $j=0$ to 3 shall be derived as follows.

- a) Set $c = 1$ and $h_{<3:0>} = 0000$.
- b) Let rx_payloads be a vector representing the payloads of the four 66-bit blocks. It is derived using the following expressions.
 $\text{rx_payloads}_{<(64c+3):0>} = \text{rx_xcoded}_{<(64c+8):5>}$
 $\text{rx_payloads}_{<(64c+7):(64c+4)>} = 0000$ (an arbitrary value that is later replaced by s_c)
 $\text{rx_payloads}_{<255:(64c+8)>} = \text{rx_xcoded}_{<256:(64c+9)>}$
- c) $\text{rx_coded}_j_{<0>}=0$ and $\text{rx_coded}_j_{<1>}=0$ for $j=0$ and 2
- d) $\text{rx_coded}_j_{<0>}=1$ and $\text{rx_coded}_j_{<1>}=1$ for $j=1$ and 3

If $\text{rx_xcoded}_{<0>}$ is 0, scramble $h_{<3:0>}$ to yield $s_{<c:3:0>}$ and assign it to rx_coded_c per the following expressions.

- a) $s_{<c:i>} = h_{<c:i>} \wedge \text{rx_coded}_{(c-1)}_{<i+12>} \wedge \text{rx_coded}_{(c-1)}_{<i+31>}$ for $i=0$ to 3
- b) $\text{rx_coded}_c_{<9:6>} = s_{<c:3:0>}$

The 66-bit blocks are transmitted in order from $j=0$ to 3. Bit 0 of each block is the first bit transmitted.

91.5.3.6 Block distribution

After the data has been transcoded, it shall be distributed to multiple PCS lanes, one 66-bit block at a time in a round robin distribution from the lowest to the highest numbered PCS lanes. The distribution process is shown in Figure 82–6.

91.5.3.7 Alignment marker mapping and insertion

The alignment marker mapping function compensates for operation of lane reorder function (refer to 91.5.3.2) to derive the PCS lane alignment markers, $am_rx_x<65:0>$ for $x=0$ to 19, from $am_rxmapped<1284:0>$ (refer to 91.5.3.4).

The alignment markers shall be derived from $am_rxmapped<1284:0>$ in a manner that yields the same result as the process defined below.

Given $i=0$ to 3, $k=0$ to 31, and $y=i+4k$, $am_rxpayloads$ may be derived from $am_rxmapped$ per the following expression.

$$am_rxpayloads<i, (10k+9):10k> = am_rxmapped<(10y+9):10y>$$

Given $i=0$ to 3, $j=0$ to 4, and $x=i+4j$, the am_rx_x may be derived from $am_rxpayloads$ by the following expression.

$$am_rx_x<65:2> = am_rxpayloads<i, (64j+63):64j>$$

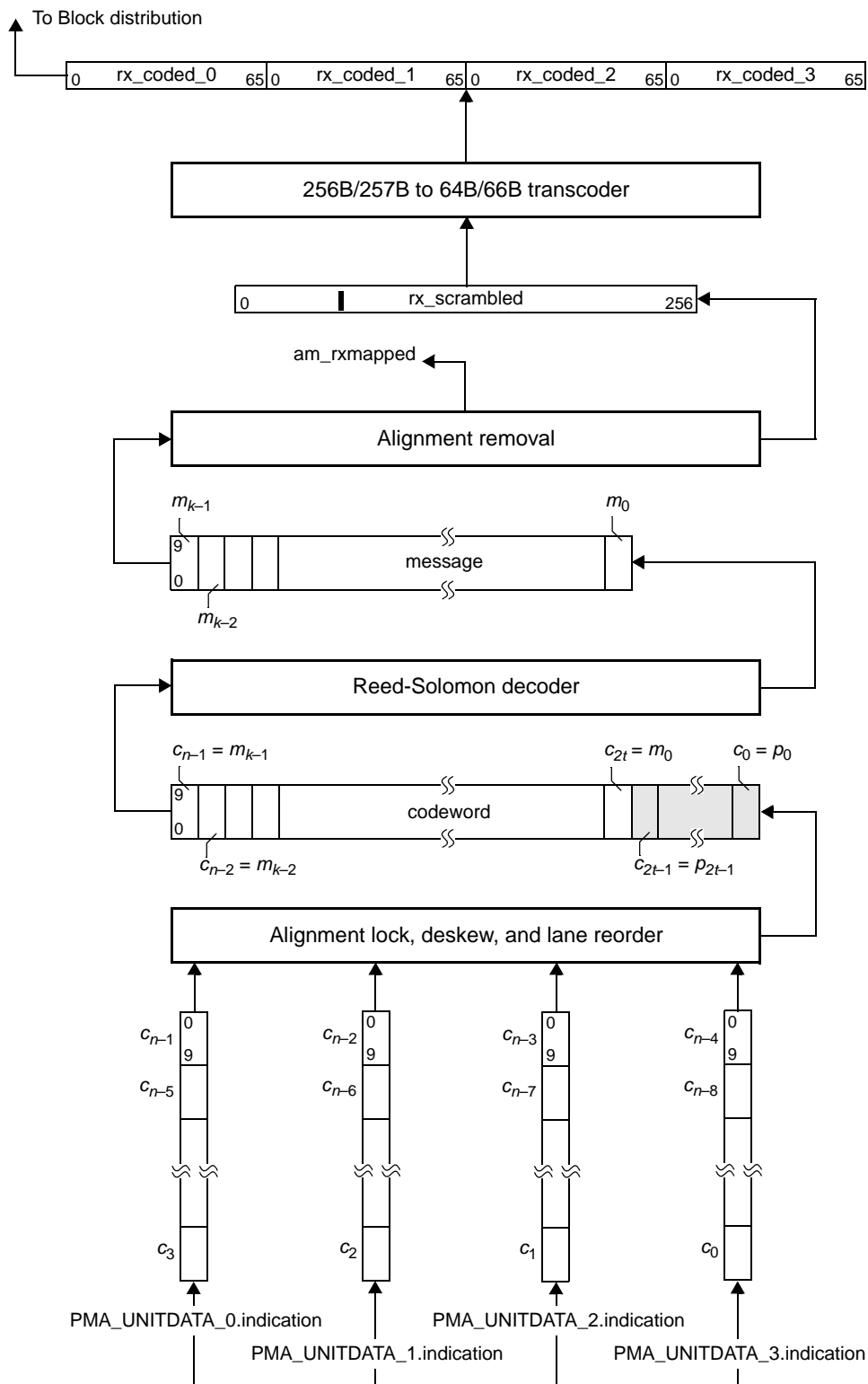
Finally, $am_rx_x<0>=1$ and $am_rx_x<1>=0$ for all $x=0$ to 19.

One vector is mapped to 20 alignment markers every 4096 Reed-Solomon codewords (see 91.5.3.4). The alignment markers are simultaneously transmitted on the 20 PCS lanes after every 16383rd column of 20 66-bit blocks.

For the optional EEE capability, when rx_lpi_active is true, one vector is mapped to 20 Rapid Alignment Markers every 2 Reed-Solomon codewords. The Rapid Alignment Markers are simultaneously transmitted on the 20 PCS lanes after every 7th column of 20 66-bit blocks.

91.5.3.8 Receive bit ordering

The receive bit ordering is illustrated in Figure 91–7. This illustration shows the case where the FEC lanes appear across the $PMA:IS_UNITDATA_i.indication$ primitives in the correct order.

**Figure 91-7—Receive bit ordering**

91.5.4 Detailed functions and state diagrams

91.5.4.1 State diagram conventions

The body of this subclause is comprised of state diagrams, including the associated definitions of variables, functions, and counters. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. The notation ++ after a counter or integer variable indicates that its value is to be incremented.

91.5.4.2 State variables

91.5.4.2.1 Variables

align_status

Boolean variable that is set by the alignment lock and deskew function (see 91.5.2.2).

all_locked

A Boolean variable that is set to true when $\text{amps_lock}_{<x>}$ is true for all x and is set to false when $\text{amps_lock}_{<x>}$ is false for any x .

amp_counter_done

Boolean variable that indicates that **amp_counter** has reached its terminal count.

amp_match

Boolean variable that holds the output of the function **AMP_COMPARE**.

amp_valid

Boolean variable that is set to true if the received 64-bit block is a valid alignment marker payload. The alignment marker payload, mapped to an FEC lane according to the process described in 91.5.2.6, consists of 48 known bits unique to each PCS lane and 16 variable bits (the BIP_3 or CD_3 field and its complement BIP_7 or CD_7 , see 82.2.7). The bits of the candidate block that are in the positions of the known bits in the alignment marker payload are compared on a nibble-wise basis (12 comparisons). If no more than 3 nibbles in the candidate block fail to match the corresponding known nibbles in the alignment marker payload, the candidate block is considered a valid alignment marker payload. For the normal mode of operation, each FEC lane compares the candidate block to the alignment marker payload for PCS lanes 0, 1, 2, and 3. For the optional EEE capability, each FEC lane also compares the candidate block to the alignment marker payload for PCS lanes 16, 17, 18, and 19.

Editor's note (to be removed prior to final publication):

The maximum distance permitted between the candidate block and the reference pattern (3 nibbles) was calculated for the 100GBASE-KR4 PHY. It should be confirmed that this value is also suitable for the 100GBASE-KP4 PHY.

amps_lock<x>

Boolean variable that is set to true when the receiver has detected the location of the alignment marker payload sequence for a given FEC lane where $x = 0:3$.

current_pcs1

A variable that holds the PCS lane number corresponding to the current alignment marker payload that is recognized on a given FEC lane. It is compared to the variable **first_pcs1** to confirm that the location of the alignment marker payload sequence has been detected.

cw_bad	1
A Boolean variable that is set to true if the Reed-Solomon decoder (see 91.5.3.3) fails to correct the current FEC codeword and is set to false otherwise.	2
fec_align_status	3
A variable set by the FEC alignment process to reflect the status of FEC lane-to-lane alignment. Set to true when all lanes are synchronized and aligned and set to false when the deskew process is not complete.	4
fec_alignment_valid	5
Boolean variable that is set to true if all FEC lanes are aligned. FEC lanes are considered to be aligned when amps_lock<x> is true for all x and the FEC lanes are deskewed. Otherwise, this variable is set to false.	6
fec_enable_deskew	7
A Boolean variable that enables and disables the deskew process. Received bits may be discarded whenever deskew is enabled. It is set to true when deskew is enabled and it is set to false when deskew is disabled.	8
first_pcs1	9
A variable that holds the PCS lane number that corresponds to the first alignment marker payload that is recognized on a given FEC lane. It is compared to the PCS lane number corresponding to the second alignment marker payload that is tested.	10
reset	11
Boolean variable that controls the resetting of the FEC. It is true whenever a reset is necessary including when reset is initiated from the MDIO, during power on, and when the MDIO has put the PCS into low-power mode.	12
restart_lock	13
Boolean variable that is set by the FEC alignment process to reset the synchronization process on all FEC lanes. It is set to true after 3 consecutive uncorrected codewords are received (3_BAD state) and set to false upon entry into the LOSS_OF_ALIGNMENT state.	14
signal_ok	15
Boolean variable that is set based on the most recently received value of <i>inst:IS_SIGNAL.indication</i> (SIGNAL_OK). It is true if the value was OK and false if the value was FAIL.	16
slip_done	17
Boolean variable that is set to true when the SLIP requested by the synchronization state diagram has been completed indicating that the next candidate 64-bit block position can be tested.	18
test_amp	19
Boolean variable this is set to true when a candidate block position is available for testing and false when the FIND_1ST state is entered.	20
test_cw	21
Boolean variable that is set to true when a new FEC codeword is available for decoding and is set to false when the TEST_CW state is entered.	22
The following variables are only used for the optional EEE capability. If this capability is not supported, the values of tx_lpi_active and rx_lpi_active are set to false.	23
1st_ram_counter_done	24
Boolean variable that indicates that 1st_ram_counter has reached its terminal count.	25
1st_ramps_counter_done	26
Boolean variable that indicates that 1st_ramps_counter has reached its terminal count.	27
ram_counter_done	28
Boolean variable that indicates that ram_counter has reached its terminal count.	29
ram_valid	30
Boolean variable that is set to true when the 66-bit blocks concurrently received on at TBD PCS lanes are valid alignment markers and is set to false otherwise.	31
ramps_counter_done	32
Boolean variable that indicates that ramps_counter has reached its terminal count.	33

ramps_valid

Boolean variable that is set to true when the 66-bit blocks concurrently received on at least TBD PCS lanes are valid alignment markers and is set to false otherwise.

rx_down_count

The value that results from the bit-wise exclusive-OR of the Count Down (CD₃) byte and the M₀ byte of the current Rapid Alignment Marker payload (see 82.2.8a).

rx_lpi_active

A Boolean variable that is set to true when the RS-FEC sublayer infers that the Low Power Idle is being received from the link partner and is set to false otherwise.

rx_quiet_timer_done

A Boolean variable that indicates that rx_quiet_timer has reached its terminal count.

tx_down_count

The value that results from the bit-wise exclusive-OR of the Count Down (CD₃) byte and the M₀ byte of the current Rapid Alignment Marker (see 82.2.8a).

tx_lpi_active

A Boolean variable that is set to true when the RS-FEC sublayer infers that the local PCS is transmitting Low Power Idle and is set to false otherwise.

tx_quiet_timer_done

Boolean variable that indicates that tx_quiet_timer has reached its terminal count.

91.5.4.2.2 Functions

AMP_COMPARE

This function compares the values of first_pcs1 and current_pcs1 to determine if a valid alignment marker payload sequence has been detected and returns the result of the comparison using the variable amp_match. When rx_lpi_active is false, if current_pcs1 equals first_pcs1, amp_match is set to true. When rx_lpi_active is true, the comparison is performed as follows. If first_pcs1 is either 0, 1, 2, or 3 then amp_match is set to true if current_pcs1 is first_pcs1+16. If first_pcs1 is 16, 17, 18, or 19 then amp_match is set to true if current_pcs1 is first_pcs1-16. Otherwise, amp_match is set to false.

SLIP

Causes the next candidate block position to be tested. The precise method for determining the next candidate block position is not specified and is implementation dependent. However, an implementation shall ensure that all possible block positions are evaluated.

91.5.4.2.3 Counters

amp_counter

When rx_lpi_active is false, this counter counts the 4096 FEC codewords that separate the ends of two consecutive normal alignment marker payload sequences. An FEC codeword is 1320 bits per FEC lane for 100GBASE-KR4 and 1360 bits per FEC lane for 100GBASE-KP4. When rx_lpi_active is true, then amp_counter is defined as follows. If first_pcs1 corresponds to PCS lane 0, 1, 2, or 3, it counts the 256 bits to the end of the expected location of the Rapid Alignment Marker payload corresponding to PCS lanes 16, 17, 18, or 19. If first_pcs1 corresponds to PCS lane 16, 17, 18, or 19, this counter counts the 2 FEC codewords minus 256 bits to the end of the expected location of the next Rapid Alignment Marker payload corresponding to PCS lanes 0, 1, 2, or 3.

cw_bad_count

Counts the number of consecutive uncorrected FEC codewords. This counter is set to zero when an FEC codeword is received and cw_bad is false for that codeword.

The following counters are only used for the optional EEE capability.

1st_ram_counter	1
This counter counts 4 66-bit blocks from the end of one candidate RAM position to the end of the next candidate RAM position. The first instance of the counter counts from the end of the last normal alignment marker received.	2
	3
	4
1st_ramps_counter	5
This counter counts one FEC codeword from the end of one candidate RAM payload to the end of the next RAM payload position. An FEC codeword is 1320 bits per FEC lane for 100GBASE-KR4 and 1360 bits per FEC lane for 100GBASE-KP4	6
	7
	8
ram_counter	9
This counter counts 8 66-bit blocks from the end of the current RAM to the end of the next expected RAM position.	10
	11
ramps_counter	12
This counter counts 2 FEC codewords from the end of the current RAM payload to the end of the next expected RAM payload position.	13
	14
rx_quiet_timer	15
This timer limits the maximum time fec_align_status may be deasserted before the Transmit LPI state diagram concludes that the link has failed. The value of this timer is between TBD and TBD ,ms.	16
	17
	18
tx_quiet_timer	19
This timer limits the maximum time align_status may be deasserted before the Transmit LPI state diagram concludes that the link has failed. The value of this timer is between TBD and TBD ,ms.	20
	21

91.5.4.3 State diagrams

The FEC shall implement four synchronization processes as shown in Figure 91–8. The synchronization process operates independently on each lane. The synchronization state diagram determines when the FEC has detected the location of the alignment marker payload sequence in the received bit stream for a given lane of the service interface.

The FEC shall implement the alignment process as shown in Figure 91–9.

When the optional EEE capability is supported, the FEC shall also implement the Transmit LPI process as shown in Figure 91–10 and the Receive LPI process as shown in Figure 91–11. The Transmit LPI state diagram infers when Low Power Idle is being transmitted by the local PCS by checking for the presence of Rapid Alignment Markers. The Receive LPI state diagram infers when Low Power Idle is being received from the link partner using a similar mechanism. Monitoring the position and frequency of alignment markers is also critical to the operation of the alignment marker removal function (see 91.5.2.4 and 91.5.3.4).

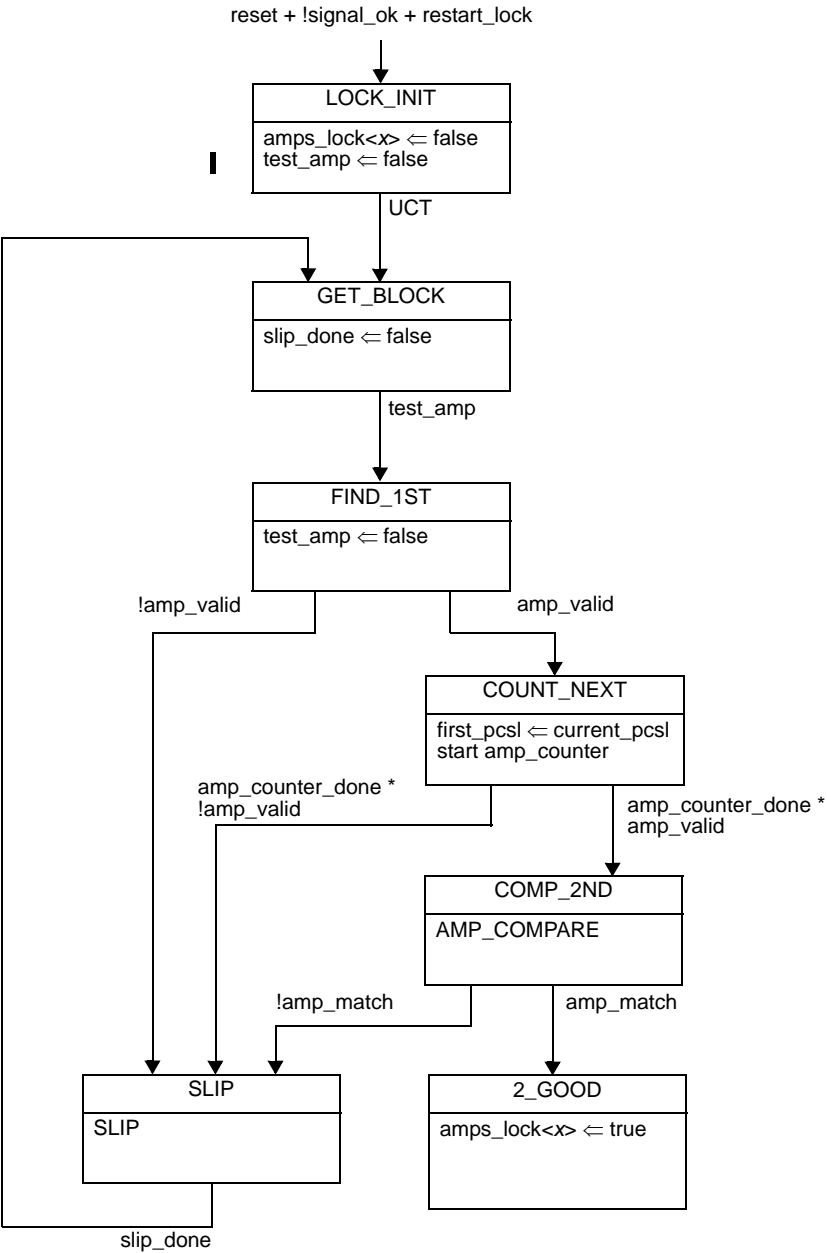
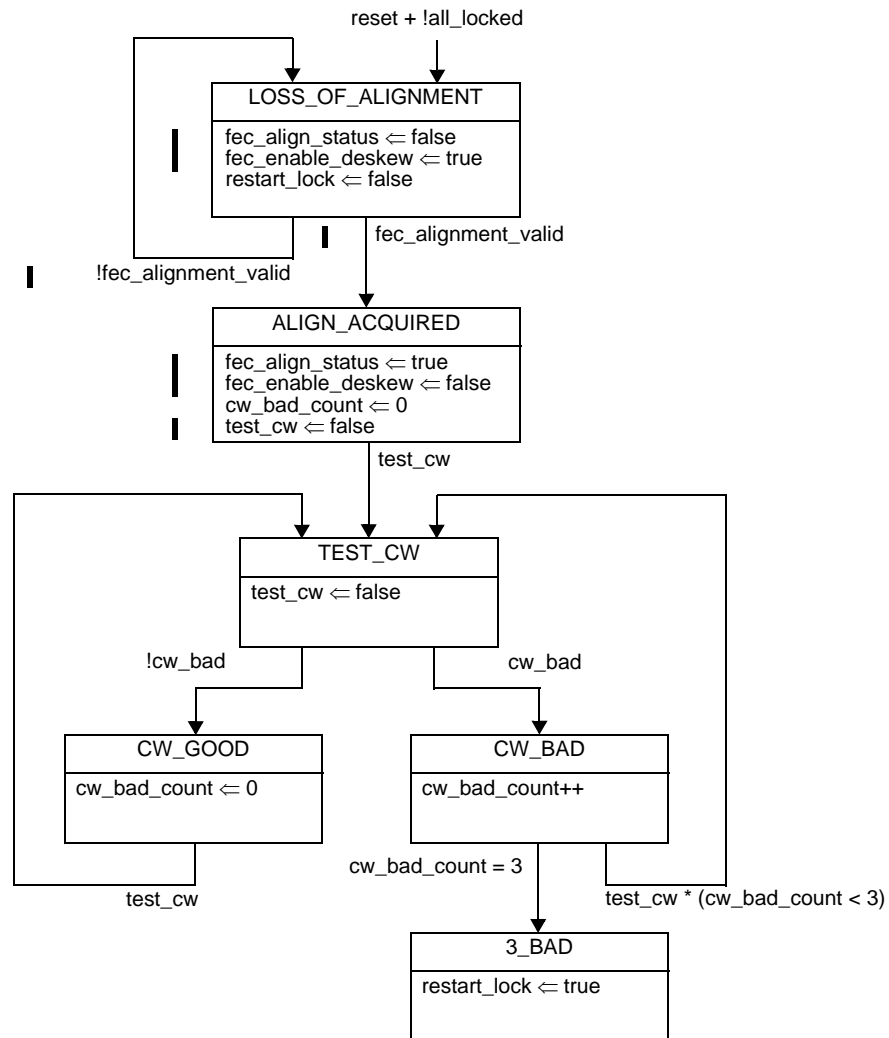


Figure 91–8—FEC synchronization state diagram

**Figure 91–9—FEC alignment state diagram**

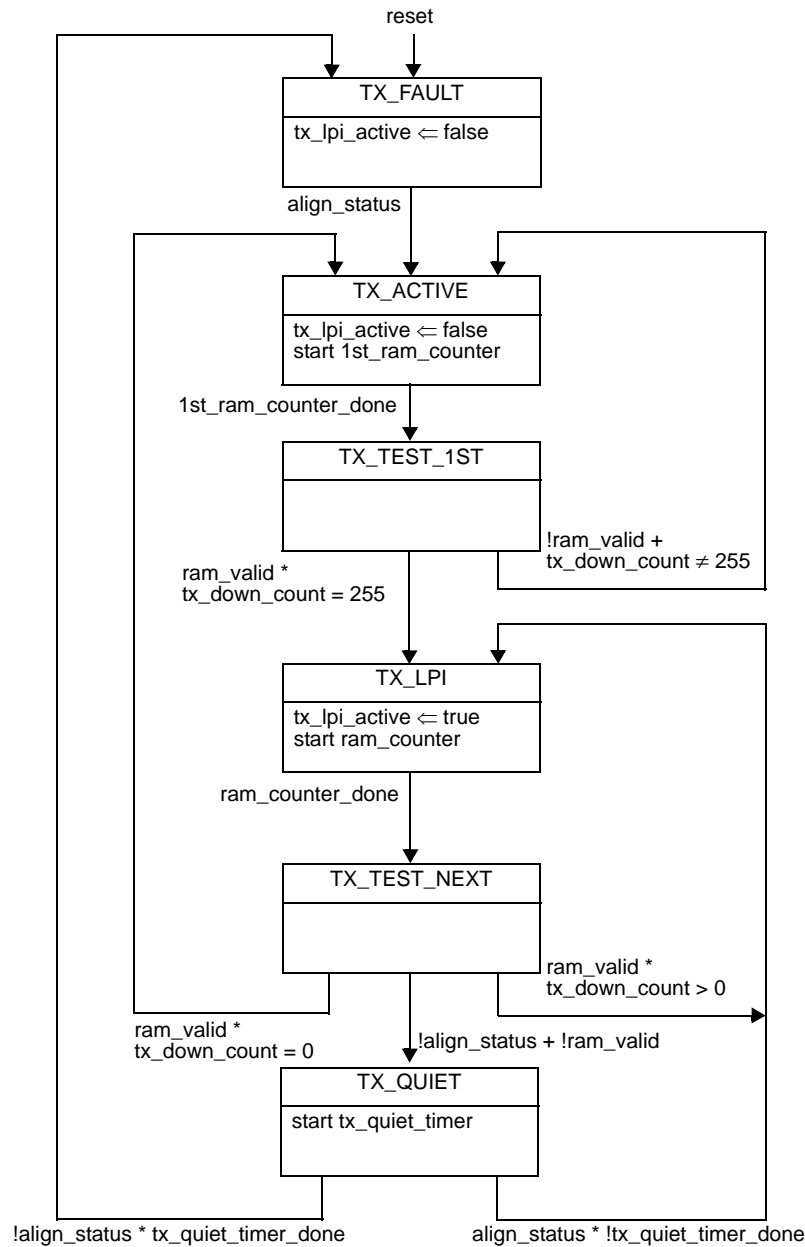
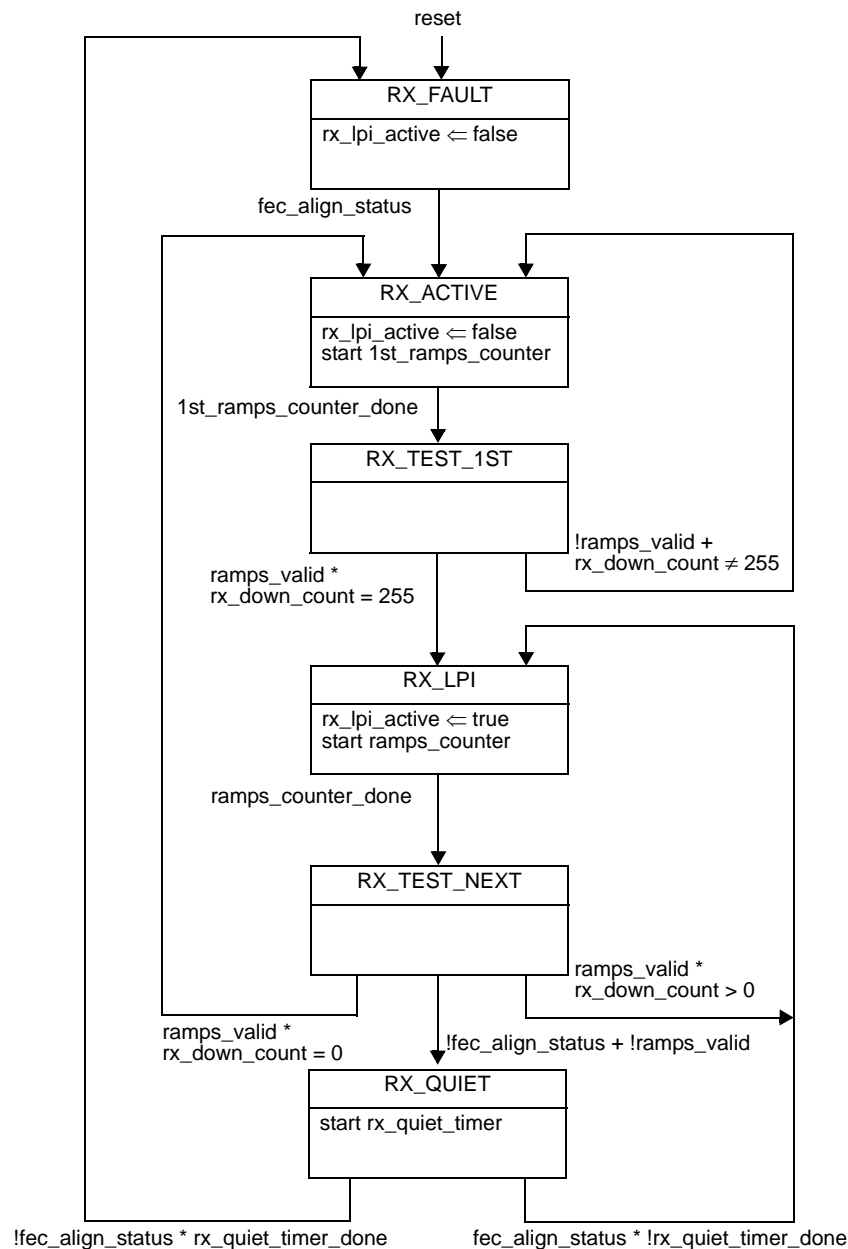


Figure 91–10—Transmit LPI state diagram

**Figure 91-11—Receive LPI state diagram**

91.6 RS-FEC management

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the RS-FEC. If MDIO is implemented, it shall map MDIO control variables to RS-FEC control variables as shown in Table 91-2, and MDIO status variables to RS-FEC status variables as shown in Table 91-3.

Table 91–2—MDIO/RS-FEC control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	FEC variable
FEC bypass correction enable	RS-FEC control register	1.200.0	FEC_bypass_correction_enable
FEC error indication enable	RS-FEC control register	1.200.1	FEC_error_indication_enable

Table 91–3—MDIO/RS-FEC status variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	FEC variable
FEC bypass correction ability	RS-FEC status register	1.201.0	FEC_bypass_correction_ability
FEC error indication ability	RS-FEC status register	1.201.1	FEC_error_indication_ability
FEC corrected codewords	RS-FEC corrected code-words counter register	1.202, 1.203	FEC_corrected_cw_counter
FEC uncorrected codewords	RS-FEC uncorrected code-words counter register	1.204, 1.205	FEC_uncorrected_cw_counter
FEC symbol errors, FEC lanes 0 to 3	RS-FEC symbol error counter register, FEC lanes 0 to 3	1.210 to 1.217	FEC_symbol_error_counter_i
BIP errors, PCS lanes 0 to 19	RS-FEC BIP error counter register, PCS lanes 0 to 19	1.230 to 1.249	BIP_error_counter_i

91.6.1 FEC_bypass_correction_enable

When this variable is set to one the Reed-Solomon decoder performs error detection without error correction (see 91.5.3.3). When this variable is set to zero, the decoder also performs error correction. This variable is mapped to the bit defined in 45.2.1.93a (1.200.0).

91.6.2 FEC_error_indication_enable

This variable is set to one to enable indication of decoding errors to the PCS sublayer (see 91.5.3.3) when this feature is supported. When set to zero, the error indication function is disabled. This variable is mapped to the bit defined in 45.2.1.93a (1.200.1).

91.6.3 FEC_bypass_correction_ability

The Reed-Solomon decoder may have the option to perform error detection without error correction (see 91.5.3.3) to reduce the delay contributed by the RS-FEC sublayer. This variable is set to one to indicate that the decoder has the ability to bypass error correction. The variable is set to zero if this ability is not supported. This variable is mapped to the bit defined in 45.2.1.93b (1.201.0).

91.6.4 FEC_error_indication_ability

The RS-FEC sublayer may have the option to indicate decoding errors to the PCS sublayer by intentionally corrupting 66-bit block synchronization headers as defined in 91.5.3.3. This variable is set to one to indicate that the RS-FEC sublayer has the ability to indicate decoding errors to the PCS sublayer. The variable is set to zero if this ability is not supported. This variable is mapped to the bit defined in 45.2.1.93b (1.201.1).

91.6.5 FEC_corrected_cw_counter

FEC_corrected_cw_counter is a 32-bit counter that counts once for each corrected FEC codeword processed when fec_align_status is true. This variable is mapped to the registers defined in 45.2.1.93c (1.202, 1.203).

91.6.6 FEC_uncorrected_cw_counter

FEC_uncorrected_cw_counter is a 32-bit counter that counts once for each uncorrected FEC codeword processed when fec_align_status is true. This variable is mapped to the registers defined in 45.2.1.93d (1.204, 1.205).

91.6.7 FEC_symbol_error_counter_{*i*}

FEC_symbol_error_counter_{*i*}, where $i=0$ to 3, is a 32-bit counter that counts once for each 10-bit symbol corrected on FEC lane i when fec_align_status is true. This variable is mapped to the registers defined in 45.2.1.93e (1.210 to 1.217).

91.6.8 BIP_error_counter_{*i*}

BIP_error_counter_{*i*}, where $i=0$ to 19, is a 16-bit counter that holds the BIP error count for PCS lane i as calculated by the RS-FEC transmit function (see 91.5.2.4). This variable is mapped to the registers defined in 45.2.1.93g (1.230 to 1.249).

1 **91.7 Protocol implementation conformance statement (PICS) proforma for**
2 **Clause 91, Reed-Solomon Forward Error Correction (RS-FEC) sublayer for**
3 **100GBASE-R PHYs⁹**
4

5 **91.7.1 Introduction**
6

7 The supplier of a protocol implementation that is claimed to conform to Clause 91, Reed-Solomon Forward
8 Error Correction (RS-FEC) sublayer for 100GBASE-R PHYs, shall complete the following protocol imple-
9 mentation conformance statement (PICS) proforma.

10
11 A detailed description of the symbols used in the PICS proforma, along with instructions for completing the
12 PICS proforma, can be found in [Clause 21](#).
13

14 **91.7.2 Identification**
15

16 **91.7.2.1 Implementation identification**
17

Supplier ¹	
Contact point for enquiries about the PICS ¹	
Implementation Name(s) and Version(s) ^{1,3}	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s) ²	
NOTE 1— Required for all implementations. NOTE 2— May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier’s terminology (e.g., Type, Series, Model).	

31
32
33 **91.7.2.2 Protocol summary**
34
35

Identification of protocol standard	IEEE Std 802.3bj-20XX, Clause 91, Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 100GBASE-R PHYs
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [] Yes [] (See Clause 21 ; the answer Yes means that the implementation does not conform to IEEE Std 802.3bj-20XX.)	

Date of Statement	
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53 ⁹*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can
54 be used for its intended purpose and may further publish the completed PICS.

91.7.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*KR4	100GBASE-KR4		Used to form complete 100GBASE-KR4 PHY	O	Yes [] No []
*KP4	100GBASE-KP4		Used to form complete 100GBASE-KR4 PHY	O	Yes [] No []
DC	Delay constraints	91.4	Conforms to delay constraints specified in 91.4	M	Yes []
*MD	MDIO capability	91.6	Registers and interface supported	O	Yes [] No []
*EEE	EEE capability	91.5.4.3	Capability is supported	O	Yes [] No []
*EI	Error indication function	91.5.3.3	Function is supported	O	Yes [] No []

91.7.4 PICS proforma tables for Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 100GBASE-R PHYs

91.7.4.1 Transmit function

Item	Feature	Subclause	Value/Comment	Status	Support
TF1	Skew tolerance	91.5.2.2	Maximum Skew of 49 ns between PCS lanes and a maximum Skew Variation of 400 ps	M	Yes []
TF2	Lane reorder	91.5.2.3	Order the PCS lanes according to the PCS lane number	M	Yes []
TF3	64B/66B to 256B/257B transcoder	91.5.2.5	tx_xcoded<256:0> constructed per 91.5.2.5	M	Yes []
TF4	257-bit block transmission order	91.5.2.5	First bit transmitted is bit 0	M	Yes []
TF5	Alignment maker mapping	91.5.2.6	Map to am_txmapped<1284:0> per 91.5.2.6	M	Yes []
TF6	Pad value	91.5.2.6	Binary values 00101 and 11010 (the leftmost bit is assigned to the highest bit index) in an alternating pattern	M	Yes []
TF7	Alignment marker insertion	91.5.2.6	First 1285 message bits to be transmitted from every 4096 th codeword	M	Yes []
TF8	Alignment marker insertion when tx_lpi_active is true	91.5.2.6	First 1285 message bits to be transmitted from every other codeword	EEE:M	Yes [] N/A []
TF9	Reed-Solomon encoder for 100GBASE-KR4	91.5.2.7	RS(528,514)	KR4:M	Yes [] N/A []
TF10	Reed-Solomon encoder for 100GBASE-KP4	91.5.2.7	RS(528,514)	KP4:M	Yes [] N/A []
TF11	Symbol distribution	91.5.2.8	Distributed to 4 FEC lanes, one 10-bit symbol at a time in a round robin distribution from the lowest to the highest numbered FEC lane	M	Yes []

91.7.4.2 Receive function

Item	Feature	Subclause	Value/Comment	Status	Support
RF1	Skew tolerance	91.5.3.1	Maximum Skew of 180 ns between FEC lanes and a maximum Skew Variation of 4 ns	M	Yes []
RF2	Lane reorder	91.5.3.2	Order the FEC lanes according to the FEC lane number	M	Yes []
RF3	Reed-Solomon decoder for 100GBASE-KR4	91.5.3.3	Capable of correcting any combination of up to $t=7$ symbol errors in a codeword	KR4:M	Yes [] N/A []
RF4	Reed-Solomon decoder for 100GBASE-KP4	91.5.3.3	Capable of correcting any combination of up to $t=15$ symbol errors in a codeword	KP4:M	Yes [] N/A []
RF5	Reed-Solomon decoder	91.5.3.3	Capable of detecting uncorrectable codewords	M	Yes []
RF6	Error indications function	91.5.3.3	When enabled, corrupts 66-bit block synchronization headers for uncorrectable codewords (or errored codewords when correction is bypassed)	EI:M	Yes [] N/A []
RF7	Alignment marker removal	91.5.2.4	am_rxmapped removed prior to transcoding	M	Yes []
RF8	256B/257B to 64B/66B transcoder	91.5.3.5	rx_coded_j<65:0>, j=0 to 3 constructed per 91.5.3.5	M	Yes []
RF9	Block distribution	91.5.3.6	One 66-bit block at a time in a round robin fashion from the lowest to the highest numbered PCS lane	M	Yes []
RF10	Alignment marker mapping	91.5.3.7	Map to am_rx_x, x=0 to 19 per 91.5.3.7	M	Yes []

91.7.4.3 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	SLIP function	91.5.4.2.2	Ensure that all possible block positions are evaluated	M	Yes []
SD2	Synchronization process	91.5.4.3	One instance per FEC lane per Figure 91–8	M	Yes []
SD3	Alignment process	91.5.4.3	Per Figure 91–9	M	Yes []
SD4	Transmit LPI process	91.5.4.3	Per Figure 91–10	EEE:M	Yes [] N/A []
SD5	Transmit LPI process	91.5.4.3	Per Figure 91–11	EEE:M	Yes [] N/A []

92. Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-CR4

92.1 Overview

This clause specifies the 100GBASE-CR4 PMD and baseband medium. Annex 92A, an associated annex, provides information on parameters with test points that may not be testable in an implemented system.

When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA as shown in Table 92–1, to the medium through the MDI and to the management functions that are optionally accessible through the management interface defined in Clause 45, or equivalent.

When forming a complete 100GBASE-CR4 Physical Layer, the following guidelines apply..

Table 92–1—Physical Layer clauses associated with the 100GBASE-CR4 PMD

Associated clause	100GBASE-CR4
81—RS	Required
81—CGMII ^a	Optional
82—PCS for 100GBASE-R	Required
91—RS-FEC	Required
83—PMA for 100GBASE-R ^b	Required
83A—CAUI	Optional
73—Auto-Negotiation	Required
78—Energy Efficient Ethernet	Optional

^aThe CGMII is an optional interface. However, if the CGMII is not implemented, a conforming implementation must behave functionally as though the RS and CGMII were present.

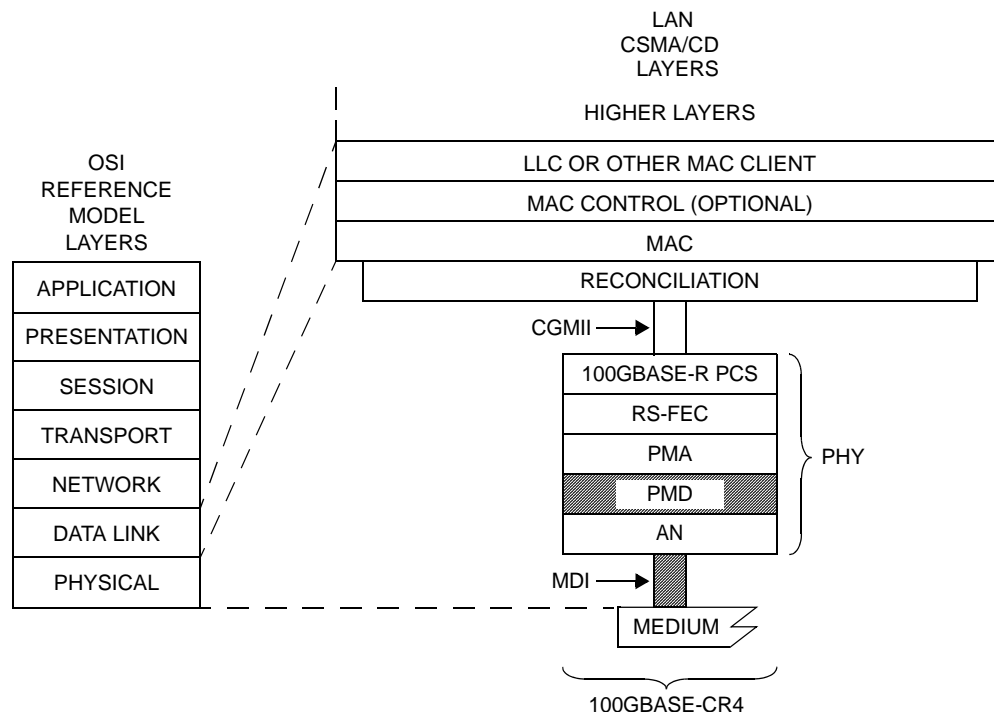
^bThere are limitations on the number of PMA lanes that may be used between sublayers, see 83.3.

A 100GBASE-CR4 PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization.

Differential signals received at the MDI from a transmitter that meets the requirements of 92.8.3 and have passed through the cable assembly specified in 92.10 are received with a BER less than 10^{-5} .

For a complete Physical Layer, this specification is considered to be satisfied by a frame error ratio less than 1.7×10^{-10} for 64 octet frames with minimum inter-packet gap.

Figure 92–1 shows the relationship of the 100GBASE-CR4 PMD sublayers and MDI to the ISO/IEC Open System Interconnection (OSI) reference model.



AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE

PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION

Figure 92–1—100GBASE-CR4 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

92.2 Physical Medium Dependent (PMD) service interface

This subclause specifies the services provided by the 100GBASE-CR4 PMD. The service interface for this PMD is described in an abstract manner and does not imply any particular implementation. The PMD service interface supports the exchange of encoded data. The PMD translates the encoded data to and from signals suitable for the medium.

The PMD service interface is an instance of the inter-sublayer service interface defined in 80.3. The PMD service interface primitives are summarized as follows:

PMD:IS_UNITDATA_*i*.request
PMD:IS_UNITDATA_*i*.indication
PMD:IS_SIGNAL.indication

The 100GBASE-CR4 PMD has four parallel bit streams, hence $i = 0$ to 3. The PMA (or the PMD) continuously sends four parallel bit streams to the PMD (or the PMA), one per lane, each at a nominal signaling rate of 25.78125 GBd.

The SIGNAL_OK parameter in PMD:IS_UNITDATA(SIGNAL_OK) indicates the value of SIGNAL_DETECT specified in 92.7.4.

If the optional EEE capability is supported, then the PMD service interface includes two additional primitives as follows:

PMD:IS_TX_MODE.request
PMD:IS_RX_MODE.request

Editor's note (to be removed prior to final publication):

The PMD service interface has been augmented as implied by barrass_01_0312 per the motion passed in the March Task Force meeting.

“Move that the 802.3bj Task Force adopt barrass_01_0312.pdf as a baseline for optional Energy Efficient Ethernet operation for 100G Backplane and Twinaxial cable PHYs. (M: M. Gustlin, S: M. Brown, Y: 54, N: 0, A: 3)”

Per barrass_01_0312, PMD transmit function behavior changes as a function of the tx_mode parameter.

DATA, SLEEP, or WAKE: normal behavior
ALERT: send the ALERT signal
FW: send a PMA-specific pattern that is TBD (PMD normal behavior?)
QUIET: disable the transmitter

Per barrass_01_0312, the PMD receive function infers rx_mode from the received signal.

Normal or rapid alignment markers: DATA, SLEEP, or WAKE (mapping not defined)
No signal: QUIET
Alert signal: ALERT
PMA-specific pattern for FW that is TBD: FW (PMA function?)

Given the ambiguity surrounding PMD behavior and the TBD signaling for ALERT, FW, etc., these functions have not been added to the clause. The functions will be added to the clause upon adoption of a detailed proposal describing the desired behavior.

92.3 PCS requirements for Auto-Negotiation (AN) service interface

The PCS associated with this PMD is required to support the AN service interface primitive AN_LINK.indication defined in 73.9. (See 82.6.)

92.4 Delay constraints

The sum of the transmit and the receive delays at one end of the link contributed by the 100GBASE-CR4 PMD, AN, and the medium in one direction shall be no more than TBD bit times (TBD pause_quanta or TBD ns). It is assumed that the one way delay through the medium is no more than TBD bit times (TBD ns).

A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 80.4 and its references.

92.5 Skew constraints

The Skew (relative delay) between the lanes must be kept within limits so that the information on the lanes can be reassembled by the PCS. The Skew Variation must also be limited to ensure that a given PCS lane always traverses the same physical lane. Skew and Skew Variation are defined in 80.5 and specified at the points SP1 to SP6 shown in Figure 80–4 and Figure 80–5.

If the PMD service interface is physically instantiated so that the Skew at SP2 can be measured, then the Skew at SP2 is limited to TBD ns and the Skew Variation at SP2 is limited to TBD ps.

The Skew at SP3 (the transmitter MDI) shall be less than TBD ns and the Skew Variation at SP3 shall be less than TBD ps.

The Skew at SP4 (the receiver MDI) shall be less than TBD ns and the Skew Variation at SP4 shall be less than TBD ns.

If the PMD service interface is physically instantiated so that the Skew at SP5 can be measured, then the Skew at SP5 shall be less than TBD ns and the Skew Variation at SP5 shall be less than TBD ns.

For more information on Skew and Skew Variation see 80.5.

92.6 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 92–2, and MDIO status variables to PMD status variables as shown in Table 92–3.

Table 92–2—100GBASE-CR4 MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	PMD control variable
Reset	PMA/PMD control 1	1.0.15	PMD_reset
Global PMD transmit disable	PMD transmit disable	1.9.0	Global_PMD_transmit_disable
PMD transmit disable 3 to PMD transmit disable 0	PMD transmit disable	1.9.4 to 1.9.1	PMD_transmit_disable_3 to PMD_transmit_disable_0
Restart training	BASE-R PMD control	1.150.0	mr_restart_training
Training enable	BASE-R PMD control	1.150.1	mr_training_enable

92.7 PMD functional specifications

92.7.1 Link block diagram

A 100GBASE-CR4 link in one direction is illustrated in Figure 92–2. For purposes of system conformance, the PMD sublayer is standardized at the test points described in this subclause. The electrical transmit signal is defined at TP2. Unless specified otherwise, all transmitter measurements and tests defined in 92.8.3 are made at TP2 utilizing the test fixture specified in 92.11.1. Unless specified otherwise, all receiver

Table 92–3—100GBASE-CR4 MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMD status variable
Fault	PMA/PMD status 1	1.1.7	PMD_fault
Transmit fault	PMA/PMD status 2	1.8.11	PMD_transmit_fault
Receive fault	PMA/PMD status 2	1.8.10	PMD_receive_fault
Global PMD receive signal detect	PMD receive signal detect	1.10.0	Global_PMD_signal_detect
PMD receive signal detect 3 to PMD receive signal detect 0	PMD receive signal detect	1.10.4 to 1.10.1	PMD_signal_detect_3 to PMD_signal_detect_0
Receiver status 3	BASE-R PMD status	1.151.12	rx_trained_3
Frame lock 3	BASE-R PMD status	1.151.13	frame_lock_3
Start-up protocol status 3	BASE-R PMD status	1.151.14	training_3
Training failure 3	BASE-R PMD status	1.151.15	training_failure_3
Receiver status 2	BASE-R PMD status	1.151.8	rx_trained_2
Frame lock 2	BASE-R PMD status	1.151.9	frame_lock_2
Start-up protocol status 2	BASE-R PMD status	1.151.10	training_2
Training failure 2	BASE-R PMD status	1.151.11	training_failure_2
Receiver status 1	BASE-R PMD status	1.151.4	rx_trained_1
Frame lock 1	BASE-R PMD status	1.151.5	frame_lock_1
Start-up protocol status 1	BASE-R PMD status	1.151.6	training_1
Training failure 1	BASE-R PMD status	1.151.7	training_failure_1
Receiver status 0	BASE-R PMD status	1.151.0	rx_trained_0
Frame lock 0	BASE-R PMD status	1.151.1	frame_lock_0
Start-up protocol status 0	BASE-R PMD status	1.151.2	training_0
Training failure 0	BASE-R PMD status	1.151.3	training_failure_0

measurements and tests defined in 92.8.4 are made at TP3 utilizing the test fixture specified in 92.11.1. A mated connector pair has been included in both the transmitter and receiver specifications defined in 92.8.3 and 92.8.4. The maximum insertion loss from TP0 to TP2 or TP3 to TP5 including the test fixture is specified in 92.8.3.5.

The 100GBASE-CR4 channel is defined between the transmitter (TP0) and receiver blocks (TP5) to include the transmitter and receiver differential controlled impedance printed circuit board insertion loss and the cable assembly insertion loss as illustrated in Figure 92–2. Annex 92A provides information on parameters associated with test points TP0 and TP5 that may not be testable in an implemented system. All cable assembly measurements are to be made between TP1 and TP4 as illustrated in Figure 92–2. The cable assembly test fixture of Figure 92–14 or its equivalent, is required for measuring the cable assembly specifications in 92.10 at TP1 and TP4. Two mated connector pairs and the cable assembly test fixture have been included in the cable assembly specifications defined in 92.10. Transmitter and receiver differential controlled impedance printed circuit board insertion losses defined between TP0–TP1 and TP4–TP5

respectively are provided informatively in Annex 92A.

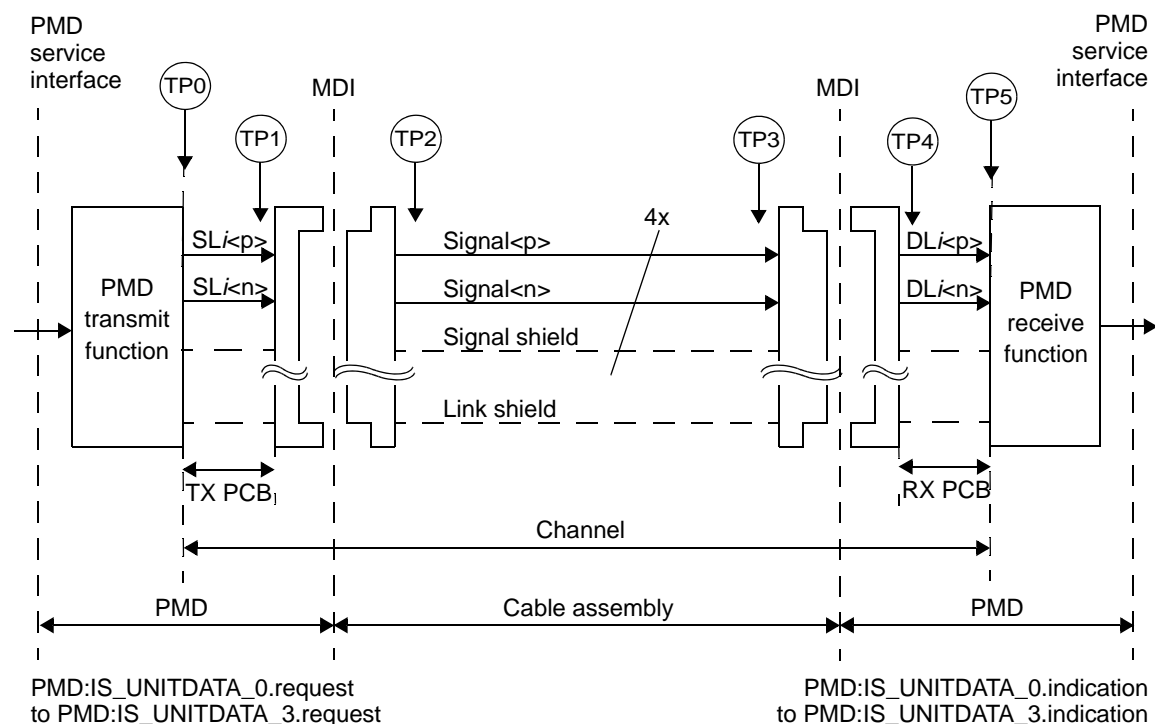


Figure 92-2—100GBASE-CR4 link (one direction is illustrated)

Note that the source lanes (SL), signals $SLi<p>$, and $SLi<n>$ are the positive and negative sides of the transmitters differential signal pairs and the destination lanes (DL) signals, $DLi<p>$, and $DLi<n>$ are the positive and negative sides of the receivers differential signal pairs for lane i ($i = 0, 1, 2, 3$)

Table 92-4 describes the defined test points illustrated in Figure 92-2.

Table 92-4—100GBASE-CR4 test points

Test points	Description
TP0 to TP5	The 100GBASE-CR4 channel including the transmitter and receiver differential controlled impedance printed circuit board insertion loss and the cable assembly insertion loss.
TP1 to TP4	All cable assembly measurements are to be made between TP1 and TP4 as illustrated in Figure 92-2. The cable assembly test fixture of Figure 92-14 or its equivalent, is required for measuring the cable assembly specifications in 92.10 at TP1 and TP4.
TP0 to TP2 TP3 to TP5	A mated connector pair has been included in both the transmitter and receiver specifications defined in 92.8.3 and 92.8.4. The maximum insertion loss from TP0 to TP2 or TP3 to TP5 including the test fixture is specified in 92.8.3.5.
TP2	Unless specified otherwise, all transmitter measurements defined in Table 92-5 are made at TP2 utilizing the test fixture specified in 92.11.1.
TP3	Unless specified otherwise, all receiver measurements and tests defined in 92.8.4 are made at TP3 utilizing the test fixture specified in 92.11.1.

92.7.2 PMD Transmit function

The PMD transmit function shall convert the four bit streams requested by the PMD service interface messages PMD:IS_UNITDATA_0.request to PMD:IS_UNITDATA_3.request into four separate electrical streams. The four electrical signal streams shall then be delivered to the MDI, all according to the transmit electrical specifications in 92.8.3. A positive output voltage of $SLi<p>$ minus $SLi<n>$ (differential voltage) shall correspond to tx_bit = one.

92.7.3 PMD Receive function

The PMD receive function shall convert the four electrical streams from the MDI into four bit streams for delivery to the PMD service interface using the messages PMD:IS_UNITDATA_0.indication to PMD:IS_UNITDATA_3.indication. A positive input voltage of $DLi<p>$ minus $DLi<n>$ (differential voltage) shall correspond to rx_bit = one.

92.7.4 Global PMD signal detect function

The Global PMD signal detect function shall continuously report the message PMD:IS_SIGNAL.indication (SIGNAL_DETECT) to the PMD service interface. SIGNAL_DETECT, while normally intended to be an indicator of signal presence, is used by the 100GBASE-CR4 PMD to indicate the successful completion of the start-up protocol on all lanes. The SIGNAL_DETECT parameter defined in this clause maps to the SIGNAL_OK parameter in the PMD:IS_SIGNAL.indication primitive (see 92.2).

SIGNAL_DETECT shall be set to FAIL following system reset or the manual reset of the training state diagram in Figure 72-5. Upon successful completion of training on all lanes, SIGNAL_DETECT shall be set to OK.

If training is disabled by management, SIGNAL_DETECT shall be set to OK.

If the MDIO interface is implemented, then Global_PMD_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

92.7.5 PMD lane-by-lane signal detect function

When the MDIO is implemented, each PMD_signal_detect_*i* value, where *i* represents the lane number in the range 0 to 3, shall be continuously updated as described in the following two paragraphs.

PMD_signal_detect_0 (1.10.1), PMD_signal_detect_1 (1.10.2), PMD_signal_detect_2 (1.10.3), and PMD_signal_detect_3 (1.10.4) shall be set to one or zero depending on whether a particular lane's signal_detect, as defined by the training state diagram in Figure 72-5, returns true or false.

92.7.6 Global PMD transmit disable function

The Global_PMD_transmit_disable function is optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

- a) When Global_PMD_transmit_disable variable is set to one, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 92-5.
- b) If a PMD_fault (92.7.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
- c) Loopback, as defined in 92.7.8, shall not be affected by Global_PMD_transmit_disable.

92.7.7 PMD lane-by-lane transmit disable function

The PMD lane-by-lane transmit disable function is optional and allows the electrical transmitter in each lane. When this function is supported, it shall meet the following requirements:

- a) When a `PMD_transmit_disable_i` variable (where *i* represents the lane number in the range 0 to 3) is set to one, this function shall turn off the transmitter associated with that variable such that it drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 92–5.
- b) If a `PMD_fault` (92.7.9) is detected, then the PMD may set each `PMD_transmit_disable_i` to one, turning off the electrical transmitter in each lane.
- c) Loopback, as defined in 92.7.8, shall not be affected by `PMD_transmit_disable_i`.

92.7.8 Loopback mode

Local loopback mode is provided by the adjacent PMA (see 83.5.8) as a test function. When loopback mode is enabled, transmission requests passed to each transmitter are sent directly to the corresponding receiver, overriding any signal detected by each receiver on its attached link. Note that loopback mode does not affect the state of the transmitter, which continues to send data (unless disabled).

Control of the loopback function is specified in 45.2.1.1.5.

NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

92.7.9 PMD_fault function

If the MDIO is implemented, `PMD_fault` shall be mapped to the fault bit as specified in 45.2.1.2.1. `PMD_fault` is the logical OR of `PMD_receive_fault`, `PMD_transmit_fault`, and any other implementation specific fault.

92.7.10 PMD transmit fault function

The `PMD_transmit_fault` function is optional. The faults detected by this function are implementation specific, but the assertion of `Global_PMD_transmit_disable` is not considered a transmit fault.

If a `PMD_transmit_fault` is detected, then the `Global_PMD_transmit_disable` function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the Transmit fault bit as specified in 45.2.1.7.4.

92.7.11 PMD receive fault function

The `PMD_receive_fault` function is optional. The faults detected by this function are implementation specific.

If the MDIO interface is implemented, then this function shall contribute to the Receive fault bit as specified in 45.2.1.7.5.

92.7.12 PMD control function

Each lane of the 100GBASE-CR4 PMD shall use the same control function as 10GBASE-KR, as defined in [72.6.10](#).

The training frame structure used by the 100GBASE-CR4 PMD control function shall be as defined in 72.6.10 with the exception that 25.78125 GBd symbols replace 10.3125 GBd symbols and 100GBASE-CR4 UI replace 10GBASE-KR UI.

The seeds of the training pattern described in 72.6.10.2.6 should be chosen to minimize the correlation between lanes on the medium.

The variables *rx_trained_i*, *frame_lock_i*, *training_i*, and *training_failure_i* (where *i* goes from 0 to 3) report status for each lane and are equivalent to *rx_trained*, *frame_lock*, *training*, and *training_failure* as defined in [72.6.10.3.1](#).

If the MDIO interface is implemented, then this function shall map these variables to the appropriate bits in the BASE-R PMD status register (Register 1.151) as specified in [45.2.1.80](#).

92.8 100GBASE-CR4 electrical characteristics

92.8.1 Signal levels

The 100GBASE-CR4 MDI is a low-swing AC coupled differential interface. AC coupling at the receiver, as defined in 92.8.4.6, allows for interoperability between components operating from different supply voltages.

92.8.2 Signal paths

The 100GBASE-CR4 MDI signal paths are point-to-point connections. Each path corresponds to a 100GBASE-CR4 MDI lane and comprises two complementary signals, which form a balanced differential pair. For 100GBASE-CR4, there are four differential paths in each direction for a total of eight pairs, or sixteen connections. The signal paths are intended to operate on twinaxial cable assemblies ranging from 0.5 m to 5 m in length, as described in 92.10.

92.8.3 Transmitter characteristics

Transmitter characteristics are summarized in Table 92–5. Unless specified otherwise, all transmitter measurements defined in Table 92–5 are made at TP2 utilizing the test fixtures specified in 92.11.1. A fourth-order 33 GHz Bessel-Thompson filter is to be used for all transmitter signal measurements. The transmitter

specifications at TP0 are provided informatively in Annex 92A.

Table 92–5—Transmitter characteristics at TP2 summary

Parameter	Subclause reference	Value	Units
Signaling rate, per lane	92.8.3.7	25.78125±100 ppm	GBd
Unit interval nominal	92.8.3.7	38.787879	ps
Differential peak-to-peak output voltage (max) with Tx disabled	92.8.3.1	35	mV
Common-mode voltage (max)	92.8.3.1	1.9	V
Differential output return loss (min)	92.8.3.2	See Equation (92–1)	dB
Common-mode AC output voltage (max., RMS)	92.8.3.1	30	mV
Amplitude peak-to-peak (max)	92.8.3.1	1200 ^a	mV
Transmitter Steady state voltage, v_f	92.8.3.4.1	0.34 min, 0.6 max	V
Linear fit pulse (min) ^b	92.8.3.4	0.52 x Transmitter Steady state voltage	V
Transmitted waveform			
max RMS normalized error (linear fit), “e”	92.8.3.4.2	0.037	
abs coefficient step size	92.8.3.4.4	0.0083 min, 0.05 max	
minimum precursor fullscale ratio	92.8.3.4.5	1.54	
minimum post cursor fullscale ratio	92.8.3.4.5	4	
Far-end transmit output noise (max)	92.8.3.3		mV
Low insertion loss channel		2	
High insertion loss channel		1	
Max output jitter (peak-to-peak)	92.8.3.6		
Effective random jitter		0.15	UI
Even-odd jitter		0.035	UI
Total jitter excluding data dependent jitter		0.28	UI

^aThe 100GBASE-CR4 Style-1 connector may support 100GBASE-CR4 or XLPPI interfaces. For implementations that support both interfaces, the transmitter should not exceed the XLPPI voltage maximum until a 100GBASE-CR4 cable assembly has been identified.

^bThe peak of the linear fit pulse response $p(k)$ from step 3).

92.8.3.1 Signal levels

The differential output voltage v_{di} is defined to be $SLi<p>$ minus $SLi<n>$. The common-mode output voltage v_{cmi} is defined to be one half of the sum of $SLi<p>$ and $SLi<n>$. These definitions are illustrated by Fig-

Figure 92–3.

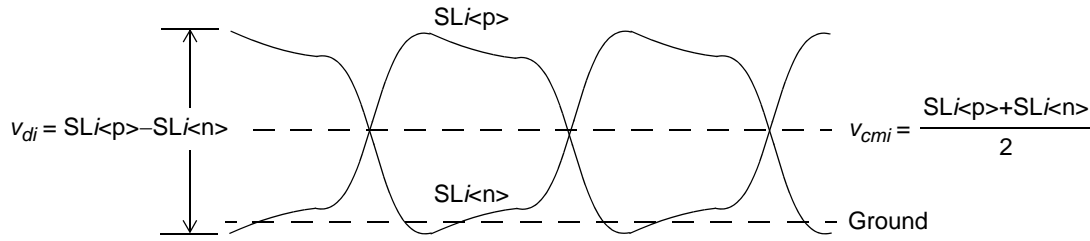


Figure 92–3—Transmitter output voltage definitions

The peak-to-peak differential output voltage shall be less than or equal to 1200 mV regardless of the transmit equalizer setting. The peak-to-peak differential output voltage shall be less than or equal to 35 mV when the transmitter is disabled (refer to 92.7.6 and 92.7.7).

The DC common-mode output voltage shall be between 0 V and 1.9 V with respect to signal ground. The AC common-mode output voltage shall be less than or equal to 30 mV RMS with respect to signal ground. Common-mode output voltage requirements shall be met regardless of the transmit equalizer setting.

Differential and common-mode signal levels are measured with a PRBS9 test pattern.

92.8.3.2 Transmitter differential output return loss

The differential output return loss, in dB, of the transmitter shall meet Equation (92–1). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω .

$$Return_loss(f) \geq \begin{cases} 12 - 0.5f & 0.01 \leq f \leq 8 \\ 5.65 - 9.71 \log_{10}(f/14) & 8 < f \leq 25 \end{cases} \quad (\text{dB}) \quad (92-1)$$

where

f is the frequency in GHz

$Return_loss(f)$ is the return loss at frequency f

92.8.3.3 Transmitter noise parameter measurements

The far-end transmitter output noise is an additional source of noise to the cable assembly's integrated crosstalk noise (ICN) specified in 92.10.7. The far-end transmitter output noise parameter is characterized using two reference channels; a "low-loss" cable assembly with insertion loss on the reference pair of 8.0 dB \pm 1.6 dB at 12.8906 GHz and cable assembly integrated crosstalk noise (ICN) meeting the requirements of 92.10.7 and a "high-loss" cable assembly with insertion loss on the reference pair of 20.0 dB \pm 1.5 dB at 12.8906 GHz and cable assembly ICN meeting the requirements of 92.10.7. The far-end transmitter output noise is characterized as a deviation from the cable assembly ICN using the following procedure:

- 1) Compute the far-end integrated crosstalk noise σ_{fx} into the reference lane of the cable assembly using the methodology of 92.10.7 and the parameters in Table 92–11.
- 2) Denote σ_l as the far-end ICN for the low-loss cable assembly.
- 3) Denote σ_h as the far-end ICN for the high-loss cable assembly.

- 4) The transmitter under test is connected to one end of the reference cable assembly and the other end is connected to the cable assembly test fixture specified in 92.11.2.
- 5) All lanes of the cable assembly test fixture are terminated in the reference impedance with the reference lane connected to the measuring instrument.
- 6) The reference lane of the transmitter under test sends a square wave test pattern as specified in 83.5.10 while all other adjacent transmitter lanes send either scrambled idle or PRBS31.
- 7) A fixed point on the square wave test pattern is chosen and the RMS deviation from the mean voltage at this observation point is measured. The histogram for RMS noise measurement is 1 UI wide.
- 8) The measurement should not include the measurement system noise.

For the low-loss cable assembly, the measured RMS deviation from the cable assembly ICN due to the far-end transmitter output noise shall meet the values determined using Equation (92-2).

$$RMSI_{dev} \leq \sqrt{\sigma_l^2 + 2^2} \quad (92-2)$$

For the high-loss cable assembly, the measured RMS deviation from the cable assembly ICN due to the far-end transmitter output noise shall meet the values determined using Equation (92-3).

$$RMSh_{dev} \leq \sqrt{\sigma_h^2 + 1^2} \quad (92-3)$$

92.8.3.4 Transmitter output waveform

The 100GBASE-CR4 transmit function includes programmable equalization to compensate for the frequency-dependent loss of the channel and facilitate data recovery at the receiver. The functional model for the transmit equalizer is the three tap transversal filter shown in Figure 92-4.

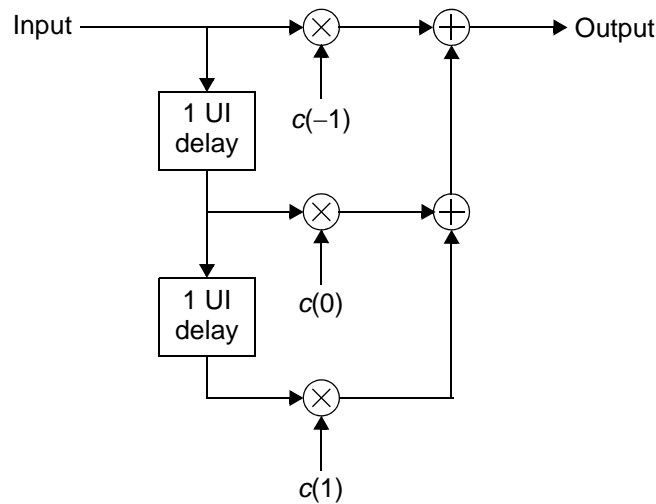


Figure 92-4—Transmit equalizer functional model

The state of the transmit equalizer and hence the transmitted output waveform may be manipulated via the PMD control function defined in 92.7.12 or via the management interface. The transmit function responds to a set of commands issued by the link partner's receive function and conveyed by a back-channel communications path.

This command set includes instructions to

- a) Increment coefficient $c(i)$.
- b) Decrement coefficient $c(i)$.
- c) Hold coefficient $c(i)$ at its current value.
- d) Set the coefficients to a pre-defined value (preset or initialize).

In response, the transmit function relays status information to the link partner's receive function. The status messages indicate that

- a1) The requested update to coefficient $c(i)$ has completed (updated).
- b1) Coefficient $c(i)$ is at its minimum value.
- c1) Coefficient $c(i)$ is at its maximum value.
- d1) Coefficient $c(i)$ is ready for the next update request (not_updated).

The transmitter output waveform is characterized using the procedure described in 85.8.3.3. The parameters of the linear pulse fit and equalizer are summarized in Table 92–6 .

Table 92–6—Linear fit pulse and equalizer parameters

Description	Symbol	Value	Units
Linear fit pulse length	N_p	11	UI
Linear fit pulse delay	D_p	2	UI
Equalizer length	N_w	11	UI
Equalizer delay	D_w	2	UI

92.8.3.4.1 Steady state voltage and linear fit pulse peak

The steady state voltage v_f is defined to be the sum of the linear fit pulse $p(k)$ divided by M (refer to 85.8.3.3 step 3). The steady state voltage shall be greater than or equal to 0.34 V and less than or equal to 0.6 V after the transmit equalizer coefficients have been set to the "preset" values.

The peak value of $p(k)$ shall be greater than $0.5 \times v_f$ after the transmit equalizer coefficients have been set to the "preset" values.

92.8.3.4.2 Linear fit error

For any configuration of the transmit equalizer, the RMS value of the error between the linear fit and the measured waveform, $e(k)$, normalized to the peak value of the linear fit pulse, $p(k)$, shall be less than or equal to 0.037.

92.8.3.4.3 Coefficient initialization

When the PMD enters the INITIALIZE state of the Training state diagram (Figure 72–5) or receives a valid request to “initialize” from the link partner, the coefficients of the transmit equalizer shall be configured such that the ratio $(c(0)+c(1)-c(-1))/(c(0)+c(1)+c(-1))$ is $1.29 \pm 10\%$ and the ratio $(c(0)-c(1)+c(-1))/(c(0)+c(1)+c(-1))$ is $2.57 \pm 10\%$. These requirements apply upon the assertion of a coefficient status report of “updated” for all coefficients.

92.8.3.4.4 Coefficient step size

The change in the normalized amplitude of coefficient $c(i)$ corresponding to a request to “increment” that coefficient shall be between 0.0083 and 0.05. The change in the normalized amplitude of coefficient $c(i)$ corresponding to a request to “decrement” that coefficient shall be between -0.0083 and -0.05 .

The change in the normalized amplitude of the coefficient is defined to be the difference in the value measured prior to the assertion of the “increment” or “decrement” request (e.g., the coefficient update request for all coefficients is “hold”) and the value upon the assertion of a coefficient status report of “updated” for that coefficient.

92.8.3.4.5 Coefficient range

When sufficient “increment” or “decrement” requests have been received for a given coefficient, the coefficient will reach a lower or upper bound based on the coefficient range or restrictions placed on the minimum steady state differential output voltage or the maximum peak-to-peak differential output voltage.

With $c(-1)$ set to zero and both $c(0)$ and $c(1)$ having received sufficient “decrement” requests so that they are at their respective minimum values, the ratio $(c(0) - c(1))/(c(0) + c(1))$ shall be greater than or equal to 4.

With $c(1)$ set to zero and both $c(-1)$ and $c(0)$ having received sufficient “decrement” requests so that they are at their respective minimum values, the ratio $(c(0) - c(-1))/(c(0) + c(-1))$ shall be greater than or equal to 1.54.

Note that a coefficient may be set to zero by first asserting a coefficient preset request and then manipulating the other coefficients as required by the test.

92.8.3.5 Insertion loss TP0 to TP2 or TP3 to TP5

Transmitter measurements and tests defined in Table 92–5 are made at TP2 or TP3 using the test fixture of Figure 92–13, or its equivalent. The recommended maximum insertion loss from TP0 to TP2 or TP3 to TP5 including the test fixture is given by Equation (92–4). Note that the insertion loss from TP0 to TP2 or from TP3 to TP5 is 10 dB at 12.8906 GHz.

$$Insertion_loss(f) \leq \begin{cases} 1.076(0.075 + 0.537\sqrt{f} + 0.566f) & 0.01 \leq f < 14 \\ 1.076(-18 + 2f) & 14 \leq f \leq 18.75 \end{cases} \quad (\text{dB}) \quad (92-4)$$

for $0.01 \text{ GHz} \leq f \leq 18.75 \text{ GHz}$

where

f is the frequency in GHz
 $Insertion_loss(f)$ is the insertion loss at frequency f

The maximum insertion loss of TP0 to TP2 or TP3 to TP5 is illustrated in Figure 92–5.

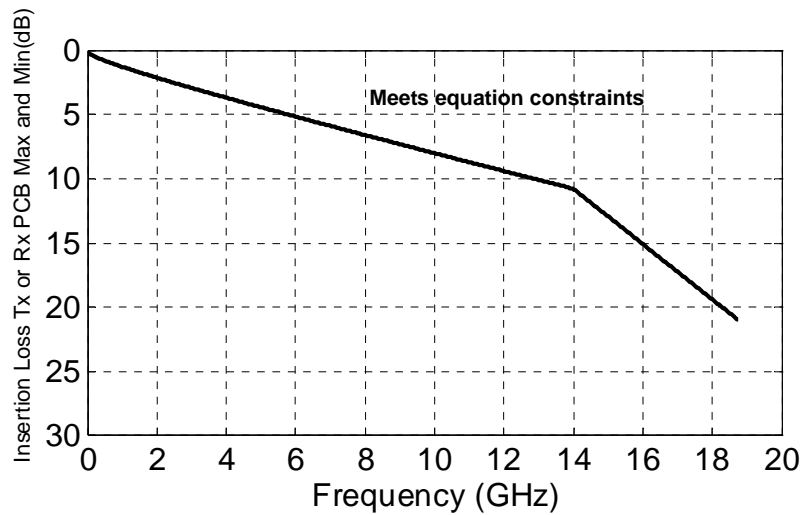


Figure 92-5—Maximum insertion loss TP0 to TP2 or TP3 to TP5

92.8.3.6 Transmitter output jitter

Even-odd jitter is measured from the two symbols in the middle of a sequence of no fewer than 8 symbols of alternating polarity. If PRBS9 is the test pattern, a suitable sequence may be found starting at either bit 161 or bit 383 where bits 1 to 9 are the run of 9 ones. A correct measurement of even-odd jitter requires that the period of the test pattern is an even number of symbols. When the base pattern period is an odd number of symbols, such as PRBS9, the test pattern for the purpose of even-odd jitter measurement must be two periods of the base pattern.

Even-odd jitter is defined to be half of the magnitude of the difference between the mean width of the positive pulse and the mean width of the negative pulse. The reference voltage for pulse width measurements is the mid-point between the positive pulse amplitude and the negative pulse amplitude. The pulse amplitude is defined to be the mean amplitude of the pulse within the central 20% of the nominal unit interval.

Even-odd jitter shall be less than or equal to 0.035 UI regardless of the transmit equalization setting.

NOTE—Even-odd jitter has been referred to as duty cycle distortion by other Physical Layer specifications for operation over electrical backplane or twinaxial copper cable assemblies (see 72.7.1.9). The term even-odd jitter is introduced to distinguish it from the duty cycle distortion referred to by Physical Layer specifications for operation over fiber optic cabling.

The total jitter (TJ) of a signal is defined as the range (the difference between the lowest and highest values) of sampling times around the signal transitions for which the BER at these sampling times is greater than or equal to 10^{-12} . Data dependent jitter (DDJ) is characterized using the procedure defined in 85.8.3.8.

Total jitter excluding data dependent jitter is the difference between TJ and DDJ and shall be less than or equal to 0.28 UI regardless of the transmit equalization setting.

Editor's note (to be removed prior to final publication):

Clause 85 was not clear on what was meant by "excluding" DDJ from TJ. In this draft, it has been interpreted to be the value of TJ as defined above minus the value of DDJ as defined in 85.8.3.8.

The effective random jitter (RJ) of a signal is defined to be the difference between the TJ and effective deterministic jitter (DJ). Effective DJ is derived from a fit of the measured jitter distribution to a dual-Dirac mathematical model. The fit is computed as follows.

- a) Measure the jitter J_n which is defined to be the range of sampling times around the signal transitions for which the BER at these sampling times is BER_n . Measure two values J_0 and J_1 where BER_0 is 10^{-9} and BER_1 is 10^{-5} .
- b) For each BER_n , determine the associated Q_n from the inverse normal cumulative probability distribution adjusted for an assumed transition density of 0.5. For example, Q_n is 5.77 if BER_n is 10^{-9} and Q_n is 3.94 if BER_n is 10^{-5} .
- c) Calculate the effective DJ as $(Q_0J_1 - Q_1J_0)/(Q_0 - Q_1)$.

The effective RJ shall be less than or equal to 0.15 UI regardless of the transmit equalization setting.

Editor's note (to be removed prior to final publication):

Clause 72 specifies that transmit equalization is off (preset) for the measurement of jitter. Clause 85 does not specify the conditions for jitter measurement and this is interpreted to mean that it applies for all transmit equalization settings. There has been some discussion as to which approach is appropriate.

The effect of a single-pole high-pass filter with a 3 dB frequency of 10 MHz is applied to the jitter. The test pattern for TJ and RJ measurements is either PRBS31 (see 83.5.10) or scrambled idle (see 82.2.10). The voltage threshold for the measurement of BER or crossing times is the mid-point (0 V) of the AC-coupled differential signal.

92.8.3.7 Signaling rate range

The 100GBASE-CR4 MDI signaling rate shall be 25.78125 GBd \pm 100 ppm per lane. The corresponding unit interval is approximately 38.787879 ps.

92.8.4 Receiver characteristics

The receiver characteristics are summarized in Table 92–7. Unless specified otherwise, all receiver measurements defined in Table 92–7 are made at TP3 utilizing the test fixtures specified in 92.11.1. A fourth-order 33 GHz Bessel-Thompson filter is to be used for receiver stressor measurements. The receiver

specifications at TP5 are provided informatively in Annex 92A

Table 92–7—Receiver characteristics at TP3 summary

Parameter	Subclause reference	Value	Units
Bit error ratio	92.8.4.4	10^{-12} or better	
Signaling rate, per lane	92.8.4.5	25.78125 ± 100 ppm	GBd
Unit interval (UI) nominal	92.8.4.5	38.787879	ps
Differential peak-to-peak input amplitude tolerance (max)	72.7.2.4	1200	mV
Differential input return loss (min) ^a	92.8.4.1	Equation (92–5)	dB
Differential to common-mode input return loss	92.8.4.2	10 min from 0.01 GHz to 25 GHz	dB

^aRelative to 100 Ω differential.

92.8.4.1 Receiver differential input return loss

The differential input return loss, in dB, of the receiver shall meet Equation (92–5). This return loss requirement applies at all valid input levels. The reference impedance for differential return loss measurements is 100 Ω .

$$Return_loss(f) \geq \begin{cases} 12 - 0.5f & 0.01 \leq f \leq 8 \\ 5.65 - 9.71 \log_{10}(f/14) & 8 < f \leq 25 \end{cases} \quad (\text{dB}) \quad (92-5)$$

where

f is the frequency in GHz
 $Return_loss(f)$ is the return loss at frequency f

92.8.4.2 Differential to common-mode input return loss

The differential to common-mode input return loss, in dB, of the receiver shall meet Equation (92–6).

$$Return_loss(f) \geq 10 \quad (\text{dB}) \quad (92-6)$$

for $0.01 \text{ GHz} \leq f \leq 25 \text{ GHz}$

where

f is the frequency in GHz
 $Return_loss(f)$ is the return loss at frequency f

92.8.4.3 Receiver interference tolerance test

The receiver interference tolerance of each lane shall comply with both test 1 and test 2 using the parameters of Table 92–8 when measured according to the requirements of 92.8.4.3.1 to 92.8.4.3.5.

Table 92–8—100GBASE-CR4 interference tolerance parameters

Parameter	Test 1 values	Test 2 values	Units
Maximum BER	10^{-12}	10^{-12}	
Fitted insertion loss coefficients	$a_1 = 1.7$ $a_2 = 0.546$ $a_4 = 0.01$	$a_1 = 4.3$ $a_2 = 0.571$ $a_4 = 0.04$	dB/ $\sqrt{\text{GHz}}$ dB/GHz dB/GHz ²
Applied SJ ^a (peak-to-peak)	0.115	0.115	UI
Applied RJ ^b (peak-to-peak)	0.13	0.13	UI
Even-odd jitter	0.035	0.035	UI
Calibrated far-end crosstalk (RMS)	6.3	2.2	mV
Calibrated ICN (RMS) – σ_{nx} ^c	3.7	3.7	mV

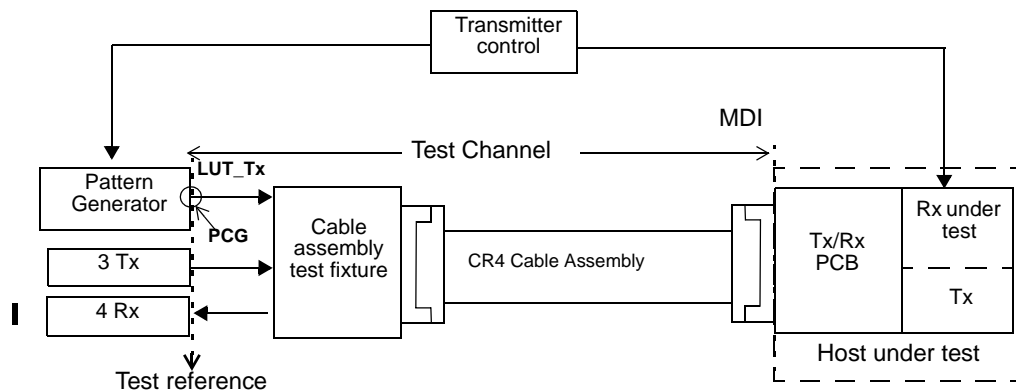
^aApplied SJ frequency >15 MHz, specified at TP0.

^bApplied random jitter at TP0 is specified at 10^{-12} .

^c σ_{nx} is subtracted from Calibrated ICN (RMS) in square root of the sum of the squares sense.

92.8.4.3.1 Test setup

The interference tolerance test is performed with the setup shown in Figure 92–6. The requirements of this subclause are verified at the pattern generator connection (PCG) or test references in Figure 92–6 and Figure 92–7. The lanes under test (LUT) are illustrated in Figure 92–6 and Figure 92–7. The cable assembly single ended receive lanes are terminated in 50 Ohm to provide 100 Ohm differential termination.

**Figure 92–6—Interference tolerance test setup**

92.8.4.3.2 Test channel

The test channel consists of the following:

- a) A cable assembly
- b) A cable assembly test fixture
- c) A connecting path from the pattern generator to the cable assembly test fixture

92.8.4.3.3 Test channel calibration

The insertion loss, near-end integrated crosstalk noise, and far-end crosstalk of the test channels are characterized at the test references as illustrated in Figure 92–7 using the cable assembly test fixtures specified in 92.11.2.

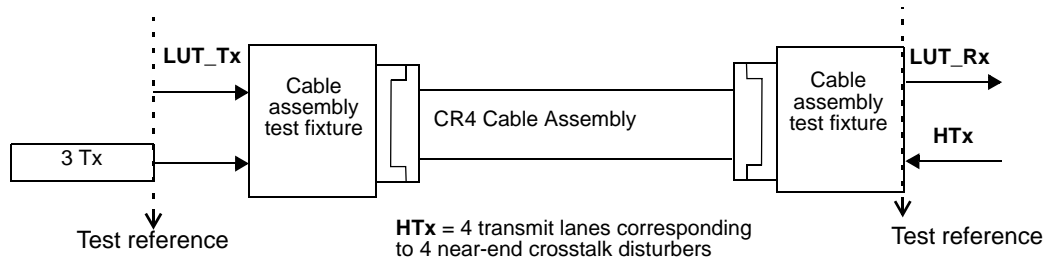


Figure 92–7—Test channel calibration

The fitted insertion loss coefficients of the lane under test (LUT), derived using the fitting procedure in 92.10.2, shall meet the test values in Table 92–8. It is recommended that the deviation between the insertion loss and the fitted insertion loss be as small as practical and that the fitting parameters be as close as practical to the values given in Table 92–8.

The MDNEXT is measured from points HTx to adjacent point LUT_Rx in Figure 92–7. HTx is the set of 4 transmit lanes of the device under test corresponding to the 4 near-end crosstalk disturbers with the parameters given in Table 92–11. The RMS value of the integrated MDNEXT crosstalk noise, determined using Equation (92–15), Equation (92–17), and Equation (92–19), shall meet the test values in Table 92–8.

The far-end crosstalk disturbers consist of 100GBASE-CR4 transmitters. It is recommended that the transition time, equalization setting, and path from the far-end crosstalk disturbers to the cable assembly test fixture emulate the pattern generator as much as practical. For 100GBASE-CR4 test channels, the crosstalk that is coupled into a receive lane is from three transmitters. The disturber transmitters send either scrambled idle codes or PRBS31. The amplitudes of each of the disturbers should not deviate more than 3 dB from the mean of the disturber amplitudes. The amplitudes of the disturbers should be such that the calibrated far-end crosstalk in Table 92–8 is met in the calibration setup at the LUT point with no signal applied at the PGC, and HTx and PGC terminated in 100 Ω differentially.

92.8.4.3.4 Pattern generator

The pattern generator transmits data to the device under test. Its output amplitude shall be no more than TBD mV peak-to-peak differential when measured on an alternating one zero pattern. The transition times of the pattern generator, as defined in 93.8.1.5 are TBD ps. If the transition times of the pattern generator, T_r , are less than TBD ps the value of a_4 in Table 92–8 is increased by da_4 from Equation (92–7).

$$\text{TBD} \quad (92-7)$$

where T_r is the rise time in ps.

The pattern generator shall be set to match the jitter specification in Table 92–8. The output waveform of the pattern generator shall comply to 93.8.1.

92.8.4.3.5 Test procedure

For 100GBASE-CR4 testing, the pattern generator is first configured to transmit the training pattern defined in 72.6.10.2. During this initialization period, the device under test (DUT) configures the pattern generator equalizer, via transmitter control, to the coefficient settings it would select using the protocol described in 72.6.10 and the receiver will be tuned using its optimization method.

After the pattern generator equalizer has been configured and the receiver tuned, the pattern generator is set to either scrambled idle or PRBS31. The receiver under test shall meet the target BER listed in Table 92–8. During the tests, the disturbers transmit at their calibrated level and all of the transmitters in the device under test transmit either scrambled idle or PRBS31, with the maximum compliant amplitude and equalization turned off (preset condition).

92.8.4.4 Bit error ratio

The receiver shall operate with a BER 10^{-12} or better when receiving a compliant transmit signal, as defined in 92.8.3, through a compliant cable assembly as defined in 92.10.

92.8.4.5 Signaling rate range

A 100GBASE-CR4 receiver shall comply with the requirements of 92.8.4.4 for any signaling rate in the range $25.78125 \text{ GBd} \pm 100 \text{ ppm}$. The corresponding unit interval is approximately 38.787879 ps.

92.8.4.6 AC coupling

The 100GBASE-CR4 plug connector receive lanes are AC coupled; the coupling capacitors shall be within the plug connectors. It should be noted that there may be various methods for AC coupling in actual implementations. The low frequency 3 dB cutoff of the AC coupling shall be less than 50 kHz.

It is recommended that the value of the coupling capacitors be 100 nF. The capacitor will limit the inrush charge and baseline wander.

92.9 Channel characteristics

The 100GBASE-CR4 channel is defined between TP0 and TP5 to include the transmitter and receiver differential controlled impedance printed circuit board and the cable assembly as illustrated in Figure 92–2. The channel parameters insertion loss, insertion loss deviation (ILD), insertion loss to crosstalk ratio, and the transmitter and receiver differential controlled impedance printed circuit boards for each differential lane are provided informatively in 92A.4 through 92A.8.

92.10 Cable assembly characteristics

The 100GBASE-CR4 cable assembly contains insulated conductors terminated in a connector at each end for use as a link segment between MDIs. This cable assembly is primarily intended as a point-to-point interface of up to 5 m between network ports using controlled impedance cables. All cable assembly measurements are to be made between TP1 and TP4 with cable assembly test fixtures as specified in 92.11.2 and illustrated in Figure 92–14. These cable assembly specifications are based upon twinaxial cable characteristics, but other cable types are acceptable if the specifications of 92.10 are met.

Table 92–9 provides a summary of the cable assembly differential characteristics at 12.8906 GHz and references to the subclauses addressing each parameter.

Table 92–9—Cable assembly differential characteristics summary

Description	Reference	Value	Unit
Maximum insertion loss at 12.8906 GHz	92.10.2	22.64	dB
Minimum insertion loss at 12.8906 GHz	92.10.2	8	dB
Insertion loss deviation at 12.8906 GHz	92.10.3	max = 2.97 min = –2.97	dB
Minimum return loss at 12.8906 GHz	92.10.4	6.0	dB
MDNEXT loss	92.10.5	Equation (92–15)	dB
MDFEXT loss	92.10.6	Equation (92–16)	dB
Maximum integrated crosstalk noise	92.10.7	Equation (92–22)	mV

92.10.1 Characteristic impedance and reference impedance

The nominal differential characteristic impedance of the cable assembly is 100 Ω. The differential reference impedance for cable assembly specifications shall be 100 Ω.

92.10.2 Cable assembly insertion loss

The fitted cable assembly insertion loss $IL_{fitted}(f)$ as a function of frequency f is defined in Equation (92–8).

$$IL_{fitted}(f) = a_1\sqrt{f} + a_2f + a_4f^2 \quad (\text{dB}) \quad (92-8)$$

where

f is the frequency in GHz
 $IL_{fitted}(f)$ is the fitted cable assembly insertion loss at frequency f

Given the cable assembly insertion loss measured between TP1 and TP4 is at N uniformly-spaced frequencies f_n spanning the frequency range 50 MHz to 18750 MHz with a maximum frequency spacing of 10 MHz, the coefficients of the fitted insertion loss are determined using Equation (92–9) and Equation (92–10).

Define the frequency matrix F as shown in Equation (92–9).

$$F = \begin{bmatrix} \sqrt{f_1} & f_1 & f_1^2 \\ \sqrt{f_2} & f_2 & f_2^2 \\ \dots & \dots & \dots \\ \sqrt{f_N} & f_N & f_N^2 \end{bmatrix} \quad (92-9)$$

The polynomial coefficients a_1 , a_2 , and a_4 are determined using Equation (92–10). In Equation (92–10), T denotes the matrix transpose operator and IL is a column vector of the measured insertion loss values, IL_n at each frequency f_n .

$$\begin{bmatrix} a_1 \\ a_2 \\ a_4 \end{bmatrix} = (F^T F)^{-1} F^T IL \quad (92-10)$$

The maximum allowed values of the polynomial coefficients a_1 , a_2 , and a_4 of the fitted cable assembly insertion loss of each pair of the 100GBASE-CR4 in Equation (92–8) corresponding to the maximum insertion loss at 12.8906 GHz shall meet the specifications summarized in Table 92–10 unless otherwise noted. The fitted insertion loss corresponding to one example of the maximum insertion loss at 12.8906 GHz and the maximum allowed values of a_1 , a_2 , and a_4 are illustrated in Figure 92–8

The maximum allowed values of the polynomial coefficients a_1 , a_2 , and a_4 of the fitted cable assembly insertion loss of each pair of the 100GBASE-CR4 in Equation (92–8) corresponding to the minimum insertion loss at 12.8906 GHz shall meet the specifications summarized in Table 92–10 unless otherwise noted. The fitted insertion loss corresponding to one example of the minimum insertion loss at 12.8906 GHz and the maximum allowed values of a_1 , a_2 , and a_4 are illustrated in Figure 92–9.

Table 92–10—Maximum and minimum cable assembly insertion loss characteristics

Description	Value	Unit
Maximum insertion loss at 12.8906 GHz	22.64 ^a	dB
Maximum fitted insertion loss coefficient a_1	4.28	dB/ $\sqrt{\text{GHz}}$
Maximum fitted insertion loss coefficient a_2	0.326	dB/GHz
Maximum fitted insertion loss coefficient a_4	0.0185	dB/GHz ²
Minimum insertion loss at 12.8906 GHz	8 ^b	dB
Maximum fitted insertion loss coefficient a_1	0.7	dB/ $\sqrt{\text{GHz}}$
Maximum fitted insertion loss coefficient a_2	0.3	dB/GHz
Maximum fitted insertion loss coefficient a_4	0.01	dB/GHz ²

^aThe limit on the maximum insertion loss at 12.8906 GHz precludes the coefficients a_1 , a_2 , and a_4 from simultaneous maximum values.

^bThe limit on the maximum insertion loss at 12.8906 GHz precludes the coefficients a_1 , a_2 , and a_4 from simultaneous maximum values.

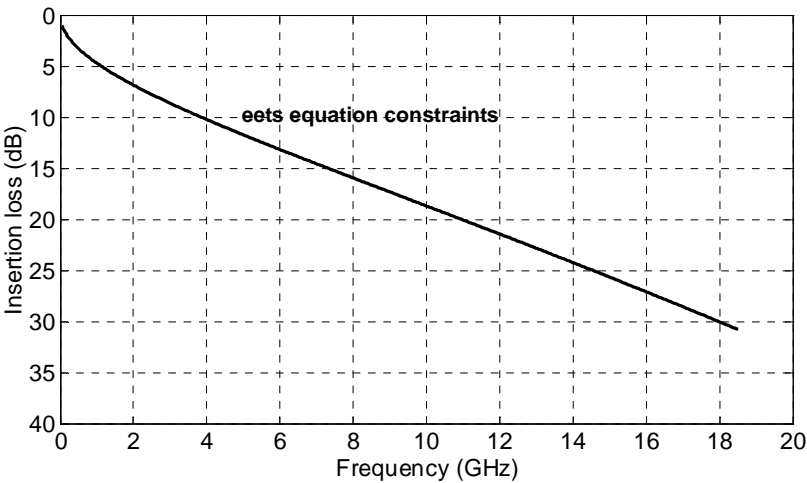


Figure 92-8—Example maximum cable assembly insertion loss

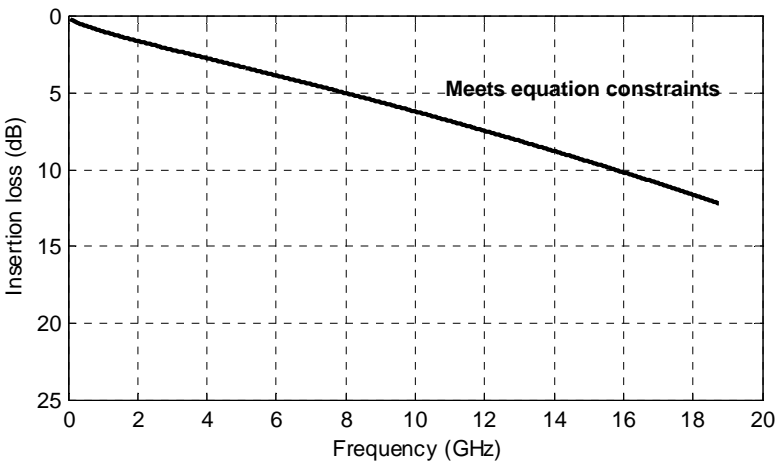


Figure 92-9—Example minimum cable assembly insertion loss

92.10.3 Cable assembly insertion loss deviation (ILD)

The cable assembly insertion loss deviation is the difference between the cable assembly insertion loss and the fitted cable assembly insertion loss determined using Equation (92-11).

$$ILD(f) = IL(f) - IL_{fitted}(f)$$

(92-11)

where

f is the frequency in GHz
 $ILD(f)$ is the cable assembly insertion loss deviation at frequency f

The ILD shall be within the region defined by Equation (92–12) and Equation (92–13). This includes the insertion loss of the differential cabling pairs and the cable assembly connectors.

$$ILD(f) \geq ILD_{\min}(f) = -0.7 - 0.176f \quad (\text{dB}) \quad (92-12)$$

$$ILD(f) \leq ILD_{\max}(f) = 0.7 + 0.176f \quad (\text{dB}) \quad (92-13)$$

for $0.05 \text{ GHz} \leq f \leq 18.75 \text{ GHz}$

where

f is the frequency in GHz

The insertion loss deviation limits are illustrated in Figure 92–10.

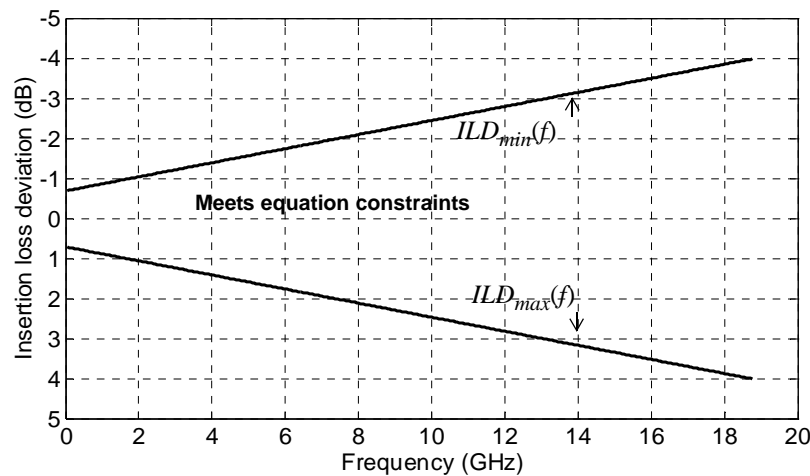


Figure 92–10—Maximum cable assembly insertion loss deviation

92.10.4 Cable assembly return loss

The return loss of each pair of the 100GBASE-CR4 cable assembly shall meet the values determined using Equation (92–14).

$$Return_loss(f) \geq \begin{cases} 16.50 - 2\sqrt{f} & 0.05 \leq f < 4.1 \\ 10.80 - 13\log_{10}(f/5.5) & 4.1 \leq f \leq 25 \end{cases} \quad (\text{dB}) \quad (92-14)$$

where

f is the frequency in GHz

$Return_loss(f)$ is the return loss at frequency f

The minimum cable assembly return loss is illustrated in Figure 92–11.

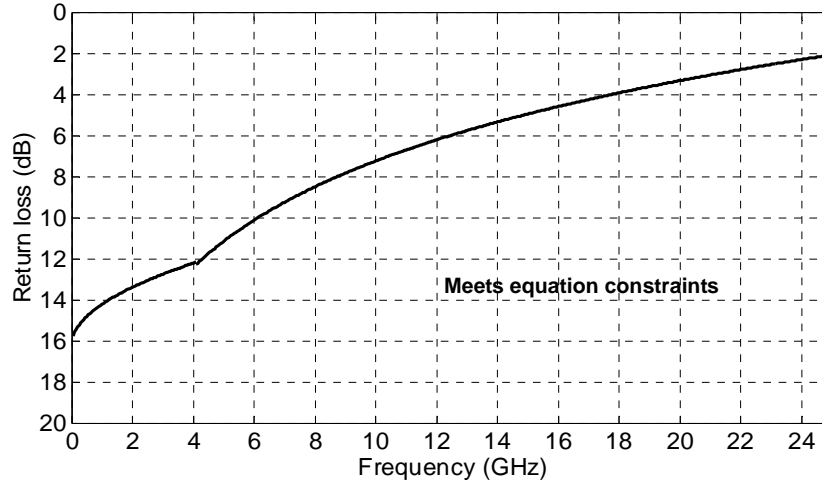


Figure 92–11—Minimum cable assembly return loss

92.10.5 Cable assembly multiple disturber near-end crosstalk (MDNEXT) loss

Since four lanes are used to transfer data between PMDs, the NEXT that is coupled into a receive lane will be from the four transmit lanes. Multiple Disturber Near-End Crosstalk (MDNEXT) loss is determined using the individual NEXT losses.

MDNEXT loss is determined from the four individual pair-to-pair differential NEXT loss values using Equation (92–15).

$$MDNEXT_loss(f) = -10\log_{10}\left(\sum_{i=0}^{i=3} 10^{-NL_i(f)/10}\right) \quad (\text{dB}) \quad (92-15)$$

for $0.05 \text{ GHz} \leq f \leq 20 \text{ GHz}$

where

$MDNEXT_loss(f)$ is the MDNEXT loss at frequency f
 $NL_i(f)$ is the NEXT loss at frequency f of pair combination i , in dB
 f is the frequency in GHz
 i is the 0 to 3 (pair-to-pair combination)

92.10.6 Cable assembly multiple disturber far-end crosstalk (MDFEXT) loss

Since four lanes are used to transfer data between PMDs, the FEXT that is coupled into a data carrying lane will be from the three other lanes or nine other lanes in the same direction. MDFEXT loss is specified using the individual FEXT losses. MDFEXT loss is determined from the three individual pair-to-pair differential FEXT loss values using Equation (92–16).

$$MDFEXT_loss(f) = -10\log_{10}\left(\sum_{i=0}^{i=2} 10^{-NL_i(f)/10}\right) \text{ (dB)} \quad (92-16)$$

for $0.05 \text{ GHz} \leq f \leq 20 \text{ GHz}$

where

$MDFEXT_loss(f)$ is the MDFEXT loss at frequency f
 $NL_i(f)$ is the FEXT loss at frequency f of pair combination i , in dB
 f is the frequency in GHz
 i is the 0 to 2 (pair-to-pair combination)

92.10.7 Cable assembly integrated crosstalk noise (ICN)

In order to limit multiple disturber crosstalk noise at a receiver, the cable assembly integrated crosstalk noise (ICN) is specified in relationship to the measured insertion loss. ICN is calculated from the MDFEXT and MDNEXT. Given the multiple disturber near-end crosstalk loss $MDNEXT_loss(f)$ and multiple disturber far-end crosstalk loss $MDFEXT_loss(f)$ measured over N uniformly-spaced frequencies f_n spanning the frequency range 50 MHz to 20000 MHz with a maximum frequency spacing of 10 MHz, the RMS value of the integrated crosstalk noise shall be determined using Equation (92-17) through Equation (92-21). The RMS crosstalk noise is characterized at the output of a specified receive filter utilizing a specified transmitter waveform and the measured multiple disturber crosstalk transfer functions. The transmitter and receiver filters are defined in Equation (92-17) and Equation (92-18) as weighting functions to the multiple disturber crosstalk in Equation (92-19) and Equation (92-20). The sinc function is defined by $\text{sinc}(x) = \sin(\pi x)/(\pi x)$.

Define the weight at each frequency f_n using Equation (92-17) and Equation (92-18).

$$W_{nt}(f_n) = (A_{nt}^2/f_b)\text{sinc}^2(f_n/f_b)\left[\frac{1}{1+(f_n/f_{nt})^4}\right]\left[\frac{1}{1+(f_n/f_r)^8}\right] \quad (92-17)$$

$$W_{ft}(f_n) = (A_{ft}^2/f_b)\text{sinc}^2(f_n/f_b)\left[\frac{1}{1+(f_n/f_{ft})^4}\right]\left[\frac{1}{1+(f_n/f_r)^8}\right] \quad (92-18)$$

where the equation parameters are given in Table 92-11.

Note that the 3 dB transmit filter bandwidths f_{nt} and f_{ft} are inversely proportional to the 20% to 80% rise and fall times T_{nt} and T_{ft} respectively. The constant of proportionality is 0.2365 (e.g., $T_{nt}f_{nt} = 0.2365$; with f_{nt} in hertz and T_{nt} in seconds). In addition, f_r is the 3 dB reference receiver bandwidth, which is set to 18.75 GHz.

The near-end integrated crosstalk noise σ_{nx} is calculated using Equation (92-19).

$$\sigma_{nx} = \left[2\Delta f \sum_n W_{nt}(f_n) 10^{-MDNEXT_loss(f_n)/10}\right]^{1/2} \quad (92-19)$$

The far-end integrated crosstalk noise σ_{fx} is calculated using Equation (92-20).

$$\sigma_{fx} = \left[2\Delta f \sum_n W_{ft}(f_n) 10^{-MDFEXT_loss(f_n)/10}\right]^{1/2} \quad (92-20)$$

where Δf is the uniform frequency step of f_n .

The total integrated crosstalk noise σ_x is calculated using Equation (92–21).

$$\sigma_x = \sqrt{\sigma_{nx}^2 + \sigma_{fx}^2} \quad (92-21)$$

The total integrated crosstalk noise for the cable assembly shall be computed using the parameters shown in Table 92–11.

Table 92–11—Cable assembly integrated crosstalk parameters

Description	Symbol	Value	Units
Symbol rate	f_b	25.78125	GBd
Near-end disturber peak differential output amplitude	A_{nt}	600	mV
Far-end disturber peak differential output amplitude	A_{ft}	600	mV
Near-end disturber 20% to 80% rise and fall times	T_{nt}	9.6	ps
Far-end disturber 20% to 80% rise and fall times	T_{ft}	9.6	ps

The total integrated crosstalk RMS noise voltage shall meet the values determined by Equation (92–22) illustrated in Figure 92–12.

$$\sigma_{x, ca} \leq \begin{cases} 8 & 4 \leq IL \leq 10.4 \\ 12.1 - 0.393IL & 10.4 < IL \leq 22.64 \end{cases} \quad (\text{mV}) \quad (92-22)$$

where IL is the value of the cable assembly insertion loss in dB at 12.8906 GHz.

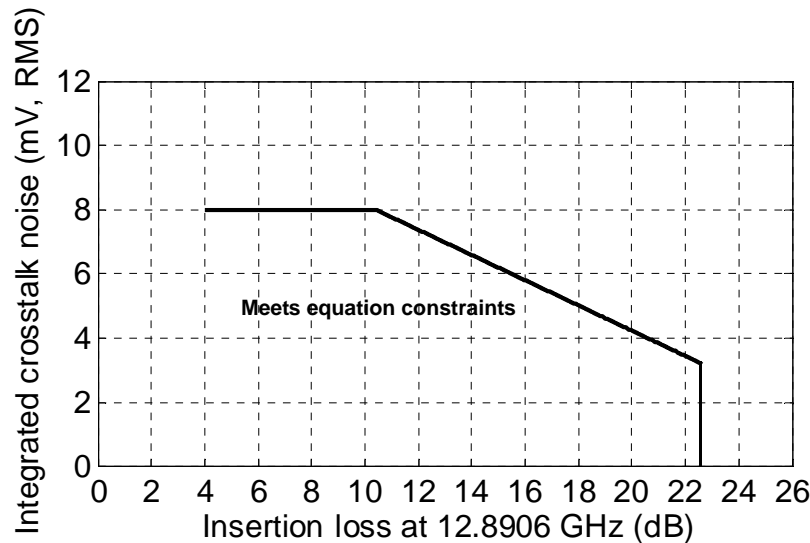


Figure 92-12—Integrated crosstalk noise limits

92.11 Test Fixtures

Transmitter and receiver measurements are made at TP2 or TP3 utilizing the test fixture specified in 92.11.1. and illustrated in Figure 92-13. All cable assembly measurements are to be made between TP1 and TP4 with cable assembly test fixtures as specified in 92.11.2 and illustrated in Figure 92-14. The test fixtures of Figure 92-13 and Figure 92-14 are specified in a mated state, illustrated in Figure 92-15, to enable connections to measurement equipment. The requirements in this section are not MDI specifications for an implemented design.

92.11.1 TP2 or TP3 Test fixture

The test fixture of Figure 92-13, or its equivalent, is required for measuring the transmitter specifications in 92.8.3 at TP2 and the receiver return loss at TP3. The TP2 and TP3 test points are illustrated in Figure 92-2. Figure 92-13 illustrates the test fixture attached to TP2 or TP3.

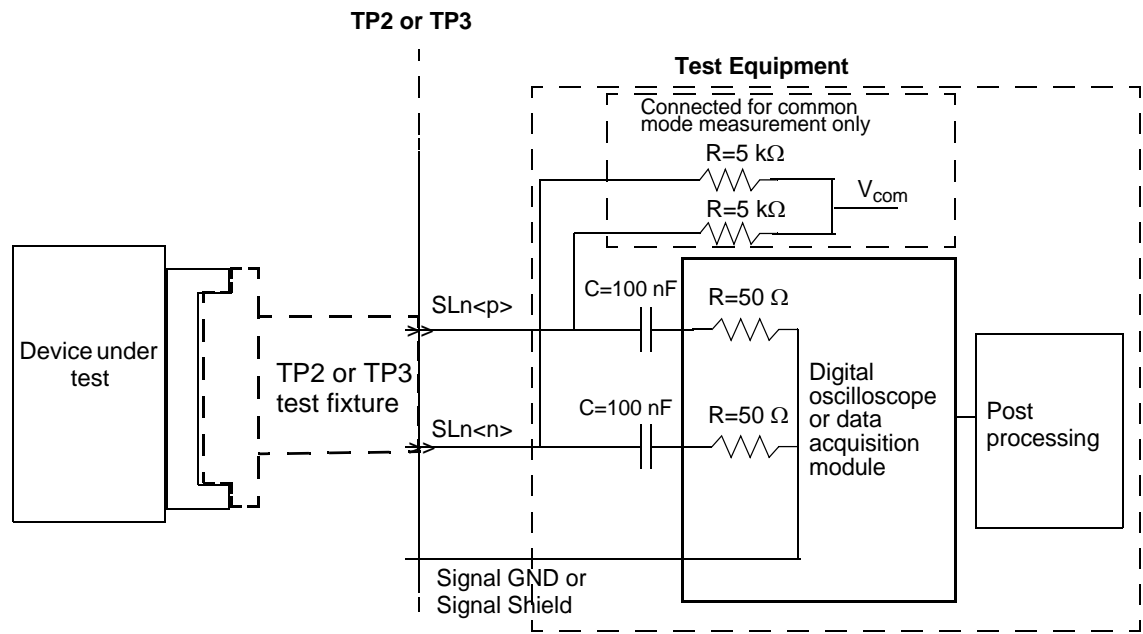


Figure 92-13—Transmitter and receiver test fixture

92.11.1.1 Test fixture return loss

The differential return loss, in dB, of the test fixture is specified in a mated state and shall meet the requirements of 92.11.3.2.

92.11.1.2 Test fixture insertion loss

The test fixture printed circuit board insertion loss values determined using Equation (92-23) shall be used as the reference test fixture insertion loss. The effects of differences between the insertion loss of an actual test fixture and the reference insertion loss are to be accounted for in the measurements.

$$IL_{tfrf}(f) = 2(-0.001 + 0.096\sqrt{f} + 0.046f) \text{ (dB)} \tag{92-23}$$

for $0.01 \leq f \leq 18.75 \text{ GHz}$

where

f is the frequency in GHz

$IL_{tfrf}(f)$ is the reference test fixture PCB insertion loss at frequency f

92.11.2 Cable assembly test fixture

The test fixture of Figure 92-14 or its equivalent, is required for measuring the cable assembly specifications in 92.10 at TP1 and TP4. The TP1 and TP4 test points are illustrated in Figure 92-2 and Figure 92-14. The test fixture return loss is equivalent to the test fixture return loss specified in 92.11.3.2. The reference test fixture printed circuit board insertion loss is given in Equation (92-24). The effects of differences between the insertion loss of an actual test fixture and the reference insertion loss are to be accounted for in the measurements.

$$IL_{\text{catf}}(f) = 1.25(-0.001 + 0.096\sqrt{f} + 0.046f) \text{ (dB)}$$

(92-24)

for 0.01 GHz ≤ *f* ≤ 18.75 GHz

where

f

*IL*_{catf}(*f*)

is the frequency in GHz

is the reference test fixture printed circuit board insertion loss at frequency *f*

Editor’s note (to be removed prior to final publication):

In Annex 92A, the insertion loss of the test fixture printed circuit board is 1.25 dB at 12.8906 GHz.

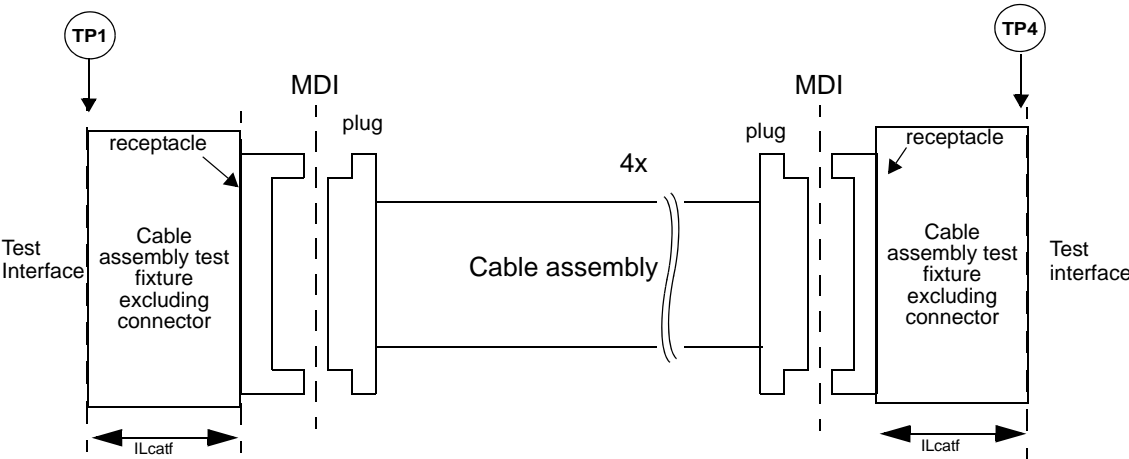


Figure 92-14—Cable assembly test fixtures

92.11.3 Mated test fixtures

The test fixtures of Figure 92-13 and Figure 92-14 are specified in a mated state illustrated in Figure 92-15.

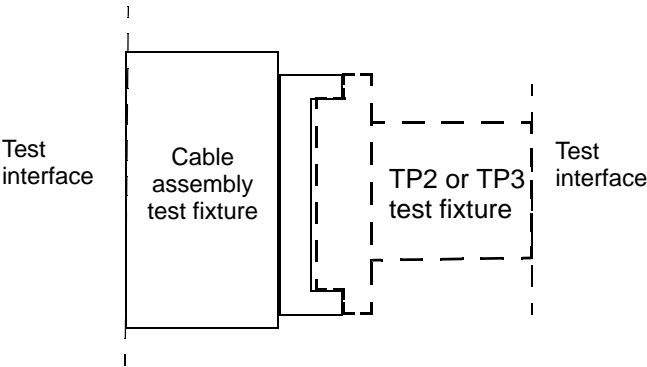


Figure 92-15—Mated test fixtures

92.11.3.1 Mated test fixtures insertion loss

The insertion loss of the mated test fixtures shall meet the values determined using Equation (92–25) and Equation (92–26).

$$IL(f) \geq IL_{MTFmin}(f) = TBD \quad TBD \leq f \leq TBD \quad (dB) \tag{92-25}$$

$$IL(f) \leq IL_{MTFmax}(f) = \{TBD\} \quad (dB) \tag{92-26}$$

where

f is the frequency in GHz
 $IL(f)$ is the mated test fixture insertion loss at frequency f

Editor’s note (to be removed prior to final publication):

In Annex 92A, the insertion loss of the mated test fixtures is 3.82 dB at 12.8906 GHz.

The mated test fixtures insertion loss limits are illustrated in Figure 92–16.

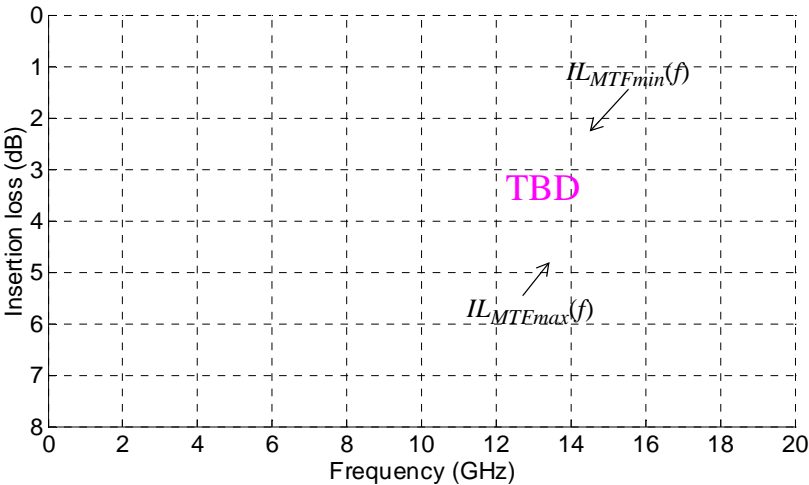


Figure 92–16—Mated test fixtures Insertion loss

92.11.3.2 Mated test fixtures return loss

The return loss of the mated test fixtures measured at each test fixture interface shall meet the values determined using Equation (92–27).

$$Return_loss(f) \geq \left\{ \begin{array}{ll} 20 - f & 0.01 \leq f < 4 \\ 18 - 0.5f & 4 \leq f \leq 16 \\ 11.2 - 20.5 \log_{10}(f/14) & 16 < f \leq 18.75 \end{array} \right\} \quad (\text{dB}) \quad (92-27)$$

for $0.01 \text{ GHz} \leq f \leq 18.75 \text{ GHz}$

where

f is the frequency in GHz

$Return_loss(f)$ is the return loss at frequency f

The mated test fixtures return loss is illustrated in Figure 92–17.

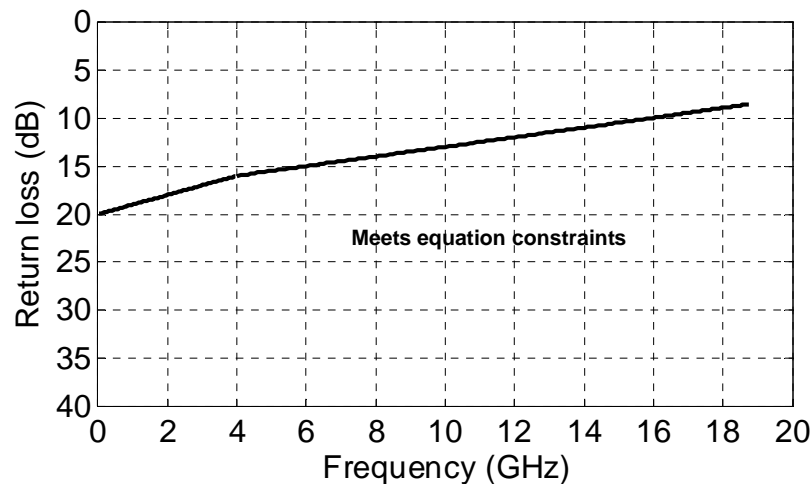


Figure 92–17—Mated test fixtures return loss

92.11.3.3 Mated test fixtures common-mode conversion loss

The common-mode conversion loss of the mated test fixtures measured at either test fixture test interface shall meet the values determined using Equation (92–28).

$$Conversion_loss(f) \geq \left\{ \begin{array}{ll} 30 - 1.143f & 0.01 \leq f < 14 \\ 14 & 14 \leq f \leq 25 \end{array} \right\} \quad (\text{dB}) \quad (92-28)$$

where

f is the frequency in GHz

$Conversion_loss(f)$ is the return loss at frequency f

The mated test fixtures common-mode conversion loss is illustrated in Figure 92–18.

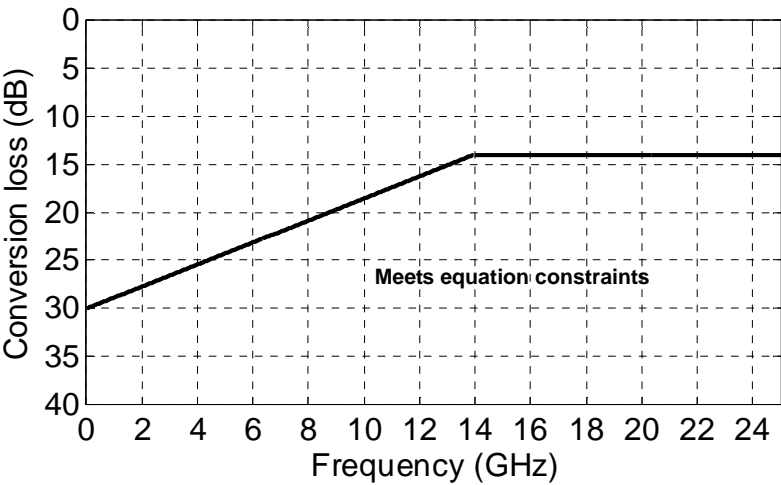


Figure 92-18—Common-mode conversion loss

92.11.3.4 Mated test fixtures common-mode return loss

The common-mode return loss of the mated test fixtures measured at either test fixture test interface shall meet the values determined using Equation (92-29).

$$Return_loss(f) \geq \begin{cases} 12 - 9f & 0.01 \leq f < 1.0 \\ 3 & 1.0 \leq f \leq 20.0 \end{cases} \quad (\text{dB})$$

(92-29)

where

f

is the frequency in GHz

$Return_loss(f)$

is the return loss at frequency f

The mated test fixtures common-mode return loss is illustrated in Figure 92-17.

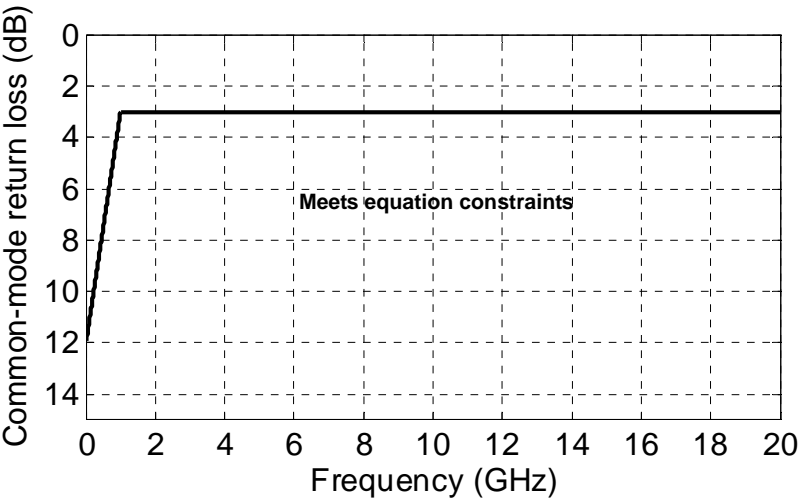


Figure 92-19—C

92.11.3.5 Mated test fixtures integrated crosstalk noise

The mated test fixtures integrated crosstalk RMS noise voltages for the single-disturber near-end crosstalk loss and the single-disturber far-end crosstalk loss are determined using Equation (92-17) through Equation (92-21) by substituting the single disturber near-end crosstalk loss for the multiple disturber near-end crosstalk loss and the single disturber far-end crosstalk loss for the multiple disturber far-end crosstalk loss. The values of the mated test fixtures integrated crosstalk RMS noise voltages determined using Equation (92-17) through Equation (92-21) for the single-disturber near-end crosstalk loss, the single-disturber far-end crosstalk loss, the multiple disturber near-end crosstalk loss, and the multiple disturber far-end crosstalk loss shall meet the specifications in Table 92-12.

Table 92-12—Mated test fixtures integrated crosstalk noise

Parameter	100GBASE-CR4	Units
Near-end integrated crosstalk noise voltage (max, RMS)	TBD	mV
Far-end integrated crosstalk noise voltage (max, RMS)	TBD	mV
MDNEXT integrated crosstalk noise voltage (max, RMS)	TBD	mV
MDFEXT integrated crosstalk noise voltage (max, RMS)	TBD	mV

92.12 MDI specification

Editor's note (to be removed prior to final publication):

The following text is based on tracy_01_0312 per the motion passed at the March 2012 Task Force meeting.

“Move that QSFP28, per tracy_01_0312.pdf, be adopted as a baseline proposal for a type of MDI for 100GBASE-CR4. (M: N. Tracy, S: J. Goergen, Y: 55, N: 0, A: 2)”

This sub-clause defines the Media Dependent Interface (MDI). The 100GBASE-CR4 PMD, as per 92.7, is coupled to the cable assembly, as per 92.10, by the MDI.

92.12.1 100GBASE-CR4 MDI connectors

Connectors meeting the requirements of 92.11.1.1 (Style-1) or 92.11.1.2 (Style-2) shall be used as the mechanical interface between the PMD of 92.7 and the cable assembly of 92.10. The plug connector shall be used on the cable assembly and the receptacle on the PHY. Style-1 or Style-2 connectors may be used as the MDI interface.

For Style-1 and Style 2 100GBASE-CR4 plug connectors the receive lanes are AC coupled; the coupling capacitors are contained within the plug connectors as specified in 92.8.4.5.

92.12.1.1 Style-1 100GBASE-CR4 MDI connectors

The plug connector for each end of the cable assembly shall be the QSFP+ 28 Gb/s 4X Pluggable (QSFP28) plugs defined in SFF-8665 and illustrated in Figure 92–20. The MDI connector shall be the QSFP+ 28 Gb/s 4X Pluggable (QSFP28) receptacle with the mechanical mating interface defined in SFF-8665 and illustrated in Figure 92–21. These connectors have contact assignments matching that in Table 92–13 and electrical performance consistent with the signal quality and electrical requirements of 92.8 and 92.9.

The plug connectors on the receive lanes are AC coupled, i.e. the coupling capacitors are contained within the plug connectors..

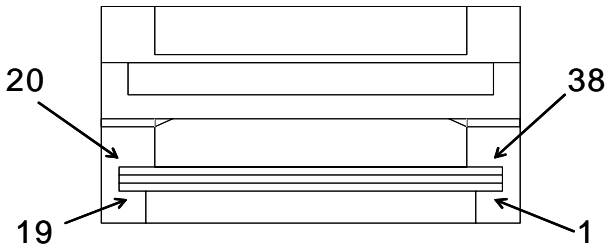


Figure 92-20—Style-1 example cable assembly

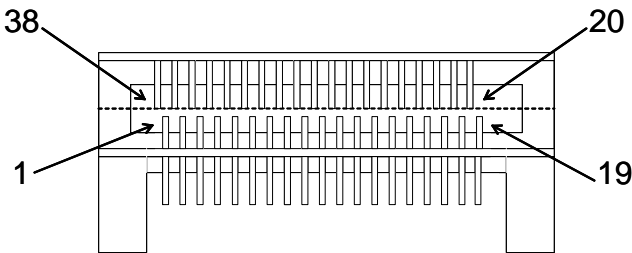


Figure 92-21—Style-2 example MDI board receptacle

The Style-1 MDI connector of the 100GBASE-CR4 PMD comprises 38 signal connections. The Style-1

Table 92-13—100GBASE-CR4 lane to MDI connector contact mapping

Tx lane	MDI connector contact	Rx lane	MDI connector contact
signal gnd	S1	signal gnd	S13
SL1<n>	S2	DL2<p>	S14
SL1<p>	S3	DL2<n>	S15
signal gnd	S4	signal gnd	S16
SL3<n>	S5	DL0<p>	S17
SL3<p>	S6	DL0<n>	S18
signal gnd	S7	signal gnd	S19
SL2<p>	S33	DL1<n>	S21
SL2<n>	S34	DL1<p>	S22
signal gnd	S35	signal gnd	S23
SL0<p>	S36	DL3<n>	S24
SL0<n>	S37	DL3<p>	S25
signal gnd	S38	signal gnd	S26

100GBASE-CR4 MDI connector contact assignments shall be as defined in Table 92–13.

92.12.1.2 Style-2 100GBASE-CR4 MDI connectors

The connector for each end of the cable assembly shall be the 100G Form Factor Pluggable 4 (CFP4) with the mechanical mating interface defined in CFP4 MSA HW Specification and illustrated in Figure 92-20. The MDI connector shall be the 100G Form Factor Pluggable (CFP4) receptacle with the mechanical mating interface defined by CFP4 MSA HW Specification and illustrated in Figure 92-21. These connectors have contact assignments matching that in Table 92–14, and electrical performance consistent with the signal quality and electrical requirements of 92.8 and 92.9.

The plug connectors on the receive lanes are AC coupled, i.e. the coupling capacitors are contained within the plug connectors...



Figure 92–22—Style-2 example cable assembly

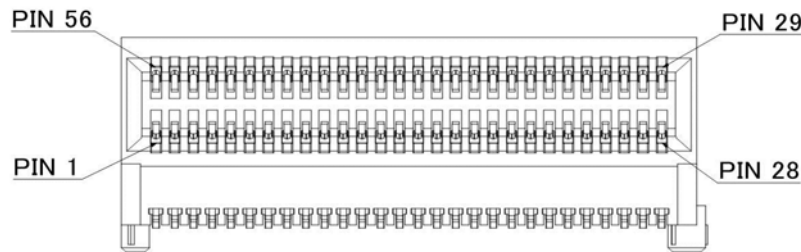


Figure 92–23—Style-2 example MDI board receptacle

The Style-2 MDI connector of the 100GBASE-CR4 PMD comprises 56 signal connections. The Style-2

Table 92–14—100GBASE-CR4 lane to MDI connector contact mapping

MDI connector contact	MDI connector bottom	MDI connector contact	MDI connector Top	MDI connector Top ALT1
1	3.3V_GND	56	signal gnd	signal gnd
2	3.3V_GND	55	SL3<n>	SL0<n>
3	3.3V	54	SL3<p>	SL0<p>
4	3.3V	53	signal gnd	signal gnd
5	3.3V	52	SL2<n>	SL1<n>
6	3.3V	51	SL2<p>	SL1<p>
7	3.3V_GND	50	signal gnd	signal gnd
8	3.3V_GND	49	SL1<n>	SL2<n>
9	VND_IO_A	48	SL1<p>	SL2<p>
10	VND_IO_B	47	signal gnd	signal gnd
11	TX_DIS	46	SL0<n>	SL3<n>
12	RX_LOS	45	SL0<p>	SL3<p>
13	GLB_ALRMn	44	signal gnd	signal gnd
14	MOD_LOPWR	43	(REFCLKn)	(REFCLKn)
15	MOD_ABS	42	(REFCLKp)	(REFCLKp)
16	MOD_RSTn	41	signal gnd	signal gnd
17	MDC	40	DL3<n>	DL3<p>
18	MDIO	39	DL3<p>	DL3<n>
19	PRTADR0	38	signal gnd	signal gnd
20	PRTADR1	37	DL2<n>	DL2<p>
21	PRTADR2	36	DL2<p>	DL2<n>
22	VND_IO_C	35	signal gnd	signal gnd
23	VND_IO_D	34	DL1<n>	DL1<p>
24	VND_IO_E	33	DL1<p>	DL1<n>
25	GND	32	signal gnd	signal gnd
26	(MCLKn)	31	DL0<n>	DL0<p>
27	(MCLKp)	30	DL0<p>	DL0<n>
28	GND	29	signal gnd	signal gnd

100GBASE-CR4 MDI connector contact assignments shall be as defined in Table 92–14. Note that the

source lanes (SL), signals $SLi<p>$, and $SLi<n>$ are the positive and negative sides of the transmitters differential signal pairs and the destination lanes (DL) signals, $DLi<p>$, and $DLi<n>$ are the positive and negative sides of the receivers differential signal pairs for lane i ($i = 0, 1, 2, 3$).

92.13 .Environmental specifications

All equipment subject to this clause shall conform to the applicable requirements of [14.7](#).

92.13 Protocol implementation conformance statement (PICS) proforma for Clause 92, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-CR4¹⁰

92.13.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 92, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-CR4, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in [Clause 21](#).

92.13.2 Identification

92.13.2.1 Implementation identification

Supplier ¹	
Contact point for enquiries about the PICS ¹	
Implementation Name(s) and Version(s) ^{1,3}	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s) ²	
NOTE 1— Required for all implementations. NOTE 2— May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

92.13.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3bj-20XX, Clause 92, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-CR4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [] Yes [] (See Clause 21 ; the answer Yes means that the implementation does not conform to IEEE Std 802.3bj-20XX.)	

Date of Statement	
-------------------	--

¹⁰Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

92.13.3 Major capabilities/options

Item ^a	Feature	Subclause	Value/Comment	Status	Support
CGMII	CGMII	92.1	Interface is supported	O	Yes [] No []
PCS	100GBASE-R PCS	92.1		M	Yes []
RS-FEC	100GBASE-R RS-FEC	92.1		M	Yes []
PMA	100GBASE-R PMA	92.1		M	Yes []
CAUI	CAUI	92.1	Interface is supported	O	Yes [] No []
CR4	100GBASE-CR4 PMD	92.1	Can operate as 100GBASE-CR4 PMD	O.1	Yes []
AN	Auto-negotiation	92.1	Device implements Auto-Negotiation	M	Yes []
DC	Delay constraints	92.4	Device conforms to delay constraints specified in 92.4	M	Yes []
DSC	Skew constraints	92.5	Device conforms to Skew and Skew Variation constraints specified in 92.5	M	Yes []
*MD	MDIO capability	92.6	Registers and interface supported	O	Yes [] No []
*EEE	EEE capability	92.1	Capability is supported	O	Yes [] No []
*CBL	Cable assembly	92.10	Items marked with CBL include cable assembly specifications not applicable to a PHY manufacturer	O	Yes [] No []
CA401	100GBASE-CR4 Style-1 cable assembly	92.10	Cable assembly supports 100GBASE-CR4 Style-1	CBL:O.2	Yes [] No []
CA402	100GBASE-CR4 Style-2 cable assembly	92.10	Cable assembly supports 100GBASE-CR4 Style-2	CBL:O.2	Yes [] No []
MDIST1	Style-1 MDI connector	92.12.1.1	100GBASE-CR4 device uses Style-1 MDI	O:2	Yes [] N/A []
MDIST2	Style-2 MDI connector	92.12.1.2	100GBASE-CR4 device uses Style-2 MDI	O:2	Yes [] N/A []

^aA “*” preceding an “Item” identifier indicates there are other PICS that depend on whether or not this item is supported.

92.13.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 40GBASE-CR4 and 100GBASE-CR10**92.13.4.1 PMD functional specifications**

Item	Feature	Sub clause	Value/Comment	Status	Support
PF1	Transmit function	92.7.2	Converts four logical bit streams into four or ten separate electrical streams	M	Yes []
PF2	Transmit function	92.7.2	Conveys four bits from PMD service interface to MDI lanes	M	Yes []
PF3	Transmitter signal	92.7.2	A positive differential voltage corresponds to tx_bit = one	M	Yes []
PF4	Receive function	92.7.3	Converts four electrical signal streams from the MDI into four logical bit streams	M	Yes []
PF5	Receive function	92.7.3	Conveys four bit streams from the MDI lanes to the PMD service interface	M	Yes []
PF6	Receiver signal	92.7.3	A positive differential voltage corresponds to rx_bit = one	M	Yes []
PF7	Global PMD Signal Detect function	92.7.4	Report state via PMD:IS_SIGNAL.indication (SIGNAL_DETECT)	M	Yes []
PF8	Signal_Detect value	92.7.4	Set to FAIL following reset	M	Yes []
PF9	Signal_Detect value	92.7.4	Set to OK on completion of training	M	Yes []
PF10	Signal_Detect value	92.7.4	Set to OK if training disabled by management	M	Yes []
PF11	Global_PMD_transmit_disable	92.7.6	Disables all transmitters by forcing a constant output state	O	Yes [] No []
PF12	Global_PMD_transmit_disable	92.7.6	Loopback not affected	O	Yes [] No []
PF13	Lane-by-lane_PMD_transmit_disable	92.7.7	Allows each lane transmitter to be selectively disabled	O	Yes [] No []
PF14	Lane-by-lane_PMD_transmit_disable	92.7.7	Disables transmitters by forcing a constant output state	O	Yes [] No []
PF15	Lane-by-lane_PMD_transmit_disable	92.7.7	Loopback not affected	O	Yes [] No []
PF16	Loopback	92.7.8	Loopback function provided	M	Yes []
PF17	PMD fault function	92.7.9	Mapped to bit 1.1.7 as listed in Table 92-3	M	Yes []
PF18	PMD control function	92.7.12	Pattern described in 72.6.10 different for each of the lanes	M	Yes []

92.13.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Global_PMD_signal_detect	92.7.4	Set to the value described in 45.2.1.9.7	O	Yes []
MF2	Global_PMD_signal_detect	92.7.4	Set defined by the training state diagram in Figure 72-5	O	Yes [] No []
MF3	Lane-by-Lane Signal Detect function	92.7.5	Sets PMD_signal_detect_n values on a lane-by-lane basis per requirements of 92.7.5	MD:M	Yes [] N/A []
MF4	PMD_transmit_fault function	92.7.10	Mapped to the PMD_transmit_fault bit as specified in 45.2.1.7.4	MD:M	Yes [] N/A []
MF5	PMD_receive_fault function	92.7.11	Contributes to the PMA/PMD receive fault bit as specified in 45.2.1.7.5	MD:M	Yes [] N/A []

92.13.4.3 Transmitter specifications

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	Test fixture return loss	92.11.1.1	Meets equation constraints	M	Yes []
TC2	Test fixture insertion loss	92.11.1.2	Meets equation constraints	M	Yes []
TC3	Signaling rate per lane	92.8.3.7	25.78125 GBd \pm 100 ppm	M	Yes []
TC4	Peak-to-peak differential output voltage	92.8.3.1	Less than or equal to 1200 mV regardless of transmit equalizer setting	M	Yes []
TC5	Peak-to-peak differential output voltage, transmitter disabled	92.8.3.1	Less than or equal to 30 mV	M	Yes []
TC6	DC common-mode output voltage	92.8.3.1	Between 0 V and 1.9 V with respect to signal ground	M	Yes []
TC7	AC common-mode output voltage	92.8.3.1	Less than or equal to 30 mV RMS with respect to signal ground	M	Yes []
TC8	Common-mode output voltage requirements	92.8.3.1	Met regardless of the transmit equalizer setting	M	Yes []
TC9	Differential output return loss (min)	92.8.3.2	Meets equation constraints	M	Yes []
TC10	Reference impedance for differential return loss measurements	92.8.3.2	100 Ω	M	
TC11	Steady state voltage, v_f	92.8.3.4.1	0.34 min, 0.6 max	M	Yes []

Item	Feature	Subclause	Value/Comment	Status	Support
TC12	Linear fit pulse peak (min)	92.8.3.4.1	$0.52 \times v_f$	M	Yes []
TC13	Normalized linear fit error (max)	92.8.3.4.2	0.037	M	Yes []
TC14	Coefficient initialization	92.8.3.4.3	Satisfies the requirements of 92.8.3.4.3.	M	Yes []
TC15	Normalized coefficient step size for “increment”	92.8.3.4.4	Between 0.0083 and 0.05	M	Yes []
TC16	Normalized coefficient step size for “decrement”	92.8.3.4.4	Between –0.05 and –0.0083	M	Yes []
TC17	Maximum post-cursor equalization ratio	92.8.3.4.5	Greater than or equal to 4	M	Yes []
TC18	Maximum pre-cursor equalization ratio	92.8.3.4.5	Greater than or equal to 1.54	M	Yes []
TC19	Transmitter far-end output noise, low-loss channel	92.8.3.3	Less than or equal to 2 mV RMS	M	Yes []
TC20	Transmitter far-end output noise, high-loss channel	92.8.3.3	Less than or equal to 1 mV RMS	M	Yes []
TC21	Even-odd jitter	92.8.3.6	Less than or equal to 0.035 UI regardless of the transmit equalization setting	M	Yes []
TC22	The total jitter, excluding data dependent jitter	92.8.3.6	less than or equal to 0.28 UI regardless of the transmit equalization setting	M	Yes []
TC23	Effective random jitter	92.8.3.6	Shall be less than or equal to 0.15 UI regardless of the transmit equalization setting	M	Yes []

92.13.4.4 Receiver specifications

Item	Feature	Subclause	Value/Comment	Status	Support
RC1	Test fixture return loss	92.11.1.1	Meets equation constraints	M	Yes []
RC2	Test fixture insertion loss	92.11.1.2	Meets equation constraints	M	Yes []
RC3	Differential input return loss	92.8.4.1	Meets equation constraints	M	Yes []
RC4	Reference impedance for differential return loss measurements	92.8.4.1	100 Ω	M	Yes []
RC5	Common-mode input return loss	92.8.4.2	Meets equation constraints	M	Yes []
RC6	Interference tolerance	92.8.4.3	Satisfy requirements summarized in Table 92–8	M	Yes []
RC7	Interference tolerance	92.8.4.3	Pattern generator output amplitude	M	Yes []
RC8	Interference tolerance	92.8.4.3	Pattern generator jitter specification	M	Yes []
RC9	Signaling rate, per lane	92.8.4.5	25.78125 GBd \pm 100 ppm	M	Yes []
RC10	AC coupling	92.8.4.6	3 dB cutoff	M	Yes []

92.13.4.5 Cable assembly specifications

Item	Feature	Subclause	Value/Comment	Status	Support
CA1	Differential reference impedance	92.10.1	100 Ω	CBL:M	Yes [] N/A []
CA2	Insertion loss	92.10.2	Per Equation (92–8) and Table 92–10	CBL:M	Yes [] N/A []
CA3	Insertion loss deviation	92.10.3	Per Equation (92–12) and Equation (92–13)	CBL:M	Yes [] N/A []
CA4	Return loss	92.10.4	Per Equation (92–14)	CBL:M	Yes [] N/A []
CA5	Integrated crosstalk noise	92.10.7	Integrated crosstalk noise voltage per Equation (92–17) through Equation (92–22) and Table 92–11	CBL:M	Yes [] N/A []
CA6	Test fixture reference printed circuit board insertion loss	92.11.2	Per Equation (92–24)	CBL:M	Yes [] N/A []
CA7	Mated test fixture insertion loss	92.11.3.1	Per Equation (92–25) and Equation (92–26)	CBL:M	Yes [] N/A []
CA8	Mated test fixture return loss	92.11.3.2	Per Equation (92–27)	CBL:M	Yes [] N/A []
CA8	Mated test fixture common-mode conversion loss	92.11.3.3	Per Equation (92–28)	CBL:M	Yes [] N/A []
CA8	Mated test fixture common mode return loss	92.11.3.4	Per Equation (92–29)	CBL:M	Yes [] N/A []
CA9	Mated test fixtures integrated crosstalk noise	92.11.3.5	Per Equation (92–17), through Equation (92–21) and Table 92–12	CBL:M	Yes [] N/A []
CA12	Cable assembly connector type	92.12.1.1	100GBASE-CR4 Style-1 plug (SFF-8665 plug)	CA401:M	Yes [] N/A []
CA13	Pin assignments	92.12.1.1	Per Table 92–13		Yes [] N/A []
CA16	Cable assembly connector type	92.12.1.2	100GBASE-CR4 Style-2 plug (CFP4)	CA100:M	Yes [] N/A []
CA17	Pin assignments	92.12.1.2	Per Table 92–14		Yes [] N/A []
CA18	AC coupling	92.8.4.6	3 dB cutoff	M	Yes []

92.13.4.6 MDI connector specifications

Item	Feature	Subclause	Value/Comment	Status	Support
MDC1	MDI connector type	92.12.1.1	100GBASE-CR4 Style-1 receptacle (SFF-8665 receptacle)	CR4*MDIST1:M	Yes [] N/A []
MDC2	MDI connector type	92.12.1.2	100GBASE-CR4 Style-2 receptacle (CFP4 receptacle)	CR4*MDIST2:M	Yes []

92.13.4.7 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Environmental specifications	92.13		M	Yes []

93. Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KR4

93.1 Overview

This clause specifies the 100GBASE-KR4 PMD and baseband medium. There are two associated annexes. Annex 93A defines characteristics of electrical backplanes and Annex 93B extends the electrical backplane reference model with additional informative test points.

When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA as shown in Table 93–1, to the medium through the MDI and to the management functions that are optionally accessible through the management interface defined in Clause 45, or equivalent.

Table 93–1—Physical Layer clauses associated with the 100GBASE-KR4 PMD

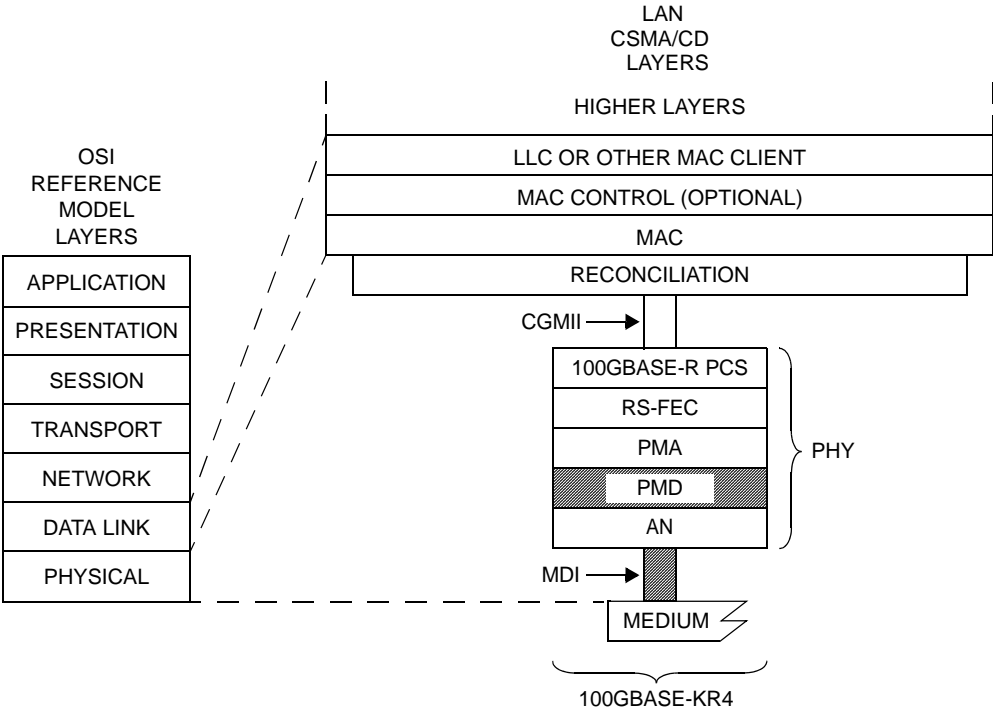
Associated clause	100GBASE-KR4
81—RS	Required
81—CGMII ^a	Optional
82—PCS for 100GBASE-R	Required
91—RS-FEC	Required
83—PMA for 100GBASE-R ^b	Required
83A—CAUI	Optional
73—Auto-Negotiation	Required
78—Energy-Efficient Ethernet	Optional

^aThe CGMII is an optional interface. However, if the CGMII is not implemented, a conforming implementation must behave functionally as though the RS and CGMII were present.

^bThere are limitations on the number of PMA lanes that may be used between sublayers, see 83.3.

A 100GBASE-KR4 PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization.

Figure 93–1 shows the relationship of the 100GBASE-KR4 PMD sublayers and MDI to the ISO/IEC Open System Interconnection (OSI) reference model.



AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE

PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION

Figure 93–1—100GBASE-KR4 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

Differential signals received at the MDI from a transmitter that meets the requirements of 93.8.1 and have passed through the channel specified in 93.9 are received with a BER less than 10^{-5} .

For a complete Physical Layer, this specification is considered to be satisfied by a frame error ratio less than 1.7×10^{-10} for 64 octet frames with minimum inter-packet gap.

93.2 Physical Medium Dependent (PMD) service interface

This subclause specifies the services provided by the 100GBASE-KR4 PMD. The service interface for this PMD is described in an abstract manner and does not imply any particular implementation. The PMD service interface supports the exchange of encoded data. The PMD translates the encoded data to and from signals suitable for the medium.

The PMD service interface is an instance of the inter-sublayer service interface defined in 80.3. The PMD service interface primitives are summarized as follows:

PMD:IS_UNITDATA_*i*.request
PMD:IS_UNITDATA_*i*.indication
PMD:IS_SIGNAL.indication

The 100GBASE-KR4 PMD has four parallel bit streams, hence $i = 0$ to 3. The PMA (or the PMD) continuously sends four parallel bit streams to the PMD (or the PMA), one per lane, each at a nominal signaling rate of 25.78125 GBd.

The SIGNAL_OK parameter of the PMD:IS_SIGNAL.indication primitive is assigned the value of SIGNAL_DETECT as defined in 93.7.4. When SIGNAL_OK is FAIL, the PMD:IS_UNITDATA_*i*.indication parameters are undefined.

If the optional EEE capability is supported, then the PMD service interface includes two additional primitives as follows:

PMD:IS_TX_MODE.request
PMD:IS_RX_MODE.request

Editor's note (to be removed prior to final publication):

The PMD service interface has been augmented as implied by barrass_01_0312 per the motion passed in the March Task Force meeting.

“Move that the 802.3bj Task Force adopt barrass_01_0312.pdf as a baseline for optional Energy Efficient Ethernet operation for 100G Backplane and Twinaxial cable PHYs. (M: M. Gustlin, S: M. Brown, Y: 54, N: 0, A: 3)”

Per barrass_01_0312, PMD transmit function behavior changes as a function of the tx_mode parameter.

DATA, SLEEP, or WAKE: normal behavior
ALERT: send the ALERT signal
FW: send a PMA-specific pattern that is TBD (PMD normal behavior?)
QUIET: disable the transmitter

Per barrass_01_0312, the PMD receive function infers rx_mode from the received signal.

Normal or rapid alignment markers: DATA, SLEEP, or WAKE (mapping not defined)
No signal: QUIET
Alert signal: ALERT
PMA-specific pattern for FW that is TBD: FW (PMA function?)

Given the ambiguity surrounding PMD behavior and the TBD signaling for ALERT, FW, etc., these functions have not been added to the clause. The functions will be added to the clause upon adoption of a detailed proposal describing the desired behavior.

93.3 PCS requirements for Auto-Negotiation (AN) service interface

The PCS associated with this PMD is required to support the AN service interface primitive AN_LINK.indication defined in 73.9. (See 82.6.)

93.4 Delay constraints

The sum of the transmit and the receive delays at one end of the link contributed by the 100GBASE-KR4 PMD, AN, and the medium in one direction shall be no more than 2048 bit times (2 pause_quanta or 20.48 ns). It is assumed that the one way delay through the medium is no more than 800 bit times (8 ns).

A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 80.4 and its references.

93.5 Skew constraints

The Skew (relative delay) between the lanes must be kept within limits so that the information on the lanes can be reassembled by the PCS. The Skew Variation must also be limited to ensure that a given PCS lane always traverses the same physical lane. Skew and Skew Variation are defined in 80.5 and specified at the points SP1 to SP6 shown in Figure 80–4 and Figure 80–5.

If the PMD service interface is physically instantiated so that the Skew at SP2 can be measured, then the Skew at SP2 is limited to 43 ns and the Skew Variation at SP2 is limited to 400 ps.

The Skew at SP3 (the transmitter MDI) shall be less than 54 ns and the Skew Variation at SP3 shall be less than 600 ps.

The Skew at SP4 (the receiver MDI) shall be less than 134 ns and the Skew Variation at SP4 shall be less than 3.4 ns.

If the PMD service interface is physically instantiated so that the Skew at SP5 can be measured, then the Skew at SP5 shall be less than 145 ns and the Skew Variation at SP5 shall be less than 3.6 ns.

For more information on Skew and Skew Variation see 80.5.

93.6 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 93–2, and MDIO status variables to PMD status variables as shown in Table 93–3.

Table 93–2—100GBASE-KR4 MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	PMD control variable
Reset	PMA/PMD control 1	1.0.15	PMD_reset
Global PMD transmit disable	PMD transmit disable	1.9.0	Global_PMD_transmit_disable
PMD transmit disable 3 to PMD transmit disable 0	PMD transmit disable	1.9.4 to 1.9.1	PMD_transmit_disable_3 to PMD_transmit_disable_0
Restart training	BASE-R PMD control	1.150.0	mr_restart_training
Training enable	BASE-R PMD control	1.150.1	mr_training_enable

Table 93–3—100GBASE-KR4 MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMD status variable
Fault	PMA/PMD status 1	1.1.7	PMD_fault
Transmit fault	PMA/PMD status 2	1.8.11	PMD_transmit_fault
Receive fault	PMA/PMD status 2	1.8.10	PMD_receive_fault
Global PMD receive signal detect	PMD receive signal detect	1.10.0	Global_PMD_signal_detect
PMD receive signal detect 3 to PMD receive signal detect 0	PMD receive signal detect	1.10.4 to 1.10.1	PMD_signal_detect_3 to PMD_signal_detect_0
Receiver status 3	BASE-R PMD status	1.151.12	rx_trained_3
Frame lock 3	BASE-R PMD status	1.151.13	frame_lock_3
Start-up protocol status 3	BASE-R PMD status	1.151.14	training_3
Training failure 3	BASE-R PMD status	1.151.15	training_failure_3
Receiver status 2	BASE-R PMD status	1.151.8	rx_trained_2
Frame lock 2	BASE-R PMD status	1.151.9	frame_lock_2
Start-up protocol status 2	BASE-R PMD status	1.151.10	training_2
Training failure 2	BASE-R PMD status	1.151.11	training_failure_2
Receiver status 1	BASE-R PMD status	1.151.4	rx_trained_1
Frame lock 1	BASE-R PMD status	1.151.5	frame_lock_1
Start-up protocol status 1	BASE-R PMD status	1.151.6	training_1
Training failure 1	BASE-R PMD status	1.151.7	training_failure_1
Receiver status 0	BASE-R PMD status	1.151.0	rx_trained_0
Frame lock 0	BASE-R PMD status	1.151.1	frame_lock_0
Start-up protocol status 0	BASE-R PMD status	1.151.2	training_0
Training failure 0	BASE-R PMD status	1.151.3	training_failure_0

93.7 PMD functional specifications

93.7.1 Link block diagram

One direction for one lane of a 100GBASE-KR4 link is shown in Figure 93–2.

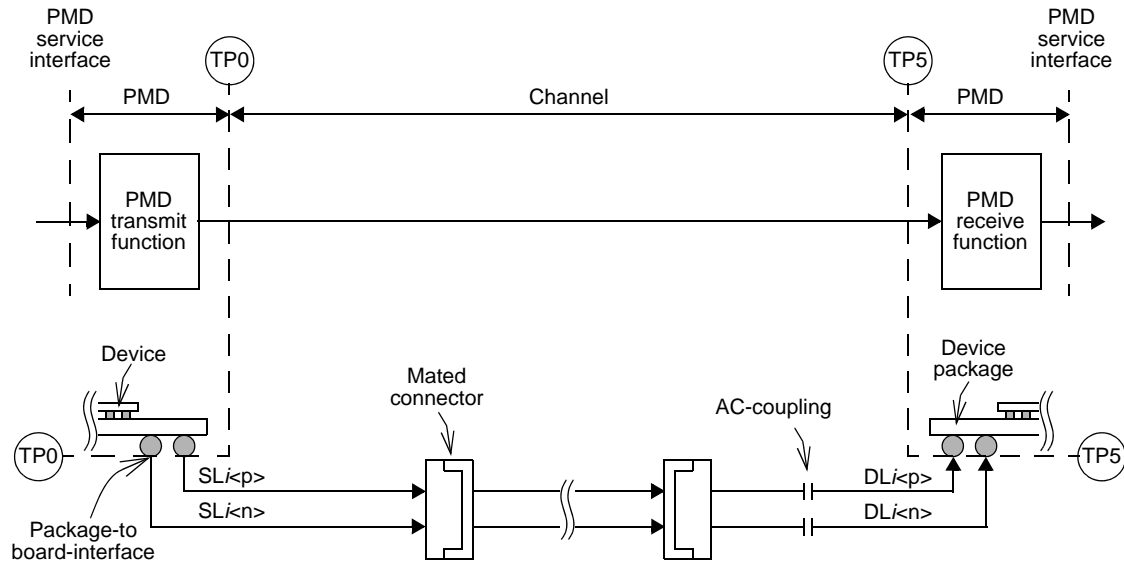


Figure 93–2—100GBASE-KR4 link (one direction for one lane is illustrated)

93.7.2 PMD Transmit function

The PMD transmit function shall convert the four bit streams requested by the PMD service interface messages `PMD:IS_UNITDATA_0.request` to `PMD:IS_UNITDATA_3.request` into four separate electrical streams. The four electrical signal streams shall then be delivered to the MDI, all according to the transmit electrical specifications in 93.8.1. A positive output voltage of $SLi<p>$ minus $SLi<n>$ (differential voltage) shall correspond to `tx_bit = one`.

93.7.3 PMD Receive function

The PMD receive function shall convert the four electrical streams from the MDI into four bit streams for delivery to the PMD service interface using the messages `PMD:IS_UNITDATA_0.indication` to `PMD:IS_UNITDATA_3.indication`. A positive input voltage of $DLi<p>$ minus $DLi<n>$ (differential voltage) shall correspond to `rx_bit = one`.

93.7.4 Global PMD signal detect function

The Global PMD signal detect function shall continuously report the message `PMD:IS_SIGNAL.indication` (`SIGNAL_DETECT`) to the PMD service interface. `SIGNAL_DETECT`, while normally intended to be an indicator of signal presence, is used by the 100GBASE-KR4 PMD to indicate the successful completion of the start-up protocol on all lanes. The `SIGNAL_DETECT` parameter defined in this clause maps to the `SIGNAL_OK` parameter in the `PMD:IS_SIGNAL.indication` primitive.

`SIGNAL_DETECT` shall be set to `FAIL` following system reset or the manual reset of the training state diagram. Upon successful completion of training on all lanes, `SIGNAL_DETECT` shall be set to `OK`.

If training is disabled by management, SIGNAL_DETECT shall be set to OK.

If the MDIO interface is implemented, then Global_PMD_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

93.7.5 PMD lane-by-lane signal detect function

When the MDIO is implemented, each PMD_signal_detect_*i* value, where *i* represents the lane number in the range 0 to 3, shall be continuously updated as described in the following two paragraphs.

PMD_signal_detect_0 (1.10.1), PMD_signal_detect_1 (1.10.2), PMD_signal_detect_2 (1.10.3), and PMD_signal_detect_3 (1.10.4) shall be set to one or zero depending on whether a particular lane's signal_detect, as defined by the training state diagram in Figure 72–5, returns true or false.

93.7.6 Global PMD transmit disable function

The Global PMD transmit disable function is optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

- a) When Global_PMD_transmit_disable variable is set to one, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 93–4.
- b) If a PMD_fault (93.7.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
- c) Loopback, as defined in 93.7.8, shall not be affected by Global_PMD_transmit_disable.

93.7.7 PMD lane-by-lane transmit disable function

The PMD transmit disable function is optional and allows the electrical transmitter in each lane to be selectively disabled. When this function is supported, it shall meet the following requirements:

- a) When a PMD_transmit_disable_*i* variable (where *i* represents the lane number in the range 0 to 3) is set to one, this function shall turn off the transmitter associated with that variable such that it drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 93–4.
- b) If a PMD_fault (93.7.9) is detected, then the PMD may set each PMD_transmit_disable_*i* to one, turning off the electrical transmitter in each lane.
- c) Loopback, as defined in 93.7.8, shall not be affected by PMD_transmit_disable_*i*.

93.7.8 Loopback mode

Local loopback mode is provided by the adjacent PMA (see 83.5.8) as a test function to the device. When loopback mode is enabled, transmission requests passed to each transmitter are sent directly to the corresponding receiver, overriding any signal detected by each receiver on its attached link. Note that loopback mode does not affect the state of the transmitter, which continues to send data (unless disabled).

Control of the loopback function is specified in 45.2.1.1.5.

NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

93.7.9 PMD_fault function

PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault, and any other implementation specific fault. If the MDIO is implemented, PMD_fault shall be mapped to the fault bit as specified in [45.2.1.2.1](#).

93.7.10 PMD transmit fault function

The PMD_transmit_fault function is optional. The faults detected by this function are implementation specific, but the assertion of Global_PMD_transmit_disable is not considered a transmit fault.

If a PMD_transmit_fault (optional) is detected, then the Global_PMD_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the Transmit fault bit as specified in [45.2.1.7.4](#).

93.7.11 PMD receive fault function

The PMD_receive_fault function is optional. The faults detected by this function are implementation specific.

If the MDIO interface is implemented, then this function shall contribute to the Receive fault bit as specified in [45.2.1.7.5](#).

93.7.12 PMD control function

Each lane of the 100GBASE-KR4 PMD shall use the same control function as 10GBASE-KR, as defined in [72.6.10](#). The training frame structure used by the 100GBASE-KR4 PMD control function shall be as defined in [72.6.10](#) with the exception that 25.78125 GBd symbols replace 10.3125 GBd symbols and 100GBASE-KR4 UI replace 10GBASE-KR UI.

The seeds of the training pattern described in [72.6.10.2.6](#) should be chosen to minimize the correlation between lanes on the medium.

The variables rx_trained_{*i*}, frame_lock_{*i*}, training_{*i*}, and training_failure_{*i*} (where *i* goes from 0 to 3) report status for each lane and are equivalent to rx_trained, frame_lock, training, and training_failure as defined in [72.6.10.3.1](#).

If the MDIO interface is implemented, then this function shall map these variables to the appropriate bits in the BASE-R PMD status register (Register 1.151) as specified in [45.2.1.80](#).

93.8 100GBASE-KR4 electrical characteristics

93.8.1 Transmitter characteristics

Transmitter characteristics measured at TP0a are summarized in Table 93–4.

93.8.1.1 Transmitter test fixture

Unless otherwise noted, measurements of the transmitter are made at the output of a test fixture as shown in Figure 93–4.

Table 93–4—Summary of transmitter characteristics at TP0a

Parameter	Subclause reference	Value	Units
Signaling rate	93.8.1.2	25.78125±100 ppm	GBd
Differential peak-to-peak output voltage (max.) Transmitter disabled ^a Transmitter enabled	93.8.1.3	30 1200	mV mV
DC common-mode output voltage (max.)	93.8.1.3	1.9	V
DC common-mode output voltage (min.)	93.8.1.3	0	V
AC common-mode output voltage (RMS, max.)	93.8.1.3	12	mV
Differential output return loss (min.)	93.8.1.4	Equation (93–2)	dB
Common-mode output return loss (min.)	93.8.1.4	Equation (93–3)	dB
Transition time (20-80%, min.), no equalization ^b	93.8.1.5	8	ps
Output waveform Steady-state voltage v_f (max.) Steady-state voltage v_f (min.) Linear fit pulse peak (min.) Normalized RMS linear fit error (max.) Normalized coefficient step size (min.) Normalized coefficient step size (max.) Pre-cursor full-scale range (min.) Post-cursor full-scale range (min.)	93.8.1.6	0.6 0.4 $0.8 \times v_f$ 0.037 0.0083 0.05 1.54 4	V V V — — — — —
Far-end output noise (max.) Low insertion loss channel High insertion loss channel	93.8.1.7	2 1	mV mV
Output jitter (max.) Effective random jitter Even-odd jitter Total jitter excluding data dependent jitter	93.8.1.8	0.15 0.035 0.28	UI UI UI

^aThe transmitter for lane i is disabled when either Global_PMD_transmit_disable or PMD_transmit_disable_ i is set to one.

^bTransmit equalization may be disabled by asserting the preset control defined in Table 45–60 and 45.2.1.81.3.

The insertion loss of the test fixture shall be between 1.2 dB and 1.6 dB at 12.89 GHz. The magnitude of the insertion loss deviation of the test fixture shall be less than or equal to 0.1 dB from 0.05 to 13 GHz.

The differential return loss of the test fixture, in dB, shall meet Equation (93–1) where f is the frequency in GHz.

$$RL(f) \geq \begin{cases} 20 - f & 0.05 \leq f \leq 5 \\ 15 & 5 < f \leq 13 \end{cases} \text{ dB} \quad (93-1)$$

The return loss limit is illustrated by Figure 93–3.

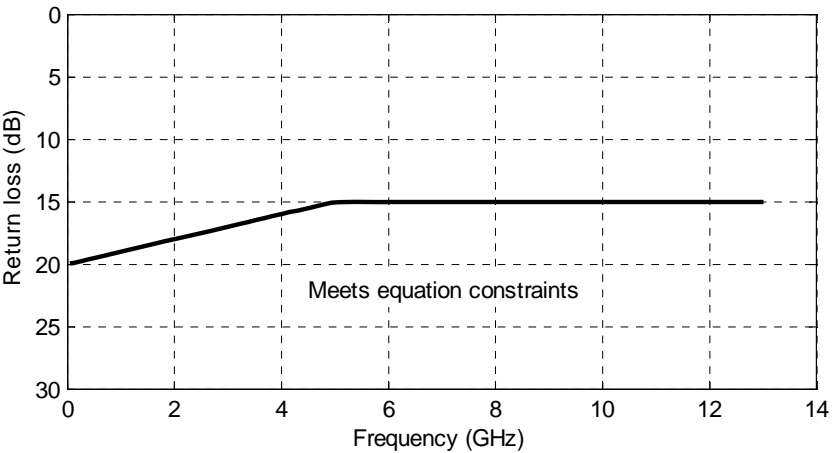


Figure 93–3—TP0a test fixture return loss limit

The common-mode return loss of the test fixture shall be greater than or equal to 10 dB from 0.05 to 13 GHz.

Unless otherwise noted, a 4th-order Bessel-Thompson filter with a 33 GHz cut-off frequency is applied to the transmitted signal prior to signal measurements.

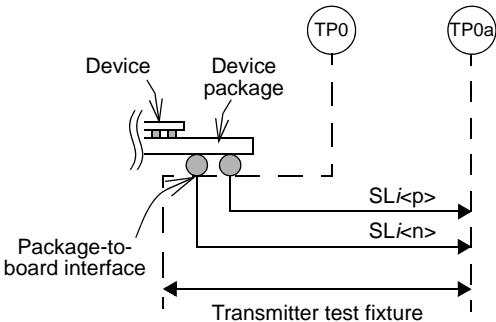


Figure 93–4—Transmitter test fixture and test points

93.8.1.2 Signaling rate and range

The 100GBASE-KR4 signaling rate shall be 25.78125 GBd ± 100 ppm per lane.

93.8.1.3 Signal levels

The differential output voltage v_{di} is defined to be $SLi<p>$ minus $SLi<n>$. The common-mode output voltage v_{cmi} is defined to be one half of the sum of $SLi<p>$ and $SLi<n>$. These definitions are illustrated by Fig-

Figure 93–5.

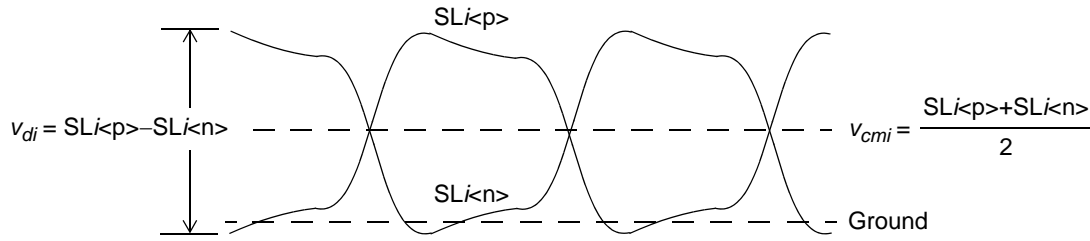


Figure 93–5—Transmitter output voltage definitions

The peak-to-peak differential output voltage shall be less than or equal to 1200 mV regardless of the transmit equalizer setting. The peak-to-peak differential output voltage shall be less than or equal to 30 mV when the transmitter is disabled (refer to 93.7.6 and 93.7.7).

The DC common-mode output voltage shall be between 0 V and 1.9 V with respect to signal ground. The AC common-mode output voltage shall be less than or equal to 12 mV RMS with respect to signal ground. Common-mode output voltage requirements shall be met regardless of the transmit equalizer setting.

Differential and common-mode signal levels are measured with a PRBS9 test pattern.

93.8.1.4 Transmitter output return loss

The differential output return loss, in dB, of the transmitter shall meet Equation (93–2) where f is the frequency in GHz. This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω .

$$RL(f) \geq -10 \log_{10} \left(\frac{449.7 + f^2}{3671 + f^2} \right) \text{ dB}, 0.05 \leq f \leq 13 \text{ GHz} \quad (93-2)$$

The return loss limit is illustrated by Figure 93–6.

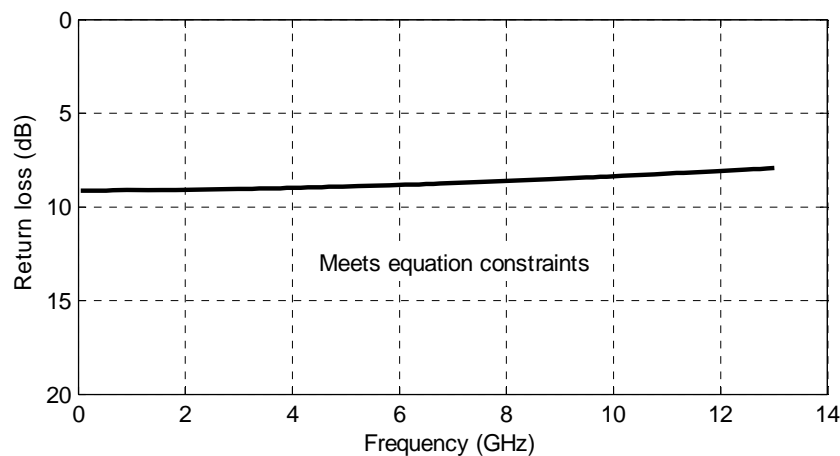


Figure 93–6—Transmitter return loss limit

The common-mode output return loss, in dB, of the transmitter shall meet Equation (93–3) where f is the frequency in GHz. This output impedance requirement applies to all valid output levels. The reference impedance for common-mode return loss measurements shall be $25\ \Omega$.

$$RL(f) \geq 6\ \text{dB}, 0.05 \leq f \leq 13\ \text{GHz} \quad (93-3)$$

93.8.1.5 Transition time

Transition times (rise and fall times) are defined in 86A.5.3.3. The transition times shall be greater than or equal to 8 ps when transmit equalization is disabled. Transmit equalization may be disabled by asserting the preset control defined in Table 45–60 and 45.2.1.81.3.

93.8.1.6 Transmitter output waveform

The 100GBASE-KR4 transmit function includes programmable equalization to compensate for the frequency-dependent loss of the channel and facilitate data recovery at the receiver. The functional model for the transmit equalizer is the three tap transversal filter shown in Figure 93–7.

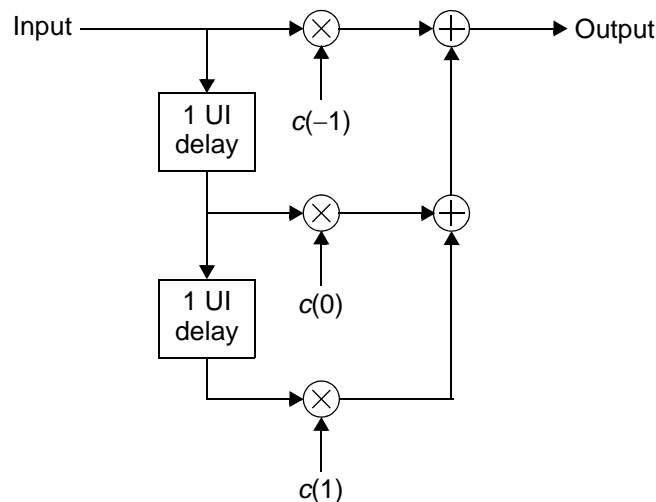


Figure 93–7—Transmit equalizer functional model

The state of the transmit equalizer and hence the transmitted output waveform may be manipulated via the PMD control function defined in 93.7.12 or via the management interface. The transmit function responds to a set of commands issued by the link partner's receive function and conveyed by a back-channel communications path.

This command set includes instructions to:

- Increment coefficient $c(i)$.
- Decrement coefficient $c(i)$.
- Hold coefficient $c(i)$ at its current value.
- Set the coefficients to a pre-defined value (preset or initialize).

In response, the transmit function relays status information to the link partner's receive function. The status messages indicate that:

The requested update to coefficient $c(i)$ has completed (updated).

Coefficient $c(i)$ is at its minimum value.

Coefficient $c(i)$ is at its maximum value.

Coefficient $c(i)$ is ready for the next update request (not_updated).

The transmitter output waveform is characterized using the procedure described in 85.8.3.3. The parameters of the linear pulse fit and equalizer are summarized in Table 93–5.

Table 93–5—Linear fit pulse and equalizer parameters

Description	Symbol	Value	Units
Linear fit pulse length	N_p	8	UI
Linear fit pulse delay	D_p	2	UI
Equalizer length	N_w	8	UI
Equalizer delay	D_w	2	UI

93.8.1.6.1 Steady state voltage and linear fit pulse peak

The steady state voltage v_f is defined to be the sum of the linear fit pulse $p(k)$ divided by M (refer to 85.8.3.3 step 3). The steady state voltage shall be greater than or equal to 0.4 V and less than or equal to 0.6 V after the transmit equalizer coefficients have been set to the "preset" values.

The peak value of $p(k)$ shall be greater than $0.8 \times v_f$ after the transmit equalizer coefficients have been set to the "preset" values.

93.8.1.6.2 Linear fit error

For any configuration of the transmit equalizer, the RMS value of the error between the linear fit and the measured waveform, $e(k)$, normalized to the peak value of the linear fit pulse, $p(k)$, shall be less than or equal to 0.037.

93.8.1.6.3 Coefficient initialization

When the PMD enters the INITIALIZE state of the Training state diagram (Figure 72–5) or receives a valid request to "initialize" from the link partner, the coefficients of the transmit equalizer shall be configured such that the ratio $(c(0)+c(1)-c(-1))/(c(0)+c(1)+c(-1))$ is TBD and the ratio $(c(0)-c(1)+c(-1))/(c(0)+c(1)+c(-1))$ is TBD. These requirements apply upon the assertion a coefficient status report of "updated" for all coefficients.

93.8.1.6.4 Coefficient step size

The change in the normalized amplitude of coefficient $c(i)$ corresponding to a request to "increment" that coefficient shall be between 0.0083 and 0.05. The change in the normalized amplitude of coefficient $c(i)$ corresponding to a request to "decrement" that coefficient shall be between -0.05 and -0.0083 .

The change in the normalized amplitude of the coefficient is defined to be the difference in the value measured prior to the assertion of the "increment" or "decrement" request (e.g., the coefficient update request for all coefficients is "hold") and the value upon the assertion of a coefficient status report of "updated" for that coefficient.

93.8.1.6.5 Coefficient range

When sufficient “increment” or “decrement” requests have been received for a given coefficient, the coefficient will reach a lower or upper bound based on the coefficient range or restrictions placed on the minimum steady state differential output voltage or the maximum peak-to-peak differential output voltage.

With $c(-1)$ set to zero and both $c(0)$ and $c(1)$ having received sufficient “decrement” requests so that they are at their respective minimum values, the ratio $(c(0)-c(1))/(c(0)+c(1))$ shall be greater than or equal to 4.

With $c(1)$ set to zero and both $c(-1)$ and $c(0)$ having received sufficient “decrement” requests so that they are at their respective minimum values, the ratio $(c(0)-c(-1))/(c(0)+c(-1))$ shall be greater than or equal to 1.54.

Note that a coefficient may be set to zero by first asserting the preset control and then manipulating the other coefficients as required by the test.

93.8.1.7 Transmitter far-end output noise

The transmitter far-end output noise is a source of noise in addition to the channel integrated crosstalk noise (ICN) specified in 93.9.4. The transmitter far-end output noise is characterized using the procedure defined in 85.8.3.2.

The far-end transmitter output noise is characterized using two reference channels:

- A “low-loss” channel with 16 dB insertion loss at 12.89 GHz and ICN that meets the requirements of 93.9.4.

- A “high-loss” channel with 35 dB insertion loss at 12.89 GHz and ICN that meets the requirements of 93.9.4.

For the low-loss channel, the far-end transmitter output noise shall be less than or equal to 2 mV RMS. For the high-loss channel, the far-end transmitter output noise shall be less than or equal to 1 mV RMS.

93.8.1.8 Transmitter output jitter

Even-odd jitter is defined in 92.8.3.8. Even-odd jitter shall be less than or equal to 0.035 UI regardless of the transmit equalization setting.

Total jitter is characterized using the procedure defined in 92.8.3.8. Data dependent jitter is characterized using the procedure defined in 85.8.3.8. The total jitter, excluding data dependent jitter, shall be less than or equal to 0.28 UI regardless of the transmit equalization setting.

The effective random jitter is characterized using the procedure defined in 92.8.3.8. The effective random jitter shall be less than or equal to 0.15 UI regardless of the transmit equalization setting.

93.8.2 Receiver characteristics

Receiver characteristics measured at TP5a are summarized in Table 93–6.

93.8.2.1 Receiver test fixture

Unless otherwise noted, measurements of the receiver are made at the input to a test fixture as shown in Figure 93–9.

The insertion loss of the test fixture shall be between 1.2 dB and 1.6 dB at 12.89 GHz. The magnitude of the insertion loss deviation of the test fixture shall be less than or equal to 0.1 dB from 0.05 to 13 GHz.

Table 93–6—Summary of receiver characteristics at TP5a

Parameter	Subclause reference	Value	Units
Differential input return loss (min.)	93.8.2.2	Equation (93–5)	dB
Common-mode input return loss (min.)	93.8.2.2	Equation (93–6)	dB
Differential to common-mode return loss (min.)	93.8.2.2	Equation (93–7)	dB

The differential return loss of the test fixture, in dB, shall meet Equation (93–1) where f is the frequency in GHz.

$$RL(f) \geq \left\{ \begin{array}{ll} 20 - f & 0.05 \leq f \leq 5 \\ 15 & 5 < f \leq 13 \end{array} \right\} \text{ dB}$$

(93–4)

The return loss limit is illustrated by Figure 93–3.

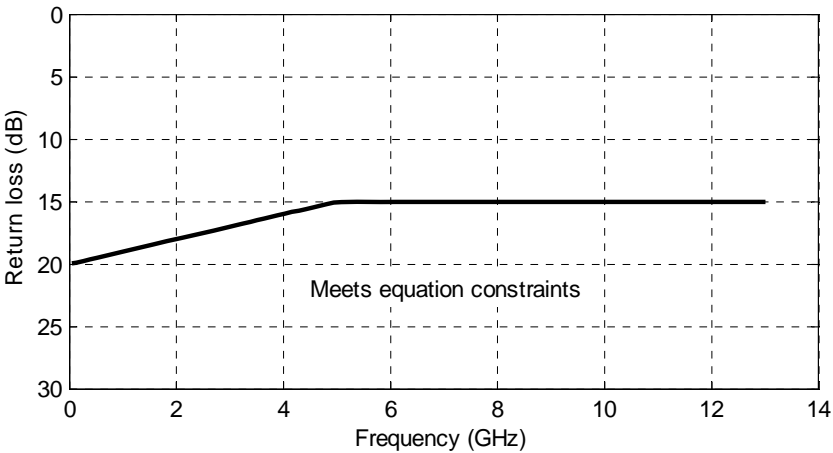


Figure 93–8—TP5a test fixture return loss limit

The common-mode return loss of the test fixture shall be greater than or equal to 10 dB from 0.05 to 13 GHz.

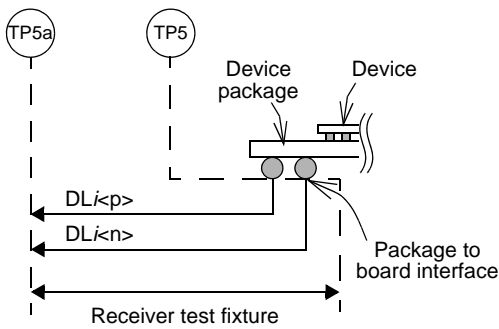


Figure 93–9—Receiver test fixture and test points

93.8.2.2 Receiver input return loss

The differential input return loss, in dB, of the receiver shall meet Equation (93–5) where f is the frequency in GHz. The reference impedance for differential return loss measurements shall be 100 Ω

$$RL(f) \geq -10\log_{10}\left(\frac{449.7 + f^2}{3671 + f^2}\right) \text{ dB}, 0.05 \leq f \leq 13 \text{ GHz}$$

(93–5)

The return loss limit is illustrated by Figure 93–10.

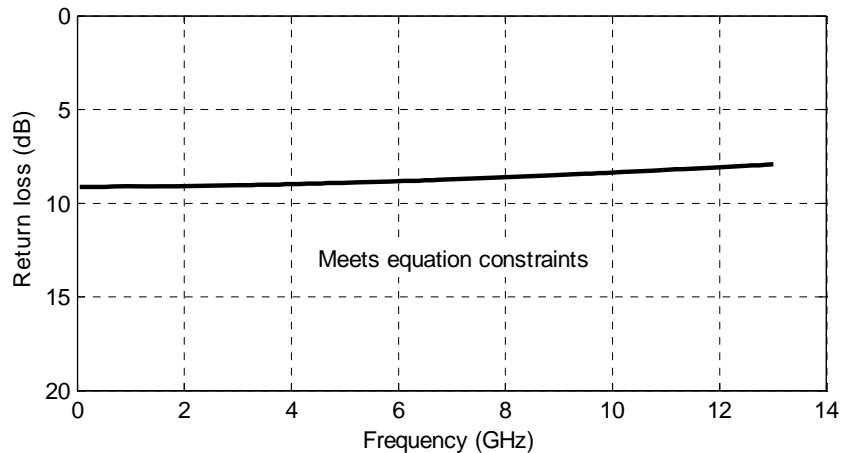


Figure 93–10—Receiver return loss limit

The common-mode input return loss, in dB, of the receiver shall meet Equation (93–6) where f is the frequency in GHz. The reference impedance for common-mode return loss measurements shall be 25 Ω

$$RL(f) \geq 6 \text{ dB}, 0.05 \leq f \leq 13 \text{ GHz}$$

(93–6)

The differential to common-mode return loss, in dB, of the receiver shall meet Equation (93–7).

TBD

(93–7)

93.8.2.3 Receiver interference tolerance

Receiver interference tolerance is characterized using the procedure defined in Annex 69A. The receiver shall satisfy the requirements for interference tolerance summarized in Table 93–7.

Editor’s note (to be removed prior to final publication):

The channel insertion loss fit methodology is intended to be based on OIF-CEI-3.0 section 12.2.

Table 93–7—Receiver interference tolerance parameters

Parameter	Test 1 values	Test 2 values	Test 3 values	Test 4 values	Units
Maximum BER without FEC	10^{-12}	10^{-12}	2×10^{-5}	2×10^{-5}	
Channel insertion loss at 12.89 GHz	16	30	30	35	dB
Real part of a_0 , min. ^a	–0.1	–0.1	–0.1	–0.1	
Real part of a_1 , min.	-1.2×10^{-5}	-1.2×10^{-5}	-1.2×10^{-5}	-1.2×10^{-5}	$\text{Hz}^{-1/2}$
Real part of a_2 , min.	—	—	—	—	Hz^{-1}
Real part of a_4 , min.	-2.5×10^{-21}	-3.5×10^{-21}	-3.5×10^{-21}	-5×10^{-21}	Hz^{-2}
Applied peak-to-peak sinusoidal jitter ^b	0.115	0.115	0.115	0.115	UI
Applied peak-to-peak random jitter ^c	0.15	0.15	0.15	0.15	UI
Applied even-odd jitter	0.035	0.035	0.035	0.035	UI
Applied RMS broadband noise	10	2.8	6.3	3.2	mV

^aFor each test channel, a_0 is limited to a maximum value of 0.1 and a_1 , a_2 , and a_4 are limited to a maximum value of 0.

There is no minimum value specified for a_2 .

^bThe frequency of the sinusoid must be greater than 100 MHz.

^cRandom Jitter is specified at a BER of 10^{-12} .

A 4th-order Bessel-Thompson filter with a 33 GHz cut-off frequency is applied to measurements of the signal applied by the pattern generator and to measurements of the broadband noise.

93.9 Channel characteristics

93.9.1 Channel operating margin

The channel operating margin (COM) computed using the procedure in Annex 93A and the parameters in Table 93–8 shall be greater than or equal to 3 dB.

93.9.2 Insertion loss

The insertion loss, in dB, of the channel is recommend to meet Equation (93–8).

$$IL(f) \leq \begin{cases} 1.50 + 4.60\sqrt{f} + 1.318f & 0.05 \leq f \leq f_b/2 \\ -12.71 + 3.70f & f_b/2 < f \leq f_b \end{cases} \text{ dB} \quad (93-8)$$

where

- f is the frequency in GHz
- f_b is the signaling rate (25.78125) in GHz
- $IL(f)$ is the insertion loss at frequency f

The insertion loss limit is illustrated by Figure 93–11.

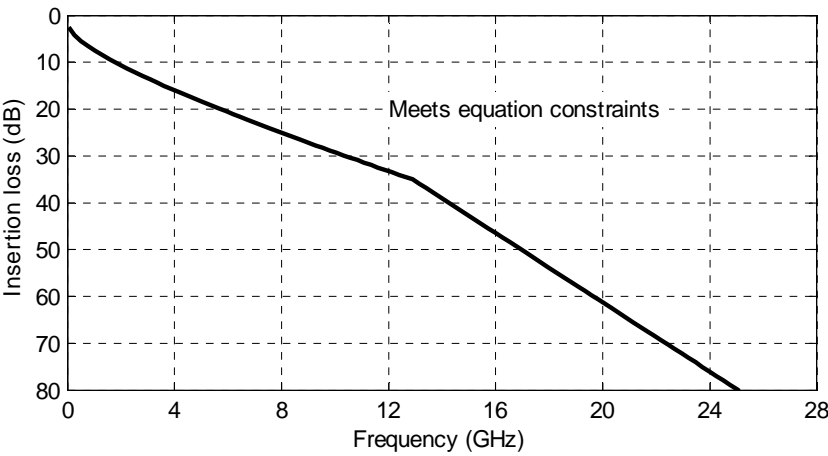


Figure 93–11—Insertion loss limit

93.9.3 Return loss

The return loss, in dB, of the channel is recommend to meet Equation (93–9).

$$RL(f) \geq \left\{ \begin{array}{ll} 12 & 0.05 \leq f \leq f_b/4 \\ 12 - 15\log_{10}(4f/f_b) & f_b/4 < f \leq f_b \end{array} \right\} \text{ dB}$$

(93–9)

where

- f is the frequency in GHz
- f_b is the signaling rate (25.78125) in GHz
- $RL(f)$ is the return loss at frequency f

Table 93–8—Channel operating margin parameters

Parameter	Symbol	Value	Units
Signaling rate	f_b	25.78125	GHz
Maximum start frequency	f_{\min}	0.05	GHz
Maximum frequency step	Δf	0.01	GHz
Transmitter reflection coefficient	Γ_1		
DC value	Γ_{01}	0.315	V/V
Reference frequency	f_1	$0.8 \times f_b$	GHz
Receiver reflection coefficient	Γ_2		
DC value	Γ_{02}	0.315	V/V
Reference frequency	f_2	$0.8 \times f_b$	GHz
Transmitter differential peak output voltage			
Victim	A_v	0.4	V
Far-end aggressor	A_f	0.4	V
Near-end aggressor	A_n	0.6	V
Transmitter 3 dB bandwidth			
Victim	f_v	$0.55 \times f_b$	GHz
Far-end aggressor	f_f	$0.55 \times f_b$	GHz
Near-end aggressor	f_n	f_b	GHz
Receiver 3 dB bandwidth	f_r	$0.75 \times f_b$	
Transmitter equalizer, pre-cursor coefficient	$c(-1)$		
Minimum value		–0.1	—
Maximum value		0	—
Step size		0.02	—
Transmitter equalizer, post-cursor coefficient	$c(1)$		
Minimum value		–0.4	—
Maximum value		0	—
Step size		0.02	—
Continuous time filter, DC gain	g_{DC}		
Minimum value		–12	dB
Maximum value		0	dB
Step size		1	dB
Number of signal levels	L	2	—
Number of samples per unit interval	M	32	—
Decision feedback equalizer (DFE) length	N_b	14	UI
DFE coefficient magnitude limit	b_{max}	1	V
Random jitter, RMS	σ_{RJ}	0.01	UI
Dual-Dirac jitter, peak	A_{DD}	0.1	UI
Receiver additive Gaussian noise, RMS	σ_r	0.001	V
Target uncorrected symbol error ratio	SER_0	10^{-5}	—

The return loss limit is illustrated by Figure 93–12.

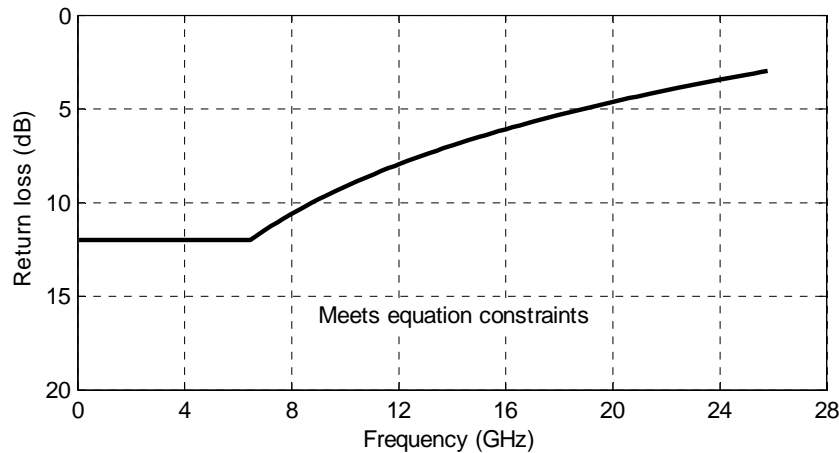


Figure 93–12—Return loss limit

93.9.4 Channel Integrated Crosstalk Noise (ICN)

Editor’s note (to be removed prior to final publication):

This is a placeholder to be referenced by the transmitter far-end output noise specification (refer to 93.8.1.7).

93.9.5 AC-coupling

The 100GBASE-KR4 transmitter shall be AC-coupled to the receiver. Common-mode specifications are defined as if the DC-blocking capacitor is implemented between TP0 and TP5. Should the capacitor be implemented outside TP0 and TP5, the common-mode specifications in Table 93–4 may not be appropriate.

The impact of a DC-blocking capacitor implemented between TP0 and TP5 is accounted for within the channel specifications. Should the capacitor be implemented outside TP0 and TP5, it is the responsibility of implementers to consider any necessary modifications to common-mode and channel specifications required for interoperability as well as any impact on the verification of transmitter and receiver compliance.

The low frequency 3 dB cutoff of the AC coupling shall be less than 50 kHz.

93.10 Environmental specifications

93.10.1 General safety

All equipment subject to this clause shall conform to applicable sections (including isolation requirements) of IEC 60950-1.

93.10.2 Network safety

The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

93.10.3 Installation and maintenance guidelines

It is recommended that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

93.10.4 Electromagnetic compatibility

A system integrating the 100GBASE-KR4 PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.

93.10.5 Temperature and humidity

A system integrating the 100GBASE-KR4 PHY is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

93.11 Protocol implementation conformance statement (PICS) proforma for Clause 93, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KR4¹¹

93.11.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 93, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KR4, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in [Clause 21](#).

93.11.2 Identification

93.11.2.1 Implementation identification

Supplier ¹	
Contact point for enquiries about the PICS ¹	
Implementation Name(s) and Version(s) ^{1,3}	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s) ²	
<p>NOTE 1— Required for all implementations.</p> <p>NOTE 2— May be completed as appropriate in meeting the requirements for the identification.</p> <p>NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).</p>	

93.11.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3bj-20XX, Clause 93, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KR4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
<p>Have any Exception items been required? No [] Yes []</p> <p>(See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3bj-20XX.)</p>	

Date of Statement	
-------------------	--

¹¹Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

93.11.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
CGMII	CGMII	93.1	Interface is supported	O	Yes [] No []
PCS	100GBASE-R PCS	93.1		M	Yes []
RS-FEC	100GBASE-R RS-FEC	93.1		M	Yes []
PMA	100GBASE-R PMA	93.1		M	Yes []
CAUI	CAUI	93.1	Interface is supported	O	Yes [] No []
AN	Auto-negotiation	93.1		M	Yes []
DC	Delay constraints	93.4	Conforms to delay constraints specified in 93.4	M	Yes []
DSC	Skew constraints	93.5	Conforms to the Skew and Skew Variation constraints specified in 93.5	M	Yes []
*MD	MDIO capability	93.6	Registers and interface supported	O	Yes [] No []
*EEE	EEE capability	93.1	Capability is supported	O	Yes [] No []
*GTD	Global PMD transmit disable function	93.7.6	Function is supported	O	Yes [] No []
*LTD	PMD lane-by-lane transmit disable function	93.7.7	Function is supported	O	Yes [] No []

93.11.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and base-band medium, type 100GBASE-KR4

93.11.4.1 Functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	PMD transmit function	93.7.2	Convey four bit streams from the PMD service interface to the MDI	M	Yes []
FS2	Mapping of logical signals to electrical signals	93.7.2	Positive output voltage of corresponds to tx_bit = one	M	Yes []
FS3	PMD receive function	93.7.3	Convey four bit streams from the MDI to the PMD service interface	M	Yes []
FS4	Mapping of electrical signals to logical signals	93.7.3	Positive input voltage corresponds to rx_bit = one.	M	Yes []
FS5	Global PMD signal detect function	93.7.4	Continuously report the message PMD:IS_SIGNAL.indication(SIGNAL_DETECT) to the PMD service interface	M	Yes []
FS6	SIGNAL_DETECT=FAIL	93.7.4	Following system reset or the manual reset of the training state diagram	M	Yes []
FS7	SIGNAL_DETECT=OK	93.7.4	Upon successful completion of training on all lanes or if training is disabled by management	M	Yes []
FS8	SIGNAL_DETECT mapping to MDIO	93.7.4	Continuously set Global_PMD_signal_detect (1.10.0) to the value of SIGNAL_DETECT	MD:M	Yes [] N/A []
FS9	PMD lane-by-lane signal detect mapping to MDIO	93.7.5	Continuously updated per 93.7.5	MD:M	Yes [] N/A []

Item	Feature	Subclause	Value/Comment	Status	Support
FS10	Global_PMD_transmit_disable variable	93.7.6	When set to one, all transmitters satisfy the requirements of 93.7.6	GTD:M	Yes [] N/A []
FS10	Global PMD transmit disable function affect on loopback	93.7.6	No effect	GTD:M	Yes [] N/A []
FS11	PMD_transmit_disable_ <i>i</i> variable	93.7.7	When set to one, the transmitter for lane <i>i</i> satisfies the requirements of 93.7.7	LTD:M	Yes [] N/A []
FS12	PMD lane-by-lane transmit disable function affect on loopback	93.7.7	No effect	LTD:M	Yes [] N/A []
FS13	PMD_fault variable mapping to MDIO	93.7.9	Mapped to the fault bit as specified in 45.2.1.2.1	MD:M	Yes [] N/A []
FS13	PMD_transmit_fault variable mapping to MDIO	93.7.10	Mapped to Transmit fault bit as specified in 45.2.1.7.4	MD:M	Yes [] N/A []
FS14	PMD_receive_fault variable mapping to MDIO	93.7.11	Mapped to Receive fault bit as specified in 45.2.1.7.5	MD:M	Yes [] N/A []
FS15	PMD control function	93.7.12	Defined in 72.6.10	M	Yes []
FS16	Training frame struction	93.7.12	Defined in 72.6.10 but adjusted for 100GBASE-KR4 signaling rate	M	Yes []
FS17	PMD control function variable mapping to MDIO	93.7.12	Map variables as specified in 93.7.12	MD:M	Yes [] N/A []

93.11.4.2 Transmitter characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	Test fixture insertion loss	93.8.1.1	Between 1.2 dB and 1.6 dB at 12.89 GHz.	M	Yes []
TC2	Test fixture insertion loss deviation	93.8.1.1	Magnitude less than 0.1 dB	M	Yes []
TC3	Test fixture differential return loss	93.8.1.1	Meets equation constraints	M	Yes []
TC4	Test fixture common-mode return loss	93.8.1.1	Greater than or equal to 10 dB from 0.05 to 13 GHz	M	Yes []
TC5	Signaling rate per lane	93.8.1.2	25.78125 GBd \pm 100 ppm	M	Yes []
TC6	Peak-to-peak differential output voltage	93.8.1.3	Less than or equal to 1200 mV regardless of transmit equalizer setting	M	Yes []
TC7	Peak-to-peak differential output voltage, transmitter disabled	93.8.1.3	Less than or equal to 30 mV	M	Yes []
TC8	DC common-mode output voltage	93.8.1.3	Between 0 V and 1.9 V with respect to signal ground	M	Yes []
TC9	AC common-mode output voltage	93.8.1.3	Less than or equal to 12 mV RMS with respect to signal ground	M	Yes []
TC10	Common-mode output voltage requirements	93.8.1.3	Met regardless of the transmit equalizer setting	M	Yes []
TC11	Differential input return loss	93.8.1.4	Meets equation constraints	M	Yes []
TC12	Reference impedance for differential return loss measurements	93.8.1.4	100 Ω	M	
TC13	Common-mode input return loss	93.8.1.4	Meets equation constraints	M	Yes []
TC14	Reference impedance for common-mode return loss measurements	93.8.1.4	25 Ω	M	Yes []
TC15	Transition times	93.8.1.5	Greater than or equal to 8 ps when transmit equalization is disabled	M	Yes []
TC16	Steady state voltage, v_f	93.8.1.6.1	Greater than or equal to 0.4 V and less than or equal to 0.6 V after the transmit equalizer coefficients have been set to the "preset" values	M	Yes []
TC17	Linear fit pulse peak	93.8.1.6.1	Greater than $0.8 \times v_f$ after the transmit equalizer coefficients have been set to the "preset" values	M	Yes []
TC18	Normalized linear fit error	93.8.1.6.2	Less than or equal to 0.037	M	Yes []

Item	Feature	Subclause	Value/Comment	Status	Support
TC19	Coefficient initialization	93.8.1.6.3	Satisfies the requirements of 93.8.1.6.3.	M	Yes []
TC20	Normalized coefficient step size for “increment”	93.8.1.6.4	Between 0.0083 and 0.05	M	Yes []
TC21	Normalized coefficient step size for “decrement”	93.8.1.6.4	Between –0.05 and –0.0083	M	Yes []
TC21	Maximum post-cursor equalization ratio	93.8.1.6.5	Greater than or equal to 4	M	Yes []
TC22	Maximum pre-cursor equalization ratio	93.8.1.6.5	Greater than or equal to 1.54	M	Yes []
TC23	Transmitter far-end output noise, low-loss channel	93.8.1.7	Less than or equal to 2 mV RMS	M	Yes []
TC24	Transmitter far-end output noise, high-loss channel	93.8.1.7	Less than or equal to 1 mV RMS	M	Yes []
TC25	Even-odd jitter	93.8.1.8	Less than or equal to 0.035 UI regardless of the transmit equalization setting	M	Yes []
TC26	The total jitter, excluding data dependent jitter	93.8.1.8	less than or equal to 0.28 UI regardless of the transmit equalization setting	M	Yes []
TC27	Effective random jitter	93.8.1.8	Shall be less than or equal to 0.15 UI regardless of the transmit equalization setting	M	Yes []

93.11.4.3 Receiver characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
RC1	Test fixture insertion loss	93.8.2.1	Between 1.2 dB and 1.6 dB at 12.89 GHz.	M	Yes []
RC2	Test fixture insertion loss deviation	93.8.2.1	Magnitude less than 0.1 dB	M	Yes []
RC3	Test fixture differential return loss	93.8.2.1	Meets equation constraints	M	Yes []
RC4	Test fixture common-mode return loss	93.8.2.1	Greater than or equal to 10 dB from 0.05 to 13 GHz	M	Yes []
RC5	Differential input return loss	93.8.2.2	Meets equation constraints	M	Yes []
RC6	Reference impedance for differential return loss measurements	93.8.2.2	100 Ω	M	Yes []
RC7	Common-mode input return loss	93.8.2.2	Meets equation constraints	M	Yes []
RC8	Reference impedance for common-mode return loss measurements	93.8.2.2	25 Ω	M	Yes []
RC9	Differential to common-mode return loss	93.8.2.2	Meets equation constraints	M	Yes []
RC10	Interference tolerance	93.8.2.3	Satisfy requirements summarized in Table 93–7	M	Yes []

93.11.4.4 Channel characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Channel operating margin (COM)	93.9.1	Greater than or equal to 3 dB	M	Yes []
CC2	AC-coupling	93.9.5	Channel AC couples the transmitter to the receiver	M	Yes []
CC3	AC-coupling 3 dB cut-off frequency	93.9.5	Less than 50 kHz	M	Yes []

93.11.4.5 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	Generate safety	93.10.1	Conform to applicable sections of IEC 60950-1	M	Yes []
ES2	Electromagnetic compatibility	93.10.4	Comply with applicable local and national codes	M	Yes []

94. Physical Medium Attachment (PMA) sublayer, Physical Medium Dependent (PMD) sublayer, and baseband medium, type 100GBASE-KP4

94.1 Overview

This clause specifies the Physical Medium Attachment (PMA) sublayers, Physical Medium Dependent (PMD) sublayer, and medium for the 100GBASE-KP4 PHY. A 100GBASE-KP4 physical shall include the required sub-layers and may include the optional sub-layers specified in Table 94–1.

Table 94–1—Physical Layer clauses associated with the 100GBASE-KP4 PMD

Associated clause	100GBASE-KP4
81—RS	Required
81—CGMII ^a	Optional
82—PCS for 100GBASE-R	Required
83—PMA	Optional
83A—CAUI	Optional
91—RS-FEC	Required
94—PMA	Required
94—PMD	Required
73—Auto-Negotiation	Required
78—Energy-Efficient Ethernet	Optional

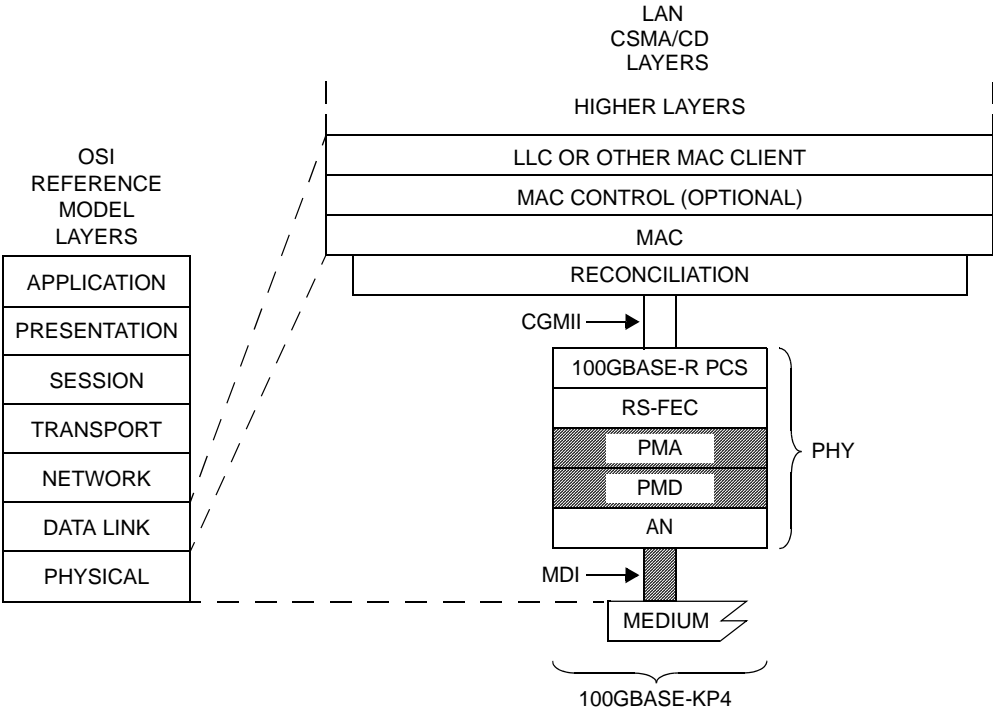
^aThe CGMII is an optional interface. However, if the CGMII is not implemented, a conforming implementation must behave functionally as though the RS and CGMII were present.

Figure 94–1 shows the relationship of the 100GBASE-KP4 PMA and PMD sublayers and MDI to the ISO/IEC Open System Interconnection (OSI) reference model.

Differential signals received at the MDI from a transmitter that meets the requirements of 94.2.2 and 94.3.12 and have passed through the channel specified in 94.4 are received with a BER less than 10^{-5} as measured at the PMA service interface.

For a complete Physical Layer, this specification is considered to be satisfied by a frame error ratio less than 1.7×10^{-10} for 64-octet frames with minimum IPG.

A 100GBASE-KP4 PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization.



AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE

PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION

Figure 94-1—100GBASE-KP4 PMA and PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

94.2 Physical Medium Attachment (PMA) Sublayer

94.2.1 PMA Service Interface

The PMA service interface for 100GBASE-KP4 PMA is based on the inter-sublayer service interface defined in 80.3. This interface is defined in an abstract manner and does not imply any particular implementation.

The PMA service interface primitives are summarized as follows:

PMA:IS_UNITDATA_0.request
PMA:IS_UNITDATA_0.indication
PMA:IS_SIGNAL.indication

If the optional Energy-Efficient Ethernet (EEE) capability is supported (see 78) then the PMA service interface includes two additional primitives as follows:

PMA:IS_TX_MODE.request
PMA:IS_RX_MODE.request

Editor's note (to be removed prior to final publication):

Per barrass_01_0312, PMA transmit function behavior changes as a function of the tx_mode parameter.

DATA, SLEEP, or WAKE: normal behavior
ALERT: send the ALERT signal
FW: send a PMA-specific pattern that is TBD (PMD normal behavior?)
QUIET: disable the transmitter

Per barrass_01_0312, the PMA receive function infers rx_mode from the received signal.

Normal or rapid alignment markers: DATA, SLEEP, or WAKE (mapping not defined)
No signal: QUIET
Alert signal: ALERT
PMA-specific pattern for FW that is TBD: FW (PMA function?)

Given the ambiguity surrounding PMA behavior and the TBD signaling for ALERT, FW, etc., these functions have not been added to the clause. The functions will be added to the clause upon adoption of a detailed proposal describing the desired behavior.

94.2.1.1 PMA:IS_UNITDATA_0.request

The PMA:IS_UNITDATA_0.request (where $i=0$ to 3) primitive is used to define the transfer of four streams of data units from the PMA client to PMA.

94.2.1.1.1 Semantics of the service primitive

PMA:IS_UNITDATA_0.request(tx_bit,start)
PMA:IS_UNITDATA_1.request(tx_bit,start)
PMA:IS_UNITDATA_2.request(tx_bit,start)
PMA:IS_UNITDATA_3.request(tx_bit.start)

The data conveyed by PMA:IS_UNITDATA_0.request to IS_UNITDATA_3.request consists of four parallel continuous streams of encoded bits, one stream for each lane. Each of the tx_bit parameters can take one of two values: one or zero. The start parameter is TRUE to indicate that the concurrent tx_bit is the first bit of the first, second, third, or fourth FEC symbol in the FEC codeword and is otherwise FALSE.

94.2.1.1.2 When generated

The PMA client continuously sends four parallel bit streams PMA:IS_UNITDATA_i.request(tx_bit,start) to the PMA, each at a nominal signaling rate of 26.5625 Gb/s.

94.2.1.1.3 Effect of receipt

Upon receiving each instance of PMA:IS_UNITDATA_i.request, the tx_bit and start parameters are passed to the PMA framing process corresponding to each stream.

94.2.1.2 PMA:IS_UNITDATA_i.indication

The PMA:IS_UNITDATA_i.indication (where $i = 0$ to 3) primitive is used to define the transfer of four streams of data units from the PMA to the PMA client.

94.2.1.2.1 Semantics of the service primitive

PMA:IS_UNITDATA_0.indication(rx_bit, start)
PMA:IS_UNITDATA_1.indication(rx_bit, start)
PMA:IS_UNITDATA_2.indication(rx_bit, start)
PMA:IS_UNITDATA_3.indication(rx_bit, start)

The data conveyed by PMA:IS_UNITDATA_0.indication to PMA:IS_UNITDATA_3.indication consists of 4 parallel continuous streams of encoded bits, one stream for each lane. Each of the rx_bit parameters can take one of two values: one or zero. The start parameter is TRUE to indicate that the concurrent rx_bit is the first bit of the first, second, third, or fourth FEC symbol in the FEC codeword and is otherwise FALSE.

94.2.1.2.2 When generated

The PMA continuously sends four parallel bit streams PMA:IS_UNITDATA_i.indication(rx_bit,start) to the PMA client, each at a nominal signaling rate of 26.5625 Gb/s.

94.2.1.2.3 Effect of receipt

The effect of receipt of this primitive is defined by the PMA client.

94.2.1.3 PMA:IS_SIGNAL.indication

The PMA:IS_SIGNAL.indication primitive is generated by the PMA to the PMA client to indicate the status of the receive process. This primitive is generated by the receive process to propagate the detection of severe error conditions (e.g., loss of synchronization) to the PMA client.

94.2.1.3.1 Semantics of the service primitive

PMA:IS_SIGNAL.indication(SIGNAL_OK)

The SIGNAL_OK parameter can take on one of two values: OK or FAIL. A value of FAIL denotes that invalid data is being presented (rx_bit parameters undefined) by the PMA to the PMA client. A value of OK does not guarantee valid data is being presented by the PMA to the PMA client.

94.2.1.3.2 When generated

The PMA generates the PMA:IS_SIGNAL.indication primitive to the PMA client whenever there is a change in the value of the SIGNAL_OK parameter.

94.2.1.4 Effect of receipt

The effect of receipt of this primitive is defined by the PMA client.

94.2.2 PMA Transmit Functional Specifications

In the transmit direction, the role of the 100GBASE-KP4 PMA is to adapt the signal from the FEC to a PAM4 encoded signal to be passed to the PMD for transfer over the attached medium. The adaptation processes shown in Figure 94–2 include insert overhead, insert termination bits, apply Gray coding, apply $1/(1+D) \bmod 4$ precoding, and apply PAM4 encoding.

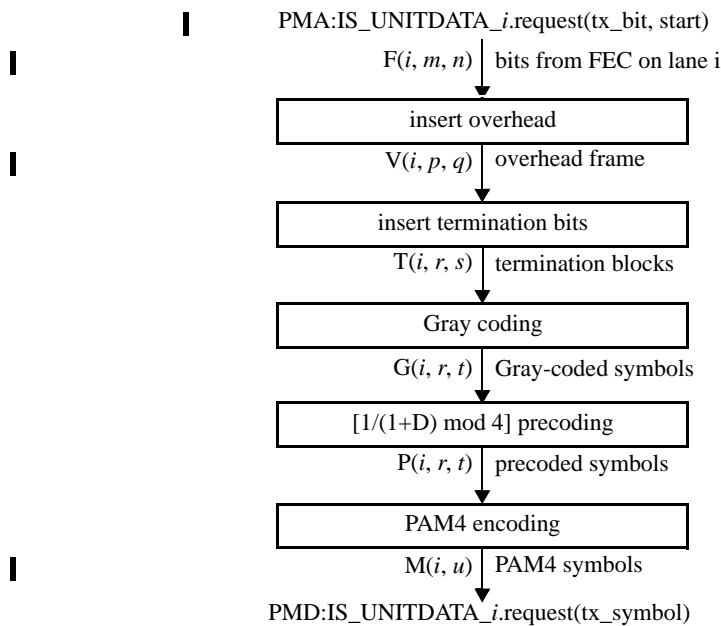


Figure 94–2—Transmit adaptation process diagram

94.2.2.1 FEC Interface

The PMA receives FEC bits via the PMA:IS_UNITDATA_i(tx_bit, start) primitive (see 94.2.1.1). The index i also indicates the PMA lane number: 0, 1, 2, or 3.

On each transaction, tx_bit is assigned to $F(i, m, n)$, where

i is the lane number

m is an index indicating the FEC codeword number and increments at the start of each codeword

n is an index indicating the bit number within a codeword with a range 1 to 1360

The start of a codeword is determined by the start parameter associated with the tx_bit parameter being equal to TRUE.

94.2.2.2 Overhead Frame

The PMA shall create a sequence of overhead frames by inserting 40 overhead bits for every 31280 FEC bits as specified in this sub-clause.

The FEC bits, $F(i, m, n)$ are mapped into a continuous sequence of overhead frames. The overhead frame is 31320 bits in length.

Each bit in the overhead frame is denoted $V(i, p, q)$, where:

i is the lane number

p is an index that indicates the frame number and increments at the start of each frame

q is an index that indicates the bit number within a frame with a range 1 to 31320

The first 40 bits of the frame, $V(i, p, 1)$ to $V(i, p, 40)$ are the overhead bits (see 94.2.2.3). The next 31280 bits, $V(i, p, 41)$ to $V(i, p, 31320)$ are composed of the bits from 23 consecutive FEC codewords.

The overhead bits are inserted in the frame as follows:

$$V(i, p, 1) = H(i, p, 1)$$

$$V(i, p, 2) = H(i, p, 2)$$

$$V(i, p, \dots) = H(i, p, \dots)$$

$$V(i, p, 40) = H(i, p, 40)$$

The FEC codeword bits are aligned such that $V(i, p, 41)$ is the first bit of a codeword, e.g., $V(i, p, 41) = F(i, m, 1)$. The FEC bits are inserted into the frame in the order in which they were received from the FEC, e.g., $V(i, p, 42) = F(i, m, 2)$, $V(i, p, 43) = F(i, m, 3)$, and so on. The method for aligning the FEC codeword with the start of the overhead frame is outside the scope of this standard.

94.2.2.3 Overhead

Editor's note (to be removed prior to final publication):

A proposal for overhead usage and content is required.

The overhead bits are denoted $H(i, p, k)$, where

i is the lane number

p is an index that indicates the frame number and increments at the start of each frame

k is an index that indicates the header bit number with a range 1 to 40.

94.2.2.4 Termination Blocks

The PMA shall create a sequence of termination blocks by inserting two termination bits for every 90 overhead frame bits as specified in this sub-clause. The overhead frame mapped into 192 consecutive termination blocks forms a PMA frame.

The termination block is 92 bits in length.

Each bit in a termination block is denoted $T(i, r, s)$, where:

i is the lane number

r is an index indicating block number and increments at the start of each block

s is an index indicating the bit number within a termination block with a range 1 to 92

The first two bits in each termination block, $T(i, r, 1)$ and $T(i, r, 2)$, are populated with the output of a PRBS13 generator, $R(i, v)$, where $T(i, r, 1) = R(i, v)$ and $T(i, r, 2) = R(i, v+1)$.

The PRBS13 pattern generator produces the same result as the implementation shown in Figure 94–2, which implements the generator polynomial shown in Equation (94–1).

$$G(x) = 1 + x + x^2 + x^{11} + x^{13} \quad (94-1)$$

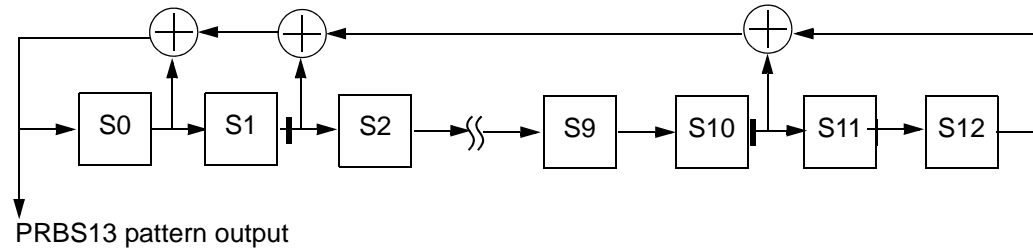


Figure 94–2—PRBS13 pattern generator

The remaining 90 bits of each termination block, $T(i, r, 3)$ to $T(i, r, 92)$, are overhead frame bits (see 94.2.2.2). The frame bits are aligned with the termination blocks such that the first bit of an overhead bit, $V(i, p, 1)$, corresponds to the third bit of a termination block, $T(i, r, 3)$.

Overhead frame bits are mapped to the termination blocks in order of location within the overhead frame, e.g., $T(i, r, 4) = V(i, p, 2)$, $T(i, r, 5) = V(i, p, 3)$, and so on.

The termination bit PRBS13 generator is initialized during the training process. When training is complete the state of the termination bit PRBS13 generator is retained and the resulting output is used for the termination bits in the PMA frame.

94.2.2.5 Gray Mapping

The PMA shall map consecutive pairs of bits to one of four Gray-coded symbols as specified in this sub-clause.

Each pair of bits, $\{A, B\}$, of each termination block are converted to a Gray-coded symbol with one of the four Gray-coded levels as follows:

- $\{0, 0\}$ maps to 0,
- $\{0, 1\}$ maps to 1,
- $\{1, 1\}$ maps to 2, and
- $\{1, 0\}$ maps to 3.

Gray-coded symbols corresponding to each termination block are denoted $G(i, r, t)$, where:

- i is the lane number
- r is an index indicating the termination block number
- t is an index indicating the symbol number within a termination block with a range 1 to 46.

Pairing of bits is such that the first two bits of each termination block, $T(i, r, 1)$ and $T(i, r, 2)$, form a pair. Each bit pair $\{T(i, r, 2t-1), T(i, r, 2t)\}$ maps to $\{A, B\}$ and the Gray-coded result is assigned to $G(i, r, t)$. The gray-coded symbol $G(i, r, 1)$ is formed from the first two bits of a termination block, the termination bits, thus forming a termination symbol.

94.2.2.6 Precoding

The PMA shall precode the Gray-coded symbols as specified in this sub-clause.

The precoder output symbols are denoted, $P(i, r, t)$, where:

i is the lane number

r is an index indicating the termination block number

t is an index indicating the symbol number within a termination block with a range 1 to 46.

For each Gray-coded symbol $G(i, r, t)$, a precoded symbol, $P(i, r, t)$ is determined by the following algorithm:

If $t = 1$ then

$$P(i, r, t) = G(i, r, t)$$

Else

$$P(i, r, t) = (G(i, r, t) - P(i, r, t-1)) \bmod 4$$

End If

The bits contributing to the Gray-coded termination symbol, $G(i, r, 1)$, are the termination bits. The precoding algorithm applies this symbol directly to the output rather than combining it with the previous non-deterministic symbols and thus this termination symbol is always deterministic.

94.2.2.7 PAM4 encoding

The PMA shall encode each precoder output symbol to one of four PAM4 levels as specified in this sub-clause.

The PAM4 encoded symbols are denoted $M(i, u)$, where

i is the lane number

u is an index indicating the symbol number.

Each consecutive precoder output symbol, $P(i, r, t)$, is mapped to one of four PAM4 levels and assigned to the PAM4 encoder output $M(i, u)$.

Mapping from the precoder output symbol $P(i, r, t)$ to a PAM4 encoded symbol $M(i, u)$ is as follows:

0 maps to -1 ,

1 maps to $-1/3$,

2 maps to $+1/3$, and

3 maps to $+1$.

94.2.2.8 PMD Interface

The PMA shall transmit each PAM4 encoded symbol, $M(i, u)$ to the PMD via the PMD:IS_UNITDATA_ i (tx_symbol) primitive at a symbol transfer rate of 13.59375 GBd.

94.2.3 PMA Transmit EEE Operation

Editor's note (to be removed prior to final publication):

EEE operation for the 100GBASE-KP4 PHY has been adopted per barrass_01_0312 but details regarding EEE operation are not provided. A proposal on this topic is required.

94.2.4 PMA Receive Functional Specifications

The receive process shall recover the data encoded by the transmit process with meeting the performance requirements specified in 94.1 after the overhead and termination bits have been removed.

The process by which the receiver recovers the data to meet this requirement is outside the scope of this standard. The signal structure encoded by the transmitter process including the overhead bits, gray coding, and termination symbols may be leveraged by the receiver implementation at the discretion of the implementer. The remainder of this subclause specifies the receiver processes to reverse the transmitter encoding and report status.

In the received direction, the role of the 100GBASE-KP4 PMA is to adapt the PAM4 encoded signal from the PMD to a FEC encoded signal to be passed to the FEC for further processing. The adaptation processes shown in Figure 94–3 include PAM4 decoding, $(1+D)$ mod 4 decoding, inverse Gray coding, remove termination bits, and remove overhead.

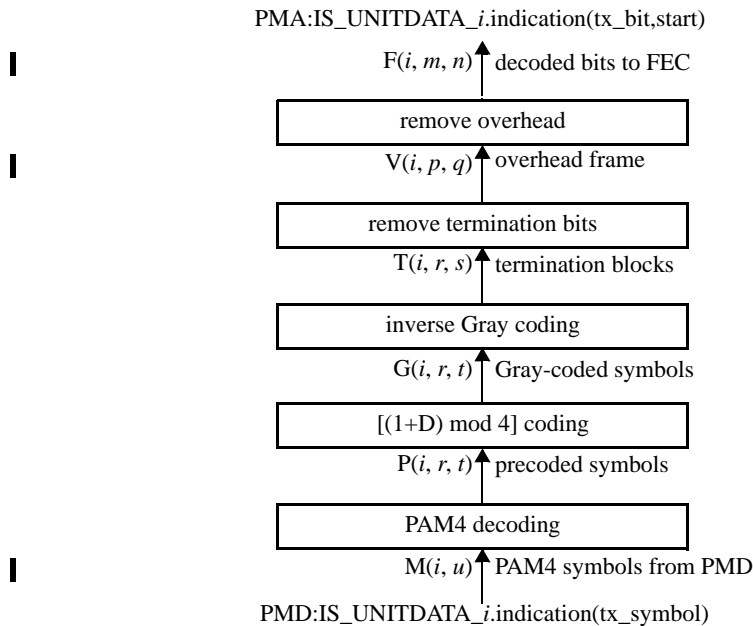


Figure 94–3—Receive adaptation process diagram

94.2.5 PMA Receive EEE Operation

Editor's note (to be removed prior to final publication):

The EEE baseline presentation, barrass_01_0312, does not provide functional details regarding the EEE for the 100GBASE-KP4 PMA. A proposal on this topic is required.

94.2.6 Skew constraints

Editor's note (to be removed prior to final publication):

The 100GBASE-KP4 PHY requires the FEC sublayer, which re-aligns all of the PCS lanes in the transmit direction and decodes aligned PMA lanes in the receive direction. Since the optional physical instantiation of the CAUI between the FEC sublayer and 100GBASE-KP4 PMA is not recommended, these requirements should limit the skew presented to the FEC sublayer from the PMA receive function. The skew is the combination of the skew contributed by the PMA, PMD, and the underlying medium.

A proposal on this topic is required.

94.2.7 Delay constraints

Delay considerations for the 100GBASE-KP4 PMA, PMD, AN, and medium are specified in 94.3.3.

94.2.8 Link status

The PMA shall provide link status information to the PMA client using the PMA:IS_SIGNAL.indication primitive (see 94.2.1.3). The PMA continuously monitors the link status reported by the PMD from the PMD:IS_SIGNAL.indication primitive, and uses this as input to Signal Indication Logic (SIL) to determine the link status to report to the PMA client. Other inputs to the SIL may include status of clock and data recovery on the lanes from the PMD and frame synchronization.

94.2.9 PMA local loopback mode

PMA local loopback shall be provided. This function involves looping back each input lane from the PMA service interface to the corresponding output lane on the PMA service interface. Each received instance of the PMA:IS_UNITDATA_i.request(tx_bit,start) primitive is looped back in the direction of the PMA client using the PMA:IS_UNITDATA_i.indication(rx_bit,start) primitive.

During local loopback, the PMA performs normal framing and precoding onto the lanes in the Tx direction toward the PMD service interface.

Ability to perform this function is indicated by the Local_loopback_ability status variable. If a Clause 45 MDIO is implemented, this variable is accessible through bit 1.8.0 (45.2.1.7.15). A device is placed in local loopback mode when the Local_loopback_enable control variable is set to one, and removed from local loopback mode when this variable is set to zero. If a Clause 45 MDIO is implemented, this variable is accessible through PMA/PMD control 1 register (bit 1.0.0, see 45.2.1.1.5).

94.2.10 PMA remote loopback mode (optional)

PMA remote loopback mode is optional. If implemented, it shall be as described in this subclause.

94.3 Physical Medium Dependent (PMD) Sublayer

94.3.1 Physical Medium Dependent (PMD) service interface

This subclause specifies the services provided by the 100GBASE-KP4 PMD. The service interface for this PMD is described in an abstract manner and does not imply any particular implementation. The PMD service interface supports the exchange of encoded data. The PMD translates the encoded data to and from signals suitable for the medium.

The PMD service interface based on the inter-sublayer service interface defined in 80.3. The PMD service interface primitives are summarized as follows:

```
PMD:IS_UNITDATA_i.request
PMD:IS_UNITDATA_i.indication
PMD:IS_SIGNAL.indication
```

If the optional EEE capability is supported, then the PMD service interface includes two additional primitives as follows:

```
PMD:IS_TX_MODE.request
PMD:IS_RX_MODE.request
```

Editor's note (to be removed prior to final publication):

Per barrass_01_0312, PMD transmit function behavior changes as a function of the tx_mode parameter.

```
DATA, SLEEP, or WAKE: normal behavior
ALERT: send the ALERT signal
FW: send a PMA-specific pattern that is TBD (PMD normal behavior?)
QUIET: disable the transmitter
```

Per barrass_01_0312, the PMD receive function infers rx_mode from the received signal.

```
Normal or rapid alignment markers: DATA, SLEEP, or WAKE (mapping not defined)
No signal: QUIET
Alert signal: ALERT
PMA-specific pattern for FW that is TBD: FW (PMA function?)
```

Given the ambiguity surrounding PMD behavior and the TBD signaling for ALERT, FW, etc., these functions have not been added to the clause. The functions will be added to the clause upon adoption of a detailed proposal describing the desired behavior.

94.3.1.1 PMD:IS_UNITDATA_i.request

The PMD:IS_UNITDATA_i.request (where $i=0$ to 3) primitive is used to define the transfer of four streams of data units from the PMA to the PMD.

94.3.1.1.1 Semantics of the service primitive

```
PMD:IS_UNITDATA_0.request(tx_symbol)
PMD:IS_UNITDATA_1.request(tx_symbol)
PMD:IS_UNITDATA_2.request(tx_symbol)
PMD:IS_UNITDATA_3.request(tx_symbol)
```

The data conveyed by `PMD:IS_UNITDATA_i.request` consists of four parallel continuous streams of encoded symbols, `tx_symbol`, one stream for each lane. Each of the `tx_symbol` parameters can take one of four values: -1 , $-1/3$, $+1/3$, or $+1$.

94.3.1.1.2 When generated

The PMA continuously sends four parallel symbol streams `PMD:IS_UNITDATA_i.request(tx_symbol)` to the PMD, each at a nominal signaling rate of 13.59375 GBd.

94.3.1.1.3 Effect of receipt

Upon receiving each instance of `PMD:IS_UNITDATA_i.request`, the `tx_symbol` parameter is passed to the PMD transmit process corresponding to each stream.

94.3.1.2 PMD:IS_UNITDATA_i.indication

The `PMD:IS_UNITDATA_i.indication` (where $i=0$ to 3) primitive is used to define the transfer of four streams of data units from the PMD to the PMA.

94.3.1.2.1 Semantics of the service primitive

`PMD:IS_UNITDATA_0.indication(rx_symbol)`
`PMD:IS_UNITDATA_1.indication(rx_symbol)`
`PMD:IS_UNITDATA_2.indication(rx_symbol)`
`PMD:IS_UNITDATA_3.indication(rx_symbol)`

The data conveyed by `PMD:IS_UNITDATA_0.indication` to `PMD:IS_UNITDATA_3.indication` consists of 4 parallel continuous streams of encoded symbols, one stream for each lane. Each of the `rx_symbol` parameters can take one of four values: -1 , $-1/3$, $+1/3$, or $+1$. The start parameter is TRUE to indicate that the concurrent `rx_bit` is the first bit of the first, second, third, or fourth FEC symbol in the FEC codeword and is otherwise FALSE.

94.3.1.2.2 When generated

The PMD continuously sends four parallel bit streams `PMD:IS_UNITDATA_i.indication(tx_symbol)` to the PMD client, each at a nominal signaling rate of 13.59375 GBd.

94.3.1.2.3 Effect of receipt

The effect of receipt of this primitive is undefined by the PMD.

94.3.1.3 PMD:IS_SIGNAL.indication

The `PMD:IS_SIGNAL.indication` primitive is generated by the PMD to the PMA to indicate the status of the PMD receive process. This primitive is generated by the PMD receive process to propagate the detection of severe error conditions (e.g., loss of synchronization) to the PMA.

94.3.1.3.1 Semantics of the service primitive

`PMD:IS_SIGNAL.indication(SIGNAL_OK)`.

`SIGNAL_DETECT` in 100GBASE-KP4 indicates the successful completion of the start-up protocol on all four lanes. The `SIGNAL_DETECT` parameter can take on one of two values: OK or FAIL. When `SIGNAL_DETECT = FAIL`, the `PMD:IS_UNITDATA_i.indication` parameters are undefined. The

SIGNAL_DETECT parameter maps to the SIGNAL_OK parameter in the PMD:IS_SIGNAL.indication primitive.

94.3.1.3.2 When generated

The PMD generates the PMD:IS_SIGNAL.indication primitive to the PMD client whenever there is change in the value of the SIGNAL_DETECT parameter.

94.3.1.3.3 Effect of receipt

The effect of receipt of this primitive is undefined by the PMD.

94.3.2 PCS requirements for Auto-Negotiation (AN) service interface

The PCS associated with this PMD is required to support the AN service interface primitive AN_LINK.indication defined in 73.9. (See 82.6.)

94.3.3 Delay constraints

The sum of the transmit and the receive delays contributed by the 100GBASE-KP4 PMA, PMD, AN, and the medium in one direction shall be no more than TBD bit times (TBD pause_quanta or TBD ns). It is assumed that the one way delay through the medium is no more than TBD bit times (TBD ns).

A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 80.4 and its references.

94.3.4 Skew constraints

Editor's note (to be removed prior to final publication):

The 100GBASE-KP4 PHY requires the FEC sublayer, which re-aligns all of the PCS lanes in the transmit direction and decodes aligned PMA lanes in the receive direction. Since the optional physical instantiation of the CAUI between the FEC sublayer and 100GBASE-KP4 PMA is not recommended, these requirements should limit the skew presented to the FEC sublayer from the PMA receive function. The skew is the combination of the skew contributed by the PMA, PMD, and the underlying medium.

A proposal on this topic is required.

The Skew (relative delay) between the lanes must be kept within limits so that the information on the lanes can be reassembled by the PCS. The Skew Variation must also be limited to ensure that a given PCS lane always traverses the same physical lane. Skew and Skew Variation are defined in 80.5 and specified at the points SP1 to SP6 shown in Figure 80-4 and Figure 80-5.

If the PMD service interface is physically instantiated so that the Skew at SP2 can be measured, then the Skew at SP2 is limited to TBD ns and the Skew Variation at SP2 is limited to TBD ps.

The Skew at SP3 (the transmitter MDI) shall be less than TBD ns and the Skew Variation at SP3 shall be less than TBD ps.

The Skew at SP4 (the receiver MDI) shall be less than TBD ns and the Skew Variation at SP4 shall be less than TBD ns.

If the PMD service interface is physically instantiated so that the Skew at SP5 can be measured, then the Skew at SP5 shall be less than **TBD** ns and the Skew Variation at SP5 shall be less than **TBD** ns.

For more information on Skew and Skew Variation see [80.5](#).

94.3.5 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 94–3, and MDIO status variables to PMD status variables as shown in Table 94–4.

Table 94–3—100GBASE-KP4 MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	PMD control variable
Reset	PMA/PMD control 1	1.0.15	PMD_reset
Global PMD transmit disable	PMD transmit disable	1.9.0	Global_PMD_transmit_disable
PMD transmit disable 3 to PMD transmit disable 0	PMD transmit disable	1.9.4 to 1.9.1	PMD_transmit_disable_3 to PMD_transmit_disable_0
Restart training	BASE-R PMD control	1.150.0	mr_restart_training
Training enable	BASE-R PMD control	1.150.1	mr_training_enable

Table 94–4—100GBASE-KP4 MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMD status variable
Fault	PMA/PMD status 1	1.1.7	PMD_fault
Transmit fault	PMA/PMD status 2	1.8.11	PMD_transmit_fault
Receive fault	PMA/PMD status 2	1.8.10	PMD_receive_fault
Global PMD receive signal detect	PMD receive signal detect	1.10.0	Global_PMD_signal_detect
PMD receive signal detect 3 to PMD receive signal detect 0	PMD receive signal detect	1.10.4 to 1.10.1	PMD_signal_detect_3 to PMD_signal_detect_0
Receiver status 3	BASE-R PMD status	1.151.12	rx_trained_3
Frame lock 3	BASE-R PMD status	1.151.13	frame_lock_3
Start-up protocol status 3	BASE-R PMD status	1.151.14	training_3
Training failure 3	BASE-R PMD status	1.151.15	training_failure_3
Receiver status 2	BASE-R PMD status	1.151.8	rx_trained_2
Frame lock 2	BASE-R PMD status	1.151.9	frame_lock_2

Table 94–4—100GBASE-KP4 MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/bit number	PMD status variable
Start-up protocol status 2	BASE-R PMD status	1.151.10	training_2
Training failure 2	BASE-R PMD status	1.151.11	training_failure_2
Receiver status 1	BASE-R PMD status	1.151.4	rx_trained_1
Frame lock 1	BASE-R PMD status	1.151.5	frame_lock_1
Start-up protocol status 1	BASE-R PMD status	1.151.6	training_1
Training failure 1	BASE-R PMD status	1.151.7	training_failure_1
Receiver status 0	BASE-R PMD status	1.151.0	rx_trained_0
Frame lock 0	BASE-R PMD status	1.151.1	frame_lock_0
Start-up protocol status 0	BASE-R PMD status	1.151.2	training_0
Training failure 0	BASE-R PMD status	1.151.3	training_failure_0

94.3.6 PMD functional specifications

94.3.6.1 Link block diagram

One direction for one lane of a 100GBASE-KP4 link is shown in Figure 94–4.

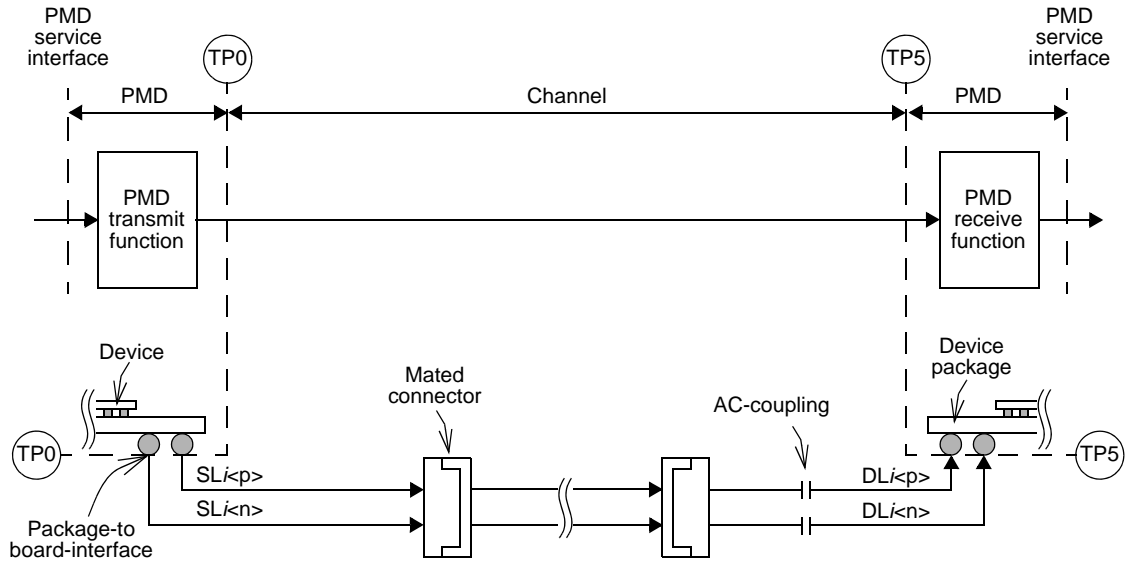


Figure 94–4—100GBASE-KP4 link (one direction for one lane is illustrated)

94.3.6.2 PMD Transmit function

The PMD transmit function shall convert the four bit streams requested by the PMD service interface messages PMD:IS_UNITDATA_0.request to PMD:IS_UNITDATA_3.request into four separate electrical streams. The four electrical signal streams shall then be delivered to the MDI, all according to the transmit

electrical specifications in 94.3.12. A positive output voltage of $SLi<p>$ minus $SLi<n>$ (differential voltage) shall correspond to a positive tx_symbol value.

94.3.6.3 PMD Receive function

The PMD receive function shall convert the four electrical streams from the MDI into four bit streams for delivery to the PMD service interface using the messages PMD:IS_UNITDATA_0.indication to PMD:IS_UNITDATA_3.indication. A positive input voltage of $DLi<p>$ minus $DLi<n>$ (differential voltage) shall correspond to a positive tx_symbol value.

94.3.6.4 Global PMD signal detect function

Editor's note (to be removed prior to final publication):

The reference to PMD:IS_SIGNAL.indication(SIGNAL_DETECT) must be reconciled with subclause 80.3 and 94.2.1.3.

The Global PMD signal detect function shall continuously report the message PMD:IS_SIGNAL.indication (SIGNAL_DETECT) to the PMD service interface. SIGNAL_DETECT, while normally intended to be an indicator of signal presence, is used by the 100GBASE-KP4 PMD to indicate the successful completion of the start-up protocol on all lanes. The SIGNAL_DETECT parameter defined in this clause maps to the SIGNAL_OK parameter in the PMD:IS_SIGNAL.indication primitive.

SIGNAL_DETECT shall be set to FAIL following system reset or the manual reset of the training state diagram. Upon successful completion of training on all lanes, SIGNAL_DETECT shall be set to OK.

If training is disabled by management, SIGNAL_DETECT shall be set to OK.

If the MDIO interface is implemented, then Global_PMD_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

94.3.6.5 PMD lane-by-lane signal detect function

When the MDIO is implemented, each PMD_signal_detect_ i value, where i represents the lane number in the range 0 to 3, shall be continuously updated as described in the following two paragraphs.

PMD_signal_detect_0 (1.10.1), PMD_signal_detect_1 (1.10.2), PMD_signal_detect_2 (1.10.3), and PMD_signal_detect_3 (1.10.4) shall be set to one or zero depending on whether a particular lane's signal_detect, as defined by the training state diagram in Figure 72-5, returns true or false.

94.3.6.6 Global PMD transmit disable function

The Global PMD transmit disable function is optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

- a) When Global_PMD_transmit_disable variable is set to one, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 94-13.
- b) If a PMD_fault (94.3.7) is detected, then the PMD may turn off the electrical transmitter in all lanes.
- c) Loopback, as defined in 94.3.6.8, shall not be affected by Global_PMD_transmit_disable.

94.3.6.7 PMD lane-by-lane transmit disable function

The PMD lane-by-lane transmit disable function is optional and allows the electrical transmitter in each lane to be selectively disabled. When this function is supported, it shall meet the following requirements:

- a) When a `PMD_transmit_disable_i` variable (where *i* represents the lane number in the range 0 to 3) is set to one, this function shall turn off the transmitter associated with that variable such that it drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 94–13.
- b) If a `PMD_fault` (94.3.7) is detected, then the PMD may set each `PMD_transmit_disable_i` to one, turning off the electrical transmitter in each lane.
- c) Loopback, as defined in 94.3.6.8, shall not be affected by `PMD_transmit_disable_i`.

94.3.6.8 Loopback mode

Local loopback mode shall be provided by the adjacent PMA (see 83.5.8) as a test function to the device. When loopback mode is enabled, transmission requests passed to each transmitter are sent directly to the corresponding receiver, overriding any signal detected by each receiver on its attached link. Note that loopback mode does not affect the state of the transmitter, which continues to send data (unless disabled).

Control of the loopback function is specified in 45.2.1.1.5.

NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

94.3.7 PMD_fault function

`PMD_fault` is the logical OR of `PMD_receive_fault`, `PMD_transmit_fault`, and any other implementation specific fault.

If the MDIO is implemented, `PMD_fault` shall be mapped to the fault bit as specified in 45.2.1.2.1.

94.3.8 PMD transmit fault function

The `PMD_transmit_fault` function is optional. The faults detected by this function are implementation specific, but the assertion of `Global_PMD_transmit_disable` is not considered a transmit fault.

If a `PMD_transmit_fault` (optional) is detected, then the `Global_PMD_transmit_disable` function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the Transmit fault bit as specified in 45.2.1.7.4.

94.3.9 PMD receive fault function

The `PMD_receive_fault` function is optional. The faults detected by this function are implementation specific.

If the MDIO interface is implemented, then this function shall contribute to the Receive fault bit as specified in 45.2.1.7.5.

94.3.10 PMD control function

94.3.10.1 Overview

The PMD control function generates the control actions required to bring the PMD from initialization to a mode in which data may be exchanged with the link partner.

The PMD control function is based upon the 10GBASE-KR start-up protocol. This protocol facilitates timing recovery and equalization while also providing a mechanism through which the receiver can tune the transmit equalizer to optimize performance over the backplane interconnect. The protocol supports these mechanisms through the continuous exchange of fixed-length training frames.

Each lane of the 100GBASE-KP4 PMD shall have an independent control function as defined in this sub-clause.

The variables rx_trained_{*i*}, frame_lock_{*i*}, training_{*i*}, and training_failure_{*i*} (where *i* goes from 0 to 3) report status for each lane and are equivalent to rx_trained, frame_lock, training, and training_failure as defined in 72.6.10.3.1. If the MDIO interface is implemented, then this function shall map these variables to the appropriate bits in the BASE-R PMD status register (Register 1.151) as specified in 45.2.1.80.

94.3.10.2 Training frame structure

The training frame is a fixed length structure that is sent continuously during training. The training frame, shown in Figure 94–4, is 192 training frame words in length and contains a frame marker, a control channel and training pattern. The frame marker delimits the beginning of a training frame. The control channel provides a means for the each receiver to control the taps on the link partner transmitter and communicate status. The training pattern provides content rich pattern for receiver convergence.

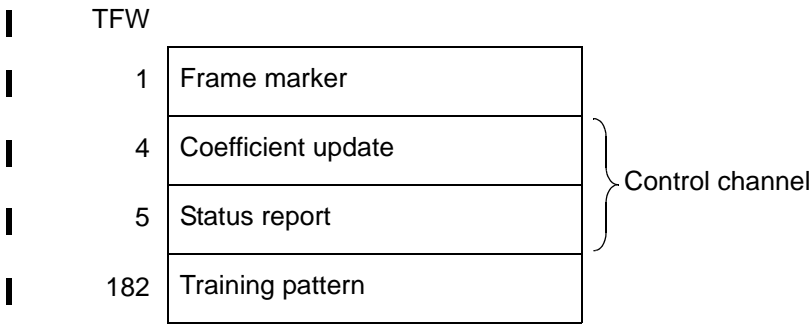


Figure 94–5—Training frame structure

94.3.10.3 Training Frame Words

Each training frame is composed of a series of 192 training frame words. Each training frame word (TFW) is 46 symbols in length, equivalent in size to a termination block described in 94.2.2.4.

94.3.10.4 Frame marker

Each training frame shall be delimited by frame marker as described in this sub-clause. The frame marker is a training frame word composed of a 46-symbol pattern of 23 +1 symbols followed by 23 -1 symbols. This pattern does not appear in the control channel or the training pattern and therefore serves as a unique indicator of the start of a training frame.

94.3.10.5 Control Channel Encoding

94.3.10.5.1 Differential Manchester Encoding

The control channel shall be transmitted using differential Manchester encoding (DME). DME guarantees transition density and DC balance while the reduced rate of transmission facilitates reception over non-optimally equalized channels.

DME cells shall be encoded using the following rules:

- a) Each DME cell represent one bit of information.
- b) A positive value is represented by a series PAM4 +1 symbols.
- c) A negative value is represented by a series of PAM4 -1 symbols.
- d) A data transition occurs at each cell boundary.
- e) A mid-cell data transition is used to signal a logical one.
- f) The absence of a mid-cell data transition is used to signal a logical zero.

If a coding violation is detected within the bounds of the control channel in a given training frame, the contents of the control channel for that frame shall be ignored.

94.3.10.5.2 Control Channel Structure

The control channel shall be constructed of a series of DME cells as described in this sub-clause.

The control channel is composed of a series of 9 training frame words. Each training frame word is composed of 4 10-symbol control channel DME cells and a 6-symbol control overhead DME cell.

The control overhead cell is always transmitted as a one following the DME rules. In other words, the control overhead cell is transmitted as either three +1 symbols followed by three -1 symbols or vice versa depending on the previously transmitted control channel cell.

The coefficient update field is transmitted in the first 16 control channel DME cells. The status report field is transmitted in the next 24 control channel DME cells. The structure of the frame marker and control channel are shown in Table 94–6.

94.3.10.6 Coefficient update field

The coefficient update field carries correction information from the local receiver to the link partner transmit equalizer. The field consists of preset controls, initialization controls, coefficient updates for three transmit equalizer taps, and parity. The coefficient update field is mapped into the first 16 control channel DME

The format of the coefficient update field shall be as shown in Table 94–7. Cell 15 of the coefficient update field sent shall be transmitted first. The preset, initialize, and coefficient updates are set by the receiver adaptation process. The algorithm employed by the receiver adaptation process is beyond the scope of this standard.

Table 94–6—Frame marker and control channel structure

Training frame word	Symbols 1:10	Symbols 11:20	Symbols 21:30	Symbols 31:40	Symbols 41:46	Training frame fields
0	1111111111	1111111111	1110000000	0000000000	000000	frame marker
1	cell 15	cell 14	cell 13	cell 12	overhead	coefficient update
2	cell 11	cell 10	cell 9	cell 8	overhead	
3	cell 7	cell 6	cell 5	cell 4	overhead	
4	cell 3	cell 2	cell 1	cell 0	overhead	
5	cell 19	cell 18	cell 17	cell 16	overhead	status report
6	cell 15	cell 14	cell 13	cell 12	overhead	
7	cell 11	cell 10	cell 9	cell 8	overhead	
8	cell 7	cell 6	cell 5	cell 4	overhead	
9	cell 3	cell 2	cell 1	cell 0	overhead	

Table 94–7—Coefficient update field

Cell(s)	Name	Description
15:14	Reserved	Transmitted as 0, ignored on reception.
13	Preset	1 = Preset coefficients 0 = Normal operation
12	Initialize	1 = Initialize coefficients 0 = Normal operation
11:7	Reserved	Transmitted as 0, ignored on reception.
6	Parity	Even parity of all other coefficient update cells.
5:4	Coefficient (+1) update	$\begin{matrix} \underline{5} & \underline{4} \\ 1 & 1 = \text{reserved} \\ 0 & 1 = \text{increment} \\ 1 & 0 = \text{decrement} \\ 0 & 0 = \text{hold} \end{matrix}$
3:2	Coefficient (0) update	$\begin{matrix} \underline{3} & \underline{2} \\ 1 & 1 = \text{reserved} \\ 0 & 1 = \text{increment} \\ 1 & 0 = \text{decrement} \\ 0 & 0 = \text{hold} \end{matrix}$
1:0	Coefficient (–1) update	$\begin{matrix} \underline{1} & \underline{0} \\ 1 & 1 = \text{reserved} \\ 0 & 1 = \text{increment} \\ 1 & 0 = \text{decrement} \\ 0 & 0 = \text{hold} \end{matrix}$

94.3.10.6.1 Preset

The behavior in response to the preset field shall be as specified in 72.6.10.2.3.1.

94.3.10.6.2 Initialize

The behavior in response to the initialize field shall be as specified in 72.6.10.3.2, except that the conditions for the INITIALIZE state are specified in 94.3.12.6.3 instead of 72.6.10.4.2.

94.3.10.6.3 Parity

The parity bit shall be set so that all bits in the coefficient update field including the parity bit exhibit even parity. The parity bit protects against acceptance of errored control messages and preserves DC balance. If a parity violation is detected within a received coefficient update field, that field shall not be used to update the transmitter coefficients.

94.3.10.6.4 Coefficient (k) update

The coefficient update fields shall be encoded as described in this sub-clause.

Each coefficient, identified by the index k , is assigned a 2-bit field describing a requested update, where $k \in \{-1, 0, 1\}$ denoting the pre-cursor, main, and post-cursor taps, respectively. The encoding of the coefficient update fields are as shown in Table 94–7.

Three request encodings are defined: increment, decrement, and hold. The default state of each tap is hold, which corresponds to no change in the coefficient. The increment or decrement encodings are transmitted to request that the corresponding coefficient be increased or decreased. The amount of change implemented by the transmitter in response to the coefficient update request meets the requirements of 94.3.12.6.4. An increment or decrement request is transmitted continuously until the update status (94.3.10.7.5) for that tap indicates updated, maximum, or minimum. At that point, the outgoing requests for that tap be set to hold. A new request to increment or decrement is not to be sent before the incoming status message for that tap reverts to not_updated.

Coefficient increment and decrement update requests are not be sent in combination with initialize or preset.

94.3.10.7 Status report field

The status report field is used to signal state information from the local PMD to the link partner. The format of the status report field shall be as shown in Table 94–8. Cell 19 of the status report field shall be transmitted first.

Table 94–8—Status report field

Cell(s)	Name	Description
19	Parity	Set to achieve even parity for status report field.
18:14	Reserved	Transmitted as zeros.
13:12	Training frame countdown	Number of training frames remaining before transition to data mode.
11:6	PMA alignment offset	Relative location of the next training frame within the PMA frame.
6	Receiver ready	1 = The local receiver has determined that training is complete and is prepared to receive data. 0 = The local receiver is requesting that training continue.

Table 94–8—Status report field

Cell(s)	Name	Description
5:4	Coefficient (+1) status	$\begin{matrix} \underline{5} & \underline{4} \\ 1 & 1 = \text{maximum} \\ 1 & 0 = \text{minimum} \\ 0 & 1 = \text{updated} \\ 0 & 0 = \text{not_updated} \end{matrix}$
3:2	Coefficient (0) status	$\begin{matrix} \underline{3} & \underline{2} \\ 1 & 1 = \text{maximum} \\ 1 & 0 = \text{minimum} \\ 0 & 1 = \text{updated} \\ 0 & 0 = \text{not_updated} \end{matrix}$
1:0	Coefficient (–1) status	$\begin{matrix} \underline{1} & \underline{0} \\ 1 & 1 = \text{maximum} \\ 1 & 0 = \text{minimum} \\ 0 & 1 = \text{updated} \\ 0 & 0 = \text{not_updated} \end{matrix}$

94.3.10.7.1 Parity

The parity cell shall be set so that all bits in the status report field including the parity bit exhibit even parity. The parity bit protects against acceptance of errored control messages and preserves DC balance. If a parity violation is detected within a received status field, that field shall not be used to determine the link partner status.

94.3.10.7.2 Training frame countdown

Editor’s note (to be removed prior to final publication):

The criteria to trigger countdown using “receiver ready” in the following paragraph is likely not robust. A future contribution on this is invited.

The training frame countdown cell shall signal the transition from training to data mode as described in this sub-clause. When training begins, countdown is set to the value 3 and remains so as long as receiver ready is 0. When received status report receiver ready is 1 and transmitted status report receiver ready is 1, the transmitter will decrement the countdown in three successive frames. In other words, in the last three training frames countdown will contain 2, 1, and 0, respectively. Immediately after the last training frame word of the last training frame is sent, transmission of the PMA frame will begin at the offset indicated by PMA alignment offset.

94.3.10.7.3 PMA Alignment Offset

The PMA alignment offset shall indicate the relative position in the PMA frame in relation to the beginning of the next training frame as described in this sub-clause. The PMA alignment offset may be used by the receiver to synchronize to the PMA frame without an additional frame synchronization process. The beginning of the PMA frame is the termination block containing the PMA overhead (94.2.2.2).

Since the training frame and PMA frame share the common divisor 24, each training frame may have one of 29 offsets relative to the start of the PMA frame. The PMA alignment offset indicates 29 offset positions in

1 multiples of 24 training frame words. The offset in number of training frame words of the next training
 2 frame is determined by multiplying PMA alignment offset by 24. As a reference point, a PMA alignment
 3 offset of zero indicates that the start of the next training frame is aligned with the start of a PMA frame.
 4 Valid values for the PMA alignment offset are {0,1,...,28}. The values {29,30,31} are not valid.
 5

6 **94.3.10.7.4 Receiver Ready**

7
 8 The receiver ready bit shall signal the local receiver state to the link partner as described in this sub-clause.
 9 When training begins the receiver ready bit will be de-asserted and remain so until the receiver has
 10 concluded training. The receiver ready bit will be asserted to indicate that the local receiver has concluded
 11 training and is prepared to receive data. The encoding of the receiver ready bit is as shown in Table 94–8.
 12

13 **94.3.10.7.5 Coefficient (k) status**

14
 15 The behavior of the coefficient (k) status fields shall be as specified in 72.6.10.2.4.5.
 16

17 **94.3.10.7.6 Coefficient update process**

18
 19 The coefficient update process shall behave as specified in 72.6.10.2.5.
 20

21 **94.3.10.8 Training Pattern**

22
 23 The training pattern shall be encoded as specified in this sub-clause.
 24

25 The training pattern is mapped into a series of 182 TFW. Each TFW is encoded as a PMA signal as specified
 26 in 94.2.2 with the exception that the input is from a PRBS13 generator rather than from the PMA service
 27 interface and no PMA overhead (94.2.2.2) is inserted.
 28

29 For each training frame, the PRBS13 generator is used to produce 16380 bits. The first 8191-bit sequence is
 30 generated using the non-inverted output from the PRBS13 generator. The next 8189-bit sequence is identical
 31 to the first, except that all bits are inverted and the last two bits are discarded.
 32

33 The PRBS13 pattern generator produces the same result as the implementation shown in Figure 94–5, which
 34 implements the generator polynomial shown in Equation (94–3). The PRBS13 pattern generator is
 35 initialized for each frame using a unique seed for each lane. The 13-bit seed and the initial 16 bits for each
 36 lane are annotated in Table 94–10.
 37

$$38 \quad G(x) = 1 + x + x^2 + x^{11} + x^{13} \quad (94-3)$$

1 **94.3.10.10 Training state diagram**

2

3 The 10GBASE-KP4 PMD shall implement the Training state diagram as depicted in [Figure 72–5](#) including

4 compliance with the associated state variables specified in [72.6.10.3](#). The training state diagram defines the

5 operation of the 100GBASE-KP4 start-up protocol.

6

7 When the training state diagram enters the INITIALIZE state, the transmitter equalizer shall be configured

8 such that the output meets the requirements of 94.3.12.6.3.

9

10 **94.3.10.11 Coefficient update state diagram**

11

12 For each tap, the 100GBASE-KP4 PMD shall implement an instance of the coefficient update state diagram

13 in [Figure 72–6](#) including compliance with the associated state variables as specified in [72.6.10.3](#). The

14 coefficient update state diagram defines the process for updating transmit equalizer coefficients in response

15 to requests from the link partner and also defines the coefficient update status to be reported in outgoing

16 training frames.

17

18 **94.3.11 PMD LPI function**

19

20 The PMD LPI function responds to the transitions between Active, Sleep, Quiet, Refresh, and Wake states

21 via the PMD_TX_MODE and PMD_RX_MODE requests. Implementation of the function is optional. EEE

22 capabilities and parameters will be advertised during the Backplane Auto-negotiation, as described in

23 45.2.7.13. The transmitter on the local device will inform the link partner’s receiver when to sleep, refresh

24 and wake. The local receiver transitions are controlled by the link partner’s transmitter and can change

25 independent of the local transmitter states and transitions.

26

27 **94.3.11.1 Alert Signal**

28

29 During refresh and wake, to enable effective detection and quick receiver synchronization an alert frame is

30 sent prior to sending normal PMA frames. The alert signal is a series of repeating alert frames.

31

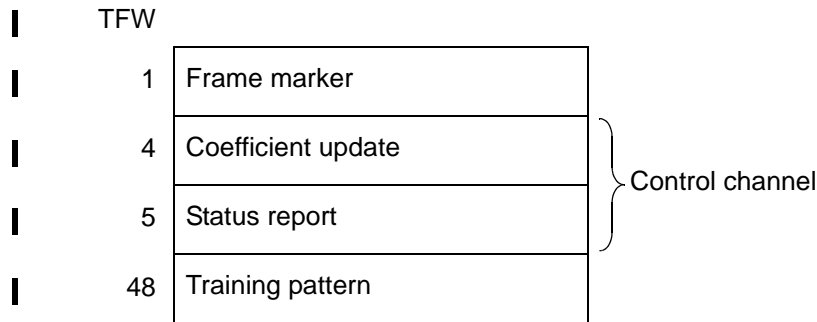
32 The alert frame shall be composed of a frame marker, control channel, and training pattern as depicted in

33 Figure 94–11. The alert frame is based on the training frame specified in 94.3.10.2. The distinguishing

34 differences are that the training pattern is truncated to 48 training frame words (4320 bits) and the control

35 and status fields are encoded differently. The alert frame is a total of 58 training frame words in length.

36



49 **Figure 94–11—Alert frame structure**

50

51

52 **94.3.11.1.1 Frame marker**

53 The frame marker shall be implemented as specified in 94.3.10.4.

54

94.3.11.1.2 Coefficient update field

The coefficient update field is unused in the alert frame. All bits in the coefficient update field are reserved and shall be transmitted as zeros.

94.3.11.1.3 Status report field

The status report field is used to signal state information from the local PMD to the link partner. The format of the status report field shall be as shown in Table 94–12. Cell 19 of the status report field shall be transmitted first.

Table 94–12—Status report field

Cell(s)	Name	Description
19	Parity	Set to achieve even parity for status report field.
18	Mode	0: training 1: EEE
17:16	EEE state	00: wake 01: refresh 10: reserved 11: reserved
15	Reserved	Transmitted as zeros.
13:12	Alert frame countdown	Number of training frames remaining before transition to data mode.
11:9	Reserved	Transmitted as zeros.
8:6	PMA alignment offset	Relative location of the next training frame within the PMA frame.
6	Receiver ready	1 = The local receiver has determined that training is complete and is prepared to receive data. 0 = The local receiver is requesting that training continue.
5:0	Reserved	Transmitted as zeros.

94.3.11.1.4 Parity

The parity field shall have the same behavior and purpose as specified for the training frame in 94.3.10.7.1.

94.3.11.1.5 Mode

The mode field indicates whether the frame is a training frame (mode = 0) or an alert frame (mode = 1). This field differentiates the alert frame from a training frame. The mode field in the alert frame shall always indicate 1.

94.3.11.1.6 EEE state

The EEE state field indicate the EEE state: wake alert or refresh alert. This field may be used by the receiver to initiate preemptive actions unique to each EEE state. The EEE state field shall be encoded as shown in Table 94–12.

94.3.11.1.7 Alert frame countdown

The alert frame countdown field shall be updated as specified for the training frame in 94.3.10.7.2. The alert frame countdown may be used by the receiver to determine when the signal will transition from the alert frame to the PMA frame.

94.3.11.1.8 PMA Alignment Offset

The PMA alignment offset shall indicate the relative position in the PMA frame in relation to the beginning of the next alert frame as described in this sub-clause. The PMA alignment offset may be used by the receiver to synchronize to the PMA frame without an additional frame synchronization process. The beginning of the PMA frame is defined as the termination block containing the PMA overhead (94.2.2.2).

The PMA frame length is exactly 6 times the alert frame length. The PMA alignment offset field indicates one of six offsets for the next alert frame within the PMA frame. The offset in number of training frame words of the next training frame is determined by multiplying PMA alignment offset by 32. As a reference point, a PMA alignment offset of zero indicates that the start of the next training frame is aligned with the start of a PMA frame. Valid values for the PMA alignment offset are {0,1,2,3,4,5}. The values {6,7} are not valid.

94.3.11.1.9 Receiver ready

The receiver ready cell shall always set to 1 to indicate training is complete and the link is up.

94.3.12 PMD Transmitter electrical characteristics

Transmitter characteristics measured at TP0a are summarized in Table 94–13.

94.3.12.1 Test Fixture

The test fixture of Figure 94–5 or its equivalent, is required for measuring the transmitter specifications described in 94.3.12.

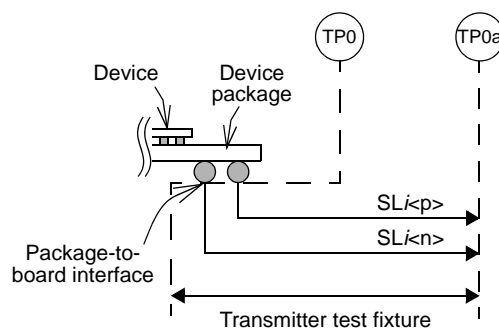


Figure 94–5—Transmitter test fixture and test points

94.3.12.1.1 Test fixture impedance

The differential load impedance applied to the transmitter output by the test fixture depicted in Figure 94–5 shall be 100 Ω .

Table 94–13—Summary of transmitter characteristics at TP0a

Parameter	Subclause reference	Value	Units
Signaling rate	94.3.12.2	13.59375 ± 100 ppm	GBd
Differential peak-to-peak output voltage (max.) Transmitter disabled ^a Transmitter enabled	94.3.12.3	30 1110	mV mV
Common-mode DC output voltage (max.)	94.3.12.3	1.9	V
Common-mode DC output voltage (min.)	94.3.12.3	0	V
Common-mode AC output voltage (RMS, max.)	94.3.12.3	30	mV
Differential output return loss (min.)	94.3.12.4	Equation (94–6)	dB
Common-mode output return loss (min.)	94.3.12.4	Equation (94–7)	dB
Transition time (20-80%, min.), no equalization ^b	94.3.12.5	TBD	ps
Output waveform Steady-state voltage v_f (max.) Steady-state voltage v_f (min.) Linear fit pulse peak (min.) Normalized RMS linear fit error (max.) Normalized coefficient step size (min.) Normalized coefficient step size (max.) Pre-cursor full-scale range (min.) Post-cursor full-scale range (min.)	94.3.12.6	0.6 TBD TBD 0.025 0.0083 0.05 1.54 4	V V V — — — — —
Far-end output noise (max.) Low insertion loss channel High insertion loss channel	94.3.12.7	0.67 0.33	mV mV
Output jitter and linearity Clock random jitter, RMS Clock deterministic jitter, peak-to-peak Even-odd jitter Signal to noise and distortion ratio	94.3.12.8.1 94.3.12.8.1 94.3.12.8.2 94.3.12.9	0.005 0.05 0.03 19	UI UI UI dB

^aThe transmitter for lane i is disabled when either Global_PMD_transmit_disable or PMD_transmit_disable $_i$ is set to one.

^bTransmit equalization may be disabled by asserting the preset control defined in Table 45–60 and 45.2.1.81.3.

The differential return loss, in dB with f in GHz, of the test fixture shall meet the requirement of Equation (94–4).

$$RL(f) \geq RL_{\max}(f) = \begin{cases} 20 - f & 0.05 \leq f \leq 5 \\ 15 & 5 \leq f \leq 10 \end{cases} \quad (94-4)$$

The common mode return loss, in dB with f in GHz, of the test fixture shall meet the requirement of Equation (94–5).

$$RL(f) \geq RL_{\max}(f) = \{ 10 \quad 0.05 \leq f \leq 10 \} \quad (94-5)$$

94.3.12.1.2 Test fixture insertion loss

The insertion loss of the test fixture measured at 12.89 GHz shall be between 1.2 dB and 1.6 dB.

Editor's note (to be removed prior to final publication):

Draft comment #135 pointed to the ILD limit on slide 9 of benartsi_3bj_01_0912, but there is no ILD limit on this slide. The editor assumed the ILD limit provided on slide 8.

The insertion loss deviation of the test fixture from 0.05 GHz to 10 GHz shall be less than 0.1 dB.

Unless otherwise noted, a 4th-order Bessel-Thompson filter with a 17 GHz cut-off frequency is applied to the transmitted signal prior to signal measurements.

94.3.12.2 Signaling rate and range

The 100GBASE-KP4 signaling rate shall be 13.59375 GBd \pm 100 ppm per lane.

94.3.12.3 Signal levels

The differential output voltage v_{di} is defined to be $SLi<p>$ minus $SLi<n>$. The common-mode output voltage v_{cmi} is defined to be one half of the sum of $SLi<p>$ and $SLi<n>$. These definitions are illustrated by Figure 94–6.

Editor's note (to be removed prior to final publication):

The transmitter disabled output voltage was reduced from 1200 to 1110 mV to account for the specified loss of the test fixture using a 2UI square wave pattern. If this test is modified to use an alternate pattern, similar to the PRBS9 for 100GBASE-KR4, the value should be reconsidered. Draft 1.1 Comment #361.

For a JP03A test pattern (94.2.11.1), the peak-to-peak differential output voltage shall be less than or equal to 1110 mV regardless of the transmit equalizer setting. The peak-to-peak differential output voltage shall be less than or equal to 30 mV when the transmitter is disabled (refer to 94.3.6.6 and 94.3.6.7).

The common-mode DC output voltage shall be between 0 V and 1.9 V with respect to signal ground. The common-mode AC output voltage shall be less than or equal to 30 mV RMS with respect to signal ground.

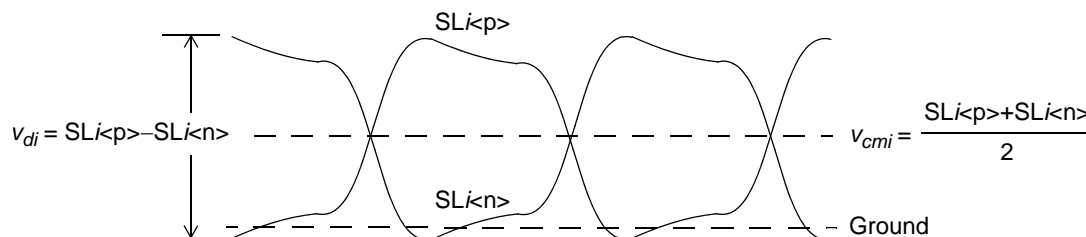


Figure 94–6—Transmitter output voltage definitions

94.3.12.4 Transmitter output return loss

The differential output return loss, in dB, of the transmitter shall meet Equation (94–6). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω

$$RL(f) \geq 20 \cdot \log_{10} \left(\sqrt{\frac{449.7 + f^2}{3671 + f^2}} \right) \quad 0.05 \text{ GHz} \leq f \leq 10 \text{ GHz} \quad (94-6)$$

The common-mode output return loss, in dB, of the transmitter shall meet Equation (94–7). This output impedance requirement applies to all valid output levels. The reference impedance for common-mode return loss measurements shall be 25 Ω

$$RL(f) \geq 6 \quad 0.05 \text{ GHz} \leq f \leq 10 \text{ GHz} \quad (94-7)$$

94.3.12.5 Transition time

Editor’s note (to be removed prior to final publication):

A suitable pattern, methodology, and values for transition time are needed.

Draft 1.1 Comment #368

Transition times (rise and fall times) are defined as the time between the 20% and 80% times, or 80% and 20% times, respectively, of isolated edges.

If the test pattern is the square wave with eight ones and eight zeros, the 0% level and the 100% level are as defined by the OMA measurement procedure (see 68.6.2).

If the test pattern is PRBS9, the transitions within sequences of five zeros and four ones, and nine ones and five zeros, respectively, are measured. These are bits 10 to 18 and 1 to 14, respectively, where bits 1 to 9 are the run of nine zeros. In this case, the 0% level and the 100% level may be estimated as ZeroLevel and ZeroLevel+MeasuredOMA in the TWDP code (see 68.6.6.2) or as the average signal within windows from –3 UI to –2 UI and from 2 UI to 3 UI relative to the edge.

NOTE—This definition is not the same as the rise and fall times typically reported by an oscilloscope from an eye diagram, which take all the edges into account.

The transition times shall be greater than or equal to TBD ps when transmit equalization is disabled. Transmit equalization may be disabled by asserting the preset control defined in Table 45–60 and 45.2.1.81.3.

94.3.12.6 Transmitter output waveform

The 100GBASE-KP4 transmit function includes programmable equalization to compensate for the frequency-dependent loss of the channel and facilitate data recovery at the receiver. The functional model for

the transmit equalizer is the three tap transversal filter shown in Figure 94–7.

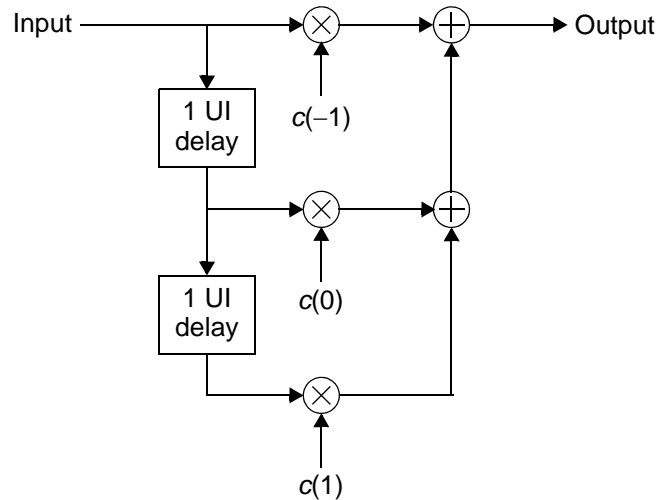


Figure 94–7—Transmit equalizer functional model

The state of the transmit equalizer and hence the transmitted output waveform may be manipulated via the PMD control function defined in 94.3.10 or via the management interface. The transmit function responds to a set of commands issued by the link partner’s receive function and conveyed by a back-channel communications path.

This command set includes instructions to:

- Increment coefficient $c(i)$.
- Decrement coefficient $c(i)$.
- Hold coefficient $c(i)$ at its current value.
- Set the coefficients to a pre-defined value (preset or initialize).

In response, the transmit function relays status information to the link partner’s receive function. The status messages indicate that:

- The requested update to coefficient $c(i)$ has completed (updated).
- Coefficient $c(i)$ is at its minimum value.
- Coefficient $c(i)$ is at its maximum value.
- Coefficient $c(i)$ is ready for the next update request (not_updated).

The transmitter output waveform is characterized using the procedure described in 85.8.3.3. The parameters of the linear pulse fit and equalizer are summarized in Table 94–14.

94.3.12.6.1 Steady state voltage and linear fit pulse peak

The steady state voltage and linear fit pulse peak values shall be verified after the transmit equalizer coefficients have been set to the “preset” values.

The steady state voltage v_f is defined to be the sum of the linear fit pulse $p(k)$ divided by M (refer to 85.8.3.3 step 3). The steady state voltage shall be greater than or equal to TBD V and less than or equal to 0.6 V.

The peak value of $p(k)$ shall be greater than TBD $\times v_f$.

Table 94–14—Linear fit pulse and equalizer parameters

Description	Symbol	Value	Units
Linear fit pulse length	N_p	8	UI
Linear fit pulse delay	D_p	2	UI
Equalizer length	N_w	8	UI
Equalizer delay	D_w	2	UI

94.3.12.6.2 Linear fit error

Editor’s note (to be removed prior to final publication):

This procedure needs to be amended to be appropriate for a PAM4 signal including the definition of a suitable test pattern (other than PRBS9) that exercises all the levels of the PAM4 signal.

Draft 1.1 Comment #370.

For any configuration of the transmit equalizer, the RMS value of the error between the linear fit and the measured waveform, $e(k)$, normalized to the peak value of the linear fit pulse, $p(k)$, shall be less than or equal to 0.025.

94.3.12.6.3 Coefficient initialization

When the PMD enters the INITIALIZE state of the Training state diagram (Figure 72–5) or receives a valid request to “initialize” from the link partner, the coefficients of the transmit equalizer shall be configured such that the ratio $(c(0)+c(1)-c(-1))/(c(0)+c(1)+c(-1))$ is TBD and the ratio $(c(0)-c(1)+c(-1))/(c(0)+c(1)+c(-1))$ is TBD. These requirements apply upon the assertion a coefficient status report of “updated” for all coefficients.

94.3.12.6.4 Coefficient step size

The change in the normalized amplitude of coefficient $c(i)$ corresponding to a request to “increment” that coefficient shall be between 0.0083 and 0.05. The change in the normalized amplitude of coefficient $c(i)$ corresponding to a request to “decrement” that coefficient shall be between -0.05 and -0.0083 .

The change in the normalized amplitude of the coefficient is defined to be the difference in the value measured prior to the assertion of the “increment” or “decrement” request (e.g., the coefficient update request for all coefficients is “hold”) and the value upon the assertion of a coefficient status report of “updated” for that coefficient.

94.3.12.6.5 Coefficient range

When sufficient “increment” or “decrement” requests have been received for a given coefficient, the coefficient will reach a lower or upper bound based on the coefficient range or restrictions placed on the minimum steady state differential output voltage or the maximum peak-to-peak differential output voltage.

With $c(-1)$ set to zero and both $c(0)$ and $c(1)$ having received sufficient “decrement” requests so that they are at their respective minimum values, the ratio $(c(0)-c(1))/(c(0)+c(1))$ shall be greater than or equal to 4.

With $c(1)$ set to zero and both $c(-1)$ and $c(0)$ having received sufficient “decrement” requests so that they are at their respective minimum values, the ratio $(c(0)-c(-1))/(c(0)+c(-1))$ shall be greater than or equal to 1.54.

Note that a coefficient may be set to zero by first asserting the preset control and then manipulating the other coefficients as required by the test.

94.3.12.7 Transmitter far-end output noise

The transmitter far-end output noise is a source of noise in addition to the channel integrated crosstalk noise (ICN) specified in 94.4.3. The transmitter far-end output noise is characterized using the procedure defined in 85.8.3.2.

The far-end transmitter output noise is characterized using two reference channels:

A “low-loss” channel with TBD dB insertion loss at 6.875 GHz and ICN that meets the requirements of 94.4.3.

A “high-loss” channel with TBD dB insertion loss at 6.875 GHz and ICN that meets the requirements of 94.4.3.

For the low-loss channel, the far-end transmitter output noise shall be less than or equal to 0.67 mV RMS. For the high-loss channel, the far-end transmitter output noise shall be less than or equal to 0.33 mV RMS.

94.3.12.8 Transmitter output jitter

94.3.12.8.1 Clock Random Jitter and Clock Deterministic Jitter

Clock random jitter (CRJrms) measured at the transmitter output using the methodology described in this sub-clause shall be less than 0.005 UI RMS regardless of transmit equalization setting.

Clock deterministic jitter (CDJ) measured at the transmitter output using the methodology described in this sub-clause shall be less than 0.05 UI peak to peak regardless of transmit equalization setting.

CRJrms and CDJ are determined using the following procedure:

- 1) CRJrms and CDJ are measured using the JP03A test pattern (94.2.11.1).
- 2) Using appropriate test equipment and procedure capture the zero-crossing times, $T_{ZC}(i)$, of a pattern of length, N , of 10^7 symbols or greater.
- 3) Determine the average pulse width ΔT_{Avg} using Equation (94–8).
- 4) Determine the jitter series, $\tau(j)$, using Equation (94–9).
- 5) Apply the effect of a single-pole high-pass filter with a 3 dB frequency of 5 MHz to the jitter samples to obtain $\tau_{HPF}(j)$.
- 6) Create a CDF as a function of $\tau_{HPF}(j)$.
- 7) From the CDF determine J_5 as the difference between τ_{HPF} at the $(1-0.5 \times 10^{-5})$ and 0.5×10^{-5} probabilities, respectively, and J_6 as the difference between τ_{HPF} at the $(1-0.5 \times 10^{-6})$ and 0.5×10^{-6} probabilities, respectively.
- 8) Calculate CRJrms and CDJ using the relationship in Equation (94–10).

$$\Delta T_{Avg} = \frac{T_{ZC}(N) - T_{ZC}(1)}{N - 1} \quad (94-8)$$

$$\tau(j) = T_{ZC}(j) - (j - 1) \cdot \Delta T_{Avg} - T_{ZC}(1) \quad j = 2, 3, \dots, N \quad (94-9)$$

$$\begin{bmatrix} CRJ_{rms} \\ CDJ \end{bmatrix} = \begin{bmatrix} 1.0538 & -1.0538 \\ -9.3098 & 10.3098 \end{bmatrix} \begin{bmatrix} J_6 \\ J_5 \end{bmatrix} \quad (94-10)$$

94.3.12.8.2 Even-Odd Jitter

Even-odd jitter (EOJ) measured at the transmitter output using the methodology described in this sub-clause shall be less than 0.03 UI peak to peak regardless of transmit equalization setting.

EOJ is determined using the following procedure:

- 1) EOJ is measured using the JP03B test pattern (94.2.11.2).
- 2) Using appropriate test equipment and procedure, capture the time for each of the 60 transitions.
- 3) Averaging of the vertical waveform or of each the zero-crossing time is recommended to mitigate the contribution of uncorrelated noise and jitter.
- 4) Denote the averaged zero-crossing times as $T_{ZC}(i)$, where $i = \{1, 2, \dots, 60\}$ and where $i = 1$ designates the transition from 3 to 0 after the consecutive pair of symbols $\{3, 3\}$.
- 5) The set of 40 pulse widths, $\Delta T(j)$, isolated from the double-width pulses are determined using the relationship in Equation (94-11).
- 6) EOJ is calculated using the relationship in Equation (94-12).

$$\Delta T(j) = \begin{cases} T_{ZC}(j+10) - T_{ZC}(j+9) & 1 \leq j \leq 20 \\ T_{ZC}(j+19) - T_{ZC}(j+18) & 21 \leq j \leq 40 \end{cases} \quad (94-11)$$

$$EOJ = \frac{\left| \sum_{j=1}^{20} \Delta T(2 \cdot j) - \sum_{j=1}^{20} \Delta T(2 \cdot j - 1) \right|}{40} \quad (94-12)$$

94.3.12.9 Transmitter output noise and distortion

Signal to noise and distortion ratio (SNDR) measured at the transmitter output using the methodology described in this sub-clause shall be greater than 19 dB.

Transmitter output linearity is determined using the following procedure:

- 1) SNDR is measured using the QPRBS13 test pattern (94.2.11.3).
- 2) Configure transmit equalization to preset values (94.3.10.6.1).
- 3) Using appropriate test equipment and procedure, capture M samples per UI over N UI, where N is an integer multiple of the test pattern length.
- 4) Designate the captured samples $y(k)$, where $k = \{1, 2, \dots, M \cdot K\}$.
- 5) Calculate a linear channel fit of the measured samples using the methodology in 85.8.3.3.5.
- 6) Designate the linear fit waveform as $f(k)$ read column-wise from the matrix F as shown in Equation (94-13).
- 7) Designate the linear fit error waveform as $e(k)$, where $e(k) = y(k) - f(k)$.
- 8) Calculate the standard deviation, $\sigma_f(p)$, for each phase, p , of $f(p+j \cdot M)$.
- 9) For p where the $\sigma_f(p)$ is greatest, determine the amplitude, S , of the +1 crossing.
- 10) Calculate the standard deviation, $\sigma_e(p)$, for each phase, p , of $e(p+j \cdot M)$. This is the RMS noise due the fit error.
- 11) $SNDR = S / \text{maximum}(\sigma_e(p))$

$$F = PX_1 = \begin{bmatrix} f(1) & f(M+1) & \dots & f(M(N_p-1)+1) \\ f(2) & f(M+2) & \dots & f(M(N_p-1)+2) \\ \dots & \dots & \dots & \dots \\ f(M) & f(2M) & \dots & f(MN_p) \end{bmatrix} \quad (94-13)$$

94.3.13 PMD Receiver electrical characteristics

Receiver characteristics measured at TP5a are summarized in Table 94-15.

Table 94-15—Summary of receiver characteristics at TP5a

Parameter	Subclause reference	Value	Units
Differential input return loss (min.)	94.3.13.2	Equation (94-14)	dB
Common-mode input return loss (min.)	94.3.13.2	Equation (94-15)	dB
Differential to common-mode return loss (min.)	94.3.13.2	Equation (94-16)	dB

94.3.13.1 Test Fixture

The test fixture of Figure 94-8 or its equivalent, is required for measuring the receiver specifications described in 94.3.13. The test fixture shall meet the requirements for insertion loss, insertion loss deviation, differential return loss, and common mode return loss in 94.3.12.1.

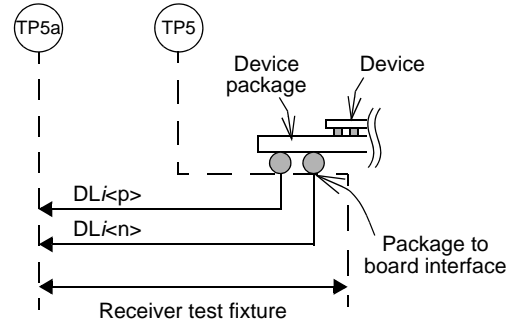


Figure 94-8—Receiver test fixture and test points

94.3.13.2 Receiver input return loss

The differential input return loss, in dB, of the receiver shall meet Equation (94-14). The reference impedance for differential return loss measurements shall be 100 Ω .

$$RL(f) \geq 20 \cdot \text{Log}_{10} \left(\sqrt{\frac{449.7 + f^2}{3671 + f^2}} \right) \quad 0.05 \text{ GHz} \leq f \leq 10 \text{ GHz} \quad (94-14)$$

The common-mode input return loss, in dB, of the receiver shall meet Equation (94-15). The reference impedance for common-mode return loss measurements shall be 25 Ω .

$$RL(f) \geq 6 \quad 0.05 \text{ GHz} \leq f \leq 10 \text{ GHz} \quad (94-15)$$

The differential to common-mode return loss, in dB, of the receiver shall meet Equation (94-16).

$$\text{TBD} \quad (94-16)$$

94.3.13.3 Receiver interference tolerance

Editor's note (to be removed prior to final publication):

Test 1 is intended to be on a low loss channel with ~15 dB IL at Nyquist, while Test 2 is intended to be on a high loss channel with ~33 dB IL at Nyquist.

Receiver interference tolerance is characterized using the procedure defined in [Annex 69A](#). The receiver shall satisfy the requirements for interference tolerance summarized in Table 94-16.

A 4th-order Bessel-Thompson filter with a 17 GHz cut-off frequency is applied to measurements of the signal applied by the pattern generator and to measurements of the broadband noise.

Table 94-16—Receiver interference tolerance parameters

Parameter	Test 1 values	Test 2 values	Units
Maximum BER without FEC	3×10^{-4}	3×10^{-4}	
Maximum BER with FEC	10^{-12}	10^{-12}	
Channel insertion loss at 6.875 GHz	TBD	TBD	dB
Real part of a_0 , min. ^a	TBD	TBD	Hz ^{-1/2}
Real part of a_1 , min.	TBD	TBD	Hz ⁻¹
Real part of a_2 , min.	TBD	TBD	Hz ⁻²
Real part of a_4 , min.	TBD	TBD	
Channel noise excluding TX-RX re-reflection noise	0	0	mV
Applied peak-to-peak Sinusoidal Jitter ^b	TBD	TBD	UI
Applied peak-to-peak Random Jitter ^c	TBD	TBD	UI
Applied even-odd jitter	TBD	TBD	UI
Applied RMS broadband noise	TBD	TBD	mV

^aFor each test channel, a_0 is limited to a maximum value of 1.5 and a_1 , a_2 , and a_4 are limited to a maximum value of 0.

^bThe frequency of the sinusoid must be greater than 100 MHz.

^cRandom Jitter is specified at a BER of 10^{-12} .

94.4 Channel characteristics

94.4.1 Channel operating margin

The channel operating margin (COM) computed using the procedure in Annex 93A and the parameters in Table 94–17 shall be greater than or equal to 3 dB.

Editor's note (to be removed prior to final publication):

Draft #1.1 comments #146 and #255 responses suggest that A_{dd} and σ_G should be reconciled with CRJrms, CDJ, and SNDR in 94.3.12.8. The relationship is not clear.

A proposal to reconcile A_{dd} and σ_G is invited.

Table 94–17—Channel operating margin parameters

Parameter	Symbol	Value	Units
Signaling rate	f_b	13.59375	GHz
Maximum start frequency	f_{\min}	0.05	GHz
Maximum frequency step	Δf	0.01	GHz
Transmitter reflection coefficient DC value Reference frequency	Γ_1 Γ_{01} f_1	0.315 20.625	V/V GHz
Receiver reflection coefficient DC value Reference frequency	Γ_2 Γ_{02} f_2	0.315 20.625	V/V GHz
Transmitter differential peak output voltage Victim Far-end aggressor Near-end aggressor	A_v A_f A_n	0.4 0.4 0.6	V V V
Transmitter 3 dB bandwidth Victim Far-end aggressor Near-end aggressor	f_v f_f f_n	$0.55 \times f_b$ $0.55 \times f_b$ f_b	GHz GHz GHz
Receiver 3 dB bandwidth	f_r	$0.75 \times f_b$	
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	$c(-1)$	–0.10 0 0.02	— — —

Table 94–17—Channel operating margin parameters

Parameter	Symbol	Value	Units
Transmitter equalizer, post-cursor coefficient	$c(1)$		
Minimum value		–0.40	—
Maximum value		0	—
Step size		0.02	—
Continuous time filter, DC gain	g_{DC}		
Minimum value		–12	dB
Maximum value		0	dB
Step size		1	dB
Number of signal levels	L	4	—
Number of samples per unit interval	M	32	—
Decision feedback equalizer (DFE) length	N_b	16	UI
DFE coefficient magnitude limit	b_{max}	0.2	—
Random jitter, RMS	σ_{RJ}	0.005	UI
Dual-Dirac jitter, peak	A_{DD}	.05	UI
Receiver additive Gaussian noise, RMS	σ_r	15	mV
Target uncorrected symbol error ratio	SER_0	10^{-5}	—

94.4.2 Channel insertion loss

The insertion loss, in dB, of the channel is recommended to meet Equation (94–17). The insertion loss limit is shown Figure 94–9.

$$IL(f) \leq IL_{max}(f) = \begin{cases} a_0 + a_1 \cdot \sqrt{f} + a_2 \cdot f + a_3 \cdot f^2 + a_4 \cdot f^3 & f_{min} \leq f \leq f_2 \\ a_5 + a_6 \cdot f - f_2 & f_2 < f \leq f_{max} \end{cases} \quad (94-17)$$

where

$IL(f)$ is the insertion loss at frequency f

$IL_{max}(f)$ is the maximum allowable insertion loss at frequency f

f is the measurement frequency in Hz

$f_{min} = 0.05$ GHz

$f_2 = 7.0$ GHz

$f_{max} = 15$ GHz

$a_0 = 0.8$

$a_1 = 1.7372 \times 10^{-4}$

$a_2 = 1.1554 \times 10^{-9}$

$a_3 = 2.7795 \times 10^{-19}$

$a_4 = -1.0423 \times 10^{-29}$

$a_5 = 33.467$

$a_6 = 1 \times 10^{-8}$

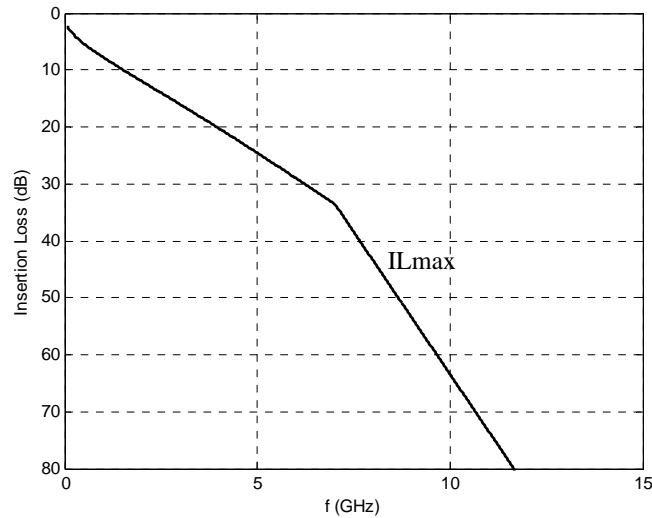


Figure 94-9—Channel Insertion Loss limit

94.4.3 Channel Integrated Crosstalk Noise (ICN)

Editor's note (to be removed prior to final publication):

This is a placeholder to be referenced by the transmitter far-end output noise specification (refer to 94.3.12.7).

94.4.4 Channel Return Loss

The return loss, in dB, of the channel is recommended to meet Equation (94-18). The return loss limit $RL_{\min}(f)$ is shown Figure 94-10.

$$RL(f) \geq RL_{\min}(f) = \begin{cases} 12 & 0.05 \leq f \leq f_b/4 \\ 12 - 15 \log_{10} 4f/f_b & f_b/4 < f \leq f_b \end{cases} \quad (94-18)$$

where

$RL(f)$ is the return loss at frequency f in dB
 $RL_{\min}(f)$ is the minimum allowable return loss in dB
 f is the measurement frequency in GHz
 f_b is the signalling rate (13.59375) in GHz

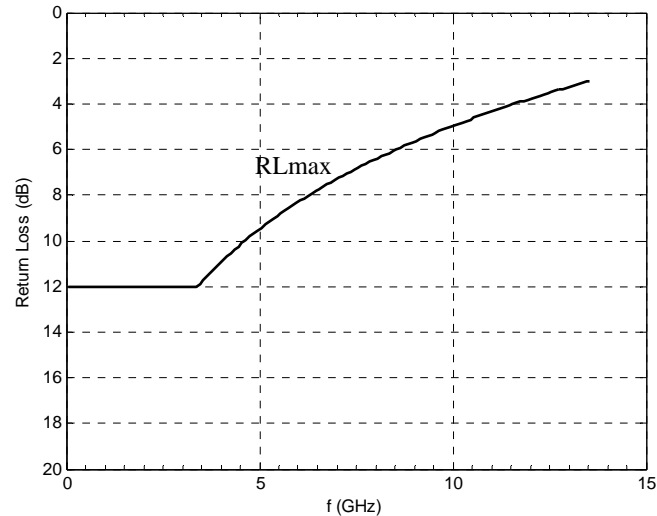


Figure 94-10—Channel Return Loss limit

94.4.5 Channel AC-coupling

The 100GBASE-KP4 transmitter shall be AC-coupled to the receiver. Common-mode specifications are defined as if the DC-blocking capacitor is implemented between TP0 and TP5. Should the capacitor be implemented outside TP0 and TP5, the common-mode specifications in Table 94-13 may not be appropriate.

The impact of a DC-blocking capacitor implemented between TP0 and TP5 is accounted for within the channel specifications. Should the capacitor be implemented outside TP0 and TP5, it is the responsibility of implementers to consider any necessary modifications to common-mode and channel specifications required for interoperability as well as any impact on the verification of transmitter and receiver compliance.

The low frequency 3 dB cutoff of the AC coupling shall be less than 50 kHz.

94.5 Environmental specifications

94.5.1 General safety

All equipment subject to this clause shall conform to applicable sections (including isolation requirements) of IEC 60950-1.

94.5.2 Network safety

The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

94.5.3 Installation and maintenance guidelines

It is recommended that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

94.5.4 Electromagnetic compatibility

A system integrating the 100GBASE-KP4 PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.

94.5.5 Temperature and humidity

A system integrating the 100GBASE-KP4 PHY is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

94.6 Protocol implementation conformance statement (PICS) proforma for Clause 94, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KP4¹²

94.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 93, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KP4, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in [Clause 21](#).

94.6.2 Identification

94.6.2.1 Implementation identification

Supplier ¹	
Contact point for enquiries about the PICS ¹	
Implementation Name(s) and Version(s) ^{1,3}	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s) ²	
NOTE 1— Required for all implementations. NOTE 2— May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

94.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3bj-20XX, Clause 93, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KP4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [] Yes [] (See Clause 21 ; the answer Yes means that the implementation does not conform to IEEE Std 802.3bj-20XX.)	

Date of Statement	
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¹²Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

94.6.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
CGMII	CGMII	94.1	Interface is supported	O	Yes [] No []
PCS	100GBASE-R PCS	94.1		M	Yes []
RS-FEC	100GBASE-R RS-FEC	94.1		M	Yes [] No []
PMA	100GBASE-R PMA	94.1		M	Yes []
CAUI	CAUI	94.1	Interface is supported	O	Yes [] No []
AN	Auto-negotiation	94.1		M	Yes []
*MD	MDIO capability	94.3.5	Registers and interface supported	O	Yes [] No []
*EEE	EEE capability	94.1	Capability is supported	O	Yes [] No []
*GTD	Global PMD transmit disable function	94.3.6.6	Function is supported	O	Yes [] No []
*LTD	PMD lane-by-lane transmit disable function	94.3.6.7	Function is supported	O	Yes [] No []

94.6.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-KP4**94.6.4.1 PMA functional specifications**

Item	Feature	Subclause	Value/Comment	Status	Support
AFS1	Overhead frame	94.2.2.2	Transmitter maps FEC bits to overhead frame	M	Yes []
AFS2	Termination blocks	94.2.2.4	Transmitter maps overhead frame bits to termination blocks.	M	Yes []
AFS3	Gray mapping	94.2.2.5	Transmitter maps each pair of termination block bits to Gray-mapped symbols	M	Yes []
AFS4	Precoder	94.2.2.6	Transmitter precodes each Gray-mapped symbol	M	Yes []
AFS5	PAM4 encoder	94.2.2.7	Transmitter map each pre-coded symbol to PAM4 levels	M	Yes []
AFS6	Transmit symbols	94.2.2.8	Transmitter sends each PAM4 symbol to the PMD.	M	Yes []

Item	Feature	Subclause	Value/Comment	Status	Support
AFS7	Recover data	94.2.4	Receiver recovers data, meet performance requirements, and removes termination bits and overhead.	M	Yes []
AFS8	Link status	94.2.8	Provide link status to PMA client via PMA:IS_SIGNAL.indication primitive.	M	Yes []
AFS9	PMA local loopback	94.2.9	Provide loopback from PMA SI input to PMA SI output.	M	Yes []
AFS10	PMA remote loopback	94.2.10	Provide loopback from PMA SI output to PMA SI input.	O	Yes [] No []
AFS11	JP03A pattern	94.2.11.1	Provide JP03A test pattern.	M	Yes []
AFS12	JP03B pattern	94.2.11.2	Provide JP03B test pattern.	M	Yes []
AFS13	QPRBS13 test pattern	94.2.11.3	Provide QPRBS13 test pattern	M	Yes []

94.6.4.2 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
DFS1	Sum of receive and transmit delays in one direction for PMA, PMD, and AN.	94.3.3	Less than TBD bit times.	M	Yes []
DFS2	Skew at SP3	94.3.4	Less than TBD ns	M	Yes []
DFS3	Skew variation at SP3	94.3.4	Less than TBD ns	M	Yes []
DFS4	Skew at SP4	94.3.4	Less than TBD ns	M	Yes []
DFS5	Skew variation at SP4	94.3.4	Less than TBD ns	M	Yes []
DFS6	Skew at SP5	94.3.4	Less than TBD ns	M	Yes []
DFS7	Skew variation at SP5	94.3.4	Less than TBD ns	M	Yes []
DFS8	PMD control variables	94.3.5	Map PMD control variables to MDIO per Table 94–3.	MD:M	Yes [] N/A []
DFS9	PMD status variables	94.3.5	Map PMD status variables to MDIO per Table 94–4.	MD:M	Yes [] N/A []
DFS10	Transmit function	94.3.6.2	Convert 4 bit streams from PMD SI to 4 electrical streams at the MDI.	M	Yes []
DFS11	Transmit symbol value	94.3.6.2	A positive value for SLi<p> minus SLi<n> corresponds to a positive symbol value.	M	Yes []
DFS12	Receive function	94.3.6.3	Convert 4 electrical bit streams from MDI to 4 bit streams at the PMD SI.	M	Yes []
DFS13	Receive symbol value	94.3.6.3	A positive value for DLi<p> minus DLi<n> corresponds to a positive symbol value.	M	Yes []
DFS14	Signal detect parameter	94.3.6.4	Continuously send SIGNAL_DETECT to PMD SI.	M	Yes []
DFS15	Signal detect FAIL	94.3.6.4	SIGNAL_DETECT set to FAIL following system or manual reset.	M	Yes []
DFS16	Signal detect OK	94.3.6.4	SIGNAL_DETECT set to OK upon training complete on all lanes	M	Yes []
DFS17	Signal detect without training	94.3.6.4	SIGNAL_DETECT set to OK if training disabled.	M	Yes []
DFS18	Global_PMD_signal_detect	94.3.6.4	Continuously set to value of SIGNAL_DETECT.	MD:M	Yes [] N/A []
DFS19	PMD_signal_detect_i update	94.3.6.5	Update per lane based on signal_detect in Figure 72-5.	MD:M	Yes [] N/A []
DFS20	PMD_signal_detect_i update per lane	94.3.6.5	Update per lane based on signal_detect in Figure 72-5.	MD:M	Yes [] N/A []

Item	Feature	Subclause	Value/Comment	Status	Support
DFS21	Global_PMD_transmit_disable variable	94.3.6.6	When set to one, all transmitters satisfy the requirements of 94.3.12.3.	GTD:M	Yes [] N/A []
DFS22	Loopback when transmitter disabled	94.3.6.6	Loopback not affected.	GTD:M	Yes [] N/A []
DFS23	PMD_transmit_disable_ <i>i</i> variable	94.3.6.7	When set to one, the transmitter for lane <i>i</i> satisfies the requirements of 94.3.12.3	LTD:M	Yes [] N/A []
DFS24	PMD lane-by-lane transmit disable function affect on loopback	94.3.6.7	No effect	LTD:M	Yes [] N/A []
DFS25	Loopback mode	94.3.6.8	Provided in adjacent PMA.	M	Yes []
DFS26	PMD_fault variable mapping to MDIO	94.3.7	Mapped to the fault bit as specified in 45.2.1.2.1	MD:M	Yes [] N/A []
DFS27	PMD_transmit_fault variable mapping to MDIO	94.3.8	Mapped to Transmit fault bit as specified in 45.2.1.7.4	MD:M	Yes [] N/A []
DFS28	PMD_receive_fault variable mapping to MDIO	94.3.9	Mapped to Receive fault bit as specified in 45.2.1.7.5	MD:M	Yes [] N/A []
DFS29	Control function	94.3.10.1	Independent per lane	M	Yes []
DFS30	Training variables	94.3.10.1	Map to MDIO bits per 45.2.1.80.	MD:M	Yes [] N/A []
DFS31	Training frame marker	94.3.10.4	Frame marker encoded per 94.3.10.4.	M	Yes []
DFS32	Training frame control channel encoding	94.3.10.5.1	Differential manchester encoding	M	Yes []
DFS33	Training frame control channel DME	94.3.10.5.1	Encoded based on rules in 94.3.10.5.1.	M	Yes []
DFS34	Training frame coding violation	94.3.10.5.1	Discard control channel if there is any coding violation.	M	Yes []
DFS35	Training frame control channel structure	94.3.10.5.2	Series of DME cells specified in 94.3.10.5.2.	M	Yes []
DFS36	Training frame coefficient update field	94.3.10.6	Format per Table 94–7.	M	Yes []
DFS37	Training frame coefficient transmission order.	94.3.10.6	Cell 15 first.	M	Yes []
DFS38	Training frame coefficient update parity	94.3.10.6.3	Set for even in coefficient update field.	M	Yes []
DFS39	Training frame preset	94.3.10.6.1	Response per 72.6.10.2.3.1.	M	Yes []
DFS40	Training frame initialize	94.3.10.6.2	Response per 72.6.10.3.2 and conditions per 94.3.12.6.3.	M	Yes []
DFS41	Training frame coefficient update parity violation	94.3.10.6.3	Discard control channel if parity violation.	M	Yes []
DFS42	Training frame coefficient (k) update	94.3.10.6.4	Encoded per 94.3.10.6.4.	M	Yes []

Item	Feature	Subclause	Value/Comment	Status	Support
DFS43	Training frame status report field	94.3.10.7	Format per Table 94–8.	M	Yes []
DFS44	Training frame status report parity	94.3.10.7.1	Set for even in status report field.	M	Yes []
DFS45	Training frame countdown.	94.3.10.7.2	Indicate transition per 94.3.10.7.2.	M	Yes []
DFS46	Training frame PMA alignment offset	94.3.10.7.3	Indicate offset of PMA frame per 94.3.10.7.3.	M	Yes []
DFS47	Training frame receiver ready	94.3.10.7.4	Signal local receiver state per 94.3.10.7.4.	M	Yes []
DFS48	Training frame coefficient status	94.3.10.7.5	Behavior per 72.6.10.2.4.5.	M	Yes []
DFS49	Training frame coefficient update process	94.3.10.7.6	Update coefficients per 72.6.10.2.5.	M	Yes []
DFS50	Training frame training pattern	94.3.10.8	Encode per 94.3.10.8.	M	Yes []
DFS51	Training frame lock state diagram	94.3.10.9	Implement per Figure 72-4 and 72.6.10.3.	M	Yes []
DFS52	Training state diagram	94.3.10.10	Implement per Figure 72-5 and 72.6.10.3.	M	Yes []
DFS53	Coefficient update state diagram.	94.3.10.11	Implement per Figure 72-6 and 72.6.10.3.	M	Yes []
DFS54	Alert frame	94.3.11.1	Structure per Table 94–11.	EEE:M	Yes [] N/A []
DFS55	Alert frame marker	94.3.11.1.1	Implement per 94.3.10.4.	EEE:M	Yes [] N/A []
DFS56	Alert frame coefficient update field	94.3.11.1.2	Transmitted as all zeros.	EEE:M	Yes [] N/A []
DFS57	Alert frame status report field	94.3.11.1.3	Format per Table 94–12.	EEE:M	Yes [] N/A []
DFS58	Alert frame status report field order of transmission	94.3.11.1.3	Transmit cell 19 first.	EEE:M	Yes [] N/A []
DFS59	Alert frame status report parity	94.3.11.1.4	Behavior per 94.3.10.7.1.	EEE:M	Yes [] N/A []
DFS60	Alert frame mode	94.3.11.1.5	Always set to 1.	EEE:M	Yes [] N/A []
DFS61	Alert frame EEE state	94.3.11.1.6	Encoded per Table 94–12.	EEE:M	Yes [] N/A []
DFS62	Alert frame countdown	94.3.11.1.7	Updated per 94.3.10.7.2	EEE:M	Yes [] N/A []
DFS63	Alert frame PMA alignment offset	94.3.11.1.8	Indicate relative position of PMA frame and encoded per 94.3.11.1.8.	EEE:M	Yes [] N/A []
DFS64	Alert frame receiver ready	94.3.11.1.9	Always set to 1.	EEE:M	Yes [] N/A []

94.6.4.3 PMD transmitter characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	Test fixture impedance	94.3.12.1.1	100 Ω	M	Yes []
TC2	Test fixture differential return loss	94.3.12.1.1	Equation (94-4)	M	Yes []
TC3	Test fixture common mode return loss	94.3.12.1.1	Equation (94-5)	M	Yes []
TC4	Test fixture differential return loss	94.3.12.1.1	Meets equation constraints	M	Yes []
TC5	Test fixture common-mode return loss	94.3.12.1.1	≥ 10 dB from 0.05 to 13 GHz	M	Yes []
TC6	Test fixture differential insertion loss	94.3.12.1.2	≥ 1.2 dB and ≤ 1.6 dB at 12.89 GHz.	M	Yes []
TC7	Test fixture insertion loss deviation	94.3.12.1.2	Magnitude < 0.1 dB	M	Yes []
TC8	Signaling rate per lane	94.3.12.2	13.59375 GBd ± 100 ppm	M	Yes []
TC9	Peak-to-peak differential output voltage	94.3.12.3	≤ 1110 mV regardless of transmit equalizer setting	M	Yes []
TC10	Peak-to-peak differential output voltage, transmitter disabled	94.3.12.3	≤ 30 mV	M	Yes []
TC11	DC common-mode output voltage	94.3.12.3	Between 0 V and 1.9 V with respect to signal ground	M	Yes []
TC12	AC common-mode output voltage	94.3.12.3	≤ 30 mV RMS.	M	Yes []
TC13	Differential output return loss	94.3.12.4	Equation (94-6) with 100 Ω reference impedance	M	Yes []
TC14	Common-mode output return loss	94.3.12.4	Equation (94-7) with 25 Ω reference impedance.	M	Yes []
TC15	Transition times	94.3.12.5	\geq TBD ps when transmit equalization is disabled	M	Yes []
TC16	Steady state voltage, v_f	94.3.12.6.1	\geq TBD V and ≤ 0.6 V after the transmit equalizer coefficients have been set to the "preset" values	M	Yes []
TC17	Linear fit pulse peak	94.3.12.6.1	$>$ TBD $\times v_f$ after the transmit equalizer coefficients have been set to the "preset" values	M	Yes []
TC18	Normalized linear fit error	94.3.12.6.2	≤ 0.025	M	Yes []
TC19	Coefficient initialization	94.3.12.6.3	Satisfies the requirements of 94.3.12.6.3.	M	Yes []
TC20	Normalized coefficient step size for "increment"	94.3.12.6.4	Between 0.0083 and 0.05	M	Yes []

Item	Feature	Subclause	Value/Comment	Status	Support
TC21	Normalized coefficient step size for “decrement”	94.3.12.6.4	Between -0.05 and -0.0083	M	Yes []
TC22	Maximum post-cursor equalization ratio	94.3.12.6.5	≥ 4	M	Yes []
TC23	Maximum pre-cursor equalization ratio	94.3.12.6.5	≥ 1.54	M	Yes []
TC24	Transmitter far-end output noise, low-loss channel	94.3.12.7	≤ 0.67 mV RMS	M	Yes []
TC25	Transmitter far-end output noise, high-loss channel	94.3.12.7	≤ 0.33 mV RMS	M	Yes []
TC26	Clock random jitter RMS	94.3.12.8.1	≤ 0.005 UI RMS regardless of the transmit equalization setting	M	Yes []
TC27	Clock deterministic jitter	94.3.12.8.1	≤ 0.05 UI regardless of the transmit equalization setting	M	Yes []
TC28	Even-odd jitter	94.3.12.8.2	≤ 0.03 UI regardless of the transmit equalization setting	M	Yes []
TC29	SNDR	94.3.12.9	≥ 19 dB	M	Yes []

94.6.4.4 PMD receiver characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
RC1	Test fixture insertion loss	94.3.13.1	Meet requirements in 94.3.12.1.	M	Yes []
RC2	Differential input return loss	94.3.12.9	Meets Equation (94–14) measured with a reference impedance of 100 Ω	M	Yes []
RC3	Common-mode input return loss	94.3.12.9	Meets Equation (94–15) measured with a reference impedance of 25 Ω	M	Yes []
RC4	Differential to common-mode return loss	94.3.12.9	Meets Equation (94–16).	M	Yes []
RC5	Interference tolerance	94.3.12.9	Satisfy requirements summarized in Table 94–16	M	Yes []

94.6.4.5 Channel characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Channel operating margin (COM)	94.4.1	Greater than or equal to 3 dB	M	Yes []
CC2	AC-coupling	94.4.5	Channel AC couples the transmitter to the receiver	M	Yes []
CC3	AC-coupling 3 dB cut-off frequency	94.4.5	Less than 50 kHz	M	Yes []

94.6.4.6 Environment specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	94.5.1	Complies with application section of IEC 60950-1	M	Yes []
ES2	Electromagnetic interference	94.5.4	Complies with applicable local and national codes.	M	Yes []

Annex 83A

(normative)

40 Gb/s Attachment Unit Interface (XLAUI) and 100 Gb/s Attachment Unit Interface (CAUI)

Editor's note (to be removed prior to final publication):

The IEEE P802.3bj Task Force and IEEE 802.3 Working Group approved changes to the project objectives, 5 criteria responses, and PAR that increased the scope of the project to add the optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10. However, the change of scope is still pending LMSC EC and SASB approval. It is expected that the EC will consider the change at the November 2012 meeting and, based on that, the SASB will consider the change at their December 2012 meeting.

Based on these completed and pending actions, this clause is changed in a manner that is consistent with the increased scope. Should the PAR modification not be approved, any changes pertaining to an optional Energy Efficient Ethernet capability for 40GBASE-CR4, 40GBASE-KR4, and 100GBASE-CR10 will be removed.

Add the following after 83A.3.2:

83A.3.2a EEE operation

If the optional Energy Efficient Ethernet (EEE) capability with the normal wake mode option is supported (see Clause 78, 78.3) then the inter-sublayer service interface includes two additional primitives as described in 83.3 and may also support CAUI shutdown.

Editor's note (to be removed prior to final publication):

The following behavior has been proposed but not adopted by the Task Force for EEE behavior:

In the ingress direction, the CAUI shall transmit a repeating 16-bit pattern, hexadecimal 0xFF00 while parameter `rx_mode` = ALERT.

In the ingress direction, in addition to the transmit disable function defined by 83.5.12 and 83.5.12.1 (references changed by another comment), the CAUI shall transmit the PRBS31 pattern defined in 83.5.10 when `rx_mode` = QUIET. The requirement to disable the transmitters takes precedence over the PRBS test pattern transmission.

In the ingress direction, a PMA that is connected by a CAUI to a separated PMA may infer the state of `rx_mode` by observing this behavior of the CAUI signals.

Add the following at the end of 83A.3.3.1:

83A.3.3.1.1 Amplitude and swing

For EEE capability, the CAUI transmitter lane's differential peak-to-peak output voltage shall be less than TBD mV within TBD ns of `tx_mode` changing to QUIET in the egress direction or `rx_mode` changing to

QUIET in the ingress direction. Furthermore, the CAUI transmitter lane's differential peak-to-peak output voltage shall be greater than TBD mV within TBD ns of tx_mode ceasing to be QUIET in the egress direction or rx_mode ceasing to be QUIET in the ingress direction.

Editor's note (to be removed prior to final publication):

The baseline highlights functions that are still to be defined:

The state of tx_mode and rx_mode must both be communicated across CAUI.

When tx_mode is in state ALERT, the definition of the ALERT signaling must be defined.

When tx_mode is in state FW, some signaling must be defined.

The receiver must infer the state of rx_mode from the received signal (for states DATA, ALERT & FW)

Add the following after 83A.3.3.5 for the CAUI shutdown:

83A.3.3.6 Global transmit disable function

Global transmit disable is optional for EEE capability. The transmit disable function shall turn off all transmitter lanes for a physically instantiated AUI in either the ingress or the egress direction. In the egress direction, the PMA may turn off all the transmitter lanes for the egress direction CAUI if PEASE is asserted and tx_mode is QUIET. In the ingress direction, the PMA may turn off all the transmitter lanes for the ingress direction CAUI if PIASE is asserted and rx_mode is QUIET. In both directions, the transmit disable function shall turn on all transmitter lanes after tx_mode or rx_mode (as appropriate) changes to any state other than QUIET within a time and voltage level specified in TBD.

Add the following after 83A.3.4.6 for the CAUI shutdown:

83A.3.4.7 Global energy detect function

The global energy detect function is mandatory for EEE capability with the normal wake mode option and XLAUI/CAUI shutdown. The global energy detect function indicates whether or not signaling energy is being received on the physical instantiation of the inter sublayer interface (in each direction as appropriate). The energy detection function may be considered a subset of the signal indication logic. If no energy is being received on the CAUI for the ingress direction then rx_mode shall be assigned the value QUIET; if no energy is being received on the CAUI for the egress direction then tx_mode shall be assigned the value QUIET. In all other situations, the values of rx_mode and tx_mode remain as communicated from the adjacent sublayers across the inter sublayer interfaces.

83A.4 Protocol implementation conformance statement (PICS) proforma for Annex 83A, 40 Gb/s Attachment Unit Interface (XLAUI) and 100 Gb/s Attachment Unit Interface (CAUI)¹³

Editor's note (to be removed prior to final publication):

The PICS proforma will be updated when the content of this clause stabilizes.

¹³Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

Annex 83C

(informative)

PMA sublayer partitioning examples

Change 83C.1 as follows:

83C.1 Partitioning examples with FEC

The example of BASE-R FEC (See [Clause 74](#)) implemented in a separate device from either the PCS or the PMD is illustrated in [Figure 83–2](#).

83C.1.1 FEC implemented with PCS

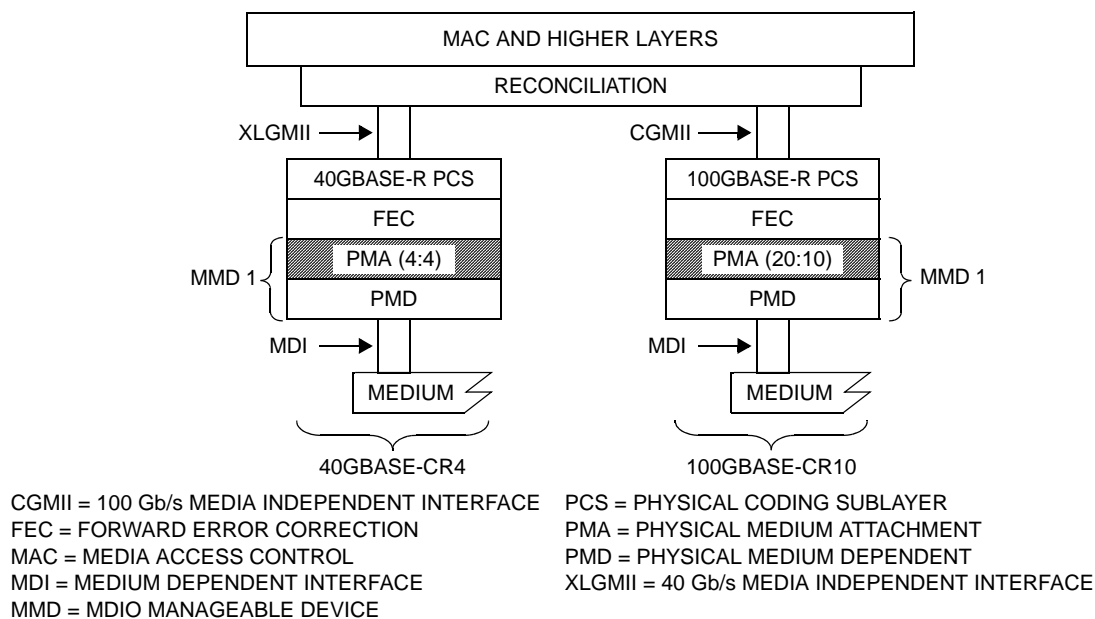


Figure 83C–1—Example FEC implemented with PCS

83C.1.2 FEC implemented with PMD

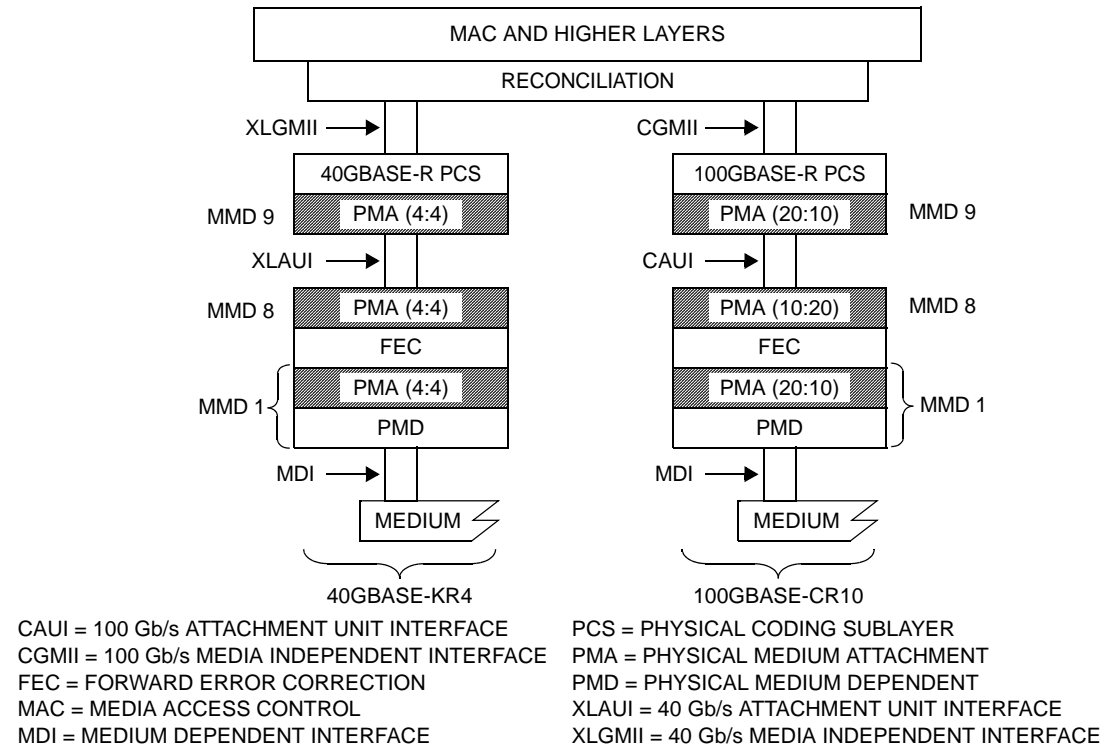


Figure 83C–2—Example FEC implemented with PMD

Add 83C.1a after 83C.1 as follows:

83C.1a Partitioning examples with RS FEC

83C.1a.1 Single PMA sublayer with RS FEC

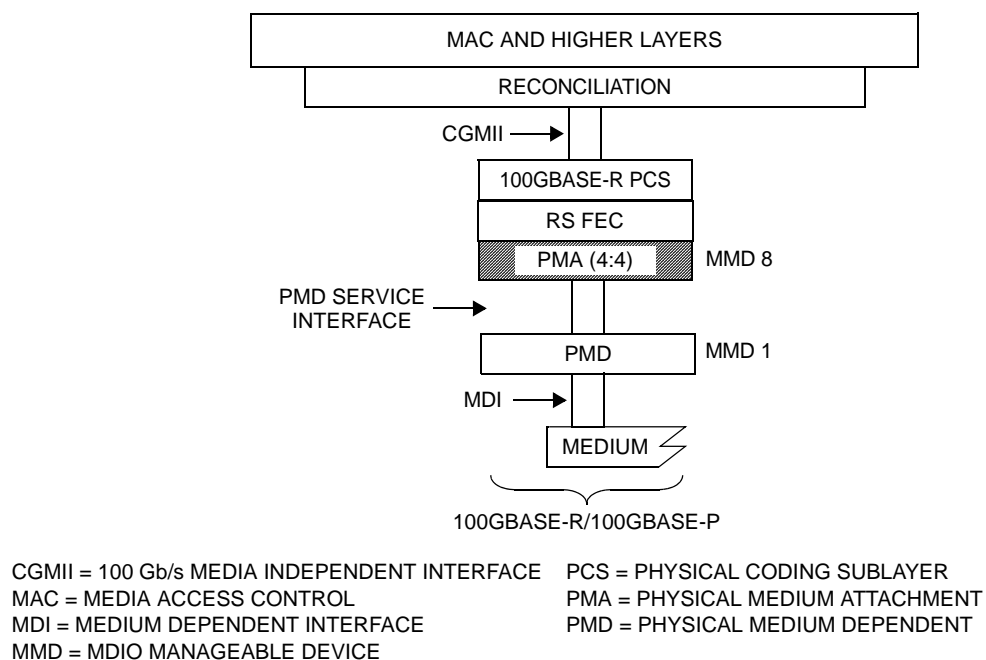


Figure 83C–2a—Example single PMA sublayer with RS FEC

83C.1a.2 Single CAUI with RS FEC

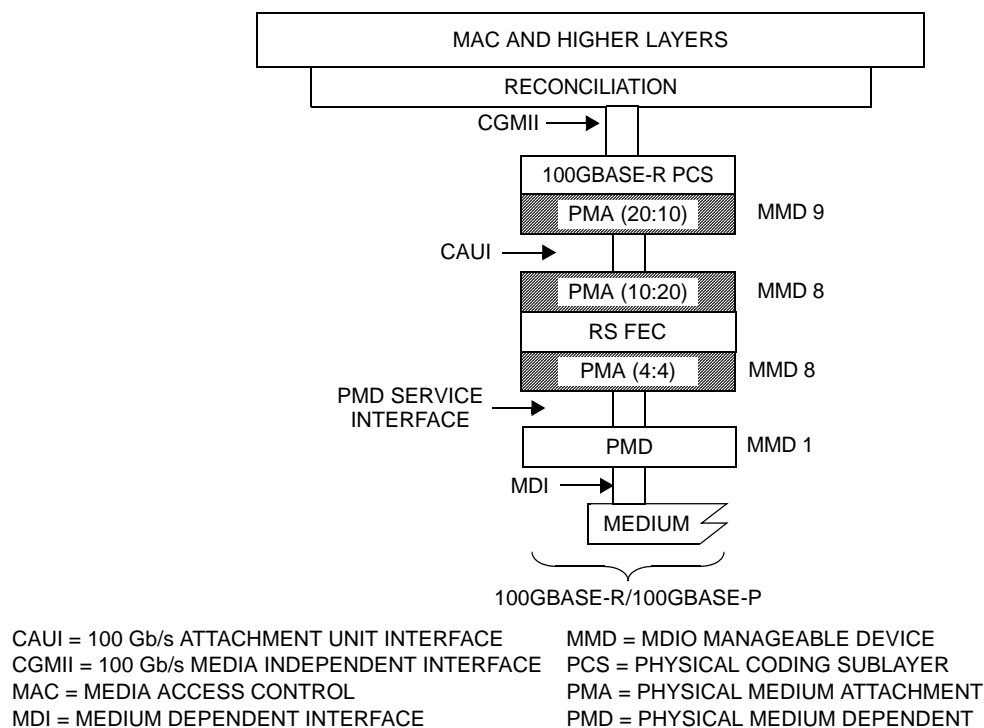


Figure 83C–2a—Example single XLAUI/CAUI with RS FEC

Annex 91A

(informative)

RS-FEC codeword examples

This annex provides example RS-FEC codewords produced by the 64B/66B to 256B/257B transcoding and Reed-Solomon encoding defined in Clause 91. This annex presents data in a tabular form. The contents of the tables are transmitted from left to right within each row starting from the top row and ending at the bottom row. The tables contain both binary and hexadecimal representations of the data. For the hexadecimal representation, the most significant bit of each hex symbol is transmitted first.

91A.1 Input to the 64B/66B to 256B/257B transcoder

Table 91A–1 contains a sequence of 80 66-bit blocks corresponding to the PCS transmission of Idle control characters. The initial value of the scrambler was set to bits 6 to 63 of the first 64-bit payload in the first row of [Table 74A–2](#). Bit 6 is assigned to S57 and bit 63 is assigned to S0 (see [49.2.6](#)).

Table 91A–1—64B/66B to 256B/257B transcoder input

Sync <0:1>	64-bit payload, hex <2:65>	Sync <0:1>	64-bit payload, hex <2:65>	Sync <0:1>	64-bit payload, hex <2:65>	Sync <0:1>	64-bit payload, hex <2:65>
10	ad5a3bf86d9acf5c	10	de55cb85df0f7ca0	10	e6ccff8e8212b1c6	10	d63bc6c309000638
10	70e3b0ce30e0497d	10	dc8df31ec3ab4491	10	66fb9139c81cd37b	10	b57477d4f05e3602
10	8cfd495012947a31	10	e7777cf0c6d06280	10	44529cf4b4900528	10	85ce1d27750ad61b
10	456d5c71743f5c69	10	c1bf62e5dc5464b5	10	dc6011be7ea1ed54	10	1cf92c450042a75f
10	cc4b940eaf3140db	10	77bb612a7abf401f	10	c22d341e90545d98	10	ce6daf1f248bbd6d
10	dd22d0b3f9551ed6	10	574686c3f9e93898	10	2e52628f4a1282ce	10	f20c86d71944aab1
10	55133c9333808a2c	10	1aa825d8b817db4d	10	637959989f3021eb	10	976806641b26aae9
10	6a37d4531b7ed5f2	10	53c3e96d3b12fb46	10	528c7eb8481bc969	10	ab8f9980d5a54559
10	9a4d2abfda65cc33	10	94fe64efe5af02d	10	9a65ae5fcd88c03a	10	5ef08673168def9b
10	220c871a953fffc6	10	ce0bb95ac263e6c1	10	4f6a917d1a676571	10	5890918c7b687d75
10	44d2b3e43096f836	10	84cdd4fc48b79608	10	b3e4503e3c824a8c	10	fd6d0b1a39687929
10	1730167c08302a69	10	4c15ff56de92b1ad	10	d0c2f0d4ff0dee95	10	e1422ee2e8b92125
10	ed5acaf86592fcee	10	de799be0b903c880	10	2714ffbf40bc09f6	10	c3be97c3c285009f
10	1020faf19f606631	10	93007cabb3f8c9d	10	ef6955f7f43df5d0	10	4dbd0616afe60e1f
10	3a1e49b7c7f7bb5d	10	901d828746ceec61	10	71ed3c097158c224	10	11adb3d81e13d263
10	a350d1a343b2394b	10	eab30ca27b5b34e3	10	90359ef711ed53d9	10	9b446763c8627ea8
10	6e891c0f4842b823	10	c4d786a25727a7fc	10	094fe7da31fb60cd	10	9f9a004de5e70767
10	054bdd77b7cb4e7b	10	c598cb710558af67	10	fc386d1f99d3a925	10	4928e0b43e781893
10	5a44dd3eb8b2ad6c	10	94462af4f583d770	10	8061ba9381f51f55	10	476d4eded7c90fcc
10	1efc25aa6a7e0b4c	10	93dd968c06a56809	10	9768e9d1ba74d3b6	10	014e9dc9f13670bb

91A.2 Output of the RS(528,514) encoder

Table 91A–2 contains a RS(528,514) codeword. Each row of Table 91A–1 is a set of 4 66-bit blocks that is converted to one 257-bit block using the procedure defined in 91.5.2.5. The resulting set of 20 257-bit blocks constitute the message portion of the codeword. The parity is computed using the encoder defined in 91.5.2.7 and is appended to the message to complete the codeword.

Table 91A–2—RS(528,514) codeword

Header <0:4>	Payload, hex <5:64>	Payload, hex <65:128>	Payload, hex <129:192>	Payload, hex <193:256>
00101	a5a3bf86d9acf5c	de55cb85df0f7ca0	e6ccff8e8212b1c6	d63bc6c309000638
11110	7e3b0ce30e0497d	dc8df31ec3ab4491	66fb9139c81cd37b	b57477d4f05e3602
01111	8fd495012947a31	e7777cf0c6d06280	44529cf4b4900528	85ce1d27750ad61b
00110	46d5c71743f5c69	c1bf62e5dc5464b5	dc6011be7ea1ed54	1cf92c450042a75f
00100	c4b940eaf3140db	77bb612a7abf401f	c22d341e90545d98	ce6daf1f248bbd6d
10010	d22d0b3f9551ed6	574686c3f9e93898	2e52628f4a1282ce	f20c86d71944aab1
10001	5133c9333808a2c	1aa825d8b817db4d	637959989f3021eb	976806641b26aae9
00011	637d4531b7ed5f2	53c3e96d3b12fb46	528c7eb8481bc969	ab8f9980d5a54559
10100	94d2abfda65cc33	94fe646efe5af02d	9a65ae5fcd88c03a	5ef08673168def9b
00000	20c871a953fffc6	ce0bb95ac263e6c1	4f6a917d1a676571	5890918c7b687d75
01101	4d2b3e43096f836	84cdd4fc48b79608	b3e4503e3c824a8c	fd6d0b1a39687929
10011	130167c08302a69	4c15ff56de92b1ad	d0c2f0d4ff0dee95	e1422ee2e8b92125
00101	e5acaf86592fcee	de799be0b903c880	2714ffbf40bc09f6	c3be97c3c285009f
10010	120faf19f606631	93007cabb3f8c9d	ef6955f7f43df5d0	4dbd0616afe60e1f
10001	31e49b7c7f7bb5d	901d828746ceec61	71ed3c097158c224	11adb3d81e13d263
00101	a50d1a343b2394b	eab30ca27b5b34e3	90359ef711ed53d9	9b446763c8627ea8
01000	6891c0f4842b823	c4d786a25727a7fc	094fe7da31fb60cd	9f9a004de5e70767
00100	04bdd77b7cb4e7b	c598cb710558af67	fc386d1f99d3a925	4928e0b43e781893
10100	544dd3eb8b2ad6c	94462af4f583d770	8061ba9381f51f55	476d4eded7c90fcc
11111	1fc25aa6a7e0b4c	93dd968c06a56809	9768e9d1ba74d3b6	014e9dc9f13670bb
Parity, hex <0:63>	Parity, hex <64:127>	Parity, hex <128:139>		
ed0e78f1734bc808	a38c0c417bd68f36	825		

91A.3 Output of the RS(544,514) encoder

Table 91A–3 contains a RS(544,514) codeword. Each row of Table 91A–1 is a set of 4 66-bit blocks that is converted to one 257-bit block using the procedure defined in 91.5.2.5. The resulting set of 20 257-bit blocks constitute the message portion of the codeword. The parity is computed using the encoder defined in 91.5.2.7 and is appended to the message to complete the codeword.

Table 91A–3—RS(544,514) codeword

Header <0:4>	Payload, hex <5:64>	Payload, hex <65:128>	Payload, hex <129:192>	Payload, hex <193:256>
00101	a5a3bf86d9acf5c	de55cb85df0f7ca0	e6ccff8e8212b1c6	d63bc6c309000638
11110	7e3b0ce30e0497d	dc8df31ec3ab4491	66fb9139c81cd37b	b57477d4f05e3602
01111	8fd495012947a31	e7777cf0c6d06280	44529cf4b4900528	85ce1d27750ad61b
00110	46d5c71743f5c69	c1bf62e5dc5464b5	dc6011be7ea1ed54	1cf92c450042a75f
00100	c4b940eaf3140db	77bb612a7abf401f	c22d341e90545d98	ce6daf1f248bbd6d
10010	d22d0b3f9551ed6	574686c3f9e93898	2e52628f4a1282ce	f20c86d71944aab1
10001	5133c9333808a2c	1aa825d8b817db4d	637959989f3021eb	976806641b26aae9
00011	637d4531b7ed5f2	53c3e96d3b12fb46	528c7eb8481bc969	ab8f9980d5a54559
10100	94d2abfda65cc33	94fe646efe5af02d	9a65ae5fcd88c03a	5ef08673168def9b
00000	20c871a953fffc6	ce0bb95ac263e6c1	4f6a917d1a676571	5890918c7b687d75
01101	4d2b3e43096f836	84cdd4fc48b79608	b3e4503e3c824a8c	fd6d0b1a39687929
10011	130167c08302a69	4c15ff56de92b1ad	d0c2f0d4ff0dee95	e1422ee2e8b92125
00101	e5acaf86592fcee	de799be0b903c880	2714ffbf40bc09f6	c3be97c3c285009f
10010	120faf19f606631	93007cabb3f8c9d	ef6955f7f43df5d0	4dbd0616afe60e1f
10001	31e49b7c7f7bb5d	901d828746ceec61	71ed3c097158c224	11adb3d81e13d263
00101	a50d1a343b2394b	eab30ca27b5b34e3	90359ef711ed53d9	9b446763c8627ea8
01000	6891c0f4842b823	c4d786a25727a7fc	094fe7da31fb60cd	9f9a004de5e70767
00100	04bdd77b7cb4e7b	c598cb710558af67	fc386d1f99d3a925	4928e0b43e781893
10100	544dd3eb8b2ad6c	94462af4f583d770	8061ba9381f51f55	476d4eded7c90fcc
11111	1fc25aa6a7e0b4c	93dd968c06a56809	9768e9d1ba74d3b6	014e9dc9f13670bb
Parity, hex <0:63>	Parity, hex <64:127>	Parity, hex <128:191>	Parity, hex <192:255>	Parity, hex <256:299>
d6983839edc3e5ac	c3cb45691ddba6cb	c26d756ea6f5b73d	249e30f415aa60b1	5743dc81c21

91A.4 Reed-Solomon encoder model

This annex also includes a model of the Reed-Solomon encoder defined in 91.5.2.7 written in the C programming language. To emulate the RS(528,514) encoder, declare global variables per 91A.4.1. To emulate the RS(544,514) encoder, declare global variables per 91A.4.2. The generic components of the model are defined in 91A.4.3 to 91A.4.6.

91A.4.1 Global variable declarations for RS(528,514)

These global variables define the codeword size (in symbols) and generator polynomial coefficients (see Table 91–1) for the RS(528, 514) code. Elements of $GF(2^{10})$ are presented as decimal values.

```
long n_symbols = 528;
unsigned long generator_polynomial[1024] =
    { 904, 6, 701, 32, 656, 925, 900, 614, 391, 592, 265, 945, 290, 432 };
```

91A.4.2 Global variable declarations for RS(544,514)

These global variables define the codeword size and generator polynomial coefficients for the RS(544, 514) code.

```
long n_symbols = 544;
unsigned long generator_polynomial[1024] =
    {575,552,187,230,552,1,108,565,282,249,593,132,94,720,495,385,942,503,883,36
    1,788,610,193,392,127,185,158,128,834,523};
```

91A.4.3 Other global variable declarations

The following global variables are declared for both RS(528,514) and RS(544,514). The field polynomial is assigned its decimal representation (1033 corresponds to $x^{10}+x^3+1$).

```
long polynomial = 1033;
long k_symbols = 514;
long check_symbols;
unsigned long codeword[1024];
```

91A.4.4 GF(2¹⁰) multiplier function

This function implements multiplication over GF(2¹⁰) using the expansion and reduction algorithm.

```
unsigned long multiply(long aa, long bb)
{
    unsigned long expand = 0;
    long k;

    for (k = 0; k < 10; k++)
    {
        if (bb & (1 << k))
            expand = expand ^ (aa << k);
    }

    for (k = 0; k < 9; k++)
    {
        if ((expand >> (18-k)) & 1)
            expand = expand ^ (polynomial << (8-k));
    }

    return expand;
}
```

91A.4.5 Reed-Solomon encoder function

This function implements the Reed-Solomon encoder. It uses the multiply() function.

```
1 void encode()  
2 {  
3     long k, j;  
4     unsigned long multiplier;  
5     unsigned long generator_vector[1024];  
6     unsigned long encoder_divide[1024];  
7  
8     for (k = 0; k < check_symbols; k++)  
9         encoder_divide[k] = 0;  
10  
11     for (k = 0; k < k_symbols; k++)  
12     {  
13         multiplier = codeword[k] ^ encoder_divide[0];  
14  
15         for (j = 0; j < check_symbols; j++)  
16             generator_vector[j] = multiply(multiplier, generator_polynomial[j]);  
17  
18         for (j = 0; j < check_symbols-1; j++)  
19             encoder_divide[j] = generator_vector[j] ^ encoder_divide[j+1];  
20  
21         encoder_divide[check_symbols-1] = generator_vector[check_symbols-1];  
22  
23         for (j = 0; j < check_symbols; j++)  
24             codeword[j+k_symbols] = encoder_divide[j];  
25     }  
26 }
```

91A.4.6 Main function

This sample main function defines a hypothetical message consisting of a countdown from 1023 to 510 (514 Reed-Solomon symbols). It then computes the parity and produces a codeword using the encode() function. The resulting codeword is printed to the console.

```
32 void main()  
33 {  
34     long k;  
35     check_symbols = n_symbols-k_symbols;  
36  
37     /*** Generate simple message symbols ***/  
38     for (k = 0; k < k_symbols; k++)  
39         codeword[k] = 1023-k;  
40  
41     encode();  
42  
43     for (k = 0; k < n_symbols; k++)  
44         printf("%ld ", codeword[k]);  
45 }
```

Annex 92A

(informative)

100GBASE-CR4 TP0 and TP5 test point parameters

92A.1 Overview

Annex 92A provides information on parameters associated with test points TP0 and TP5 that may not be testable in an implemented system. TP0 and TP5 test points are illustrated in the 100GBASE-CR4 link block diagram of Figure 92–2.

92A.2 Transmitter characteristics at TP0

The transmitter characteristics at TP0 are defined in 93.8.1.

92A.3 Receiver characteristics at TP5

The receiver characteristics at TP5 are defined in 93.8.2.

92A.4 Transmitter and receiver differential printed circuit board trace loss

The maximum insertion loss allocation for the transmitter or receiver differential controlled impedance printed circuit boards is determined using Equation (92A–1) and illustrated in Figure 92A–1. Note that the maximum insertion loss allocation for the transmitter or receiver differential controlled impedance printed circuit boards is 6.81 dB at 12.9806 GHz. The maximum insertion loss allocation for the transmitter or receiver differential controlled impedance printed circuit boards is consistent with the insertion loss TP0 to TP2 or TP3 to TP5 given in 92.8.3.5 and an assumed mated connector loss of 1.69 dB.

$$IL_{PCB}(f) \leq IL_{PCBmax}(f) = 0.5(0.0694 + 0.4248\sqrt{f} + 0.9322f) \text{ (dB)} \quad (92A-1)$$

for $0.01 \text{ GHz} \leq f \leq 18.75 \text{ GHz}$.

where

f	is the frequency in GHz
$IL_{PCB}(f)$	is the insertion loss for the transmitter and receiver PCB
$IL_{PCBmax}(f)$	is the maximum insertion loss for the transmitter and receiver PCB

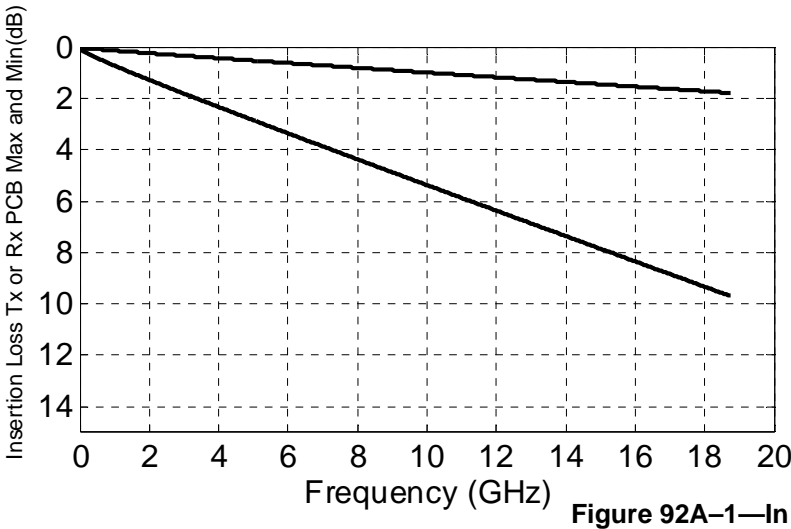
The minimum insertion loss allocation for the transmitter and receiver differential controlled impedance printed circuit boards for each differential lane (i.e., the minimum value of the sum of the insertion losses from TP0 to MDI receptacle or TP5 to MDI receptacle) are determined using Equation (92A–2) and illustrated in Figure 92A–1.

$$IL_{PCB}(f) \geq IL_{PCBmin}(f) = 0.092(0.0694 + 0.4248\sqrt{f} + 0.9322f) \text{ (dB)} \quad (92A-2)$$

for $0.01\text{ GHz} \leq f \leq 18.75\text{ GHz}$.

where

- f
 $IL_{PCB}(f)$
 $IL_{PCBmin}(f)$
- is the frequency in GHz
is the insertion loss for the transmitter and receiver PCB
is the minimum insertion loss for the transmitter and receiver PCB



92A.5 Channel insertion loss

This subclause provides information on channel insertion losses for intended topologies ranging from 0.5 m to 5 m in length. The maximum channel insertion loss associated with the 5 m topology is determined using Equation (92A-3). The channel insertion loss associated with the 0.5 m topology and a maximum host channel is determined by Equation (92A-5). The channel insertion loss budget at 12.8906 GHz for the 5 m topology is illustrated in Figure 92A-2.

The maximum channel insertion loss for the 5 m topology is determined using Equation (92A-3). The maximum channel insertion loss is 35 dB at 12.8906 GHz.

$$IL_{Chmax35dB}(f) = IL_{Cmax5m}(f) + 2IL_{Host}(f) - 2IL_{MatedTF}(f) \text{ (dB)}$$

(92A-3)

for $0.05\text{ GHz} \leq f \leq 18.75\text{ GHz}$.

where

- f
 $IL_{Chmax35dB}(f)$
- is the frequency in GHz
is the maximum channel insertion loss between TP0 and TP5 representative of a 5 m cable assembly and a maximum host channel

- $IL_{\text{Camax}5\text{m}}(f)$ is the maximum 5 m cable assembly insertion loss using Equation (92–8) and the maximum allowed values of the polynomial coefficients a_1 , a_2 , and a_4 given in Table 92–10 corresponding to the maximum insertion loss at 12.8906 GHz.
- $IL_{\text{Host}}(f)$ is the maximum insertion loss from TP0 to TP2 or TP3 to TP5 using Equation (92–4)
- $IL_{\text{MatedTF}}(f)$ is the maximum insertion loss of the mated test fixture using Equation (92–26)

The channel insertion loss between TP0 and TP5 representative of a 0.5 m cable assembly and a maximum host channel is determined using Equation (92A–5).

$$IL_{\text{Ch}0.5\text{m}}(f) = IL_{\text{Camin}}(f) + 2IL_{\text{Host}}(f) - 2IL_{\text{MatedTF}}(f) \quad (\text{dB}) \quad (92\text{A}–4)$$

for $0.05 \text{ GHz} \leq f \leq 18.75 \text{ GHz}$.

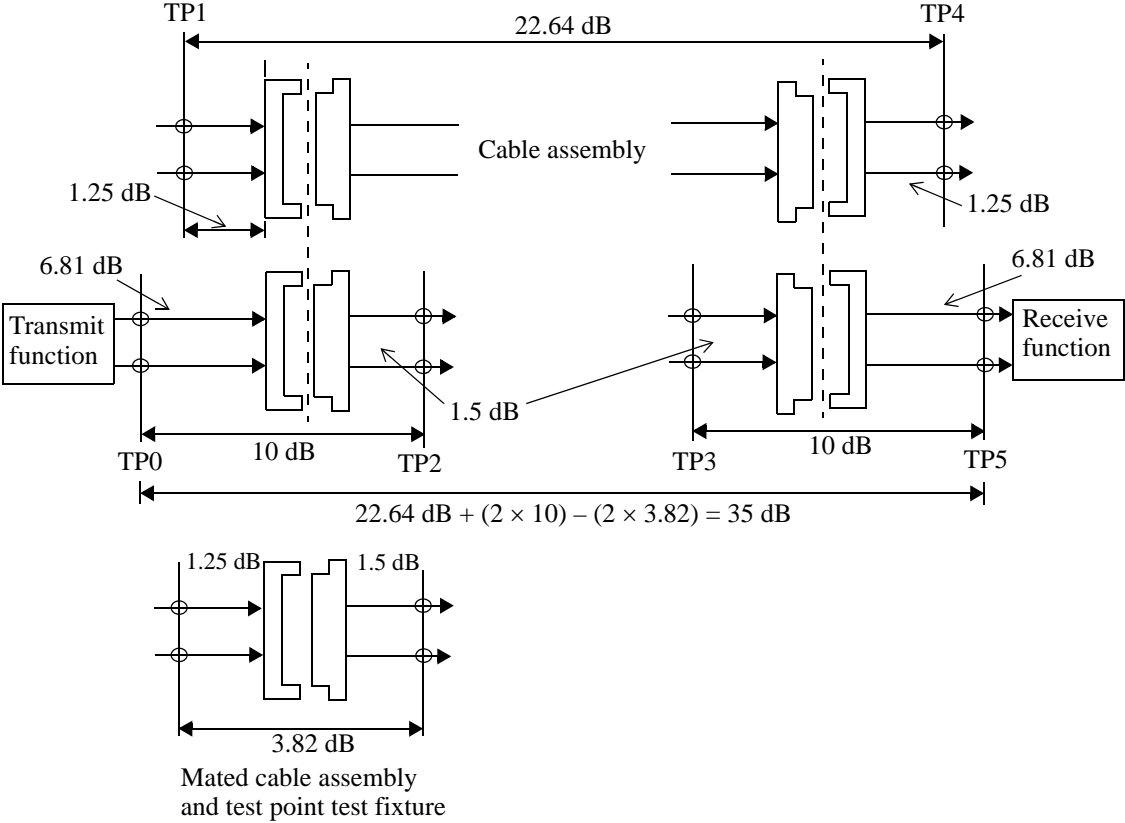
where

- f is the frequency in MHz
- $IL_{\text{Ch}0.5\text{m}}(f)$ is the channel insertion loss between TP0 and TP5 representative of a 0.5 m cable assembly and a maximum host channel
- $IL_{\text{Camin}0.5\text{m}}(f)$ is the minimum 0.5 m cable assembly insertion loss using Equation (92–8) and the maximum allowed values of the polynomial coefficients a_1 , a_2 , and a_4 given in Table 92–10 corresponding to the minimum insertion loss at 12.8906 GHz.
- $IL_{\text{Host}}(f)$ is the maximum insertion loss from TP0 to TP2 or TP3 to TP5 using Equation (92–4)

$IL_{\text{MatedTF}}(f)$ is the maximum insertion loss of the mated test fixture using Equation (92–26)

Editor’s note (to be removed prior to final publication):

The channel insertion loss budget at 12.8906 GHz, Figure 92A, will be updated when the insertion loss of the mated test fixture is determined i.e., Equation (92–24) and Equation (92–25) are defined.



NOTE—The connector insertion loss is 1.07 dB for the mated test fixture. The host connector is allocated 0.62 dB of additional margin.

Figure 92A-2—35 dB channel insertion loss budget at 12.8906 GHz

$$IL_{Ch0.5m}(f) = IL_{Camin}(f) + 2IL_{Host}(f) - 2IL_{MatedTF}(f) \quad (dB) \tag{92A-5}$$

for 0.05 GHz ≤ f ≤ 18.75 GHz.

where

- f is the frequency in MHz
- $IL_{Ch0.5m}(f)$ is the channel insertion loss between TP0 and TP5 representative of a 0.5 m cable assembly and a maximum host channel
- $IL_{Camin0.5m}(f)$ is the minimum 0.5 m cable assembly insertion loss using Equation (92-8) and the maximum allowed values of the polynomial coefficients a_1 , a_2 , and a_4 given in Table 92-10 corresponding to the minimum insertion loss at 12.8906 GHz.
- $IL_{Host}(f)$ is the maximum insertion loss from TP0 to TP2 or TP3 to TP5 using Equation (92-4)
- $IL_{MatedTF}(f)$ is the maximum insertion loss of the mated test fixture using Equation (92-26)

92A.6 Channel return loss

The return loss of each lane of the 100GBASE-CR4 channel is recommended to meet the values determined using Equation (92–14).

92A.7 Channel insertion loss deviation (ILD)

The channel insertion loss deviation is the difference between the channel insertion loss and the fitted channel insertion loss is determined using Equation (92A–6).

$$ILD(f) = IL_{Ch}(f) - IL_{fitted}(f) \text{ (dB)} \quad (92A-6)$$

where

f	is the frequency in GHz
$ILD(f)$	is the channel insertion loss deviation at frequency f
$IL_{fitted}(f)$	is defined in Equation (92–8)

Given the channel insertion loss is at N uniformly-spaced frequencies f_n spanning the frequency range 0.05 GHz to 18.75 GHz with a maximum frequency spacing of 0.01 GHz, the coefficients of the fitted channel insertion loss are determined using Equation (92–9) and Equation (92–10).

The channel insertion loss deviation is recommended to be within the region defined by Equation (92–12) and Equation (92–13) for all frequencies from 0.05 GHz to 18.75 GHz.

92A.8 Channel integrated crosstalk noise (ICN)

Since four lanes are used to transfer data between PMDs, the near-end crosstalk (NEXT) that is coupled into a victim receiver will be from the four adjacent transmitters. The channel multiple disturber NEXT loss, $MDNEXT_loss(f)$, is derived from the individual NEXT losses as shown in Equation (92–15).

In addition, the far-end Crosstalk (FEXT) that is coupled into a receiver will be from the three other transmitters adjacent to the victim transmitter. The channel multiple disturber FEXT loss, $MDFEXT_loss(f)$, is derived from the individual FEXT losses as shown in Equation (92–16).

Given the channel $MDNEXT_loss(f)$ and $MDFEXT_loss(f)$ measured over N uniformly-spaced frequencies f_n spanning the frequency range 50 MHz to 20000 MHz with a maximum frequency spacing of 10 MHz, the RMS value of the integrated crosstalk noise is determined using Equation (92–17) through Equation (92–21) and the parameters shown in Table 92–11.

The total integrated crosstalk RMS noise voltage of the channel is recommended to meet the values determined using Equation (92A–7) illustrated in Figure 92A–3.

$$\sigma_{x, ch} \leq \{TBD\} \quad (\text{mV}) \quad (92A-7)$$

where IL is the value of the channel insertion loss in dB at 12.8906 GHz.

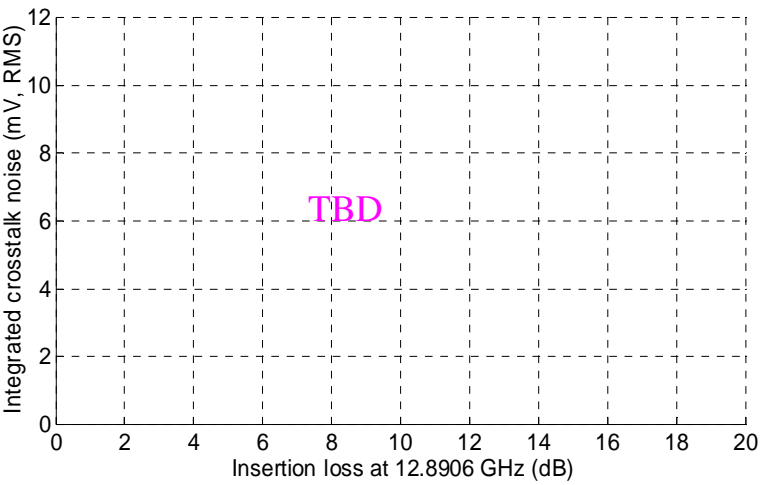


Figure 92A-3—Channel integrated crosstalk noise

Annex 93A

(normative)

Characteristics of electrical backplanes

93A.1 Channel operating margin

Editor's note (to be removed prior to final publication):

This annex contains a mathematical description of the channel operating margin computation. It is expected that a sample implementation of this calculation, in MATLAB(R) or similar computational language, will be included as a separate informative annex when the content of this annex stabilizes.

The channel operating margin (COM) is a figure of merit for a channel derived from a measurement of its scattering parameters. COM is related to the ratio of a calculated signal amplitude to a calculated noise amplitude as defined by Equation (93A–1).

$$COM = 20\log_{10}(A_s/A_n) \quad (93A-1)$$

COM shall be calculated using the method described in this annex. The signal amplitude A_s is defined in 93A.1.5 and the noise amplitude A_n is defined in 93A.1.6.

The parameters used to calculate COM are summarized in Table 93A–1. The values assigned to these parameters are defined by the Physical Layer specification that invokes the method.

93A.1.1 Measurement of the channel

The channel consists of a victim signal path plus some number of far-end and near-end crosstalk paths. The total number of paths for a given channel is denoted as K and, by convention, the path index $k=0$ corresponds to the victim path. The number of crosstalk paths is a function of the structure of the system. All significant contributors to the channel crosstalk should be included in the calculation of COM.

Each signal path is represented by a set of frequency-dependent scattering parameters. For the purpose of the calculation of COM, references to scattering parameters correspond to the differential-mode scattering parameters. The scattering parameters measured at frequency f are presented as the 2×2 matrix $S(f)$ as defined by Equation (93A–2).

$$S(f) = \begin{bmatrix} s_{11}(f) & s_{12}(f) \\ s_{21}(f) & s_{22}(f) \end{bmatrix} \quad (93A-2)$$

The relationship between $S(f)$ and other commonly cited characteristics is as follows. The insertion loss is the magnitude in dB of either $1/s_{12}(f)$ or $1/s_{21}(f)$. The input and output return loss is the magnitude in dB of $1/s_{11}(f)$ and $1/s_{22}(f)$ respectively.

The scattering parameters for the victim signal path are measured from TP0 to TP5. The scattering parameters for each crosstalk path are measured from the package-to-board interface of the aggressor transmitter to

Table 93A–1—Summary of parameters

Parameter	Symbol	Units
Signaling rate	f_b	GHz
Maximum start frequency	f_{\min}	GHz
Maximum frequency step	Δf	GHz
Transmitter reflection coefficient DC value Reference frequency	Γ_1 Γ_{01} f_1	V/V GHz
Receiver reflection coefficient DC value Reference frequency	Γ_2 Γ_{02} f_2	V/V GHz
Transmitter differential peak output voltage Victim Far-end aggressor Near-end aggressor	A_v A_f A_n	V V V
Transmitter 3 dB bandwidth Victim Far-end aggressor Near-end aggressor	f_v f_f f_n	GHz GHz GHz
Receiver 3 dB bandwidth	f_r	
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	$c(-1)$	— — —
Transmitter equalizer, post-cursor coefficient Minimum value Maximum value Step size	$c(1)$	— — —
Continuous time filter, DC gain Minimum value Maximum value Step size	g_{DC}	dB dB dB
Number of signal levels	L	—
Number of samples per unit interval	M	—
Decision feedback equalizer (DFE) length	N_b	UI
DFE coefficient magnitude limit	b_{\max}	V
Random jitter, RMS	σ_{RJ}	UI
Dual-Dirac jitter, peak	A_{DD}	UI
Receiver additive Gaussian noise, RMS	σ_r	V
Target uncorrected symbol error ratio	SER_0	—

TP5. The frequency-dependent scattering matrix for signal path k is denoted as $S^{(k)}(f)$. The reference impedance for scattering parameter measurements is 100 Ω .

It is recommended that the scattering parameters be measured with uniform time step no larger than Δf from a start frequency no larger than f_{\min} to a stop frequency of at least the signaling rate f_b .

93A.1.2 Path terminations

The input to each signal path is terminated by an impedance defined by the reflection coefficient Γ_1 . The output of each signal path is terminated by an impedance defined by the reflection coefficient Γ_2 .

The reflection coefficient Γ_1 is defined by Equation (93A-3) and the reflection coefficient Γ_2 is defined by Equation (93A-4) where $j = \sqrt{-1}$.

$$\Gamma_1 = \frac{\Gamma_{01} - j(f/f_1)}{1 + j(f/f_1)} \quad (93A-3)$$

$$\Gamma_2 = \frac{\Gamma_{02} - j(f/f_2)}{1 + j(f/f_2)} \quad (93A-4)$$

The voltage transfer function of the terminated signal path is defined by Equation (93A-5) where $\Delta S(f) = s_{11}(f)s_{22}(f) - s_{12}(f)s_{21}(f)$.

$$H_{21}(f) = \frac{s_{21}(f)}{1 - s_{11}(f)\Gamma_1(f) - s_{22}(f)\Gamma_2(f) + \Gamma_1(f)\Gamma_2(f)\Delta S(f)} \quad (93A-5)$$

The voltage transfer function for the signal path represented by $S^{(k)}(f)$ is denoted $H_{21}^{(k)}(f)$.

93A.1.3 Filters

The voltage transfer function for each signal path $H_{21}^{(k)}(f)$ (see 93A.1.2) is multiplied by a set of filter transfer functions to yield $H^{(k)}(f)$ as shown in Equation (93A-6).

$$H^{(k)}(f) = H_{ffe}(f)H_t(f)H_{dp}(f)H_{21}^{(k)}(f)H_{dp}(f)H_r(f)H_{ctf}(f) \quad (93A-6)$$

The device and package filter $H_{dp}(f)$ is defined in 93A.1.3.1, the transmitter filter $H_t(f)$ is defined in 93A.1.3.2, the receiver noise filter $H_r(f)$ is defined in 93A.1.3.3, the transmitter equalizer $H_{ffe}(f)$ is defined in 93A.1.3.4, and the receiver equalizer $H_{ctf}(f)$ is defined in 93A.1.3.5.

The filtered voltage transfer function $H^{(k)}(f)$ is used to compute the single bit response (see 93A.1.4).

93A.1.3.1 Device and package filter

$H_{dp}(f)$ is defined by Equation (93A-7) and is intended to represent the transmitter (or receiver) termination and device packaging.

$$H_{dp}(f) = \frac{s_{21}^{(dp)}(f)}{1 - s_{11}^{(dp)}(f)\Gamma_d(f) - s_{22}^{(dp)}(f)\Gamma_b(f) + \Gamma_d(f)\Gamma_b(f)\Delta S^{(dp)}(f)} \quad (93A-7)$$

The terms of Equation (93A-7) are defined by Equation (93A-8) through Equation (93A-11).

$$s_{21}^{(dp)}(f) = s_{12}^{(dp)}(f) = \exp(-L_{tl}(\alpha_1\sqrt{f} + \alpha_2f + \alpha_4f^2 + j2\pi f/\nu_p)) \quad (93A-8)$$

$$s_{11}^{(dp)}(f) = s_{22}^{(dp)}(f) = \frac{\varepsilon_{tl}}{200 + \varepsilon_{tl}} \quad (93A-9)$$

$$\Gamma_d(f) = \frac{-jf}{1/(\pi C_d R_0) + jf} \quad (93A-10)$$

$$\Gamma_b(f) = \frac{-jf}{1/(\pi C_b R_0) + jf} \quad (93A-11)$$

The parameters and values used to compute $H_{dp}(f)$ are summarized in Table 93A-2.

Table 93A-2—Device and package filter parameters

Parameter	Symbol	Value	Units
Transmission line length	L_{tl}	7.07×10^{-3}	m
Attenuation coefficients	α_1 α_2 α_4	2.9126 0.4835 0.0587	nepers/m/GHz ^{1/2} nepers/m/GHz nepers/m/GHz ²
Velocity of propagation	v_p	0.182	m/ns
Transmission line impedance tolerance	ε_{tl}	11.9	%
Single-ended shunt capacitance, device	C_d	2.5×10^{-4}	nF
Single-ended shunt capacitance, ball	C_b	2.2×10^{-4}	nF
Single-ended reference resistance	R_0	50	Ω

93A.1.3.2 Transmitter filter

$H_t(f)$ is defined by Equation (93A-12) and is intended to represent the rise and fall times of the transmitter. It is a function of the parameter f_t which is set based on the path index k . If $k=0$, i.e. the victim path, then $f_t = f_v$. If k corresponds to a far-end crosstalk path then $f_t = f_f$. If k corresponds to a near-end crosstalk path then $f_t = f_n$.

$$H_t(f) = \frac{1}{1 - (f/f_t)^2 + j1.414214(f/f_t)} \quad (93A-12)$$

93A.1.3.3 Receiver noise filter

$H_r(f)$ is a noise filter defined by Equation (93A-13).

$$H_r(f) = \frac{1}{1 - 3.414214(f/f_r)^2 + (f/f_r)^4 + j2.613126(f/f_r - (f/f_r)^3)} \quad (93A-13)$$

93A.1.3.4 Transmitter equalizer

$H_{ffe}(f)$ is defined by Equation (93A-14) and is intended to represent the transmitter equalizer. If k corresponds to a near-end crosstalk path, then $c(-1)$ and $c(1)$ are zero regardless of the values used for the other paths. The value of the “cursor” coefficient $c(0)$ is set to $1 - |c(-1)| - |c(1)|$ for any value of $c(-1)$ and $c(1)$.

$$H_{ffe}(f) = \sum_{i=-1}^1 c(i) \exp(-j2\pi(i+1)(f/f_b)) \quad (93A-14)$$

93A.1.3.5 Receiver equalizer

$H_{ctf}(f)$ is defined by Equation (93A-15).

$$H_{ctf}(f) = \frac{10^{g_{DC}/20} + j(4f/f_b)}{(1 + j(f/f_b))(1 + j(4f/f_b))} \quad (93A-15)$$

93A.1.4 Single bit response

The single bit response of a signal path is defined to be the output of the path following the application of rectangular pulse one unit interval in duration at its input. First define the function $X(f)$ per Equation (93A-16) where $\text{sinc}(x) = \sin(\pi x)/(\pi x)$ and $T_b = 1/f_b$ is the unit interval.

$$X(f) = A_t T_b \text{sinc}(f T_b) / (L - 1) \quad (93A-16)$$

$X(f)$ is a function of A_t which in turn is based on the path index k . If $k=0$, i.e. the victim path, then $A_t = A_v$. If k corresponds to a far-end crosstalk path then $A_t = A_f$. If k corresponds to a near-end crosstalk path then $A_t = A_n$.

The single bit response $h^{(k)}(t)$ is derived from the voltage transfer function $H^{(k)}(f)$ (see 93A.1.3) using Equation (93A-17).

$$h^{(k)}(t) = \int_{-\infty}^{\infty} X(f) H^{(k)}(f) \exp(j2\pi f t) dt \quad (93A-17)$$

NOTE 1—It is expected that COM will be computed from measurements at discrete frequencies that cover a limited span (see 93A.1.1). The inverse Fourier transform depicted in Equation (93A-17) will likely be implemented as a discrete Fourier transform and the filtered voltage transfer function may need to be extrapolated (both to DC and the Nyquist frequency) for this computation. The extrapolation method and Nyquist frequency must be chosen carefully to limit the error in the COM computation.

NOTE 2—The time span of the single bit response in unit intervals, N , is limited in practice by frequency step Δf ($N = f_b/\Delta f$) but in general should be set to include all significant components of the single bit response.

93A.1.5 Signal amplitude

COM is a function of the variables $c(-1)$, $c(1)$, and g_{DC} . The following procedure is used to determine the values of these variables that will be used to calculate COM.

- Compute the single bit response of the victim path $h^{(0)}(t)$ for a given $c(-1)$, $c(1)$, and g_{DC} using the procedure defined in 93A.1.4.
- Define t_z to be the time where the single bit response crosses a positive threshold equal to 1% of its peak amplitude. If there are multiple such crossings, the latest crossing time that precedes the peak of the single bit response is selected.
- Define t_s to be $t_z + T_b$.
- Sample $h^{(0)}(t)$ with uniform time step T_b around t_s to yield $h^{(0)}(n)$ as shown in Equation (93A-18). The sampled single bit response includes N terms.
- Define A_s to be $h^{(0)}(0)$.
- Compute $h_{ISI}(n)$ per Equation (93A-19). This represents the residual inter-symbol interference (ISI) after decision feedback equalization. The corresponding ISI amplitude variance is computed per

Equation (93A–20) and Equation (93A–21).

g) Compute the figure of merit (FOM) per Equation (93A–22).

$$h^{(0)}(n) = h^{(0)}(t_s + nT_b) \quad (93A-18)$$

$$h_{ISI}(n) = \begin{cases} 0, & n = 0 \\ h^{(0)}(n) - \text{sgn}(h^{(0)}(n))\min(b_{\max}, |h^{(0)}(n)|), & 1 \leq n \leq N_b \\ h^{(0)}(n), & \text{otherwise} \end{cases} \quad (93A-19)$$

$$\sigma_{ISI}^2 = \frac{\sigma_X^2}{N} \left(\sum_n h_{ISI}^2(n) \right) \quad (93A-20)$$

$$\sigma_X^2 = \frac{L^2 - 1}{3(L - 1)^2} \quad (93A-21)$$

$$FOM = 10\log_{10} \left(\frac{A_s^2}{\sigma_{ISI}^2 + (A_s \sigma_{RJ})^2 + \sigma_r^2} \right) \quad (93A-22)$$

The FOM is calculated for each permitted combination of $c(-1)$, $c(1)$, and g_{DC} values per Table 93A–1. The combination of values that maximizes the FOM, including the corresponding values of t_s and A_s , is used for the calculation of the interference and noise amplitude in 93A.1.6 and the calculation of COM in 93A.1.

93A.1.6 Interference and noise amplitude

Given the values of $c(-1)$, $c(1)$, g_{DC} , t_s , and A_s derived in 93A.1.5, compute the combined interference and noise distribution $p(y)$ per 93A.1.6.3. The corresponding cumulative distribution function is $P(y)$ as defined by Equation (93A–23).

$$P(y) = \int_{-\infty}^y p(y) dy \quad (93A-23)$$

The noise amplitude, A_n , is the magnitude of the value of y_0 that satisfies the relationship $P(y_0) = SER_0$ where SER_0 is the target uncorrected symbol error ratio.

In 93A.1.6.1 through 93A.1.6.3, “*” denotes convolution which is defined by Equation (93A–24).

$$f(t) * g(t) = \int_{-\infty}^{\infty} f(\tau)g(t - \tau)d\tau \quad (93A-24)$$

93A.1.6.1 Interference amplitude distribution

The interference amplitude distribution is computed from the sampled single bit response $h(n)$ with the assumption that the transmitted symbols are independent, identically distributed random variables and that the symbols are uniformly distributed across the set of L possible values. For the purpose of this subclause, $h(n)$ is a general notation that corresponds to either the inter-symbol interference single bit response $h_{ISI}(n)$ or the sampled single bit response $h_m^{(k)}(n)$ corresponding to the k th crosstalk path (see 93A.1.6.3).

Equation (93A–25) defines the n th component of the interference amplitude distribution function where $\delta(y)$ is the Dirac delta function.

$$p_n(y) = \frac{1}{L} \sum_{l=0}^{L-1} \delta\left(y - \left(\frac{2l}{L-1} - 1\right)h(n)\right) \quad (93A-25)$$

The set of N such components are combined via convolution to obtain the complete interference amplitude distribution. Initialize $p(y)$ to $\delta(y)$ and then evaluate Equation (93A–26) sequentially for $n=0$ to $N-1$.

$$p(y) = p(y) * p_n(y) \quad (93A-26)$$

NOTE—It is expected that COM will be numerically computed using a quantized amplitude axis y . The amplitude step Δy will introduce quantization error in the calculated distribution function that will be compounded by subsequent convolutions with other quantized distribution functions. It is recommended that Δy be no larger than 0.1 mV in order to limit the error.

93A.1.6.2 Noise amplitude distribution

The calculation of COM includes two additive noise terms that are described in terms of their distribution function. The first additive noise component has a Gaussian noise amplitude distribution function with zero mean and standard deviation σ_G . The standard deviation is defined by Equation (93A–27) where A_s is the signal amplitude computed per 93A.1.5.

$$\sigma_G = \sqrt{(A_s \sigma_{RJ})^2 + \sigma_r^2} \quad (93A-27)$$

The amplitude distribution of the additive Gaussian noise term is defined by Equation (93A–28).

$$p_G(y) = \frac{\exp(-y^2/(2\sigma_G^2))}{\sigma_G \sqrt{2\pi}} \quad (93A-28)$$

The second component of additive noise has a dual-Dirac distribution with zero mean and peak amplitude $A_s A_{DD}$. The amplitude distribution of the additive dual-Dirac noise is defined by Equation (93A–29).

$$p_{DD}(y) = \frac{1}{2} \delta(y - A_s A_{DD}) + \frac{1}{2} \delta(y + A_s A_{DD}) \quad (93A-29)$$

The components are combined using convolution to yield the overall noise amplitude distribution function as defined in Equation (93A–30).

$$p_n(y) = p_G(y) * p_{DD}(y) \quad (93A-30)$$

93A.1.6.3 Combination of interference and noise distributions

Compute the inter-symbol interference amplitude distribution from the single-bit response $h_{ISI}(n)$ as defined by Equation (93A–19) using the procedure defined in 93A.1.6.1. Denote the result as $p(y)$.

The contributions of the $K-1$ crosstalk paths to the total interference are included as follows. Sample the single bit response of the k th crosstalk path $h^{(k)}(n)$ with uniform time step T_b starting at time $t_m = mT_b/M$ as shown in Equation (93A–31).

$$h_m^{(k)}(n) = h^{(k)}(t_m + nT_b) \quad (93A-31)$$

The phase index m can assume any integer value from 0 to $M-1$. The symbol index n can assume any integer value from 0 to $N-1$ where N is the time span of the single bit response in unit intervals.

The variance of the interference amplitude for phase index m is computed from the sampled single bit response using Equation (93A-32) where σ_X is given by Equation (93A-21).

$$\sigma_m^2 = \frac{\sigma_X^2}{N} \left(\sum_n (h_m^{(k)}(n))^2 \right) \quad (93A-32)$$

Compute the variance of the interference amplitude for each phase index $m=0$ to $M-1$ and identify the value of m that maximizes the variance. Denote this phase index a i . Compute the interference amplitude distribution from $h_i^{(k)}(n)$ using the procedure defined in 93A.1.6.1 and denote the result as $p^{(k)}(y)$.

Compute $p^{(k)}(y)$ and evaluate Equation (93A-33) sequentially for integer values $k=1$ to $K-1$.

$$p(y) = p(y) * p^{(k)}(y) \quad (93A-33)$$

The additive noise distribution defined in 93A.1.6.2, $p_n(y)$, is then included to yield the combined interference and noise amplitude distribution as shown in Equation (93A-34).

$$p(y) = p(y) * p_n(y) \quad (93A-34)$$

Annex 93B

(informative)

Electrical backplane reference model

This annex describes additional informative test points that may used to partition the electrical backplane channel.

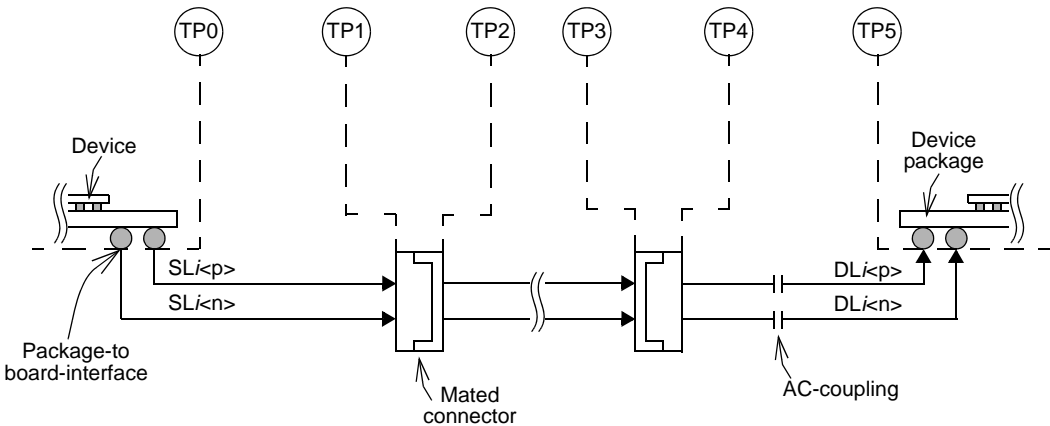


Figure 93B-1—Reference model (one direction from one lane is illustrated)

Table 93B-1—Description of channel components

Test points	Description
TP0 to TP1	The printed circuit board between the transmitter and the separable connector closest to the transmitter. TP1 is defined to be the interface between the board and connector plug.
TP2 to TP3	The electrical path from the separable connector closest to the transmitter to the separable connector closest to the receiver. TP2 and TP3 are defined to be the interface between connector receptacle and the printed circuit board.
TP4 to TP5	The printed circuit board between the receiver and the separable connector closest to the receiver. TP4 is defined to be the interface between the board and connector plug. It is recommended that the AC-coupling capacitors are implemented between TP4 and TP5
TP0 to TP5	The electrical backplane channel as defined in 93.9 and 94.4. TP0 and TP5 are defined to be the interface between the device package and the printed circuit board.