100G-DR-LPO

Revision 1.0

Specification for 100 Gb/s per Lane Linear Pluggable Optics Single-Mode Optical Fiber Transmission

Abstract

The 100G-DR-LPO specification by the LPO (Linear Pluggable Optics) MSA defines 100 Gb/s/lane 53.125 GBd PAM4 optical interfaces, optical links using standard single-mode fiber with up to 500 m reach, and host-module electrical interfaces for hosts with DSP based SerDes and RS(544,514) FEC. It builds on IEEE 802.3 and OIF CEI-112G-LINEAR-PAM4 specifications. It enables Ethernet-like links with 1, 2, 4, or 8 lanes for data centers, using low power, high port density, low cost, and low latency pluggable transceiver modules in form factors such as QSFP, QSFP-DD, and OSFP.

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Revision History

Revision	Description	Date revised
1.0	Initial revision	2025-03-19

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Contents

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Figures

Tables

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1 Introduction

AI clusters in hyperscale data centers are seeking high-speed interconnects, with low power consumption, high port density, low cost, and low latency. Volumes are large enough to demand transceiver solutions that address these specific needs.

The goal of this document is to provide an open specification for 100 Gb/s/lane 53.125 GBd PAM4 single-mode fiber links and transceiver interfaces. The 100G-DR-LPO specification provided in this document is optimized for data-center specific needs and broadly maintains interoperability with standard 100G per lane DSP based LR SerDes. This document provides specifications for single-lane and multi-lane operation: n00G-DRn-LPO, where n is the number of lanes forming a link: 1, 2, 4 or 8. Both the SMF optical signal and the host-module electrical interface are specified. It is organized as follows. Sections 1, 2, and 4, and 5 provide an overview. Sections 3, 15, and 16 provide reference material. Sections 6 to 13 provide detailed technical specifications. Section 14 describes a host setup method.

The 100G-DR-LPO specification is designed specifically to address data center product requirements of:

- Low power consumption
- Low cost
- Low latency
- Compact transceiver form factor: the 100G-DR-LPO specification is transceiver form-factor agnostic, with QSFP, QSFP-DD, and OSFP as the example form factors
- Compatibility with SMF connectors and cable infrastructure for present and future data centers, as well as telecom client-side interfaces
- Operates with industry standard RS(544,514) forward error correction (FEC)
- Enables a variety of opto-electronic implementation approaches and technologies
- Reach up to 500 m based on practical cabling design such as structured cabling or point-to-point cabling

We acknowledge the work done by the IEEE 802.3 and the OIF CEI-112G-LINEAR-PAM4 committees in their efforts in developing underlying standards.

2 Summary of 100G-DR-LPO Optical Specifications

Table 1: Summary of 100G-DR-LPO Optical Specifications

Parameter	Value	Units
Fiber type	Single mode	
Nominal wavelength	1310	nm
Required operating range	0.5 to 500	m
Signaling rate, each lane	53.125	GBd
Modulation format	PAM4	

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3 Reference Documents

The following industry standards documents are used to complete this specification:

- IEEE Std 802.3-2022, Standard for Ethernet
- IEEE Std 802.3ck-2022, Standard for Ethernet for 100 Gb/s electrical signaling
- IEEE Std 802.3df-2024, Standard for Ethernet for 800 Gb/s
- IEEE Std P802.3dj, Draft Standard for Ethernet Amendment for 1.6 Tb/s
- OIF CEI-112G-LINEAR-PAM4: Common Electrical I/O (CEI)
- OIF Implementation Agreement:
    - Common Management Interface Specification, CMIS
    - CMIS Versatile Control Set, CMIS-VCS
- QSFP2 Cage, Connector, & Module Specification (SFF-TA-1027)
- QSFP-DD/QSFP-DD800/QSFP-DD1600 Hardware Specification
- OSFP Octal Small Form Factor Pluggable Module
- ITU-T G.652, Characteristics of a single-mode optical fibre and cable
- ANSI/TIA 568.3-E - Optical Fiber Cabling and Components Standard

4 Functional Description

The LPO optical module performs transmit and receive functions that convey analog signals between the host and the medium. Its electrical interfaces are based on OIF CEI-112G-LINEAR-PAM4 host to module linear interface, while the optical interfaces are similar but not identical to 400GBASE-DR4. The host performs transmit and receive functions including forward error correction, retiming, and digital to analog and analog to digital conversion. The host specifications are based on OIF CEI-112G-LINEAR-PAM4.

5 System Overview

5.1 Link Block Diagram

Figure 1 shows a block diagram of the linear system. There are normative test points to ensure interoperability between host, module and optical fiber.

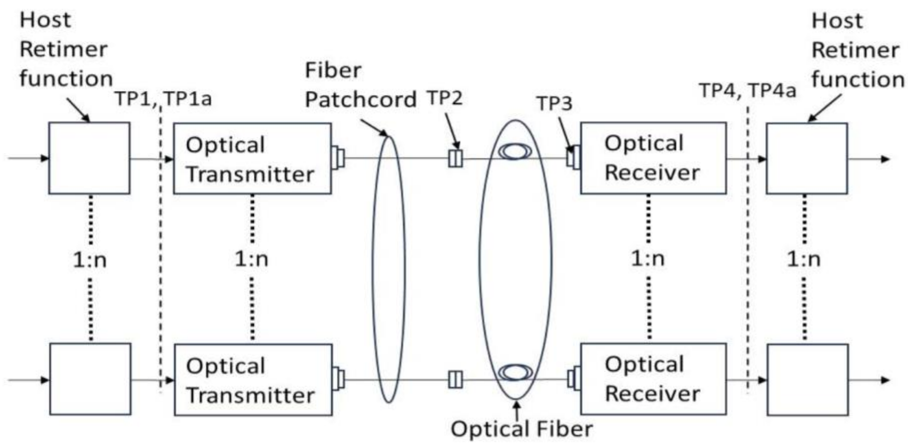

Figure 1: Link Block Diagram of a Linear Optical Interconnect

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5.2 Linear Optical System Description

5.2.1 Detailed Functional Block Diagram of Linear Optical System

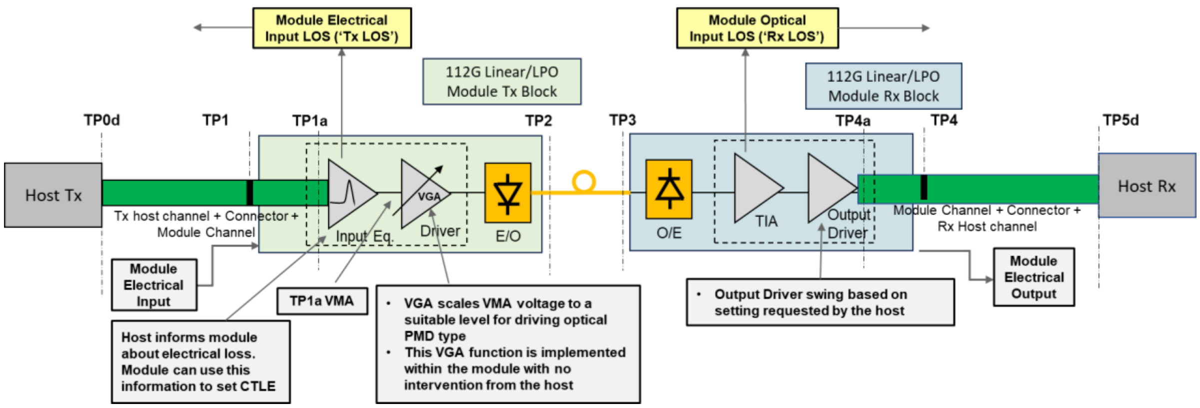

Figure 2: System Block Diagram

5.2.2 High Speed Electrical Characteristics

The data path is linear in transmit and receive directions. The electrical specifications are based on OIF CEI-112G-LINEAR-PAM4 and are adapted for an increased electrical channel loss. The deviations of the specification to OIF CEI-112G-LINEAR-PAM4 can be found in section 7.

5.2.3 Relationship between electrical and optical specifications

TP1 and TP4 test points are defined in OIF CEI-112G-LINEAR-PAM4 with exceptions which are defined in this document. The TP2 and TP3 test points are defined in this specification. Figure 16 illustrates the use of the test points.

The relevant optical specifications at TP2 (section 8.1) shall be met with any electrical input that is compliant with this specification at TP1a (section 7.3). If an optical module transmitter is tested individually at TP2, the stressors defined in section 7.4.1 need to be applied. The module output electrical specifications at TP4 shall be met with any optical input signal that is compliant to this optical specification for stressed input sensitivity (section 9.10) and input sensitivity (section 9.11) at TP3. The host error performance shall be met with the stressed host input signal defined in 7.6.

TP0d and TP5d are test points directly at the host or module die transmitter and receiver and are used to describe die to die electrical insertion loss including device packages.

5.3 Hardware Signaling

Hardware control and status signals are specified in the respective module form factor MSAs.

5.4 Module Management Interface

The contents of the various ID registers shall comply with the requirements of the module MSA and the respective standards such as CMIS with the extensions for LPO.

5.5 Module Mechanical Dimensions

Mechanical dimensions are defined in module form factor MSA specifications.

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5.6 Host FEC Requirements

The LPO system relies on the host implementation of RS(544,514) FEC encode and decode functions as defined in IEEE Std 802.3.

- For single-lane operation, the host shall use the interleaved FEC defined in IEEE Std 802.3ck-2022 Clause 161 (RS-FEC-Int). Support of Clause 91 RS-FEC is optional. Negotiation of the RS FEC type may be done by using Clause 73 Auto-Negotiation or by other means.
- For 2-lane or 4-lane operation, the host system shall use the 2-way interleaved FEC defined in IEEE Std 802.3-2022 Clause 119.
- For 8-lane operation, the host shall use the 4-way interleaved FEC defined in IEEE Std 802.3df-2024 Clause 172.

5.7 Auto-Negotiation

The use of Auto-Negotiation as defined in IEEE Std 802.3 Clause 73 as modified by IEEE Std 802.3ck-2022 and IEEE Std 802.3df-2024 for matching the port type and negotiating the use of Clause 161 or Clause 91 FEC for the single lane case is optional. Auto-negotiation is not to be enabled by default and the user needs to configure both host sides to use it. The technology ability field bits A16, A17, A18, and A19 are used to advertise 1-lane (100G), 2-lane (200G), 4-lane (400G), and 8-lane (800G), respectively.

5.8 Host Data Path Electrical Insertion Loss

In order to ensure that the LPO modules can select the desired equalization gain at a certain host port, the host system writes the test point insertion loss (TP0d to TP1a) at 26.56 GHz (see Figure 1 and Figure 4) in dB of each port to the LPO module in that port, utilizing the protocol defined in CMIS Versatile Control Set (CMIS-VCS) section 5.18. The module may use this information to set its equalization accordingly, see section 6.9.

5.9 Host Data Path Calibration Information

To ensure that the LPO modules can select the desired equalization gain at a certain host port, the host writes CTLE high frequency gain values gDC and gDC2 in dB of each port to the LPO module injected in this port, utilizing the protocol defined in CMIS Versatile Control Set (CMIS-VCS) section 5.11. The gDC and gDC2 values are the ones that would be used in the reference receiver in Figure 4 when passing the host output test at TP1a (section 7.3). It is recommended that the module uses this information to set its equalization accordingly; see section 6.9 and 7.3.3.

5.10 Host Nonlinear Compensation Function (NLC)

The host may provide a nonlinear compensation function to linearize the optical transmit eye. The module may request transmitter nonlinear compensation utilizing the protocol defined in CMIS Versatile Control Set (CMIS-VCS) section 5.19.

5.11 Host Startup Protocol Function (optional)

Hosts may optionally use a startup protocol, such as the one defined in IEEE Std 802.3ck-2022 (Clause 162.8.11, formally known as PMD control function, also known as "link training"). Usage

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of such a startup protocol is permitted if both sides of the link support it and are configured to use it.
Note: Link training for electrical channels, such as the one defined in 802.3ck-2022, will not work with LPO mainly because of AGC circuits in the driver and TIA.

If a startup protocol is used, the initial (default) electrical signal characteristics need to comply with the specifications in sections 7 and 8. The operation of the startup protocol can cause the electrical signal characteristics to change from those of the initial setting.

The details of configuring both sides to use a startup protocol and the method of optimizing the transmitter signal by the receiver are beyond the scope of this specification.

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6 Optical Module Functional Specifications

6.1 Module Transmit Function

The module transmit function shall convert the n-lane[1] electrical signals into the same number of optical signals. The optical signal streams shall then be delivered to the MDI according to the transmit optical specifications in this document.

6.2 Module Receive Function

The module receive function shall convert the n optical signals received from the optical media into the same number of electrical signals according to the receive optical specifications in this document.

6.3 Module Global Signal Detect Function

The module shall have a global signal detect function, which is an indicator of the presence of optical signals on all lanes, according to Table 2.
The module global signal detect function is not required to verify whether a compliant optical input signal is being received. No response time requirements on the generation of the signal detect state are imposed.

NOTE - Implementations need to provide adequate margin between the input optical power level at which the signal detect state is set to good, and the inherent noise level of the module including the effects of crosstalk, power supply noise, etc.

Table 2: Signal Detect Conditions

Receive conditions	Signal Detect State
For any lane: Average optical power at TP3 ≤ –15 dBm	FAIL
For all lanes: Optical power at TP3 ≥ receiver sensitivity (max) in OMA AND compliant optical input signal	Good
All other conditions	Unspecified

Various implementations of the signal detect function are permitted, including implementations that generate the signal detect state in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

6.4 Module Lane-by-Lane Signal Detect Function

Similarly, the module lane-by-lane signal detect function indicates the presence of an optical signal on a lane.

[1] n and "all" and "any" refer to the group of lanes forming a link, which may be a subset of the lanes in a module.

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6.5 Module Global Transmit Disable Function

1. This optional function turns off all the optical transmitters so that each transmitter meets the requirements of the average launch power of the OFF transmitter.
2. If a TX_fault is detected, then the module may turn off the optical transmitter in each lane. The definition of TX_fault is beyond the scope of this specification.

6.6 Module Lane-by-Lane Transmit Disable Function

1. This optional function turns off the optical transmitter associated with that lane so that the transmitter meets the requirements of the average launch power of the OFF transmitter.
2. If a TX_fault is detected, then the module may turn off the optical transmitter in each lane. The definition of TX_fault is beyond the scope of this specification.

6.7 Module Transmit Fault Function

If the module has detected a local fault on any transmit lane, it shall set TX_fault to logical one. The definition of a local fault on any transmit lane is beyond the scope of this specification.

6.8 Module Receive Fault Function

If the module has detected a local fault on any receive lane, it shall set RX_fault to logical one. The definition of a local fault on any receive lane is beyond the scope of this specification.

6.9 Module Equalization Function

The module needs to provide an equalization function in its transmit path to enable the co-equalization of the host channel from TP0d to TP1a, see Figure 2. The equalization capabilities should match the CTLE characteristics in OIF CEI-112G-LINEAR-PAM4 and in 7.3.3.

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7 Electrical Specifications

The electrical specifications refer to OIF CEI-112G-LINEAR-PAM4 with the following exceptions.

7.1 Requirements

- Operate at baud rates (fbd) within the range of 53.125 ±100 ppm Gsym/s using PAM4 encoding.
- Capable of achieving an end-to-end raw Bit Error Ratio (BER) of 2.0×10^{-4} or better. RS(544,514) FEC is assumed to be used to achieve a corrected BER of 10^{-13} or better for a maximum frame loss ratio (FLR) of 6.2×10^{-11}, provided that the error statistics are sufficiently random.
- Host output ERL at TP1a, module input ERL at TP1, module output ERL at TP4, and host input ERL at TP4a are measured according to IEEE 802.3ck Annex 120G with Nbx=0.
- ERL shall be better than 10 dB at all interfaces. Note: The test fixture used for this test needs to have a significantly better ERL than 10 dB.

7.2 Electrical Channel

The 100G-DR-LPO specification extends the maximum electrical channel loss of OIF CEI-112G-LINEAR-PAM4 by 3 dB from 13 dB to 16 dB (measured at fbd/2 = 26.56 GHz, fbd = 53.125 GHz).

7.2.1 LPO MSA Pluggable Module Channel Reference Model

The insertion loss between the host ASIC die and the module's die is expected to be no higher than 20 dB. The insertion loss of the host ASIC package, host PCB, and of the module PCB including AC coupling capacitor are recommended to be within the ranges indicated in Figure 3.

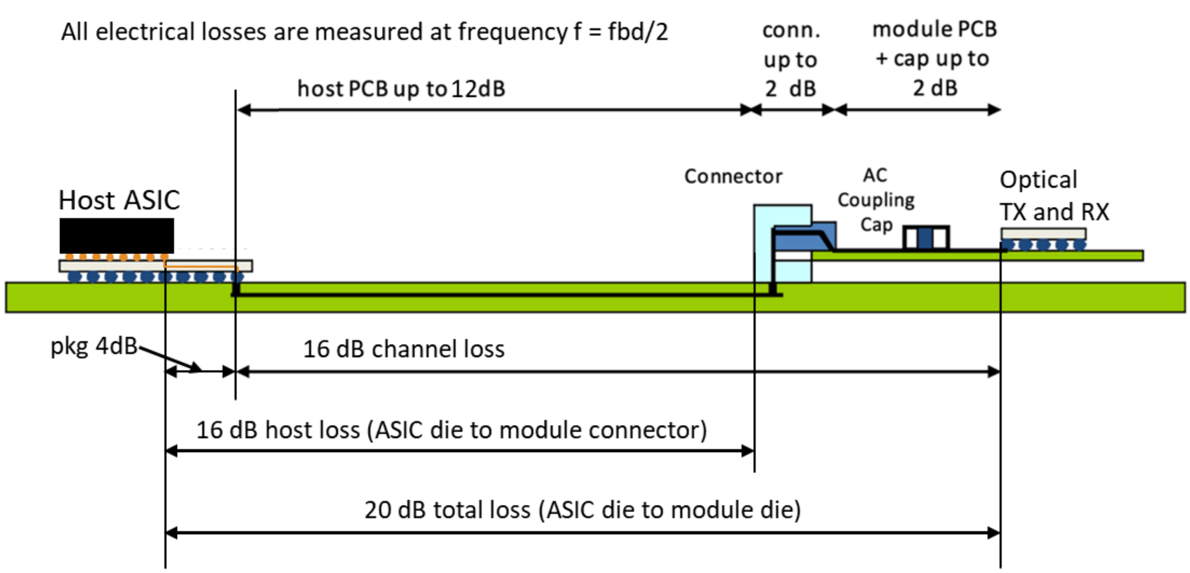

Figure 3: Channel Reference Model

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7.3 Host-to-Module Electrical Specifications at TP1a (host output)

Figure 4 shows the measurement setup for TP1a measurements. For measurements at TP1a host side nonlinear compensation (NLC) shall not be used.
The host output is assumed to meet the J3u03 (uncorrelated jitter) specification, as defined in IEEE Std 802.3ck 162.9.4.7, of 115 mUI or less. This measurement should be done on a host port with an insertion loss within the recommended host loss for 400GBASE-CR4 (see IEEE Std 802.3ck Annex 162A).

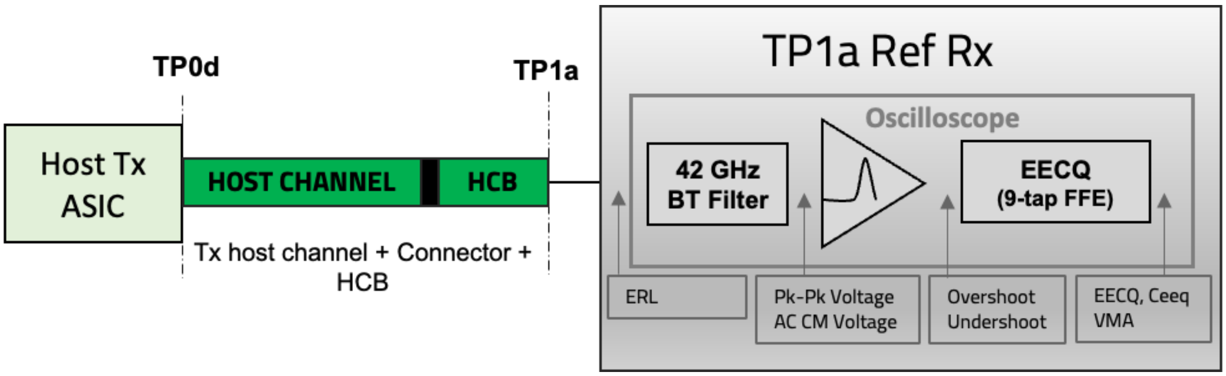

Figure 4: Measurement Setup for TP1a

7.3.1 Host-to-Module Electrical Specifications at TP1a (host output)

Host-to-module electrical specifications at TP1a are defined in Table 29-1 in OIF CEI-112G-LINEAR-PAM4 with the exceptions shown in Table 3. Note: A Qt of 3.463 representing an SER of 4.0×10^{-4} is used for calibrating EECQ at TP1a.

Table 3: TP1a (host output)

Parameter	Condition	Min.	Max.	Unit
VMA	Host loss > 13 dB	175	350	mV
	Host loss ≤ 13 dB	200	350	
EECQ[(1,2)]	Host loss > 13 dB		3.5	dB
	Host loss ≤ 13 dB		3.0	
Ceeq[3]	Host loss > 13 dB	-0.5	0.75	dB
	Host loss ≤ 13 dB		0.5	

[1] σG is added AFTER the FFE.
[2] The module may optionally request NLC from the host to improve TECQ/TDECQ at TP2 and system performance.
[3] Ceeq is determined by the FFE only. The CTLE is not included in the Ceeq calculation.

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7.3.2 Host Output Test Method at TP1a

The signal at TP1a may appear as a closed eye. A reference receiver with a Continuous Time Linear Equalizer (CTLE), identical to the CTLE used in OIF CEI-112G-LINEAR-PAM4, and a 9-tap FFE, is used to equalize the host output signal and open the eye for EECQ measurements. The FFE tap limits are given in Table 4. The recommended values for gDC and gDC2 are shown in Table 5. The impact of crosstalk should be considered in addition to single lane testing.

Table 4: Host Output 9-tap Reference FFE Characteristics

Parameter	Min.	Max.
Pre-cursor	Not allowed	Not allowed
Tap 1 (main) (1)	0.95	
Tap 2-4 (post) (1)	-0.08	0.08
Tap 5 to 9 (post) (1)	-0.05	0.05

[1] Sum of the equalizer tap coefficients is equal to 1.

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7.3.3 Recommended CTLE gDC and gDC2 Settings

Table 5 extends Table 29-8 in OIF CEI-112G-LINEAR-PAM4 with three additional rows.

Table 5: Recommended gDC and gDC2 Settings versus Insertion Loss (IL)

"Die to die IL"(1,2)	Ch IL(3,4)	gDC5	gDC25	Units
5.5	1.5	0	0.5	dB
6	2	0	0.5	dB
7	3	0	0.5	dB
8	4	0	1	dB
9	5	0.5	1	dB
10	6	1	1.5	dB
11	7	2	1.5	dB
12	8	2.5	1.5	dB
13	9	3.5	1.5	dB
14	10	4	2	dB
15	11	4.5	2	dB
16	12	5	2	dB
17	13	6	2	dB
18	14	6	2	dB
19	15	6	2	dB
20	16	6	2	dB

1 Measured from host ASIC die bump to TP1a (TP0d to TP1a), which is approximately the die to die (d2d) insertion loss.
2 For Ch IL < 1.5 dB gDC = gDC2 = 0 dB is recommended.
3 Channel IL measured from host ASIC package ball to TP1a.
4 Table 5 assumes 4 dB host package loss. Consideration should be given for actual channel loss not to exceed 20 dB die to die (d2d).
5 Alternative gDC and gDC2 settings can be used if TP1a and TP2 specifications are met. The CTLE transfer function has unity gain at low frequencies.

7.4 Host-to-Module Electrical Specifications at TP1 (module input)

The module input shall comply to OIF CEI-112G-LINEAR-PAM4 Table 29-2 Host-to Module Electrical Specifications (Module Input) with the exception shown in Table 6.

Table 6: TP1 (module input)

Parameter	Max.	Unit
VMA	350	mV

7.4.1 Module Input Test Method and Signal Calibration at TP1a

There are three stressed input signals for the module representing different host losses according to the specification given in Table 7. The measurement setup for the signal calibration is shown in Figure 5.

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Table 7: Electrical Stressor Parameters Measured at TP1a

Host loss[1]	VMA	EECQ Max.	Ceeq min / max	Over- / Undershoot max.	Random jitter[2] max.	Sinusoidal jitter	gDC	gDC2
[dB]	[mV]	[dB]	[dB]	[%]	[mUI RMS]	[mUI pk-pk]	[dB]	[dB]
5	350	3[3,4]	±0.5[3,4]	25[4]	10	50	0.5	1
13	200	3[3,4]	±0.5[3,4]	25[4]	10	50	6	2
16	175	3.5	– 0.5 / +0.75	25[4]	10	50	6	2

1 The host loss is the electrical insertion loss from the host die to the module connector, see Figure 3.
2 The random jitter in this specification is assumed to have a Gaussian probability distribution.
3 EECQ on a short port is likely to be less than 3 dB and |Ceeq| is likely to be less than 0.5dB.
4 The overshoot and undershoot may be lower than the maximum specification. They should be reasonably close to the maximum but not exceed the maximum.

Notes

- The host loss needs to be a physical transmission line loss.
- Calibrate the port using the TP1a calibration method.
- Add random jitter to the source up to 10 mUI RMS to achieve J3u03 of 115 mUI.
- J3u03 should be close to the maximum specified limit in IEEE Std 802.3ck of 115 mUI
- Sinusoidal jitter frequency should not be lower than 40 MHz.
- SSPRQ pattern should be used.

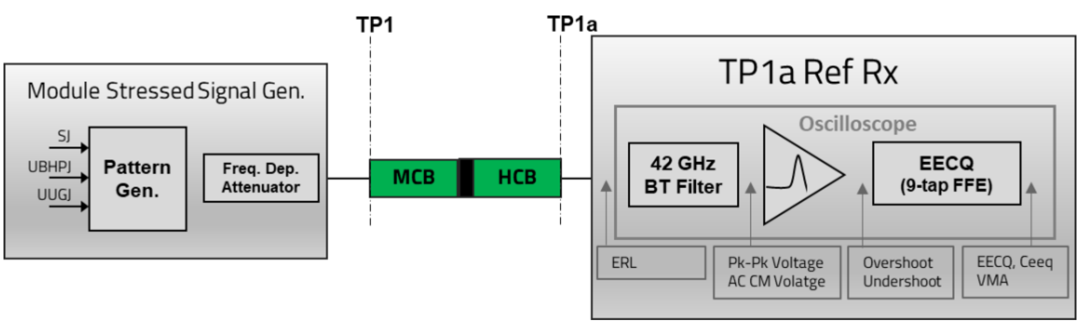

Figure 5: Module Input Stressor Calibration

7.5 Module-to-Host Electrical Specifications at TP4 (module output)

The module output shall comply to OIF CEI-112G-LINEAR-PAM4 Table 29-4 Module-to-Host Electrical Specifications (Module Output), over the entire module receive specification range given in Table 14 with the exception shown in Table 8. Figure 6 shows the measurement setup.

Table 8: Module-to-Host Electrical Specifications at TP4

Parameter	Min.	Max.	Unit
EECQ	-	7	dB

Note: A suitable algorithm for the FFE / DFE co-adaptation needs to be applied. Besides an exhaustive search, optimization methods such as minimum mean squared error (MMSE) may be used to determine equalizer tap weights to reduce test time and are expected to report equal or higher values of EECQ. These alternative methods should not be used for receiver sensitivity and stressed receiver sensitivity calibration. While a DFE tap weight close to 0 might occur, it could also indicate a failed co-adaptation of the FFE/DFE of the reference equalizer.

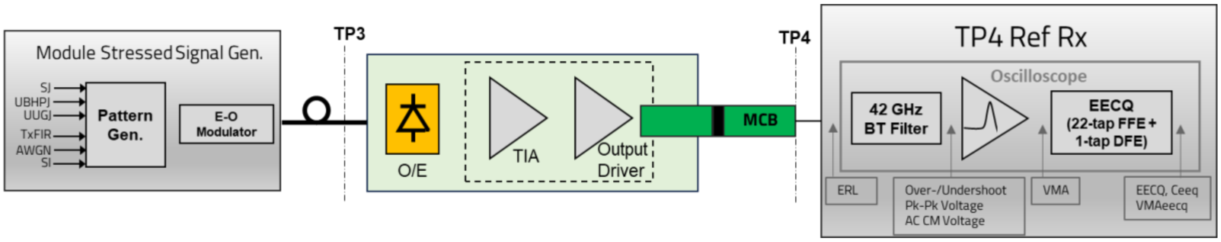

Figure 6: Measurement Setup for TP4

7.5.1 Module Optical Input Test Method and Signal Calibration at TP3

The input signal to the module at TP3 is optical and defined in section 9.10. Figure 7 shows the measurement setup.

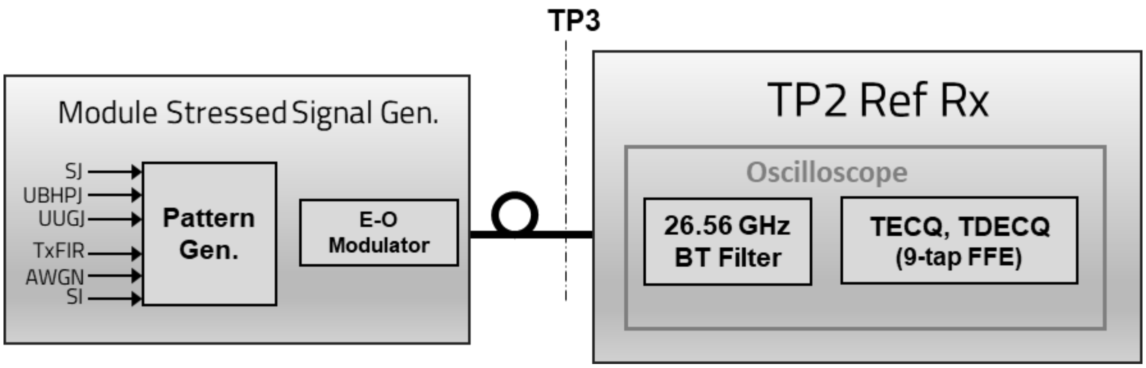

Figure 7: Stressor Calibration for TP3

7.6 Module-to-Host Electrical Specifications at TP4a (stressed host input)

The host input shall comply to OIF CEI-112G-LINEAR-PAM4 Table 29-5 Module-to-Host Electrical Specifications (Host Input), with this exception:

- Instead of the bit error ratio requirements of CEI-112G-LINEAR-PAM4, the frame loss ratio shall be less than or equal to 6.2×10^{-11} for 64-octet frames with minimum interpacket gap.

Alternatively, host testing with PRBS31Q can be performed, see section 10.2.1. The host shall comply with the specification given in Table 9 when tested with PRBS31Q.

Table 9: Host Receiver Performance with PRBS31Q

Parameter	Max
measured BER[1]	2.0×10^{-4}
t-count[2]	15

[1] Measured for 3 s.

[2] Measured for 100 s.

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Figure 8 shows the measurement setup.

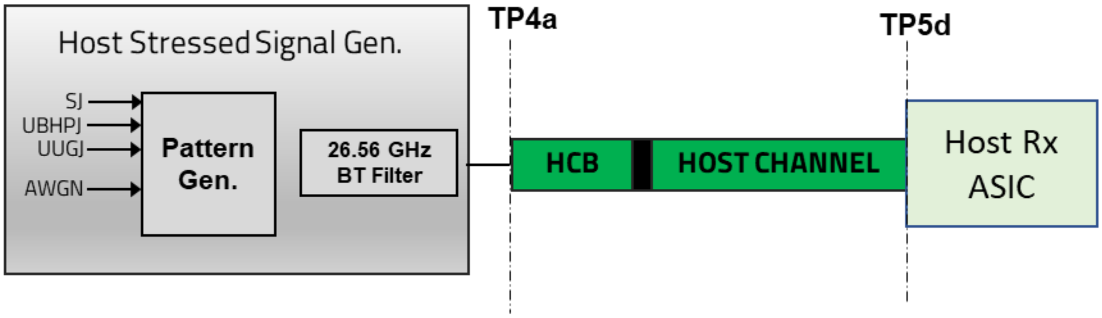

Figure 8: Measurement Setup for Stressed Host Input

7.6.1 Host Input Test Method and Signal Calibration at TP4 (stressed host input)

The stressed host input signal depends on the host loss and should meet the specification given in Table 10. Figure 9 shows the measurement setup.

Note: A Qt of 3.463 representing an SER of 4.0×10^{-4} is used for calibrating EECQ at TP4.

Table 10: Electrical Stressor Parameters Measured at TP4

Host loss[1]	VMA	EECQ	Amplitude noise	Over-/ undershoot	Random jitter	Sinusoidal jitter
[dB]	[mV]	[dB]	[mV RMS]	[%]	[mUI RMS]	[UI pk-pk]
5	250	7	3	25[2]	10	See Table 11
13	500		6			
16						

[1] The host loss is the electrical insertion loss from the host die to the module connector, see Figure 3.

[2] The overshoot and undershoot may be lower than the maximum specification. It should be reasonably close to the maximum but not exceed the maximum.

Table 11: Sinusoidal Jitter

Frequency [MHz]	Sinusoidal Jitter [UI pk-pk]
0.04	5
0.4	0.5
1.333	0.15
4	0.05
12	0.05
40	0.05

Notes

- Calibrate the stressed signal using the TP4 calibration method.
- Add 3 mV RMS or 6 mV RMS Gaussian noise depending on VMA.
- Add random jitter to the source up to 10 mUI RMS.
- Calibrate the stressed signal with PRBS13Q pattern (pattern 4) and then switch to PRBS31Q (pattern 3) or scrambled idle (pattern 5) for the compliance measurement.
- The impact of crosstalk should be considered in addition to single lane testing.

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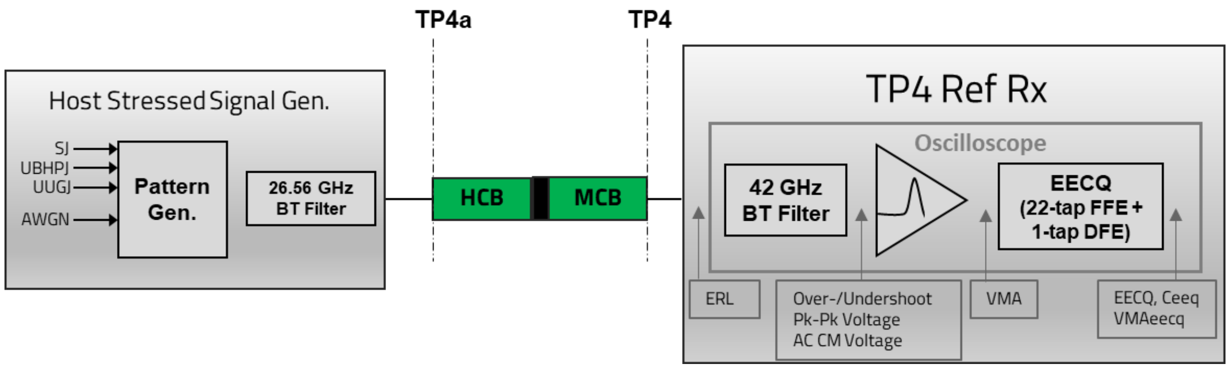

Figure 9: Host Input Stressor Calibration

8 Optical Specifications

The required operating range is defined in Table 12. A compliant LPO module operates on single-mode fibers according to the specifications of Table 21. An LPO module which exceeds the operating range requirement while meeting all other optical specifications is considered compliant (e.g., operating at 600 m meets the operating range requirement of 0.5 m to 500 m). The signaling rate for a lane of an LPO module shall be as defined in Table 13. The optical signals at the transmit and receive sides are specified in Table 13 and Table 14. Test points are defined in Figure 1.

Table 12: Operating Ranges and Interface IDs

Media Interface ID	Host Electrical Interface ID	Host Loss	Optical Operating Range
100G-DR1-LPO	LEI-100G-PAM4-1[1]	0 to 16 dB	0.5 m to 500 m
200G-DR2-LPO	LEI-200G-PAM4-2		
400G-DR4-LPO	LEI-400G-PAM4-4		
800G-DR8-LPO	LEI-800G-PAM4-8		

1 LEI: Linear Electrical Interface

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8.1 Transmit Optical Specifications at TP2

The LPO transmitter shall meet the specifications defined in Table 13 for any electrical input that complies with the specifications in Table 3, without re-optimizing host settings. The optical transmit signal is defined at TP2, the output end of a single-mode fiber patch cord between 2 m and 5 m in length. Figure 10 shows the measurement setup.

Table 13: Optical Transmit Specifications

Description	Min.	Max.	Unit
Signaling rate, each lane (range)	53.125		GBd
	- 50 ppm	+ 50 ppm	
Modulation format	PAM4		
Lane wavelength range	1304.5	1317.5	nm
Operating link reach	0.5	500	m
Average launch power, each lane	-2.9	4	dBm
Optical Modulation Amplitude (OMA_{outer}), each lane[3]		4.2	dBm
Launch power in OMA, each lane for max(TECQ,TDECQ) < 1.4 dB[1]	-1.8		dBm
Launch power in OMA, each lane for 1.4 dB ≤ max(TECQ,TDECQ) ≤ 3.4 dB	-3.2 + max(TECQ, TDECQ)		
Transmitter dispersion and eye closure (TDECQ), each lane[1]		3.4	dB
Transmitter eye closure (TECQ), each lane[1]		3.4	dB
Ceq[2] for extinction ratio ≤ 4.5 dB and OMA ≤ 3.7 dBm	-0.5	2.5	dB
Ceq[2] for extinction ratio > 4.5 dB or OMA > 3.7 dBm	0	2.5	dB
TX overshoot/undershoot		25	%
Average launch power of transmitter OFF, each lane		-15	dBm
Extinction ratio[3]	2.5		dB
RIN_xOMA[4]		-138	dB/Hz
Optical return loss tolerance		17.2	dB
Transmitter reflectance		-26	dB

1 Even if the TDECQ < 1.4dB, the OMA (min) must exceed the min value. A mask for the launch power is illustrated in Figure 11.

2 Ceq is a coefficient defined in IEEE Std 802.3-2022 Clause 121.8.5.3 which accounts for reference equalizer noise enhancement. Negative Ceq is an indication of over-equalization and typically does not lead to optimum link performance and might result in nonlinear distortion.

3 Minimum ER needs to increase for OMA > 1.4 dBm to 5 dB at 4.2 dBm OMA to keep average launch power at 4 dBm or below. High ER above 4.5 dB and OMA higher than 3.7 dBm typically do not lead to optimum link performance and might result in nonlinear distortion.

4 RIN_xOMA with “x” referring to the value for optical return loss tolerance.

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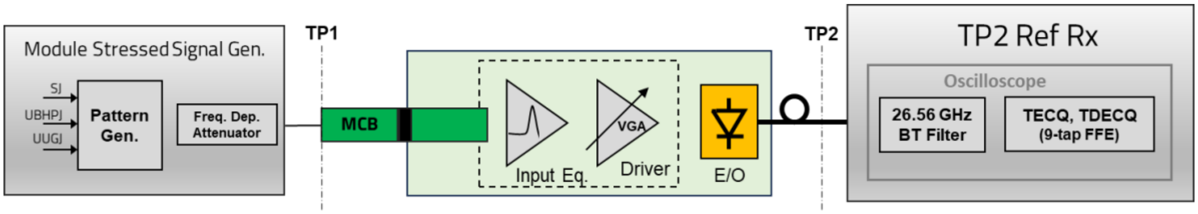

Figure 10: Measurement Setup for TP2

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8.2 Receive Optical Specifications at TP3

The module receiver shall meet the specifications defined in Table 14 and section 7.5. The optical receiver output is measured with an MCB and an oscilloscope. See CEI-112G-LINEAR-PAM4 Figure 29-7. See section 10.2 for a method of assessing a combination of host and module.

Table 14: Optical Receive Specifications

Description	Min.	Max.	Unit
Signaling rate, each lane (range)	53.125 -100 ppm	53.125 +100 ppm	GBd
Modulation format	PAM4		
Damage threshold[1]	5		dBm
Average receive power, each lane[2]	-5.9	4	dBm
Receive power, each lane (OMA_{outer})		4.2	dBm
Receiver reflectance		-26	dB
Receiver sensitivity (OMA_{outer}) for TECQ ≤ 1.4 dB, each lane[3]		-5.1	dBm
Receiver sensitivity (OMA_{outer}) for 1.4 dB ≤ TECQ ≤ 3.4 dB, each lane[3]		-6.5 + TECQ	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[4]		-3.1	dBm
Conditions of stressed receiver sensitivity test			
Stressed eye closure for PAM4 (SECQ), lane under test		3.4	dB
OMA_{outer} of each aggressor lane	4.2		dBm

[1] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.

[2] Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

[3] A mask for the receiver sensitivity is illustrated in Figure 11.

[4] Measured with conformance test signal at TP3. See section 9.10.

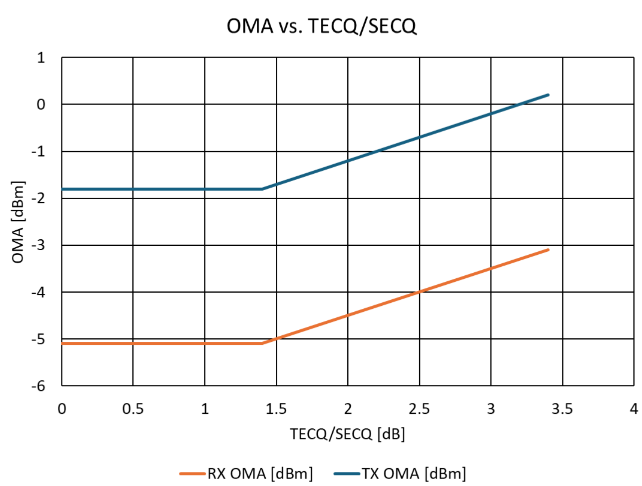

Figure 11: Illustration of Receiver Sensitivity Mask

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8.3 Illustrative Optical Link Power Budgets

An illustrative power budget and penalties for optical channels is shown in Table 15. Table 16 shows maximum optical channel insertion loss versus the number of discrete reflectances.

Table 15: Illustrative Optical Link Power Budget

Parameter	Value	Unit
Operating distance max.	0.5	km
Fiber loss	0.25	dB
Connector and splice losses	2.75	dB
Total channel loss[1]	3.0	dB
MPI penalty[1]	0.3	dB
TDECQ (max.)	3.4	dB
Total Power Budget	6.7	dB

1 Total optical channel loss and MPI penalty as part of the link power budget. See Table 16 for max. channel loss versus discrete reflectances.

Table 16: Maximum Optical Channel Insertion Loss versus Number of Discrete Reflectances

Maximum channel insertion loss (dB)		Number of discrete reflectances > -55 dB and ≤-45 dB						
		0	1	2	3	4	5	6
Number of discredit reflectances > -45 dB and ≤ -35 dB	0	3	3	3	3	3	3	3
	1	3	3	3	3	3	3	3
	2	3	2.9	2.9	2.9	2.8	2.8	2.8
	3	2.8	2.7	2.7	2.7	2.6	2.6	NA[1]
	4	2.5	2.5	2.5	2.5	NA[1]	NA[1]	NA[1]

1 Total number of connectors too high for practical purposes.

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9 Definition of Optical and Electrical Parameters and Measurement Methods

All transmitter optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

9.1 Test Patterns for Electrical and Optical Parameters

While compliance is to be achieved in normal operation, specific test patterns are defined for measurement consistency and to enable measurement of some parameters. Table 17 gives the test patterns to be used in each measurement, unless otherwise specified. Any of the test patterns given for a particular test in Table 18 may be used to perform that test.

Table 17: Test Patterns

Pattern	Pattern description	Defined in[1]
3	PRBS31Q	120.5.11.2.2
4	PRBS13Q	120.5.11.2.1
5	Scrambled idle	82.2.11 and 161 or 119.2.4.9 or 172.2.4.11. For 1-lane non interleaved, 82.2.11 and 91
6	SSPRQ	120.5.11.2.3

[1] Reference to IEEE Std 802.3-2022.

Table 18: Parameter to Test Pattern Mapping

Parameter	Pattern	Reference
Wavelength	3, 4, 5, 6	9.2
Average optical transmit power	3, 5, 6	9.3
Optical modulation amplitude (OMA_{outer})	4 or 6	9.4
Transmitter and dispersion eye closure for PAM4 (TDECQ) at TP2/TP3	6	9.5
Transmitter eye closure for PAM4 (TECQ) at TP2	6	9.5
Equalizer noise enhancement coefficient (Ceq)	6	9.6
Extinction ratio	4 or 6	9.8
RIN_xOMA	4 or 6	9.9
Module stressed receiver sensitivity at TP4	6	9.10
Module stressed receiver conformance test signal calibration at TP3	6	9.10
Module receiver sensitivity at TP4	6	9.11
Outer eye height to inner eye height ratio and outer eye height symmetry (EHR, EHS)	4 or 6	10.1
EECQ[1] at TP1a (host output, Host Output Test Method at TP1a)	4	9.12, 7.3
Ceeq[2] at TP1a (host output, Host Output Test Method at TP1a)	4	9.13, 7.3
Module Input Test Method at TP1a	6	9.12, 7.4.1
EECQ[1] at TP4 (module output)	6	9.12, 7.5
Module-to-Host Electrical Specifications at TP4a	3 or 5	9.12, 7.6
EECQ[1] at TP4 (Host Input Test Method)	4	9.12, 7.6.1
End-to-end link test	3 or 5	10.2

[1] Electrical eye closure for PAM4 (EECQ)

[2] Equalizer noise enhancement coefficient electrical (Ceeq)

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9.2 Wavelength

The wavelength of each optical lane shall be within the ranges given in Table 13 if measured per IEC 61280–1–3. The lane under test is modulated using one of the test patterns defined in Table 18.

9.3 Average Optical Transmit Power

The average optical power of each lane shall be within the limits given in Table 13 if measured using the methods given in IEC 61280–1–1.

9.4 Optical Modulation Amplitude (OMA_{outer})

The OMA_{outer} of each lane shall be within the limits given in Table 13. The OMA_{outer} is measured using a test pattern specified for OMA_{outer} in Table 13 as the difference between the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in IEEE Std 802.3-2022 Figure 124–3.

9.5 Transmitter (and Dispersion) Eye Closure for PAM4 (TECQ, TDECQ)

The TECQ and TDECQ of each lane shall be within the limits given in Table 13 if measured using the methods specified in IEEE Std 802.3-2022 clauses 121.8.5.1, 121.8.5.2, and 121.8.5.3, 140.7.5, and 140.7.6 with the following exceptions:

- The reference equalizer for 100G per lane - LPO is a 9-tap, T-spaced, feed-forward equalizer (FFE), where T is the symbol period. Tap 1, 2 or 3 has the largest coefficient magnitude of 0.8 minimum.
- The SER for the TDECQ measurement shall be 4.0×10^{-4}.

TECQ is defined by methods specified for TDECQ in this section, except that the test fiber is not used.

9.6 Equalizer Noise Enhancement Coefficient (Ceq)

Ceq shall be as defined by the measurement methodology of IEEE Std 802.3-2022 121.8.5.3 with the reference FFE defined in this specification (see 9.5).

9.7 Stressed Eye Closure for PAM4 (SECQ)

Measured with conformance test signal at TP3 with an SECQ of 3.4 dB. SECQ is equivalent to TECQ as defined in 9.5.

9.8 Extinction Ratio

The extinction ratio of each lane shall be within the limits given in Table 13 if measured using a test pattern specified in Table 18.

The extinction ratio of a PAM4 optical signal is defined as the ratio of the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in IEEE Std 802.3-2022, Figure 140–7.

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9.9 Relative Intensity Noise (RIN_xOMA)

RIN shall be as defined by the measurement methodology of IEEE Std P802.3dj, Draft Standard for Ethernet Amendment for 1.6 Tb/s, Clause 180.9.11 with the following exceptions:

- The optical return loss is 17.2 dB.
- The combination of the O/E converter and the oscilloscope has a 3 dB bandwidth of approximately 26.56 GHz with a fourth-order Bessel-Thomson response.

9.10 Module Stressed Receiver Sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 14 if measured using the method defined in IEEE Std 802.3-2022, Clause 140.7.13 with the following exceptions:

- The reference equalizer for TP4 is a CTLE according to 7.3.2 followed by a 22-tap T-spaced feed-forward equalizer (FFE) and a decision feedback equalizer (DFE) with one tap.
- Instead of bit error ratio the receiver shall meet the specification in section 7.5.

9.10.1 Stressed Optical Signal Parameters at TP3

The calibration of the stress signal at TP3 follows IEEE 802.3 Clause 124.8.10 with the following additions:

- The reference equalizer for the stress signal calibration is a 9-tap T-spaced feed-forward equalizer (FFE) according to section 9.5.

9.10.1.1 For Minimum OMA at Maximum TECQ

- OMA = -3.1 dBm
- Extinction ratio (ER) = 2.5 dB
- In addition to the 50 mUI sinusoidal Jitter, add up to 10 mUI RMS of random jitter to the pattern generator so that J3u03 measured before the E/O is close to 115 mUI
- Reduce transmitter bandwidth such that with the Gaussian noise generator and sinusoidal interferer turned off, the TECQ is close to 3 dB
- Add Gaussian noise such that with the sinusoidal interferer turned off, the TECQ is close to 3.3 dB
- Add sinusoidal interferer so that with both Gaussian noise generator and sinusoidal interferer turned on the TECQ reaches the target value of 3.4 dB

9.10.1.2 For Maximum OMA at Maximum TECQ

- OMA = 4.2 dBm
- Extinction ratio (ER) = 5 dB
- In addition to the 50 mUI sinusoidal Jitter, add up to 10 mUI RMS of random jitter to the pattern generator so that J3u03 measured before the E/O is close to 115 mUI
- Reduce transmitter bandwidth such that with the sinusoidal interferer turned off, the TECQ is close to 3.2 dB
- Add sinusoidal interferer so that the SECQ reaches the target value of 3.4 dB

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9.11 Module Receiver Sensitivity (RxS)

Receiver sensitivity is defined for a signal with a value of TECQ up to 3.4 dB and shall meet the specification in Table 8. The receiver shall meet the specification in Table 8 with a piecewise linear function Equation 1, which is illustrated in Figure 11 with the reference equalizer from section 9.10.

$$RxS = \max(-5.1, TECQ - 6.5)\ \text{dBm}, \text{Equation 1}$$

RxS: Receiver sensitivity
TECQ: TECQ of the signal used to measure the receiver sensitivity.

9.12 Electrical Eye Closure PAM4 (EECQ)

EECQ shall be as defined by the measurement methodology of OIF CEI-112G-LINEAR-PAM4 section 29.3.12 with the reference equalizer defined in section 7.3.2 for TP1a and the reference equalizer defined in section 9.10 for TP4.

9.13 Electrical Equalizer Noise Enhancement Coefficient (Ceeq)

Ceeq shall be as defined by the measurement methodology of OIF CEI-112G-LINEAR-PAM4 section 29.3.13 with the reference equalizer defined in Table 4 and 7.3.2. Ceeq is determined by the FFE only. The CTLE is not included in the Ceeq calculation.

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10 Additional Measurement Procedures (Informative)

Section 10 describes additional measurement procedures for LPO testing.

10.1 Eye Height Ratio and Eye Height Symmetry (EHR, EHS)

This measurement can be used to adjust nonlinear compensation (NLC) of the optical transmit eye at TP2 to avoid outer eye compression and improve overall bit error ratio; see also section 5.10. The calculation of EHR and EHS is shown in Equations 2 to 4. The equalized eye from TECQ is used to find the 4 levels. The left and right histograms are combined, the samples are sorted into four groups and the groups are averaged; see section 9.5. Figure 12 illustrates the measurement.

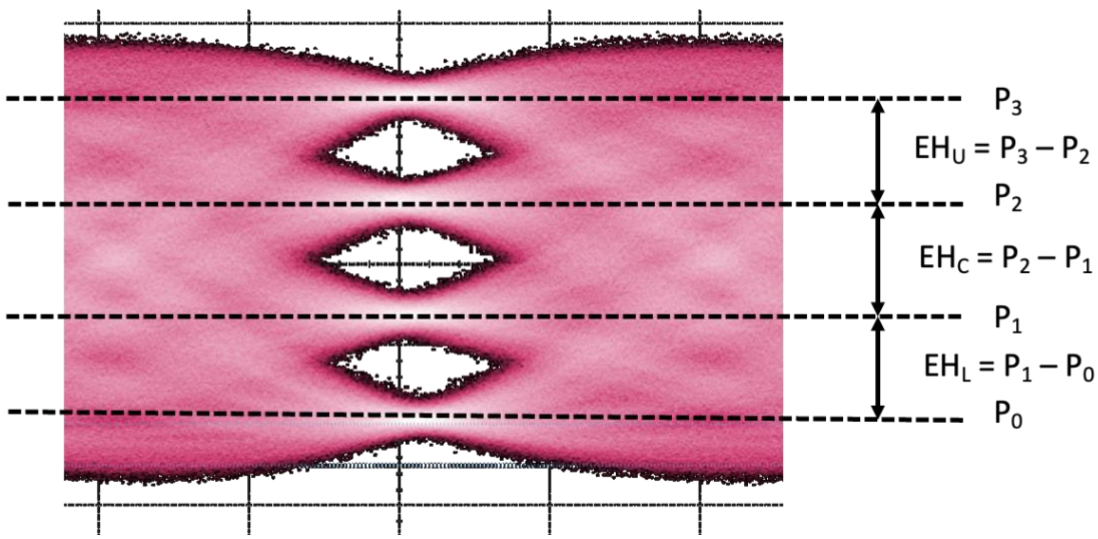

Figure 12: Eye Height Ratio and Eye Height Symmetry Measurement

$$EHR_U = \frac{EH_U}{EH_C} \cdot 100\%, \text{ Equation 2}$$

$$EHR_L = \frac{EH_L}{EH_C} \cdot 100\%, \text{ Equation 3}$$

$$EHS = \frac{EH_U}{EH_L} \cdot 100\%, \text{ Equation 4}$$

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10.2 Host-to-Host Link Test

To verify full link operation, an end-to-end or host-to-host link test as defined below may be performed. This test can be a module test with a known good host or a host test with a known good module. The test can be performed with a single host or two separate hosts. The module is inserted into the host(s), and both are set up as required. It is recommended that the host and module settings are not optimized based on link test results. The optical side of the module is looped back from the transmitter to a receiver in the same port or in a different port. Combinations of different ports are recommended to improve test coverage. Figure 13 shows a block diagram of this test with a single host. The test is performed with either PRBS31Q (see Table 17) or any FEC encoded signal. The system performance specifications in Table 20 should be achieved with an optical attenuation of 0 dB and 3 dB and electrical host PCB channel losses shown in Table 19.

Table 19: Host-to-Host Link Test Conditions

Test Parameter(1)	Min.	Max.	Unit
Electrical host PCB channel loss[2]	1	12	dB

[1] Other test conditions like temperature, air pressure, humidity, supply voltages, etc. chosen as appropriate.
[2] Host PCB channel insertion loss at 26.56 GHz. Does not include host ASIC package insertion loss, module connector, and module insertion loss. Total die to die electrical channel loss at 26.56 GHz needs to be below 20 dB die to die (d2d) as shown in Figure 13.

10.2.1 Error Statistics Test with PRBS31Q

Error statistics measured with PRBS31Q pattern do not apply forward error correction. This measurement provides an error statistics assessment by counting symbol errors within blocks of 5440 bits within the test pattern, which resembles the FEC symbol size of 10 bits and the FEC codeword size of 544 FEC symbols. The maximum number of symbol errors per FEC codeword within this framework is abbreviated to as t-count, see IEEE Std P802.3dj, Draft Standard for Ethernet Amendment for 1.6 Tb/s, Annex 174A.6. Not all host systems may provide this feature.

If an error statistics test with a PRBS31Q is performed, the measured BER and the t-count should typically not exceed the limits in Table 20, which would result in virtually error free performance after FEC and is significantly better than the required FLR maximum limit of 6.2×10^{-11}.

10.2.2 Error Statistics Test with FEC Encoded Signals

If a test with actual Ethernet signals (e.g. scrambled idle pattern) is performed, the pre-FEC BER and the FEC bin count should typically not exceed the limits in Table 20, which would result in virtually error free performance after FEC and is significantly better than the required FLR maximum limit of 6.2×10^{-11}.

Table 20: Link Performance with PRBS31Q

Parameter	Typ.
measured BER[1] / pre FEC BER[1]	10^{-6}
t-count[2] / FEC bin count	7

[1] Measured for 3s.
[2] Measured for 100s.

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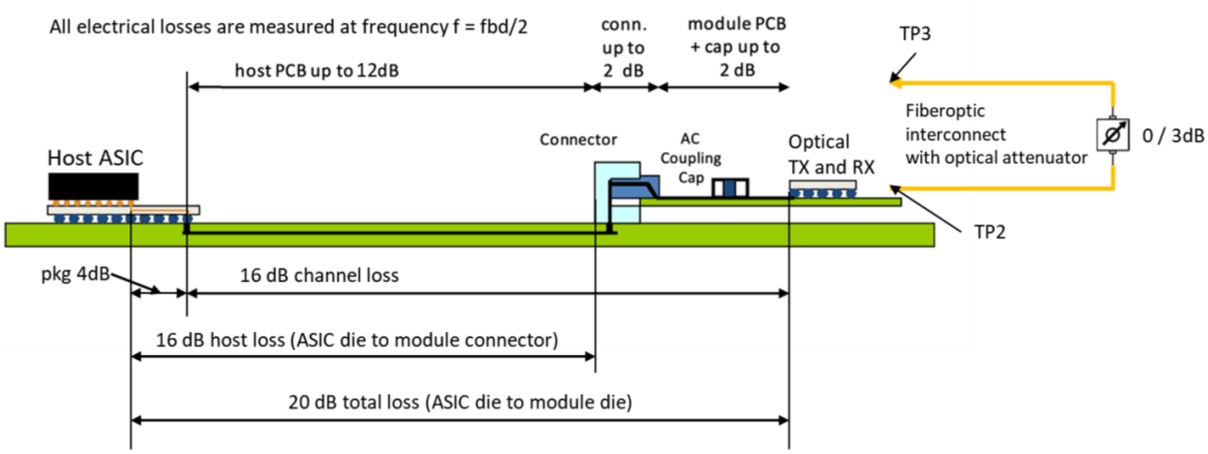

Figure 13: Host-to-Host Link Test Block Diagram

Note: The host on the transmit side can be replaced by a stress generator creating the stressed signal at TP1 and measure BER / error statistics in this configuration instead.

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11 Safety, Installation, Environment, and Labeling

11.1 General Safety

All equipment subject to this specification shall conform to IEC 60950-1.

11.2 Laser Safety

LPO optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825–1 and IEC 60825–2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation explicitly defines requirements and usage restrictions on the host necessary to meet these safety certifications.

11.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

11.4 Environment

Normative specifications in this document shall be met by a system integrating an LPO module over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

It is recommended that manufacturers indicate in the literature associated with the module the operating environmental conditions to facilitate selection, installation, and maintenance. It is further recommended that manufacturers indicate, in the literature associated with the components of the optical link, the distance and operating environmental conditions over which the requirements of this specification will be met.

11.5 Electromagnetic Emission

A system integrating an LPO module shall comply with applicable local and national codes for the limitation of electromagnetic interference.

11.6 Temperature, Humidity, and Handling

The optical link 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 beyond the scope of this standard.

11.7 Module Labeling Requirements

It is recommended that each module (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the widest SMF media interface ID ability of the module (e.g. 100G-DR1-LPO, 200G-DR2-LPO, etc.). Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 11.2.

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12 Fiber Optic Cabling Model

12.1 Characteristics of the Fiber Optic Cabling (Channel)

The fiber optic cable requirements are satisfied by cables containing IEC 60793–2–50 type B1.1 (dispersion un-shifted single-mode), type B1.3 (low water peak single-mode), or type B6_A (bend insensitive) fibers and the requirements in Table 21 where they differ.

Table 21: Optical Fiber and Cable Characteristics

Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.5[1]	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Negative dispersion[2]	-0.93	ps/nm
Positive dispersion[2]	0.8	ps/nm
DGD_max[3]	2.24	ps

[1] The 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568.3-E. Section 13.3 below exhibits connector loss for links with various numbers of LC and MPO connectors.

[2] Over the wavelength range 1304.5 nm to 1317.5 nm.

[3] Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

12.2 Connector Discrete Reflectance Requirements

Optical connectors might reduce the optical loss budget based on their reflectance and number within an optical link. Table 16 is showing the maximum optical channel loss versus the number of discrete reflectances.

12.3 Medium Dependent Interface (MDI) Requirements

The module is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the module and the “fiber optic cabling”. Examples of an MDI include the following:

a) Connectorized fiber pigtail

b) Module receptacle

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of IEC 61753–1–1 and IEC 61753–021–2.

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13 Link Budget Configuration (Informative)

13.1 Connector Reflection

LPO cable plants may include connector reflectances according to Table 16. An MPI penalty of 0.3 dB is part of the optical link budget.

13.2 Connector Loss

The maximum link distance is based on an allocation of 3 dB total connection and splice loss. For the connectors, a statistical estimation approach can be taken based on the Rayleigh probability distribution of the connector loss. By using a multiplier of 2.5 on the standard deviation, 98.4% of the population is covered.

13.3 Link Budget Example

In Table 22 examples are given including all channel loss parameters for a loss budget of 3 dB. Tradeoffs between the number of connectors, the connector reflectance, and fiber reach can be made. In the table it is assumed that the LC connectors have an average loss of 0.2 dB with a sigma of 0.15 dB and the MPO connectors have an average loss of 0.35 dB and a sigma of 0.25 dB. The fiber attenuation is assumed to be 0.47 dB/km.

Table 22: Channel Loss Examples

LC connectors		MPO connectors		All connectors	0.5 km fiber	Total[1]
No.	Total loss [dB]	No.	Total loss [dB]	Total loss [dB]	[dB]	[dB]
0	0.00	1	0.98	0.98	0.235	**1.21**
0	0.00	2	1.58	1.58	0.235	**1.82**
0	0.00	3	2.13	2.13	0.235	**2.37**
0	0.00	4	2.65	2.65	0.235	**2.89**
1	0.58	1	0.98	1.28	0.235	**1.51**
1	0.58	2	1.58	1.86	0.235	**2.10**
1	0.58	3	2.13	2.40	0.235	**2.63**
1	0.58	4	2.65	2.91	0.235	**3.14**[2]
2	0.93	1	0.98	1.57	0.235	**1.80**
2	0.93	2	1.58	2.13	0.235	**2.37**
2	0.93	3	2.13	2.66	0.235	**2.89**
2	0.93	4	2.65	3.16	0.235	**3.39**[2]
3	1.25	1	0.98	1.85	0.235	**2.09**
3	1.25	2	1.58	2.40	0.235	**2.63**
3	1.25	3	2.13	2.91	0.235	**3.15**[2]
3	1.25	4	2.65	3.41	0.235	**3.64**[2]
4	1.55	1	0.98	2.13	0.235	**2.36**
4	1.55	2	1.58	2.66	0.235	**2.89**
4	1.55	3	2.13	3.17	0.235	**3.40**[2]
4	1.55	4	2.65	3.66	0.235	**3.89**[2]

1 Does not include MPI penalty due to reflectance, see Table 16.

2 Channel losses exceeding 3 dB are beyond the scope of this specification and are shown for illustration purposes.

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14 Optimizing Host for TP1a

Figure 14 shows the setup for the host TX FFE optimization. Besides the host system a suitable HCB, cables, and scope are needed. The cables from the HCB to the scope should be de-embedded. Figure 15 shows the procedure to optimize the host settings. Before starting measurements, the host TX pattern should be set to PRBS13Q and the CTLE settings should be chosen according to 7.3.3 depending on the electrical channel loss of the measured host port. The host TX FFE is set to have a main cursor only and does not provide any equalization in the first measurement, i.e. all other tap weights are set to zero. The host FFE equalizer should have at least 3 pre-cursor, and 2 post-cursor taps. The FFE equalizer in the scope needs to match the FFE equalizer in the host regarding the number of pre- and post-cursor taps within the limitations of the host FFE settings.

After this measurement is finished, the tap weights of the FFE in the scope can be extracted and mapped back to the host TX FFE to match the tap weights of the scope FFE.

Then the measurement is repeated and the EECQ, Ceeq, and VMA measurements can be measured by the 9-tap reference equalizer. The optimization goal is to force Ceeq to zero.

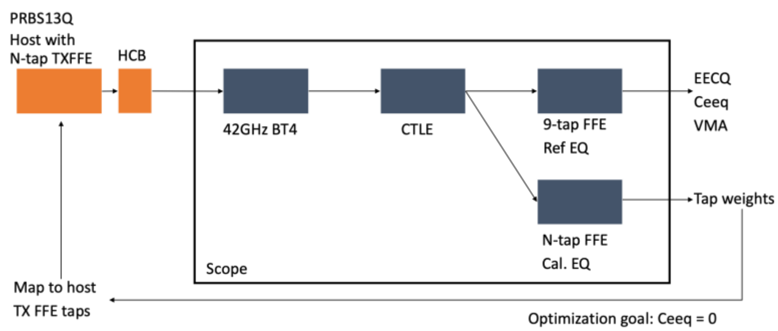

Figure 14: Optimization Setup for TP1a

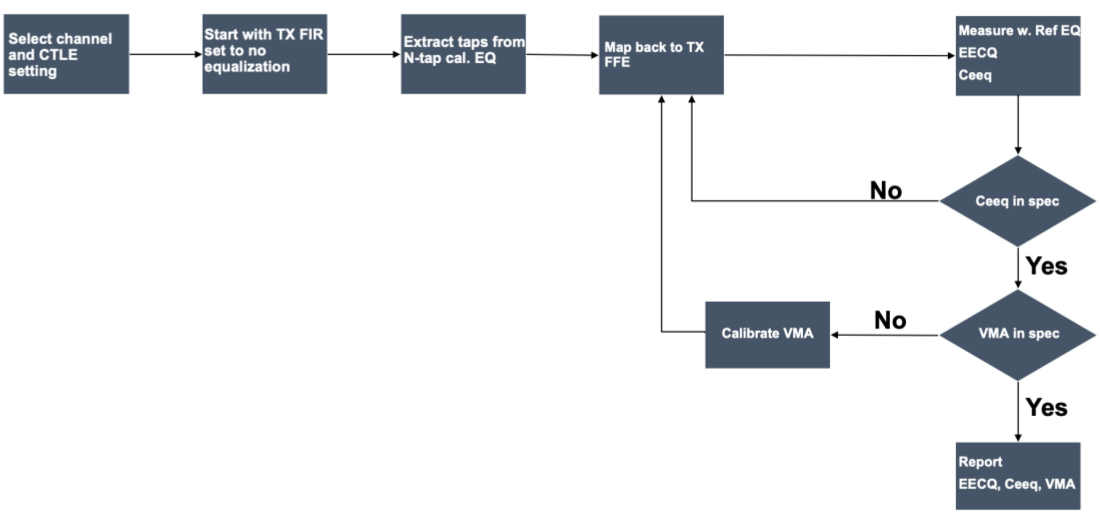

Figure 15: Procedure to Optimize Host FFE Settings

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15 Test Point Illustration

Figure 16 illustrates the test points of measurements and calibration procedures.

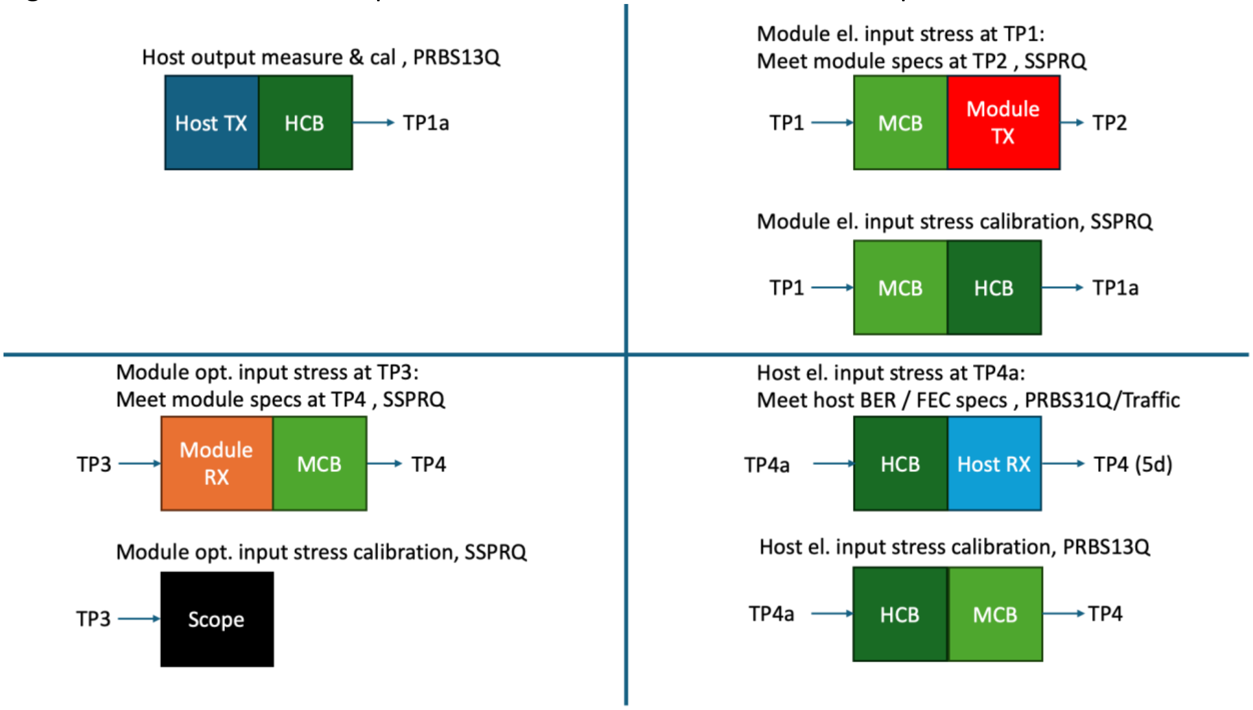

Figure 16: Test Points

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16 Glossary

BER	Bit Error Ratio
Ceeq	Electrical Noise Amplification Factor for PAM4
Ceq	Noise Amplification Factor for PAM4
CTLE	Continuous Time Linear Equalizer
DFE	Decision-Feedback Equalizer
EECQ	Electrical Eye Closure for PAM4
ERL	Effective Return Loss
fbd	Baud Rate
FEC	Forward Error Correction
FFE	Feed-Forward Equalizer
FLR	Frame Loss Ratio
gDC	CTLE High Frequency Gain
gDC2	CTLE Low Frequency Gain
HCB	Host Compliance Board
LPO	Linear Pluggable Optics
MCB	Module Compliance Board
MDI	Medium Dependent Interface
MPI	Multi Path Interference
MSA	Multi Source Agreement
Nbx	Equalizer Length Associated with Reflection Signal
NLC	Nonlinear Compensation
OMA	Optical Modulation Amplitude
PMD	Physical Media Dependent
PRBSQ	Pseudo-Random Bit Sequence for PAM4
RS	Reed-Solomon Error Correction Codes
RxS	Receiver Sensitivity
σG	Standard Deviation
SECQ	Stressed Eye Closure for PAM4
SER	Symbol Error Ratio
SMF	Single Mode Fiber
SSPRQ	Short Stress Pattern Random for PAM4
TECQ	Transmitter Eye Closure for PAM4
TDECQ	Transmitter and Dispersion Eye Closure for PAM4
UI	Unit Interval
VMA	Voltage Modulation Amplitude

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