Optical PMD-Harness Specification

Channel and Components Requirements for Multi-Gigabit Optical Automotive Ethernet

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CHAIR AND VICE CHAIR

CHAIR	NAME	ORGANIZATION
OPEN Alliance TC7 Chair	Naoshi Serizawa	Yazaki Corporation
OPEN Alliance TC7 Vice Chair	Luis Manuel Torres	KDPOF

EDITOR

NAME	ORGANIZATION
Hayato Yuki	Sumitomo electric industries ltd.

CONTRIBUTORS

NAME	ORGANIZATION
Gustavo Aguayo	Molex, LLC
Abba Alwishhah	Molex, LLC
Daniel Bergemann	LEONI Kabel GmbH
Matthias Bude	Amphenol Technologies Holding GmbH
Alexander Felgenhauer	Yazaki Europe.
Vince Ferretti	Corning Incorporated
Joe-Yong Ghang	Keysight Technologies
Ahmed Gharba	Volvo Car Corporation

Hideki Goto	Toyota Motor Corporation
Darako Hilusicka	Yazaki Europe
Yasuhiro Hyakutake	Orbray Co. Ltd.
Masayuki Iwase	Furukawa Electric Co. Ltd
Edward Jin	Molex, LLC
Manabu kagami	Nagoya Institute of Technology
Atsushi Kanno	Nagoya Institute of Technology
Keisuke Kawahara	Furukawa Electric Co. Ltd.
Angela Lambert	Corning Incorporated
Akshaya LK	Volvo Technology
Matthias Mahllich	Robert Bosch GmbH
Kjersti Martino	Inneos
Masaharu Mikami	Japan Aviation Electronics Industry, Limited
Thomas Müller	Rosenberger Hochfrequenztechnik GmbH und Co. KG
Yoshihiro Niihara	Fujikura Ltd.
Eiichirou Ooishi	Yazaki Corporation
Kevin Peters	Inneos
Vimalli Raman	Yazaki Europe
Masato Shiino	Furukawa Electric Co. Ltd.
Noritaka Taguchi	Yazaki Corporation
Hiromasa Tanaka	Japan Aviation Electronics Industry, Limited
Osami Wada	Nagoya Institute of Technology
Takahiro Yamanaka	Murata
John Yurtin	Aptiv, LLC

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4 ABBREVIATION/SYMBOLS

AGF	all glass fibre
AOP	average optical power
APC	automatic power control
DUT	device under test
ECU	electronic control unit
FOT	fibre optic transceiver
LD	laser diode
MAC	media access control
MDI	media dependent interface
OSI	open systems interconnection
PCS	physical coding sublayer
PD	photo diode
PMA	physical medium attachment
PMD	physical medium dependent
TIA	trans impedance amplifier
VCSEL	vertical cavity surface emitting laser
x-GMII	(X)-gigabit media independent interface

5 TERMS AND DEFINITIONS

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

Term definition:

Optical harness	An optical cable with optical cable plugs on both ends, consisting of one or more optical sub-harnesses connected between two ECUs.
Optical sub-harness	Optical cable terminated with an optical plug or socket in both ends. Optical sub-harnesses are connected to each other with optical in-line connectors.
Active optical header	Optical header connector that contains at least the optical-to-electrical converters in the same component and is located at the ECU board edge.
Passive optical header	Optical header connector that does not include the optical-to-electrical converters in the same component, and is an optical in-line header that is locates at the ECU board edge
Optical in-line connector	Passive component consisting of a mating of an optical cable plug and an optical cable socket.

6 NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[1] IEEE 802.3cz™:2023, Physical Layer Specifications and Management Parameters for 2.5 Gb/s, 5 Gb/s, 10 Gb/s, 25 Gb/s and 50 Gb/s Automotive Optical Ethernet.

[2] ISO 24581:2024, General requirements and test methods of optical harness for up to 100 Gigabit communication

7 INTRODUCTION

ISO TC22/SC32 has issued ISO 24581 (General requirements and test methods of in-vehicle optical harnesses for up to 100Gbit/s communication) as an optical harness standard required for the widespread use of 2.5G, 5G, 10G, 25G, and 50GBASE-AU (Multi-Gigabit Optical Automotive Ethernet) which is standardized by IEEE802.3, for in-vehicle applications. However, ISO 24581 focuses on passive optical harnesses and does not specify the various components and specific functions in the system specified in the xGBASE-AU standard, so the addition of xGBASE-AU-specific provisions is required for use in in-vehicle applications. This document specifies the requirements necessary to support ISO standardization specific to xGBASE-AU.

8 SCOPE

This document provides requirements for the communication channel used by 2.5G, 5G, 10G, 25G and 50GBASE-AU compliant transceivers according to IEEE 802.3cz.

Figure 1-1 shows the location of the communication channel, defined between the MDIs implementations of the transmitter PHY and the MDI of the receiver PHY, including the effect of both MDIs.
Figure 1-2 presents an implementation example of two ECUs connected, and the corresponding definition of communication channel. In a system implementation, the communication channel comprises the passive optical header connectors in both ends, or the passive part of the active optical header connectors in case that they include the PMD, and one or more connected optical sub-harnesses. Each optical sub-harness is composed by an optical harness terminated with an optical cable plug at each end.

Please note that this document does not include EMC-related requirements. EMC test method and requirements shall be compliant to “TBD/ EMC sub-group will develop document”. The red rectangle in Figure 1-1 indicates the subject of this document.

Figure 1-1 Subject of this document

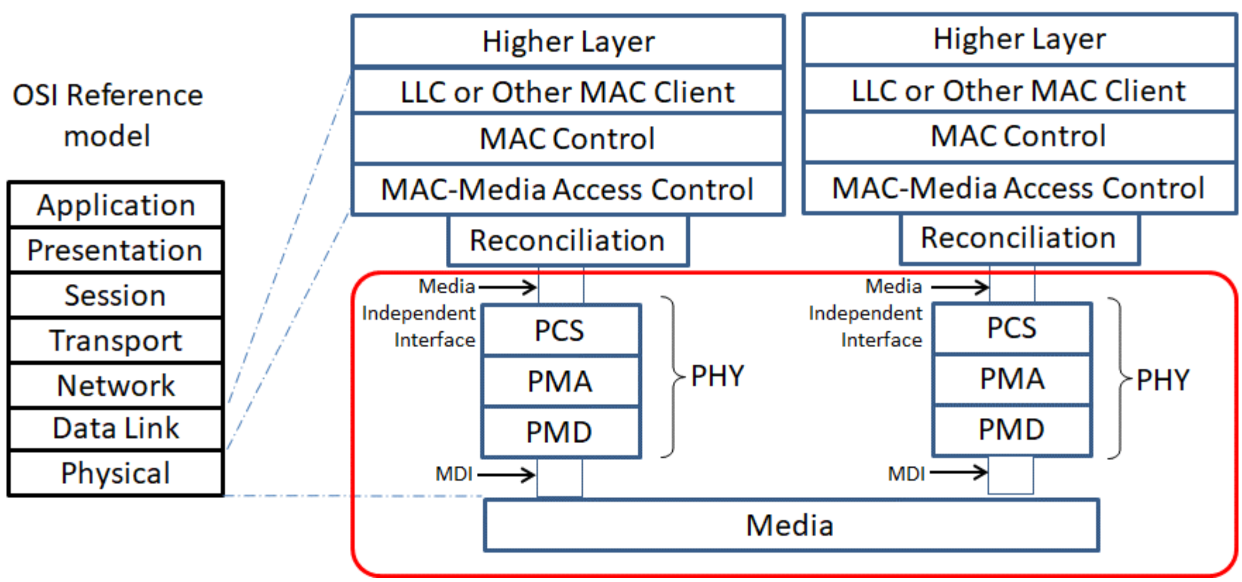
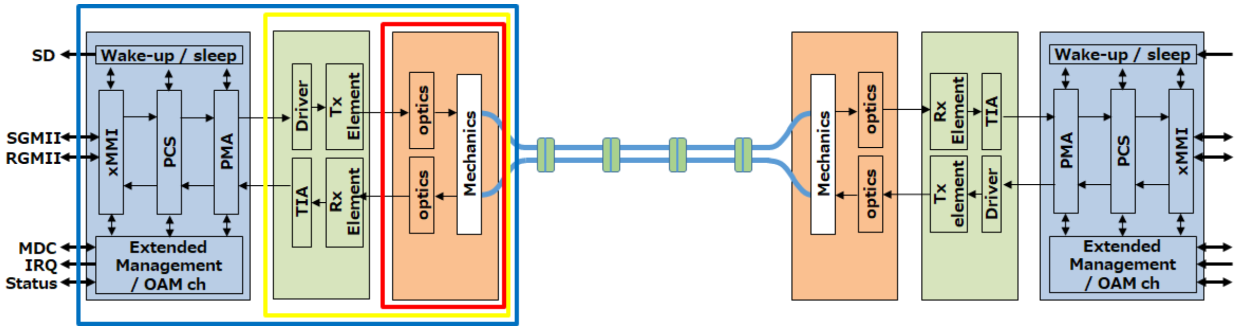


Figure 1-2 Definition of different types of Optical Headers



PCS/PMA+PMD+MDI	: Active Optical Header ; Integrated FOT Header, see subclause 9.3.2;
PCS/PMA and PMD+MDI	: Active Optical Header ; FOT Header, see subclause 9.3.3;
PCS/PMA/PMD and MDI	: Passive Optical Header ; see subclause 9.3.4;

9 CLASSIFICATION

9.1 Media, Wavelength and Components

The optical fibre and wavelength combinations that can be applicable for this system are shown in Table 9-1. The same channel shall be configured with the same type. Interoperability between different types is not guaranteed.

Table 9-1 Combination of Wavelength and optical fibre

	Components[1)]	Wavelength	Optical Fibre	Reference	Remarks
A	Type a	980 nm	AGF	IEC60793-2-10, A1 OM3	1)

1) Components specification and requirements are specified in subclause 13

9.2 Data rate

Multi-gigabit optical Automotive Ethernet shall support different data rate, as 2.5G, 5.0G, 10G, 25G and 50Gbit/s. Interoperability is not guaranteed when transceivers with different data rates are used in combination.

Table 9-2 Data rate and signal modulation

	2.5G	5G	10G	25G	50G	Remarks
IEEE 802.3cz	NRZ	NRZ	NRZ	NRZ	PAM4	

9.3 Optical header

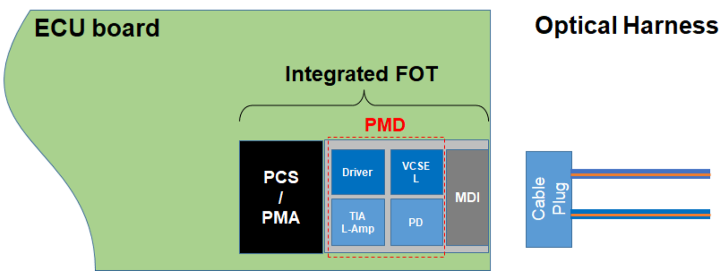
9.3.1 General

There are two types of optical header: Active optical header and passive optical header. Both are mounted on the ECU board edge and serve as optical alignment sockets that connect to the optical harness. This document describes two types of active optical headers. One is a type in which a PMD is built into the MDI that connects to the optical harness. The other is a type in which a PMD and PCS/PMA are integrated into the MDI that connects to the optical harness.

9.3.2 Active optical header (Integrated FOT)

This subtype of active optical header includes the implementation of the PMD sublayer and PCS/PMA sublayer of the PHY as well as the MDI. PMD includes the LD/PD, and a driver and TIA that are individually connected to them, and mutually converts optical signals and electrical signals. The PCS/PMA processes electrical signals between the MAC and PMD. The PCS encodes and decodes signals, and the PMA serializes and deserializes signals. It also has a buffer function. This type of active optical header is called a integrated FOT in this document. A high-speed electrical connection is required to connect the integrated FOT to the MAC of the MultiGBASE-AU PHY.

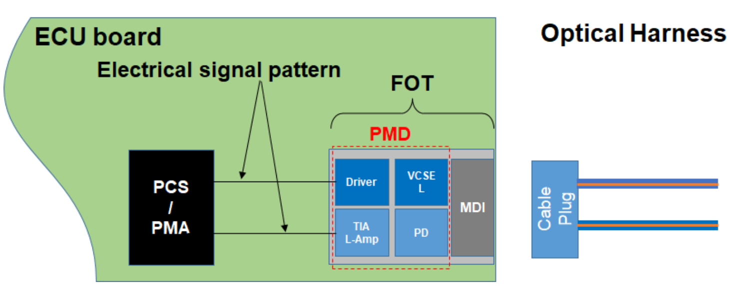
Figure 9-1 Active optical header (Integrated FOT)



9.3.3 Active optical header (FOT)

This subtype of active optical header includes the implementation of the PMD sublayer of the PHY as well as the MDI. PMD includes the LD/PD, and a driver and TIA that are individually connected to them, and mutually converts optical signals and electrical signals. This type of active optical header is called a FOT. A high-speed electrical connection is required to connect the FOT to the PCS/PMA sublayer of the MultiGBASE-AU PHY. This document specifies electrical signalling requirements between PMD and PMA implementations for 25GBASE-AU.

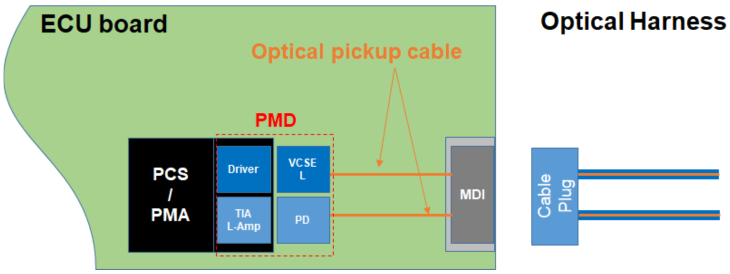
Figure 9-2 Active optical header (FOT)



9.3.4 Passive optical header

The passive optical header, also called an MDI connector relays the optical harness and the optical pickup (optical pigtail) cable that are optically coupled to the LD/PD mounted on the ECU board.

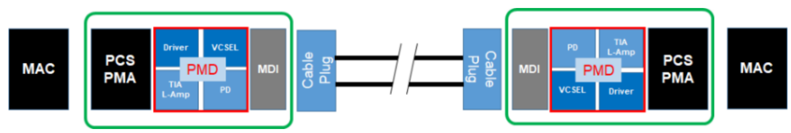
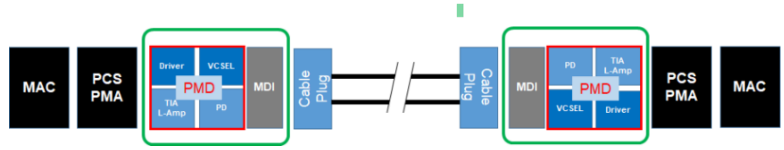
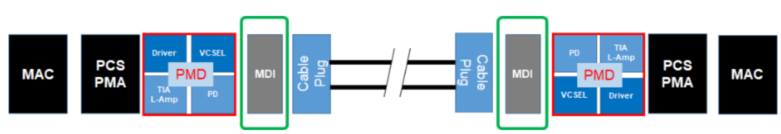
Figure 9-3 Passive optical header



10 USE CASE

The use cases for Multi-giga optical Ethernet communication channel into automobiles are shown in Table 10-1

Table 10-1 USE CASE

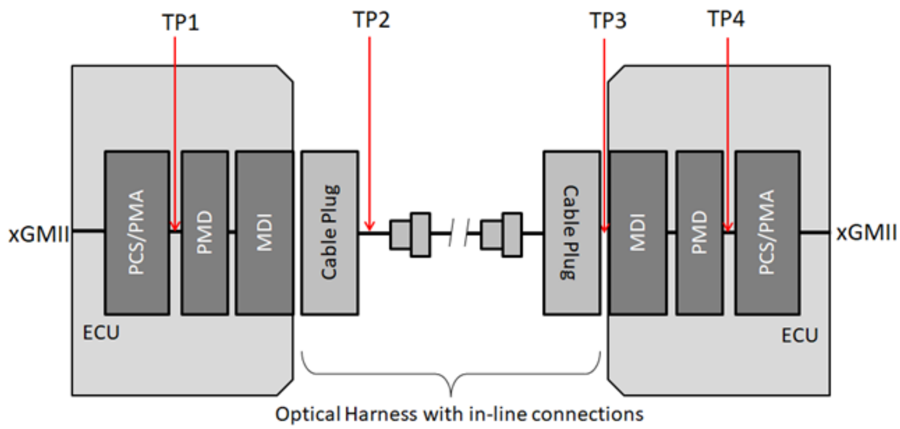
	Use case	Description
1	**Active header** **(Integrated FOT header)** The integrated FOT also implements the PCS/PMA in the FOT housing, and the specifications of the input and output electrical signals of the integrated FOT shall meet conform to the MAC specifications.	
2	**Active header** **(FOT header)** The FOT converts between serial electrical signals of the PCS/PMA and optical signals. The optical signals are output to the optical harness via the MDI built into the FOT. The opposing FOT converts the optical signals into serial electrical signals and inputs them to the PCS/PMA.	
3	**Passive header** **(MDI header)** The MDI header receives optical input and output from the VCSEL or PD mounted on the ECU board, and relays bidirectional optical signals to the optical harness.	

Note: Green rectangle defines the position of the header subtypes in the communication system

11 TEST POINT DEFINITIONS

The test points (TP) corresponding to each use case are shown in Table 10-1.

Figure 11-1 TEST POINTS



The detailed each TPs are shown in Table 11-1.

Table 11-1 I/O conditions for each use case

	TX		RX	
	Input	Output	Input	Output
PCS/PMA	xGMII	TP1	TP4	xGMII
Use case 1 **Integrated FOT** PCS/PMA+PMD+MDI	xGMII-	TP2	TP3	xGMII
Use case 2 **FOT** PMD+MDI	TP1	TP2	TP3	TP4
Use case 3 **MDI**	-	TP2	TP3	-

IEEE 802.3cz system power budget test points				

12 ELECTRICAL AND OPTICAL CHARACTERISTICS

The electro-optical characteristics of TP1 to TP4 are specified due to establish a communication channel. Each TP shall meet the following requirements.

The electrical or optical characteristics of TP1 to TP4 are specified due to establish a communication channels. Each test point shall meet the following subclauses. TP2 and TP3 are specified as optical test points for multi-gigabit optical in-vehicle Ethernet systems, regardless of the type of optical header, and their standard values shall refer to IEEE802.3cz:2023. However, in system where an active header subtype FOT is used, additional electrical test points TP1 and TP4 are specified.

For 25Gbps and 50Gbps, the "Active optical header (Integrated FOT)" format in subclause 9.3.2 or the "Passive optical header" format in subclause 9.3.4 are practical, so there are no provisions for TP1 and TP4.

12.1 Test point-1 (TP1)

12.1.1 General

The requirements for TP1 are only applicable to 10Gbps active optical header implementing the PMD. See table 10-1 in clause 10 and table 11-1 in clause 11.

12.1.2 Requirement

The requirements for TP1 are electrical signal characteristics measured at specified points (between PCS/PMA and FOT). Standard values are determined individually depending on the communication speed of Multi-Gig Optical Ethernet. Electrical definitions shall be referred to IEEE802.3 Annex 86A.

Table 12-1 Electrical signal characteristics at TP1

	Parameter	Requirements	Reference value / 10Gbps (NRZ)	Note
1	Single ended input voltage tolerance	Shall be greater than or equal to the minimum input voltage of the IC.	0.3v ~ 4.0V	
2	AC common-mode input voltage tolerance	The common mode voltage range shall be specified.	min 15mV	
3	Differential input return loss	Reflection shall be kept sufficiently small.	12 - 2√ f 0.01 ≤ F < 4.11 6.3 - 13log10(f/ 5.5) 4.11 ≤ F < 11.1	
4	Differential to common-mode input return loss	Reflection shall be kept sufficiently small.	min 10dB	

5	J2 Jitter tolerance	Shall not affect transmission characteristics by jitter.	min 0.17UI	
6	J9 Jitter tolerance	Shall not affect transmission characteristics by jitter.	min 0.29UI	
7	Data Dependent Pulse Width Shrinkage (DDPWS) tolerance	Eye waveform shall be sufficiently open.	-min 0.07UI	
8	Eye mask coordinates: X1, X2, Y1, Y2	Eye waveform shall be sufficiently open.	X1: 0.11UI, X2: 0.31UI, Y1: 95mV, Y2: 350mV	

12.2 Test point-2 (TP2)

12.2.1 General

IEEE 802.3cz:2023 defines only TP2 as a test point at the end of a 1m patch cord attached to an optical header. This test point, TP2, is useful for testing optical components. TP2 is also an applicable test point when specifying active header connectors that implement PMD.

12.2.2 Requirement

Since the minimum average optical power (AOP) specified in IEEE 802.3cz at TP2 does not guarantee a reliable link, minimum Optical Modulation Amplitude (OMA_outer), which depends on the TDFOM transmitter value, is specified in IEEE 802.3cz Table 166-9 and are taken in this document as reference.

Table 12-2 BASE-AU PMD transmitter optical characteristics at TP2

(Table 166–9 of IEEE802.3cz:2023)

Parameter	2.5GBASE-AU	5GBASE-AU	10GBASE-AU	25BASE-AU	50GBASE-AU	Unit
Average launch power (min)	-4.3	-3.3	-2.4	-1.4	-0.3	dBm
Average launch power (max)	3,9				5,0	dBm
Optical Modulation Amplitude (OMA_{outer})(max)	3.2				4.3	dBm
Optical Modulation Amplitude (OMA_{outer})(min)	Max (A, TDFOM + B)					dBm

A	-5	-4	-3.1	-2.1	-1	dBm
B	-5	-3.9	-2.7	-1.5	-0.4	dBm
Transmitter distortion figure of merit (TDFOM)(max)	1	1	2	2.5	3	dB
Transmitter distortion figure of merit (TDFOM)(min)	-0.3	-0.4	-1.0	-1.5	-1.7	dB
Average launch power of OFF transmitter (max)	-30					dBm

12.3 Test point-3 (TP3)

12.3.1 General

IEEE 802.3cz defines exclusively TP3 as the test point located at the MDI of the receiver. However, other test points at the receiver side can be useful to test optical components. (see Figure 11-1).

12.3.2 Requirement

Table 12-3 shows in the first row the minimum average receive power (AOP) specified in IEEE 802.3cz at TP3. Second row shows the minimum OMA_outer specified at TP3b (equivalent to TP3 in IEEE 802.3cz) for the condition 1 conformance test signal at TP3. Third row shows the minimum OMA_outer specified at TP3 for the condition 1 conformance test signal at TP3.

Table 12-3 BASE-AU PMD receiver optical characteristics at TP3

(Table 166–10 of IEEEE802.3cz:2023)

Parameter	2.5GBASE-AU	5GBASE-AU	10GBASE-AU	25GBASE-AU	50GBASE-AU	Units
Average receive power[b] (min)	-18	-17	-16.1	-13.1	-8.3	dBm
Average receive power[b] (max)	3,9				5,0	dBm
Receive power (OMA_{outer})(max)	3.2				4.3	dBm

Receiver reflectance (max)	-12					dBm
Stressed receiver sensitivity[c] (OMA_{outer}), condition 1 (max)	-15.1	-14	-11.8	-8.1	-2.8	dBm
Stressed receiver sensitivity[d] (OMA_{outer}), condition 2 (max)	-16.1	-15.1	-14.2	-11.2	-6.4	dBm
C	-16,1	-15,1	-14,2	-11,2	-6,4	dBm
D	-16,1	-15,0	-13,8	-10,6	-5,8	dBm

b) Average receive power (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.

c) Measured with condition 1 conformance test signal at TP3 (see 166.6.4.13.2 of IEEE802.3cz:2023) for the BER specified in 166.1 of IEEE802.3cz:2023.

d) Measured with condition 2 conformance test signal at TP3 (see 166.6.4.13.2 of IEEE802.3cz:2023) for the BER specified in 166.1 of IEEE802.3cz:2023.

NOTE: the fulfilment of minimum AOP values in Table 5 does not guarantee a reliable connection. The optical received signal shall additionally comply with the parameters given in IEEE 802.3 Table 166-10".

12.4 Test point-4 (TP4)

12.4.1 General

The requirements for TP4 are only applicable to 10GBps active optical header implementing the PMD. See table 10-1 in clause 10 and table 11-1 in clause 11.

12.4.2 Requirement

The requirements for TP4 are electrical signal characteristics measured at specified points (between PCS/PMA and FOT). Standard values are determined individually depending on the communication speed of Multi-Gig Optical Ethernet. Electrical definitions shall be referred to IEEE802.3 Annex86A.

Table 12-4 Electrical signal characteristics at TP4

	Parameter	Requirements	Reference value / 10Gbps (NRZ)	Note
1	Single ended output voltage tolerance	Shall be greater than or equal to the minimum input voltage of the IC.	0.3v ~ 4.0V	
2	AC common-mode output voltage (RMS)	The common mode voltage range shall be specified.	max 7.5mV	

3	Termination mismatch at 1MHz	Transmission line and impedance shall be matched.	max 5%	
4	Differential output return loss	Reflection shall be kept sufficiently small.	$12 - 2\sqrt{f}$ $0.01 \le F < 4.11$ $6.3 - 13\log10(f/5.5)$ $4.11 \le F < 11.1$	
5	Output transition time, 20% to 80%	Eye waveform shall be sufficiently open.	min 28ps	
6	J2 Jitter output	Shall not affect transmission characteristics by jitter.	max 0.42UI	
7	J9 Jitter output	Shall not affect transmission characteristics by jitter.	max 0.65UI	
8	Eye mask coordinates: X1, X2, Y1, Y2	Eye waveform shall be sufficiently open.	X1: 0.29UI, X2: 0.50UI, Y1: 150mV, Y2: 425mV	

13 OPTICAL COMPONENTS

Unless otherwise instructed by the OEM, the optical components specified for type-A that is defined Table 9-1 shall be used.

13.1 Optical cable

13.1.1 General

A1-OM3 or A1-OM4 as the optical transmission medium for this application has a wide range and low loss. An optical cable designed to maintain the original performance in an automobile environment is required to have various performances described below. Also, since the optical cable is bundled together with other electric cables, compatibility with them is also required.

13.1.2 Optical performance

13.1.2.1 Optical attenuation under the steady state

13.1.2.1.1 General

Since optical cables using OM3 or OM4 as transmission media have very low attenuation, optical cable attenuation is specified as the longest optical cable (40m) specified by IEEE802.3cz. If the optical cable is shorter than that, the same specified value shall be used without conversion by length.

13.1.2.1.2 Test setup and methods

The test setup or test method of optical attenuation measurement under the steady state is specified in ISO 350 24581:2024 subclause 6.3, except that in this document, the DUT is replaced by a 40 m optical cable length.

13.1.2.1.3 Requirement

The optical cable attenuation of 40 m shall be 0,2 dB or less. The cable attenuation coefficient shall be maximum 4,0 dB/km at the designated wavelength.

13.1.2.1.4 Reference

ISO 24581:2024 subclause 6.3.

13.1.2.2 Optical attenuation under the environmental load

13.1.2.2.1 General

A high temperature exposure test, a low temperature exposure test, and a high temperature/low temperature cycle test are specified as environmental property tests for optical cables. The length of the DUT during the test is 40 m, the maximum length specified in IEEE802.3cz, and a temperature load is applied to the entire DUT. If the optical cable is shorter than that, the same specified value shall be used without conversion by length.

13.1.2.2.2 Test setup and methods

The test setup or test method of optical attenuation measurement under/after the environmental load test uses the method specified in ISO 24581:2024 subclause 6.3, except that in this document, the DUT is replaced by a 40 m optical cable length.

Allowable attenuation increase after high storage temperature exposure is defined in ISO 24581:2024 subclause 6.3.4.

Allowable attenuation increase after low storage temperature exposure is defined in ISO 24581:2024 subclause 6.3.5.

Allowable attenuation increase during and after operating temperature exposure is defined in ISO 24581:2024 subclause 6.3.6.

13.1.2.2.3 Requirement

Attenuation increase of the DUT (40 m) shall be 0,8 dB or less during or after environmental loading.

13.1.2.2.4 Reference

ISO 24581:2024 subclauses 6.3.

13.1.2.3 Optical attenuation under/after the physical loading

13.1.2.3.1 General

Optical cables installed in automobiles are treated in the same way as existing electric wires for automobiles, so they are required to have the same durability.

13.1.2.3.2 Test setup and methods

Test setup or test method of optical attenuation measurement under/after the physical load test is specified in ISO 24581:2024 subclause 6.3.

Minimum attenuation increase by residual bending stress is defined in ISO 24581:2024 subclause 6.3.7.

Maximum bending attenuation is defined in ISO 24581:2024 subclause 6.3.8.

Tensile stress is defined in ISO 24581:2024 subclause 6.3.9.

Crush toughness is defined in ISO 24581:2024 subclause 6.3.10.

Impact resistance is defined in ISO 24581:2024 subclause 6.3.11.

Static torsion toughness is defined in ISO 24581:2024 subclause 6.3.12.

Resistance to flame propagation is defined in ISO 24581:2024 subclause 6.3.13.

13.1.2.3.3 Requirement

Attenuation increase shall be 0,2 dB or less during or after physical loading.

13.1.2.3.4 Reference

ISO 24581:2024 subclause 6.3.

13.1.2.4 Mechanical reliability under the specific environmental stress (Informative)

13.1.2.4.1 General

Optical cables are exposed to various environmental stresses depending on how they are handled before being assembled to the vehicle body and the route through which they are assembled to the vehicle body. This subclause describes tests to confirm that the DUT (optical cable) maintains adequate mechanical performance even under these special environmental stresses.

13.1.2.4.2 Test setup and methods

The test setup or test method for the physical resistance of optical harness is derived from ISO 19642-2:2019(E) 5.4.11 Resistance to liquid chemicals.

13.1.2.4.3 Requirement

Chemicals tested and specific mechanical performance should be agreed upon between the OEM and supplier.

13.1.2.5 Optical cable design

13.1.2.5.1 General

The optical fibre (OM3 or OM4) is reinforced with a protective member and a protective coating for use in the same environment as automotive electrical harnesses. There are many types of construction and protective materials for optical cables, but these are competitive areas among suppliers and are not standardized. The durability performance listed above are items that should be observed as an optical cable for automobiles, so they do not limit the item agreed between the automobile manufacturer and the supplier.

13.1.2.5.2 Cable design

The structural components of the optical cable are not specified. Several jacket structures have been proposed to limit the bending radius or to provide resistance to lateral pressure. In addition, a structure in which strength fibres are attached vertically to the optical fibre to provide tension resistance is also commonly used. The optical cable described in ISO 24581:2024 subclause 6.3.1 has a structure that satisfies the provisions of subclause 9.1 in this document, and it is one of the candidates for in-vehicle optical cables.

13.2 Optical header

13.2.1 General

There are three types of optical header (Active optical header (integrated FOT), Active optical header (FOT) and Passive optical header) that mate with the optical harness, and all can be installed on the board edge of the ECU. All optical header types share the same mechanical and optical requirements which are described in the following subclauses. Active header refers indistinctly to an active header (integrated FOT) as specified in 9.3.2 or to an active header (FOT) as specified in 9.3.3.

13.2.2 Optical performance

13.2.2.1 General

An optical header is a type of important optical socket that is built in the back panel of the ECU and connects with the optical harness. The connector housing itself shall keep stable dimensions under the automotive environment. If or when the optical header dimensions are standardized in ISO 24581, then interoperability between suppliers will be required. This subclause specifies the environmental performance of the optical header.

13.2.2.2 Active optical header

13.2.2.2.1 General

The DUT for evaluating the positional stability of these reference planes is either the active header itself or a passive optical header with a temporary light source attached. The test is measured as a change in the light intensity output from a standard optical plug/cable set mated to the DUT, and is evaluated as the presence or absence of deformation of the optical header connector housing. The storage temperature of the active mechanism used in this test shall be equal to or higher than the test temperature.

13.2.2.2.2 Test setup and methods

The test setup or test method for the dimensional stability of optical header connector housings after environmental stress test are specified in ISO 24581:2024 subclause 7.2.

High temperature exposure test for optical header is defined in ISO 24581:2024 subclause 7.2.5.

Low temperature exposure test for optical header is defined in ISO 24581:2024 subclause 7.2.6.

The concept of operating temperature range for optical header is defined in ISO 24581:2024 subclause 7.2.7.

13.2.2.2.3 Requirement

The optical header connector housing dimensions after the test should be within tolerances specified by the manufacture. And the optical intensity change from the standard optical cable/plug set between initial and after shall be 0,2 dB or less.

13.2.2.2.4 Reference

ISO 24581:2024 subclauses 7.2.

13.2.2.3 Passive optical header

13.2.2.3.1 General

When the PMD and MDI are separated, the PMD mounted near the communication PHY connects to the passive optical header connector mounted on the back panel of the ECU using a short optical cable or optical waveguide. A passive optical header connector is used as an optical in-line connector for connecting with an optical harness. The passive optical header only functions as MDI, so it is evaluated in the same way as the optical cable socket. Optical cable socket definitions are described in 9.1.4.

13.2.2.3.2 Test setup and methods

environmental stress test are specified in ISO 24581:2024 subclause 7.4.

High temperature exposure test for optical header connector housings is defined in ISO 24581:2024 subclaus 7.4.5.

Low temperature exposure test for optical header connector housings is defined in ISO 24581:2024 subclause 7.4.6.

The concept of operating temperature range for optical header connector housing is defined in ISO 24581:2024 subclause 7.4.7.

13.2.2.3.3 Requirement

The optical header connector housing dimensions after the test should be within tolerances specified by the manufacturer. And the optical intensity change from the standard optical cable plug set between initial and after test shall be 0,2 dB or less.

13.2.2.3.4 Reference

ISO 24581:2024 subclause 7.4.

13.2.3 Optical header design

13.2.3.1 General

The following two types of optical header connectors are available.

13.2.3.2 Optical header housing for active optical header

13.2.3.2.1 Header housing

Active headers shall be connected with the optical harnesses used in multi-gigabit optical Ethernet systems. Therefore, the mating part of the header shall have a structure that can mate with the optical cable plug that make up the optical harness. This structure is specified as a mating interface of a MDI. However, since PMD is a competitive area for suppliers, the entire design of the header housing cannot be specified, but the optical transmitting and receiving window of the PMD and the MDI shall have good optical coupling. If an optical harness compliant with ISO 24581:2024 is used in a multi-gigabit optical Ethernet system, the active header mating interface can refer to ISO 24581:2024 informative Annex C.1.1.

13.2.3.2.2 Key coding

A key coding is specified to prevent mis-mating, but it cannot be uniformly specified because it depends on the connector design used in the system. If an optical harness compliant with ISO 24581:2024 is used in a multi-gigabit optical Ethernet system, the active header mating interface can refer to ISO 24581:2024 informative Annex C.1.2.

13.2.3.3 Optical header housing for passive optical header

13.2.3.3.1 Header housing

Passive headers shall be mated with the optical harnesses used in multi-gigabit optical Ethernet systems. Therefore, the mating part of the header shall have a structure that can mate with the optical cable plug that make up the optical harness. This structure is specified as a mating interface of a MDI. If an optical harness compliant with ISO 24581:2024 is used in a multi-gigabit optical Ethernet system, the header mating interface can refer to ISO 24581:2024 informative Annex C.1.1.

13.2.3.3.2 Key Coding

A key coding is specified to prevent mis-mating, but it cannot be uniformly specified because it depends on the connector design used in the system. If an optical harness compliant with ISO 24581:2024 is used in a multi-gigabit optical Ethernet system, the passive header mating interface can refer to ISO 24581:2024 informative Annex C.1.2.

13.3 Optical cable plug

13.3.1 General

An optical cable plug is an optical connector used at both ends of an optical harness or at one end of an optical in-line connectors. A key code in an optical cable plug may be incorporated to prevent erroneous insertion. The main structure of optical cable plug is precise and be required the same environmental tolerance as electrical connectors for automobile.

13.3.2 Optical performance

13.3.2.1 Optical coupling performance under the environmental stress

13.3.2.1.1 General

Optical cable plug has both mechanical and optical reference planes within the housing for proper mating with an optical header or an optical cable socket. These reference planes shall not move from their initial position, even if the optical cable plug experiences any environmental stresses. However, since these reference planes are provided inside the optical cable plug, direct visual inspection is impossible. To test the positional stability of these reference planes, a temporary optical cable is assembled to the optical cable plug and change of the optical intensity output from a mating standard optical cable socket set is measured due to environmental stress. If the optical cable plug is deformed by the environmental stress, the mechanical and optical reference planes are moved and the optical power available through a standard optical cable socket set is decreased. This is an alternative test that uses changes in optical coupling efficiency to check for deformation of the optical connector housing itself.

13.3.2.1.2 Test setup and methods

The test setup or test method for the dimensional stability of optical cable plug housing after environmental stress test are specified in ISO 24581:2024 subclause 7.3.

High temperature exposure test for optical header connector housings is defined in ISO 24581:2024 subclause 7.3.5.

Low temperature exposure test for optical header connector housings is defined in ISO 24581:2024 subclause 7.3.6.

The concept of operating temperature range for optical header connector housing is defined in ISO 24581:2024 subclause 7.3.7.

13.3.2.1.3 Requirement

The optical cable plug housing dimensions after the test shall be within tolerances specified by the manufacturer. And the average optical power change from the standard optical cable socket set between initial and after test shall be 0,2 dB or less.

13.3.2.1.4 Reference

ISO 24581:2024 subclause 7.3.

13.3.3 Physical performance

13.3.3.1 Physical strength related to mating target (optical header, cable socket)

13.3.3.1.1 General

ISO 8092 defines required specifications for automotive electrical connectors based on the usage environment and handling conditions. Multi-Giga Optical Ethernet connectors are also used in automobiles, so existing regulations shall be complied with. The optical cable plug connector requires the same physical performance when mated with an optical cable socket connector or optical header connector. Furthermore, since the optical harness is bundled together with the automotive electrical harness, the gripping strength between the optical cable plug and the optical cable shall be the same as that of the electric wire.

13.3.3.1.2 Test setup and methods

The test setup or test method for the physical performance of optical cable plug housing after/during physical stress test are specified in ISO 24581:2024 subclause 8.7.

Minimum tensile strength of the coupling mechanism is defined in ISO 24581:2024 subclause 8.7.7.

Maximum lock cancellation force for release is defined in ISO 24581:2024 subclause 8.7.9.

Minimum cable retention is defined in ISO 24581:2024 subclause 8.7.11.

13.3.3.1.3 Requirement

Minimum tensile strength of the coupling mechanism shall be 100 N.

Maximum lock cancellation force for release shall be 20 N.

Minimum cable retention shall be 110 N.

13.3.3.1.4 Reference

ISO 24581:2024 subclause 8.7.

13.3.4 Optical cable plug design

13.3.4.1 General

The following a type of optical cable plug housing is available.

13.3.4.2 Optical cable plug housing

Since the optical cable plug mates with an optical cable socket to provide an optical in-line connection, the optical cable plug shall have the structure that can be mated with the optical cable socket. This structure is specified as the mating interface of the optical cable plug. The structure for fixing the optical cable to the optical cable plug is not regulated because it is an area of competition among suppliers. If an optical harness compliant with ISO 24581:2024 is used in a Multi-Gigabit Optical Ethernet system, the mating interface of the optical cable plug can refer to ISO 24581:2024 informative Annex C.1.3.

13.3.4.3 Key coding

A key coding is specified to prevent mis-mating, but it cannot be uniformly specified because it depends on the connector design used in the system. If an optical harness compliant with ISO 24581:2024 is used in a multi-gigabit optical Ethernet system, the optical cable plug mating interface can refer to ISO 24581:2024 informative Annex C.1.2.

13.4 Optical cable socket

13.4.1 General

An optical cable socket is an optical connector used at both ends of an optical harness or at one end of an optical in-line connectors. A key code in an optical cable socket may be incorporated to prevent erroneous insertion. The main structure of the optical cable socket is precise and requires the same environmental tolerance as electrical connectors for an automobile.

13.4.2 Optical performance

13.4.2.1 Optical coupling performance under the environmental stress

13.4.2.1.1 General

Optical cable socket has both mechanical and optical reference planes within the housing for proper mating with an optical cable plug. These reference planes shall not move from their initial position, even if the optical cable socket experiences any environmental stresses. However, since these reference planes are provided inside the optical cable socket, direct visual inspection is impossible. To test the positional stability of these reference planes, a temporary optical cable is assembled to the optical cable socket and change of the optical intensity output from a mating standard optical cable plug set is measured due to environmental stress. If the optical cable socket is deformed by the environmental stress, the mechanical and optical reference planes are moved and the optical power available through a standard optical cable plug set is decreased. This is an alternative test that uses changes in optical coupling efficiency to check for deformation of the optical connector housing itself.

13.4.2.1.2 Test setup and methods

The test setup or test method for the dimensional stability of optical cable socket housing after environmental stress test are specified in ISO 24581:2024 subclause 7.4.

High temperature exposure test for optical header connector housings is defined in ISO 24581:2024 subclause 7.4.5.

Low temperature exposure test for optical header connector housings is defined in ISO 24581:2024 subclause 7.4.6.

The concept of operating temperature range for optical header connector housing is defined in ISO 24581:2024 subclause 7.4.7.

13.4.2.1.3 Requirement

The optical cable socket housing dimensions after the test shall be within tolerances specified by the manufacturer. And the average optical power change from the standard optical cable plug set between initial and after test shall be 0,2 dB or less.

13.4.2.1.4 Reference

ISO 24581:2024 subclause 7.4.

13.4.3 Physical performance

13.4.3.1 Physical strength related to mating target

13.4.3.1.1 General

ISO 8092 defines required specifications for automotive electrical connectors based on the usage environment and handling conditions. Multi-Giga Optical Ethernet connectors are also used in automobiles, so existing regulations shall be complied with. The optical cable socket requires adequate physical performance when mated with an optical cable plug. Furthermore, since the optical harness is bundled together with the automotive electrical harness, the gripping strength between the optical cable socket and the optical cable shall be the same as that of the electric wire.

13.4.3.1.2 Test setup and methods

The test setup and test method for the physical performance of optical cable socket housing after/during physical stress test are specified in ISO 24581:2024 subclause 8.7.

Minimum tensile strength of the coupling mechanism is defined in ISO 24581:2024 subclause 8.7.7.

Maximum lock cancellation force for release is defined in ISO 24581:2024 subclause 8.7.9.

Minimum cable retention is defined in ISO 24581:2024 subclause 8.7.11.

13.4.3.1.3 Requirements

Minimum tensile strength of the coupling mechanism shall be 100 N.

Maximum lock cancellation force for release shall be 20 N.

Minimum cable retention shall be 110 N.

13.4.3.1.4 Reference

ISO 24581:2024 subclause 8.7.

13.4.4 Optical cable socket design

13.4.4.1 General

The following a type of optical cable socket housing is available.

13.4.4.2 Optical cable socket housing

Since the optical cable socket mates with an optical cable plug to provide an optical in-line connection, the optical cable socket shall have the structure that can be mated with the optical cable plug. This structure is specified as the mating interface of the optical cable socket. The structure for fixing the optical cable to the optical cable socket is not regulated because it is an area of competition among suppliers. If an optical harness compliant with ISO 24581:2024 is used in a Multi-Gigabit Optical Ethernet system, the mating interface of the optical cable socket can refer to ISO 24581:2024 informative Annex C.1.4.

13.4.4.3 Key coding

A key coding is specified to prevent mis-mating, but it cannot be uniformly specified because it depends on the connector design used in the system. If an optical harness compliant with ISO 24581:2024 is used in a multi-gigabit optical Ethernet system, the optical cable socket mating interface can refer to ISO 24581:2024 informative Annex C.1.2.

13.5 Optical in-line connector

13.5.1 General

Automotive electrical harnesses are designed in blocks as sub-harnesses. When each sub-harness is attached to a vehicle, each part is connected by in-line connectors, and the electrical harness is finally completed. Optical harnesses are treated similarly, so optical in-line connectors are important components. Therefore, the optical in-line connector should not only have low attenuation but also have optical stability under the automotive environment. In this subclause, not only the basic optical performance but also the optical stability of optical in-line connectors will be confirmed under the test conditions in accordance with ISO 16750-3 and ISO 16750-4.

13.5.2 Optical performance

13.5.2.1 Optical in-line attenuation under the steady state

13.5.2.1.1 General

Optical in-line connectors have ferrules and sleeves to align the optical axes of optical fibres (OM3, OM4). A ferrule is assembled to each opposing optical fibre end, and an annular sleeve aligns the optical axes of the opposing ferrules. Since both the ferrule and the sleeve are made of materials with excellent thermal stability, the optical fibre cores can be brought into stable physical contact with each other. Optical in-line connector housings (plug, socket) are designed so that these optical components can be used in automotive environments.

13.5.2.1.2 Test setup and methods

The test setup or test method for the optical performance of optical in-line connection is specified in ISO 24581:2024 subclause 8.7.

Coupling attenuation at optical in-line connection is defined in ISO 24581:2024 subclause 8.7.1.

Optical return loss of optical in-line connection is defined in ISO 24581:2024 subclause 8.7.2.

13.5.2.1.3 Requirement

Coupling attenuation of the in-line connection shall be 0,6 dB or less.

Optical return loss of the in-line connection shall be 20 dB or more.

13.5.2.1.4 Reference

ISO 24581:2024 subclause 8.7.

13.5.2.2 Optical in-line attenuation under the environmental stress

13.5.2.2.1 General

Optical harnesses containing optical in-line connectors that are bundled together with electrical harnesses shall have the same environmental tolerance as the electrical harnesses. The fitted state of the ferrule and sleeve which is important for optical alignment shall be maintained in the automotive environment. Therefore, the positional stability of the optical reference plane and mechanical reference plane of the optical cable plug and optical cable socket that make up the optical in-line connector shall be ensured. However, since it is difficult to evaluate each of these components, the quality is determined by measuring the attenuation change of the optical in-line connector (cable plug and cable socket) assembled with optical cables.

13.5.2.2.2 Test setup and methods

The test setup or test method for the optical performance of optical in-line connection is specified in ISO 24581:2024 subclause 8.7.

The attenuation change of an optical in-line connection after high storage temperature exposure test is defined in ISO 24581:2024 subclause 8.7.3.

The attenuation change of an optical in-line connection after low storage temperature exposure test is defined in ISO 24581:2024 subclause 8.7.4.

The attenuation increase of an in-line optical connection during and after operating temperature exposure test is defined in ISO 24581:2024 subclause 8.7.5.

13.5.2.2.3 Requirements

Attenuation increase of the optical in-line connection shall be 0,2 dB or less during and after the test for temperatures up to 85 ˚C. Furthermore, 0,4 dB or less during the test when temperatures are above 85 ˚C and 0,2 dB or less after the test of temperatures above 85 ˚C.

13.5.2.2.4 Reference

ISO 24581:2024 subclause 8.7.

13.5.2.3 Optical in-line attenuation under the physical stress

13.5.2.3.1 General

Optical harnesses containing optical in-line connectors that are bundled together with electrical harnesses shall have the same environmental tolerance as the electrical harnesses. The fitted state of the ferrule and sleeve which is important for optical alignment shall be maintained under the automotive environment. Therefore, the positional stability of the optical reference plane and mechanical reference plane of the optical cable plug and optical cable socket that make up the optical in-line connector shall be ensured. However, since it is difficult to evaluate each of these components under the vibration environment, the quality is determined by measuring the attenuation change of the optical in-line connector (cable plug and cable socket) assembled with optical cables under the vibration environment.

13.5.2.3.2 Test setup and methods

The test setup or test method for the optical performance of optical in-line connection is specified in ISO 24581:2024 subclause 8.7.

Vibration resistance of optical in-line connector is defined in ISO 24582:2024 subclause 8.7.6

13.5.2.3.3 Requirements

An optical cable plug mated to an optical cable socket operates as an optical in-line connector. The amount of attenuation shall be 0.4 dB or less when a designated vibration load is applied, and 0.2 dB or less when the vibration load is subsequently removed.

13.5.2.3.4 Reference

ISO 24581:2024 subclause 8.7.

13.5.3 Physical performance

13.5.3.1 Optical in-line connector handling performance

13.5.3.1.1 General

Automotive electrical harnesses are designed in blocks as sub-harnesses. When each sub-harness is attached to a vehicle, each part is connected by in-line connectors, and the electrical harness is finally completed. Optical harnesses are treated similarly, so optical in-line connector is important component. In order to reduce the burden of mating operations on optical in-line connector, the maximum connector insertion force is defined. And the optical in-line connector is required to have stable attenuation even after repeated mating and un-mating. Furthermore, the optical cable gripping force of an optical cable connector is also required to be the same as the electric wire gripping force of an electrical connector.

13.5.3.1.2 Test setup and methods

The test setup or test method for the optical performance of optical in-line connection is specified in ISO 24581:2024 subclause 8.7.

Minimum tensile strength of the coupling mechanism is defined in ISO 24581:2024 subclause 8.7.7.

Maximum insertion force is defined in ISO 24581:2024 subclause 8.7.8.

Maximum lock cancellation force for release is defined in ISO 24581:2024 subclause 8.7.9.

Durability of repeated mating and un-mating is defined in ISO 24581:2024 subclause 8.7.10.

Minimum cable retention is defined in ISO 24581:2024 subclause 8.7.11.

13.5.3.1.3 Requirements

The tensile strength of the coupling mechanism of optical connectors shall be 100 N or more when the lock mechanism is damaged or the plug is uncoupled from the socket.

The insertion force of optical connectors shall be 44,1 N or less when the lock mechanism is applied.

The push force to disengage the latch lever until the optical connector (plug and socket with two optical fibres in each) uncouples shall be 20 N or less.

The coupling attenuation increase after each un-mate and mate operation shall be maximum 0,2 dB.

The attenuation increase of the DUT after cable retention test (110 N) shall be 0,2 dB or less.

13.5.3.1.4 Reference

ISO 24581:2024 subclause 8.7.

13.6 Optical harness

13.6.1 General

IEEE 802.3cz specifies a maximum optical attenuation between MDI interfaces of transmitter and receiver which can be used to accommodate connector, cable and other losses in the system. For typical attenuation values, 2.5G, 5G, 10G and 25Gbps BASE-AU systems can support a 40 m long harness with 4 inline connectors. 50Gbps can support 40 m long harness with 2 inline connectors. For connector with lower attenuation, more inline connectors can be added. The environmental requirements for automotive optical harnesses are the same as the ones specified for automotive electrical harnesses.

13.6.2 Optical performance

13.6.2.1 Total attenuation of an optical harness under the steady state

13.6.2.1.1 General

The total attenuation of the optical harness under the steady state is calculated by the total length of the optical cable and the number of optical in-line connectors. IEEE 802.3cz:2023 specifies a maximum insertion loss including all possible attenuation impairments. This insertion loss can be distributed among the effect of several inline connectors and fibre sections, which is typically assumed to be 4 inline connectors up to 25 Gbps and 2 inline connectors for 50 Gbps.

13.6.2.1.2 Test setup and methods

The test setup or test method for the optical performance of optical harness is specified in ISO 24581:2024 subclause 8.8.

The test setup or test method for the optical attenuation of optical harness is specified in ISO 24581:2024 subclause 8.8.1.

13.6.2.1.3 Requirements

The total attenuation of optical harness for 2.5G, 5G, 10G and 25G that is 40m harness length with 4 in-line connections shall be 2,6 dB or less

The total attenuation of optical harness for 50G that is 40m harness length with 2 in-line connections shall be 1,4 dB or less.

13.6.2.1.4 Reference

ISO 24581:2024 subclause 8.8.

13.6.2.2 Optical attenuation under the environment stress

13.6.2.2.1 General

Optical harnesses containing optical in-line connectors that are bundled together with electrical harnesses shall have the same environmental tolerance as the electrical harnesses. Although optical cable and optical in-line connector are individually checked for environmental tolerance, the optical harness that combines each shall also be checked for environmental tolerance. Of course, environmental tolerance is affected by the technology used to assemble optical connector to optical cable, so the evaluation tests described in this subclause are extremely important.

13.6.2.2.2 Test setup and methods

The test setup or test method for the optical performance of optical harness is specified in ISO 24581:2024 subclause 8.8.

High storage temperature exposure are defined in ISO 24581:2024 subclause 8.8.2.

Low storage temperature exposure are defined in ISO 24581:2024 subclause 8.8.3.

High operating temperature exposure are defined in ISO 24581:2024 subclause 8.8.4.

Low operating temperature exposure are defined in ISO 24581:2024 subclause 8.8.5.

13.6.2.2.3 Requirements

The optical attenuation change of optical harness with 4 in-line connections during and after the test for high/low temperature test shall be 1,8 dB or less for environmental conditions 85 ˚C or less. Furthermore, 2,6 dB or less when environmental conditions are above 85 ˚C and 1,8 dB after the test.

The optical attenuation change of optical harness with 2 in-line connections during and after the test for high/low temperature test shall be 1,4 dB or less for environmental conditions 85 ˚C or less. Furthermore, 1,8 dB or less when environmental conditions are above 85 ˚C and 1,4 dB after the test.

13.6.2.2.4 Reference

ISO 24581:2024 subclause 8.8.

13.6.2.3 Optical attenuation under the physical stress

13.6.2.3.1 General

Optical harnesses containing optical in-line connectors that are bundled together with electrical harnesses shall have the same physical resistance as the electrical harnesses. Although optical cable and optical in-line connector are individually checked for physical resistance, the optical harness that combines each shall also be checked for physical resistance. Of course, physical resistance is affected by the technology used to assemble optical connector to optical cable, so the evaluation tests described in this subclause are extremely important. These test groups are often tested using the same DUT and following a designated flowchart. Furthermore, the referenced flowchart may be changed to the contents agreed upon between the automobile manufacturer and the supplier.

13.6.2.3.2 Test setup and methods

The test setup or test method for the physical resistance of optical harness is specified in ISO 24581:2024 subclause 9.3.

Operation test after durability of mate and un-mate is defined in ISO 24581:2024 subclause 9.3.3.

Operation test after high temperature exposure is defined in ISO 24581:2024 subclause 9.3.4.

Operation test after high temperature exposure with vibration is defined in ISO 24581:2024 subclause 9.3.5.

Operation test after heat shock is defined in ISO 24581:2024 subclause 9.3.6.

Operation test after humidity / temperature cycle procedure is defined in ISO 24581:2024 subclause 9.3.7.

Operation test after specific vibration is defined in ISO 24581:2024 subclause 9.3.8.

13.6.2.3.3 Requirements

Total attenuation change of optical harness that includes 4 in-line connections shall be 1,8 dB or less.

Total attenuation change of optical harness that includes 2 in-line connections shall be 1,4 dB or less.

13.6.2.3.4 Reference

ISO 24581:2024 subclause 9.3

13.6.2.4 Optical attenuation under the specific environmental stress

13.6.2.4.1 General

Optical harnesses are exposed to various environmental stresses depending on how they are handled before being assembled to the vehicle body and the route through which they are assembled to the vehicle body. This subclause describes tests to confirm that the DUT (optical harness) maintains normal communication performance even under these special environmental stress. Because the test conditions are unique and unlikely to occur simultaneously, these tests are performed by preparing the DUT individually.

13.6.2.4.2 Test setup and methods

The test setup or test method for the physical resistance of optical harness is specified in ISO 24581:2024 subclause 9.4.

Operation test after specific physical shock is defined in ISO 24581:2024 subclause 9.4.2.

Operation test after chemical durability procedure is defined in ISO 24581:2024 ubclause 9.4.3.

Operation test after noxious gas exposure is defined in ISO 24581:2024 subclause 9.4.4.

Operation test after specific dust condition exposure is defined in ISO 24581:2024 subclause 9.4.5.

Operation test after specific drop impact procedure is defined in ISO 24581:2024 subclause 9.4.6.

13.6.2.4.3 Requirements

Total attenuation change of optical harness that includes 4 in-line connections shall be 1,8 dB or less.

Total attenuation change of optical harness that includes 2 in-line connections shall be 1,4 dB or less.

13.6.2.4.4 Reference

ISO 24581:2024 subclause 9.4

14 GENERAL SETUP AND MEASUREMENT FIXTURES

This subclause specifies measurement fixures which are used in test setups for measuring parameters at test points TP1, TP2, TP3 and TP4. See Figure 11-1.

14.1 Optical fixtures

1) Standard DC light source

The LD light source with designated wavelength output with the APC (automatic power control) to stabilize optical power. The optical light source shall meet the requirements specified in IEC 61300-3-4. The wavelength of the measurement light source shall be agreed between vehicle manufacturer and supplier. Unless otherwise provided, 980nm shall be used.

2) Standard modulated light source

The test light source should not only be able to specify the test modulation mode specified by IEEE802.3cz:2023, but also be equipped with PMD and MDI. It shall be possible to connect a DUT to which the optical signal at TP2 or TP3 can be evaluated. The wavelength of the measurement light source shall be agreed between vehicle manufacturer and supplier. Unless otherwise provided, 980nm shall be used.

3) Optical power meter

It shall meet the requirements specified in IEC 61300-3-4.

4) Optical continuous wave reflectometer (OCWR) or optical time domain reflectometer (OTDR)

These optical fixtures capable of measuring an optical return loss from 0 dB to 40 dB around designated wavelength shall be required. These are treated as dedicated instruments for return loss measurements.

14.2 Electrical fixtures

1) Function generator

It is defined by physical layer component manufacturer. Unless otherwise specified, signal generator that is able to generate a voltage signal from 2.5GHz to 50 GHz;

See Table 26 in the OPEN Alliance TC7 Test House document

2) Power supply

It is defined by physical layer component manufacturer. Unless otherwise specified, power supply that can drive LD and driver for convenience;

For the applied power, refer to the specifications of the LD and driver.

14.3 Atmospheric fixtures

1) Programmable oven

It can be controlled from −40 °C to +125 °C with a precision of ±3 °C.

2) Humidity/temperature chamber

It is controllable from −40 °C to +125 °C and is available for up to 90 % of humidity control.

3) Combined temperature/vibration chamber

It is defined in ISO 8092-2:2005, subclause 4.11.

4) Test chamber with temperature and time duration for temperature cycling

It is defined in ISO 16750-4:2010, subclause 5.3.2.

14.4 Mechanical fixtures

1) Tensile strength tester

It can measure the strength up to 200 N with 50 mm/min moving stage

2) Push-pull tester

It can measure the strength up to 200 N.

3) Vibration chamber

It is defined in ISO 16750-3:2012, subclause 4.1.

15 MEASUREMENT SETUPS

15.1 TP1 measurement method

15.1.1 General

The evaluation indices for the 10Gbps TP1 parameters shown in Table 8-1 are specified.

15.1.2 Electrical characteristics

The test setup or test method for the TP1 is specified in IEEE802.3 Annex 86A. Single ended input voltage tolerance is defined in in IEEE802.3 Annex 86A subclause 86A.5.3.1. AC common mode input voltage tolerance is defined in in IEEE802.3 Annex 86A subclause 86A.5.3.1. Differential input return loss is defined in IEEE802.3 Annex 86A subclause 86A.4.1.1. Differential to common-mode input return loss is defined in IEEE802.3 Annex 86A subclause 86A.4.1.1.

J2 Jitter tolerance is defined in IEEE802.3 Annex 86A subclause 86A.5.3.8.3.

J9 Jitter tolerance is defined in IEEE802.3 Annex 86A subclause 86A.5.3.8.3.

Data Dependent Pulse Width Shrinkage (DDPWS) tolerance is defined in IEEE802.3 Annex 86A subclause 86A.5.3.4. Eye mask coordinates is defined in IEEE802.3 Annex 86A subclause 86A.5.3.6. Evaluation conditions for “Crosstalk calibration signal VMA” and “Crosstalk calibration signal transition times, 20% to 80%” are defined in in IEEE802.3 Annex 86A Table 86A-2.

15.2 TP2 measurement method

15.2.1 General

Evaluation indicators in TP2 include not only AOP specified by ISO 24581, but also modal noise, eye pattern, and other indicators.

15.2.2 Optical power at TP2

AOP at TP2 is measured using "Substitution method" described in ISO 24581 subclause 8.4.

For the measurement light source, a designated Active optical header (FOT) connected to the function generator or a designated MDI mounted on the evaluation board specified in IEEE802.3cz shall be prepared. To measure the AOP at TP2, a 1 m long optical cable with designated optical cable plugs attached to both ends is prepared. In this test, the optical cable assembly is referred to as the "reference jumper wire”. A reference jumper wire is connected to the Active optical header (FOT) on the evaluation board, and the measurement light source is driven under the specified conditions. See Figure 25 of ISO 24581 subclause 8.4.2.

The optical power measured at the output side of the reference jumper wire shall not be less than the AOP at TP2 specified in 8.2.2.

15.3 TP3 measurement method

15.3.1 General

Evaluation indicators in TP3 include not only optical power specified by ISO 24581, but also modal noise, eye pattern, and other indicators.

15.3.2 Optical power at TP3

AOP at TP3 is measured using "Substitution method" described in ISO 24581 subclause 8.4.

As for the measurement light source, a designated FOT (Active optical header) or a designated passive optical header mounted on the evaluation board specified in IEEE802.3cz shall be prepared. And it is connected to the function generator. To measure AOP with TP3, prepare a designated optical harness instead of the reference jumper wire. An optical harness is connected to the active or the passive optical header on the evaluation board, and the measurement light source is driven under the specified conditions. See Figure 25 of ISO 24581 subclause 8.4.2.

The optical power measured at the output side of the optical harness shall not be less than the AOP at TP3 specified in 8.3.2.

15.4 TP4 measurement method

15.4.1 General

The evaluation indices for the 10Gbps TP4 parameters shown in Table 8-4 are specified.

15.4.2 Electrical characteristics

The test setup or test method for the TP4 is specified in IEEE802.3 Annex 86A. Single ended output voltage tolerance is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.1. AC common-mode output voltage (RMS) is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.1. Termination mismatch at 1 MHz is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.2 Differential output return loss is defined in in IEEE802.3 Annex 86A.subclause 86A.4.2.1. Output transition time, 20% to 80% is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.3

J2 Jitter output is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.8.3

J9 Jitter output is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.8.3.

Eye mask coordinates is defined in in IEEE802.3 Annex 86A.subclause 86A.5.3.6. Evaluation conditions for “Crosstalk source VMA, each lane” and “Crosstalk source transition times, 20% to 80%” are defined in IEEE802.3 Annex 86A Table 86A-3.

16 INDICATORS OF COMMUNICATION RELIABILITY

16.1 General

The optical characteristics of an optical transmitter or optical harness change due to various communication environments, which ultimately causes deterioration of optical signal characteristics themselves. The optical signal is obtained at TP2 or TP3 and be used as an index for evaluating the environmental characteristics of the FOT and the optical harness. DUT, test method, environmental load condition and the evaluation criteria shall be agreed upon between the supplier and the vehicle manufacturer. Unless otherwise provided, these shall comply with IEEE 802.3cz:2023 subclause 166.6.4.8 and subclause 166.6.4.13.

16.2 TDFOM (Transmitter distortion figure of merit)

16.2.1 Test setup and method

TDFOM is specified in IEEE 802.3cz:2023, subclause 166.6.4.8. TDFOM is measured as a parameter on the optical transmitter side at TP2. The measurement is performed using the test setup specified in subclause 166.6.4.8.1 of that document and following the procedures specified in subclause 166.6.4.8.2 of that document.

16.2.2 Requirement

The TDFOM of the BASE-AU PMD transmitter optical characteristics is specified for each throughput, and shall be referred to Table 166–9 of IEEE 802.3cz:2023.

16.2.3 Reference

IEEE 802.3cz:2023, subclause 166.6.4.8;

OPEN Alliance TC7_Test House D1.0, subclause 6.3.3.

16.3 STDFOM (Stressed transmitter distortion figure of merit)

16.3.1 Test setup and method

STDFOM is the transmitter state used to measure receiver sensitivity, but receiver sensitivity is optional. A mandatory requirement for a receiver is the stressed receiver sensitivity. The receiver sensitivity and STDFOM range for each throughput are given in IEEE 802.3cz:2023 subclause 166.6.4.12.

A block diagram for the receiver conformance test shall be referred to IEEE 802.3cz:2023, Figure 166–45. The equalizer on the receiving side is designed to take into account the attenuation of the optical harness, but does not take into account the vibration stress in the automotive environment. Therefore, it is necessary to add an optical in-line connector to the "40 meter fibre" in IEEE 802.3cz:2023, Figure 166–45, and apply a load under the designated vibration conditions to the optical in-line portion. Vibration condition shall refer to ISO 24581 subclause 8.7.6. If the performance of the optical in-line connector is insufficient, modal noise will be generated and the receiving performance of the receiving side will be deviated from the initial system design.

16.3.2 Requirement

The stressed receiver sensitivity measured at TP3 for each throughput is specified in Table 166–10 of IEEE 802.3cz:2023.

16.3.3 Reference

IEEE 802.3cz:2023, subclause 166.6.4.13;

OPEN Alliance TC7_Test House D1.0, subclause 6.3.4;

ISO 24581:2024, subclause 8.7.6.

Annex A
(informative)

Harness design guideline

A.1 Optical harness for 25G, 10G, 5G, 2.5G based on IEEE802.3cz:2023

A.1.1 General

The optical harness implementation route is limited by the layout of the ECU to be connected, so the length of the optical harness and the number of in-line connections differ depending on the optical communication system installed in the car. Optical harnesses used for 2.5G, 10G, and 5G optical Ethernet defined by IEEE802.3cz:2023 are allowed to have a maximum length of 40 m and 4 optical in-line connections. Optical sub-harnesses designed for each block are individually mounted on a vehicle, and then finally completed as one optical harness through optical in-line connections.

A.1.2 System power budget

The system power budget is calculated from the specified value of TP2 in subclause 12.2 and the specified value of TP3 in subclause 12.3 in this document.

For 25G: TP2 – TP3 = (-2,1) – (-11,2) = 9,1 dB

For 10G: TP2 – TP3 = (-3,1) – (-14,2) = 11,1 dB

For 5G: TP2 – TP3 = (-4,0) – (-15,1) = 11,1 dB

For 2.5G: TP2 – TP3 = (-5,0) – (-16.1) = 11,1 dB

NOTE: the fulfilment of system power values does not guarantee a reliable connection. The optical received signal shall additionally comply with the parameters given in IEEE 802.3 Table 166-10 at TP3.

A.1.3 Total attenuation of optical harness under the automotive conditions

A.1.3.1 Attenuation of optical harness

The total attenuation of the 50 m, 4 in-lines optical harness is calculated from the specified values listed in the following subclauses. The steady state optical cable attenuation is 0,2 dB as specified in subclause 13.1.2.1.3 of this document. The steady state optical in-line connection attenuation is 0,6 dB as specified in subclause 13.6.2.1.3 of this document. Therefore, the total attenuation of a 50 m, 4 in-lines optical harness is 2,6 dB.

A.1.3.2 Environmental tolerance of optical harness

For maximum environmental tolerances for 50 m, 4 in-lines optical harnesses, refer to the following subclauses. The temperature environmental stress is 1,8 dB as specified in subclause 13.6.2.2.3 of this document. 1,8 dB is the sum of 1,0 dB of temperature and environmental stress of the optical cable and 0,8 dB of optical in-line connection at 4 locations.

The physical environmental stress is 1,8 dB as specified in subclause 13.6.2.3.3 of this document. 1,8 dB is the sum of 1,0 dB of the physical environmental stress of the optical cable and 0,8 dB of the optical in-line connection at 4 locations.

The special environmental stress is 1,8 dB as specified in subclause 13.6.2.4.3 of this document. 1,8 dB is the sum of 1,0 dB of the special environmental stress of the optical cable and 0,8 dB of the optical in-line connection at 4 locations.

Since these individual environmental stresses do not occur simultaneously, the environmental tolerance is a maximum of 1,8 dB.

A.1.3.3 Maximum attenuation of optical harness

Optical in-line connections may experience a temporary increase in attenuation under vibration environments. subclause 13.5.2.3.3 of this document specifies that the maximum attenuation of optical in-line connection in vibration environments is 0,4 dB. Therefore, the maximum attenuation variation of an optical harness that includes 4 in-line connections shall be calculated by replacing the 0,2 dB of the optical in-line connection handled in environmental tolerance with 0,4 dB. The maximum environmental tolerance of the optical harness is 2.6 dB, which is the sum of the 1,0 dB physical environmental stress of the optical cable and 1,6 dB of the optical in-line connections at 4 locations. The maximum attenuation of the optical harness is the sum of 2,6 dB in steady state and the maximum attenuation variation due to environmental stress, so it is 5,2 dB.

A.1.4 Guideline

The minimum allowed system power budget up to 10G specified by IEEE802.3cz:2023:2023 is 11,1 dB, and it is 9,1 dB for 25G (See A.1.2). On the other hand, the maximum attenuation of 40 m, 4 in-lines optical harness is 5,2 dB. Therefore, the difference between the system power budget and the maximum attenuation of the optical harness is 5,9 dB up to 10G and 3,9 dB for 25G , which can be understood as the system margin. A multi-giga optical Ethernet system designed based on IEEE802.3cz:2023 can use the optical harness specified in this document without any restrictions. The system margin can be used to allow more attenuation in the in-line connectors or in other places of the harness. However, those in-line connectors must meet the environmental specifications described in ISO 24581:2024.

A.2 Optical harness for 50G based on IEEE802.3cz:2023

A.2.1 General

The optical harness implementation route is limited by the layout of the ECU to be connected, so the length of the optical harness and the number of in-line connections differ depending on the optical communication system installed in the car. Optical harnesses used for 50G optical Ethernet defined by IEEE802.3cz:2023 are allowed to have a maximum length of 40 m and 2 optical in-line connections. Optical sub-harnesses designed for each block are individually mounted on a vehicle, and then finally completed as one optical harness through optical in-line connections.

A.2.2 System power budget

The system power budget is calculated from the specified value of TP2 in subclause 12.2 and the specified value of TP3 in subclause 12.3 in this document.

For 50G: TP2 – TP3 = (-1,0) – (-6,4) = 5,4 dB

NOTE: the fulfilment of system power values does not guarantee a reliable connection. The optical received signal shall additionally comply with the parameters given in IEEE 802.3 Table 166-10 at TP3.

A.2.3 Total attenuation of optical harness under the automotive conditions

A.2.3.1 Attenuation of optical harness

The total attenuation of the 50 m, 2 in-lines optical harness is calculated from the specified values listed in the following subclauses. The steady state optical cable attenuation is 0,2 dB as specified in subclause 13.1.2.1.3 of this document. The steady state optical in-line connection attenuation is 0,6 dB as specified in subclause 13.6.2.1.3 of this document. Therefore, the total attenuation of a 50 m, 4 in-lines optical harness is 1,4 dB.

A.2.3.2 Environmental tolerance of optical harness

For maximum environmental tolerances for 50 m, 2 in-lines optical harnesses, refer to the following subclauses. The temperature environmental stress is 1,4 dB as specified in subclause 13.6.2.2.3 of this document. 1,8 dB is the sum of 1,0 dB of temperature and environmental stress of the optical cable and 0,4 dB of optical in-line connection at 2 locations.

The physical environmental stress is 1,4 dB as specified in subclause 13.6.2.3.3 of this document. 1,4 dB is the sum of 1,0 dB of the physical environmental stress of the optical cable and 0,4 dB of the optical in-line connection at 2 locations.

The special environmental stress is 1,4 dB as specified in subclause 13.6.2.4.3 of this document. 1,4 dB is the sum of 1,0 dB of the special environmental stress of the optical cable and 0,4 dB of the optical in-line connection at 2 locations.

Since these individual environmental stresses do not occur simultaneously, the environmental tolerance is a maximum of 1,4 dB.

A.2.3.3 Maximum attenuation of optical harness

Optical in-line connections may experience a temporary increase in attenuation under vibration environments. subclause 13.5.2.3.3 of this document specifies that the maximum attenuation of optical in-line connection in vibration environments is 0,4 dB. Therefore, the maximum attenuation variation of an optical harness that includes 2 in-line connections shall be calculated by replacing the 0,2 dB of the optical in-line connection handled in environmental tolerance with 0,4 dB. The maximum environmental tolerance of the optical harness is 1,8 dB, which is the sum of the 1,0 dB physical environmental stress of the optical cable and 0,8 dB of the optical in-line connections at 2 locations. The maximum attenuation of the optical harness is the sum of 1,4 dB in steady state and the maximum attenuation variation due to environmental stress, so it is 3,2 dB.

A.2.4 Guideline

The minimum allowed system power budget of 50G specified by IEEE802.3cz:2023:2023 is 5,4 dB (See A.2.2). On the other hand, the maximum attenuation of 40 m, 2 in-lines optical harness is 3,2 dB. Therefore, the difference between the system power budget and the maximum attenuation of the optical harness is 1,5 dB, which can be understood as the system margin. A multi-giga optical Ethernet system designed based on IEEE802.3cz:2023 can use the optical harness specified in this document without any restrictions. The system margin can be used to allow more attenuation in the in-line connectors or in other places of the harness. However, those in-line connectors must meet the environmental specifications described in ISO 24581:2024.