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Road vehicles — In-vehicle Ethernet —

Part 4:
General requirements and test methods of optical gigabit Ethernet components

Véhicules routiers — Ethernet embarqué —

Partie 4: Exigences générales et méthodes de test des composants optiques pour l'Ethernet gigabit

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

A list of all parts in the ISO 21111 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 21111 series includes in-vehicle Ethernet requirements and test plans that are disseminated in other International Standards and complements them with additional test methods and requirements. The resulting requirement and test plans are structured in different documents following the Open Systems Interconnection (OSI) reference model and grouping the documents that depend on the physical media and bit rate used.

In general, the Ethernet requirements are specified in ISO/IEC/IEEE 8802-3. The ISO 21111 series provides supplemental specifications (e.g. wake-up, I/O functionality), which are required for in-vehicle Ethernet applications. In road vehicles, Ethernet networks are used for different purposes requiring different bit-rates. Currently, the ISO 21111 series specifies the 1-Gbit/s optical and 100-Mbit/s electrical physical layer.

The ISO 21111 series contains requirement specifications and test methods related to the in-vehicle Ethernet. This includes requirement specifications for physical layer entity (e.g. connectors, physical layer implementations) providers, device (e.g. electronic control units, gateway units) suppliers, and system (e.g. network systems) designers. Additionally, there are test methods specified for conformance testing and for interoperability testing.

Safety (electrical safety, protection, fire, etc.) and electromagnetic compatibility (EMC) requirements are out of the scope of the ISO 21111 series.

The structure of the specifications given in the ISO 21111 series complies with the Open Systems Interconnection (OSI) reference model specified in ISO/IEC 7498-1[13] and ISO/IEC 10731[14].

ISO 21111-1 defines the terms which are used in this series of standards and provides an overview of the standards for in-vehicle Ethernet including the complementary relations to ISO/IEC/IEEE 8802-3, the document structure, type of physical entities, in-vehicle Ethernet specific functionalities and so on.

ISO 21111-2 specifies the interface between reconciliation sublayer and physical entity including reduced gigabit media independent interface (RGMII), and the common physical entity wake-up and synchronized link sleep functionalities, independent from physical media and bit rate.

ISO 21111-3 specifies supplemental requirements to a physical layer capable of transmitting 1-Gbit/s over plastic optical fibre compliant with ISO/IEC/IEEE 8802-3, with specific application to communications inside road vehicles, and a test plan for physical entity conformance testing.

This document specifies the optical components requirements and test methods for 1-Gbit/s optical in-vehicle Ethernet.

ISO 21111-5 specifies, for 1-Gbit/s optical in-vehicle Ethernet, requirements on the physical layer at system level, requirements on the interoperability test set-ups, the interoperability test plan that checks the requirements for the physical layer at system level, requirements on the device-level physical layer conformance test set-ups, and device-level physical layer conformance test plan that checks a set of requirements for the OSI physical layer that are relevant for device vendors.

ISO 21111-6 specifies advanced features of an ISO/IEC/IEEE 8802-3 in-vehicle Ethernet physical layer (often also called transceiver), e.g. for diagnostic purposes for in-vehicle Ethernet physical layers. It specifies advanced physical layer features, wake-up and sleep features, physical layer test suite, physical layer control requirements and conformance test plan, physical sublayers test suite and physical sublayers requirements and conformance test plan.

ISO 21111-7 specifies the implementation for ISO/IEC/IEEE 8802-3:2017/Amd 1:2017, which defines the interface implementation for automotive applications together with requirements on components used to realize this Bus Interface Network (BIN). ISO 21111-7 also defines further testing and system requirements for systems implemented according to the system specification. In addition, ISO 21111-7 defines the channels for tests of transceivers with a test wiring harness that simulates various electrical communication channels.

ISO 21111-8 specifies the transmission media, the channel performance and the tests for ISO/IEC/IEEE 8802-3 in-vehicle Ethernet.

ISO 21111-9 specifies the data link layer requirements and conformance test plan. It specifies the requirements and test plan for devices and systems with bridge functionality.

ISO 21111-10 specifies the application to network layer requirements and test plan. It specifies the requirements and test plan for devices and systems that include functionality related with OSI layers from 3 to 7.

Figure 1 shows the parts of the ISO 21111 series and the document structure.

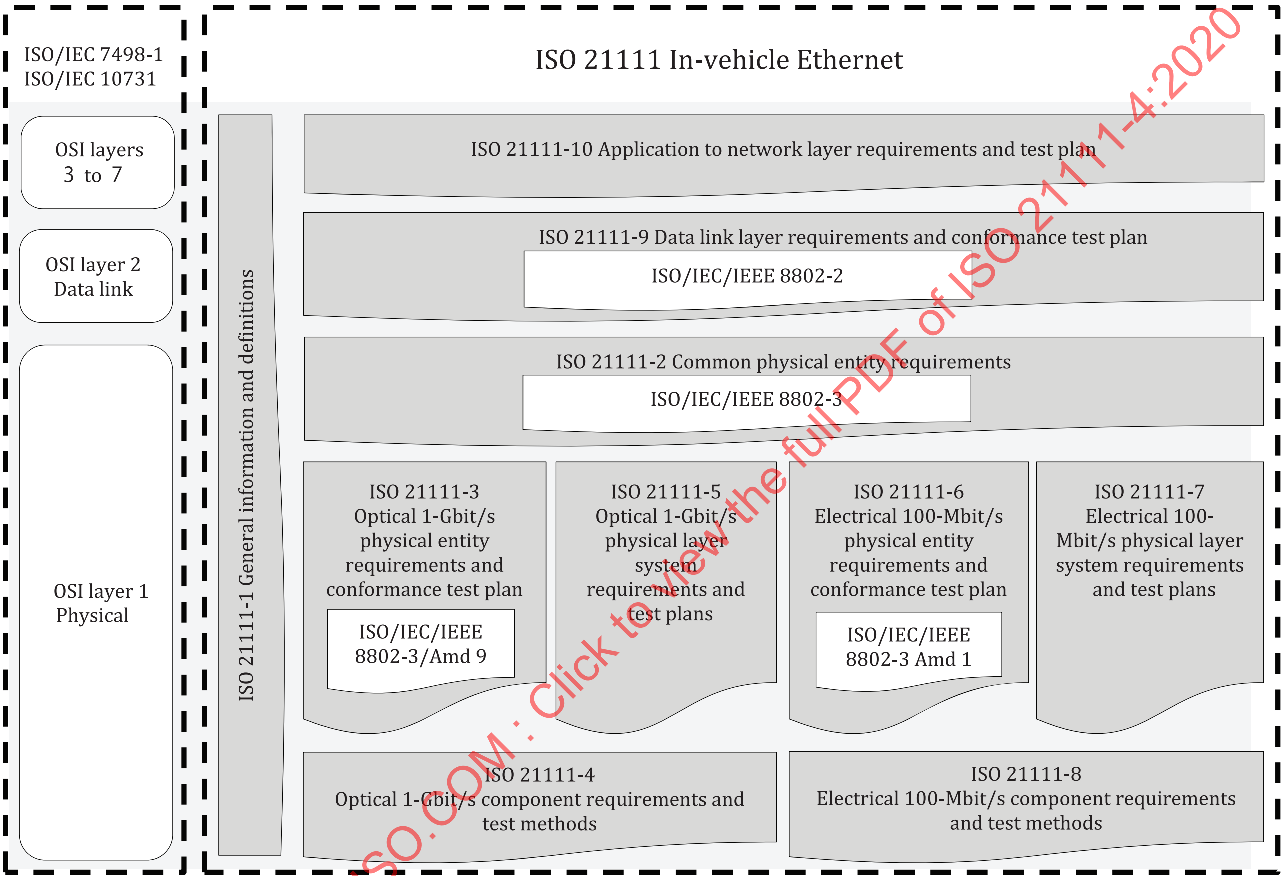


Figure 1 — In-vehicle Ethernet document reference according to OSI model

Road vehicles — In-vehicle Ethernet —

Part 4:
General requirements and test methods of optical gigabit Ethernet components

1 Scope

This document specifies the optical components requirements and test methods for optical gigabit transmission of in-vehicle Ethernet. Safety (electrical safety, protection, fire, etc.) and electromagnetic compatibility (EMC) requirements are outside the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of 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.

ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, *Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation over Plastic Optical Fibre*

ISO 8092-2, *Road vehicles — Connections for on-board electrical wiring harnesses — Part 2: Definitions, test methods and general performance requirements*

ISO 8092-3, *Road vehicles — Connections for on-board electrical wiring harnesses — Part 3: Tabs for multi-pole connections — Dimensions and specific requirements*

ISO 16750-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 16750-3:2012, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4:2010, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

ISO 16750-5, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 5: Chemical loads*

ISO 21111-1, *Road vehicles — In-vehicle Ethernet —General information and definitions*

IEC 60068-2-60, *Environmental testing — Part 2: Tests — Test Ke: Flowing mixed gas corrosion test*

IEC 60793-1-20, *Optical fibres — Part 1-20: Measurement methods and test procedures — Fibre geometry*

IEC 60793-1-21, *Optical fibres — Part 1-21: Measurement methods and test procedures — Coating geometry*

IEC 60793-1-40, *Optical fibres — Part 1-40: Attenuation measurement methods*

IEC 60793-2-40, *Optical fibres — Part 2-40: Product specifications — Sectional specification for category A4 multimode fibres*

IEC 60793-1-43, *Optical fibres — Part 1-43: Measurement methods and test procedures — Numerical aperture measurement*

IEC 60793-1-51, *Optical fibres — Part 1-51: Measurement methods and test procedure – Dry heat (steady state) tests*

IEC 60794-1-21, *Optical fibre cables — Part 1-21: Generic specification — Basic optical cable test procedures — Mechanical tests methods*

IEC 60794-2-41, *Optical fibre cables — Part 2-41: Indoor cables — Product specification for simplex and duplex buffered A4 fibres*

IEC 61300-3-53, *Fibre optic interconnecting devices and passive components — Basic test and measurement procedures — Part 3-53: Examinations and measurements — Encircled angular flux (EAF) measurement method based on two-dimensional far field data from step index multimode waveguide (including fibre)*

ANSI/EIA 364-13, *Mating and Un-mating Force Test Procedure for Electrical Connectors and Sockets*

EIA 364-38, *Cable pull-out test procedure for electrical connectors*

EIA/TIA 455-13A, *Visual and mechanical inspection of fibre optic components, devices, and assemblies*

EIA/TIA 455-20A, *Measurement of Change in Optical Transmittance*

EIA/TIA 455-34A, *Interconnection Device Insertion Loss Test*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21111-1 and the following 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/

3.1
1000BASE-H
physical coding sublayer (PCS) and physical medium attachment (PMA) sublayers for 1 000 Mb/s Ethernet that support physical medium dependent (PMD) using duplex plastic optical fibre

3.2
1000BASE-RHC
physical layer specification for 1 000 Mb/s Ethernet using *1000BASE-H* (3.1) encoding and red light (approximately 650 nm) PMD tailored for automotive application requirements

3.3
extinction ratio
ER
ratio of two optical power levels of a digital signal generated (high or low) by an optical source

3.4
FORx
part of an *optical PMD receiver* (3.10) that includes a photo detector and an amplifier

3.5
FOTx
part of an *optical PMD transmitter* (3.12) that includes a light emitting device and a driver

3.6
in-line connector
connector resulting of the match of a cable plug and a cable socket

3.7
launch optics
light source with some additional optical components

3.8
mode filter
optical filter that eliminates higher order modes in order to suppress modal dispersion

3.9
mode scrambler
optical component defined in IEC 60793-2-40

3.10
optical PMD receiver
receiver optical front end composed of a photo detector, an amplifier and a *waveguide* (3.15) for optical coupling

3.11
optical PMD transceiver
optical front end composed of an *optical PMD receiver* (3.10) and an *optical PMD transmitter* (3.12)

3.12
optical PMD transmitter
transmitter optical front end composed of a light emitting device, a driver and *waveguide* (3.15) for optical coupling

3.13
passive component
module that does not require energy to operate

Note 1 to entry: POF cable or optical connector as defined in Clause 7 is in this category.

3.14
system power budget
allocation of available optical power in order to ensure that adequate signal strength is available at the receiver

Note 1 to entry: As defined in A.2.

3.15
waveguide
optical coupling device that is set between the end face of POF and the optical window of the LED or Photodiode

4 Abbreviated terms

AOP	average optical power
DUT	device under test
EAF	encircled angular flux
FFP	far field pattern
FOT	fibre optic transceiver
GEPOF	gigabit ethernet over plastic optical fibre
I/F	interface

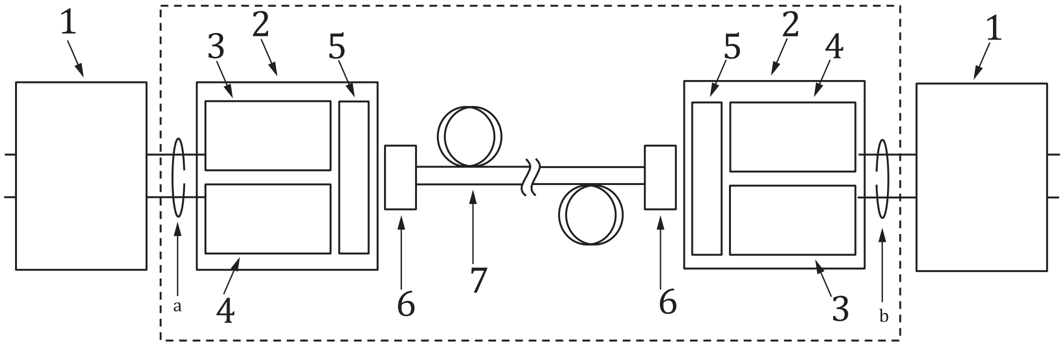
LD	laser diode
LED	light emitting diode
MDI	media dependent interface
MRP	mechanical reference plane
NA	numerical aperture
ORP	optical reference plane
PCB	printed circuit board
PCS	physical coding sublayer
PMA	physical media attachment
PMD	physical media dependent
POF	plastic optical fibre

5 1000BASE-RHC components

Figure 2 specifies the components used for the connection between two GEPOF entities that conform to the ISO 21111 series. The 1000BASE-H transceiver component includes the functionality described for the 1000BASE-H transmitter and receiver defined in ISO/IEC/IEEE 8802-3:2017/Amd 9 and for the GEPOF entity in ISO 21111-3. The optical PMD transceiver component includes the functionality described for the optical PMD transmitter and receiver defined in ISO/IEC/IEEE 8802-3:2017/Amd 9 and optical coupling elements defined in this document. These elements are enclosed in broken line in Figure 2.

A GEPOF entity may be integrated in a single component that includes the 1000BASE-H transceiver, the optical PMD transceiver and the cable socket. The resulting component is defined as integrated header connector. In an alternative configuration, the GEPOF entity may be implemented by using two different components. The first one includes the 1000BASE-H transceiver and the second one integrates the optical PMD transceiver and the cable socket. The resulting component is defined as header connector.

Two GEPOF entities are connected through their MDI bi-directionally through a duplex POF cable or a pair of simplex POF cables (see 8.4). The POF cable is terminated with two cable plugs that fulfils the characteristics defined in Clause 9. The connection between two GEPOF entities may include or not one or more in-line connectors.



Key

1 1000BASE-H transceiver

2 header connector

3 optical PMD transmitter

4 optical PMD receiver

5 mechanics for axis alignment

6 cable plug

7 POF cable

a Electrical I/F between PMA and PMD.

b Electrical I/F between PMD and PMA.

Figure 2 — 1000BASE-RHC components

6 Header connector

6.1 Dimension criteria

Two types of header connector are defined.

Type A header connector is defined in Figure 3 and type B header connector is defined in Figure 4. MRP is used to determine a mechanical position when a header connector and a plug connector are mated. Additionally, ORP is used to determine an optical position for the efficient optical coupling performance. The detail H and J of type A and the detail C of type B specify the position of the tip of ferrule of the cable plug in mated condition.

— Type A

A type A header connector shall comply with the dimensions and tolerances defined in Figure 3.

Dimensions in millimetres

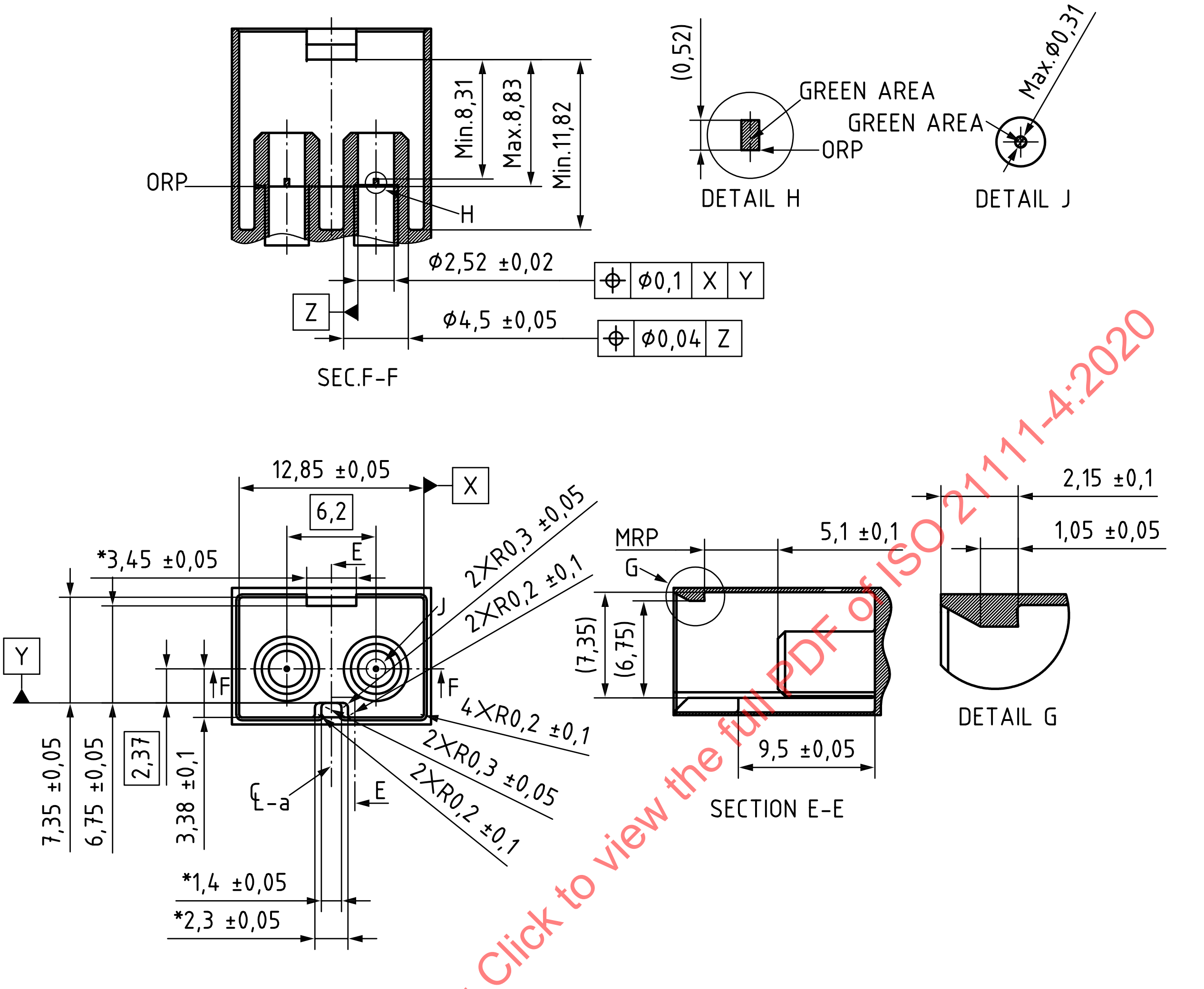
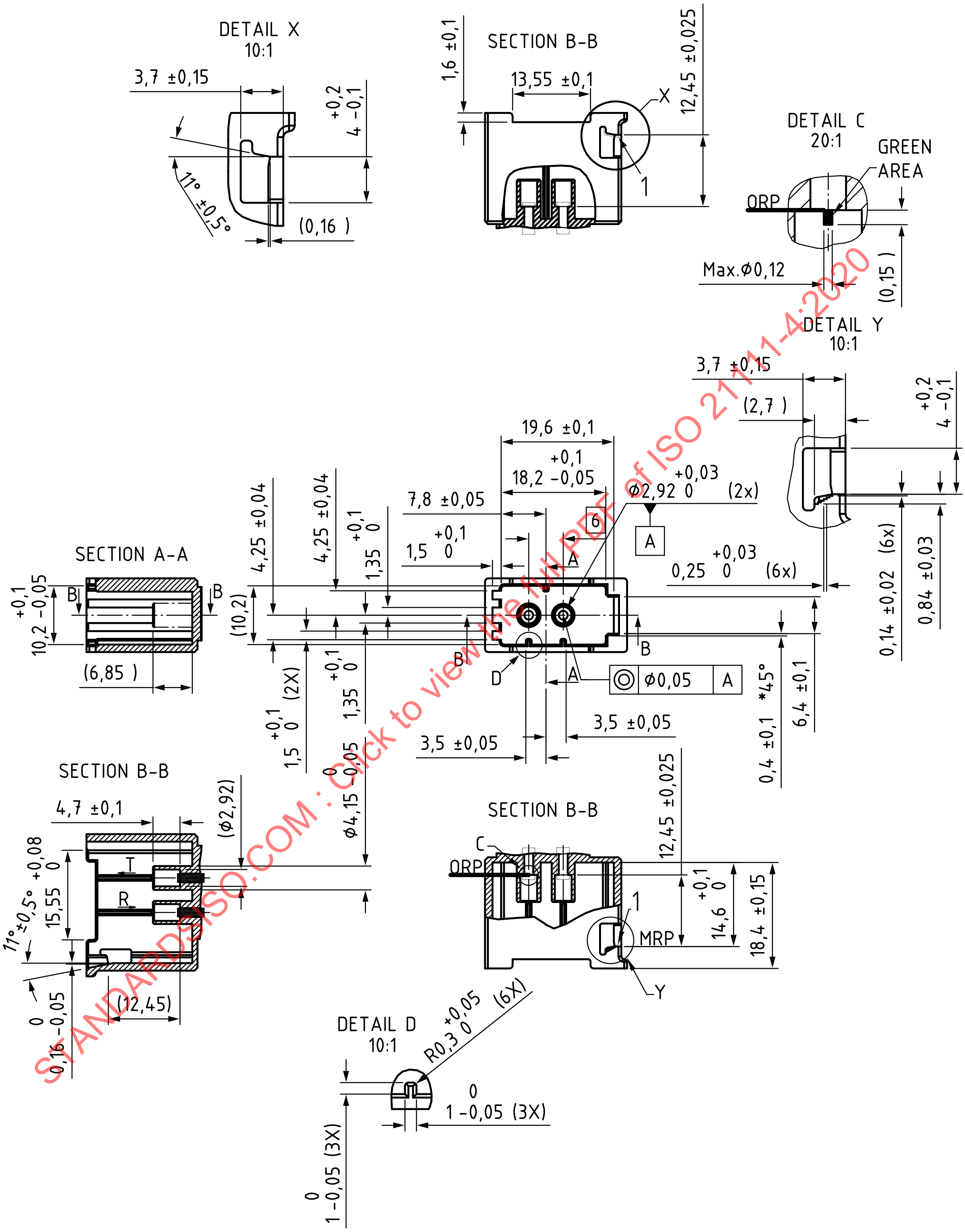


Figure 3 — Header connector (type A)

— Type B

A type B header connector shall comply with the dimensions and tolerances defined in Figure 4.

Dimensions in millimetres



Key

1 in this area no burr permitted, COD Z as shown

Figure 4 — Header connector (type B)

6.2 Mechanical coding

Mechanical coding that prevents possible wrong connection is prepared on the header connector. A set of different coding for each connector type A and type B is defined. Cable plug and cable socket shall follow the mechanical coding defined in this subclause.

— Type A

Four types of mechanical coding (A, B, C, D) are defined in Figure 5 for type A.

Dimensions in millimetres

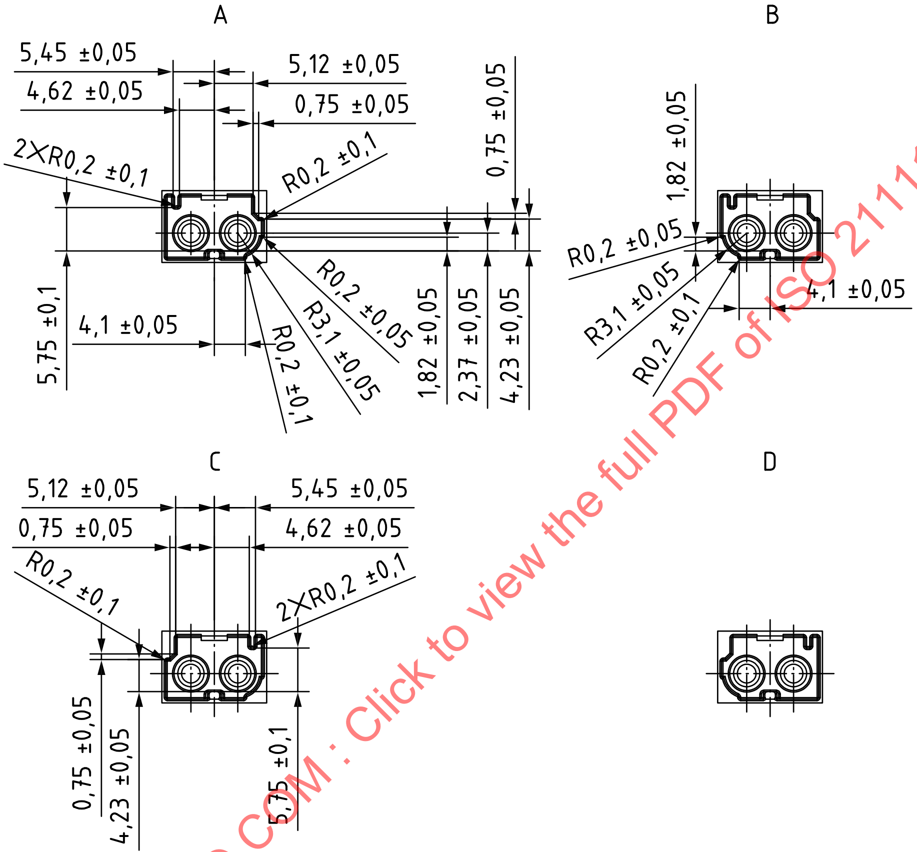


Figure 5 — Mechanical coding (type A)

— Type B

Six types of mechanical coding (A, B, C, D, E, Z) are defined in Figure 6 for type B.

Dimensions in millimetres

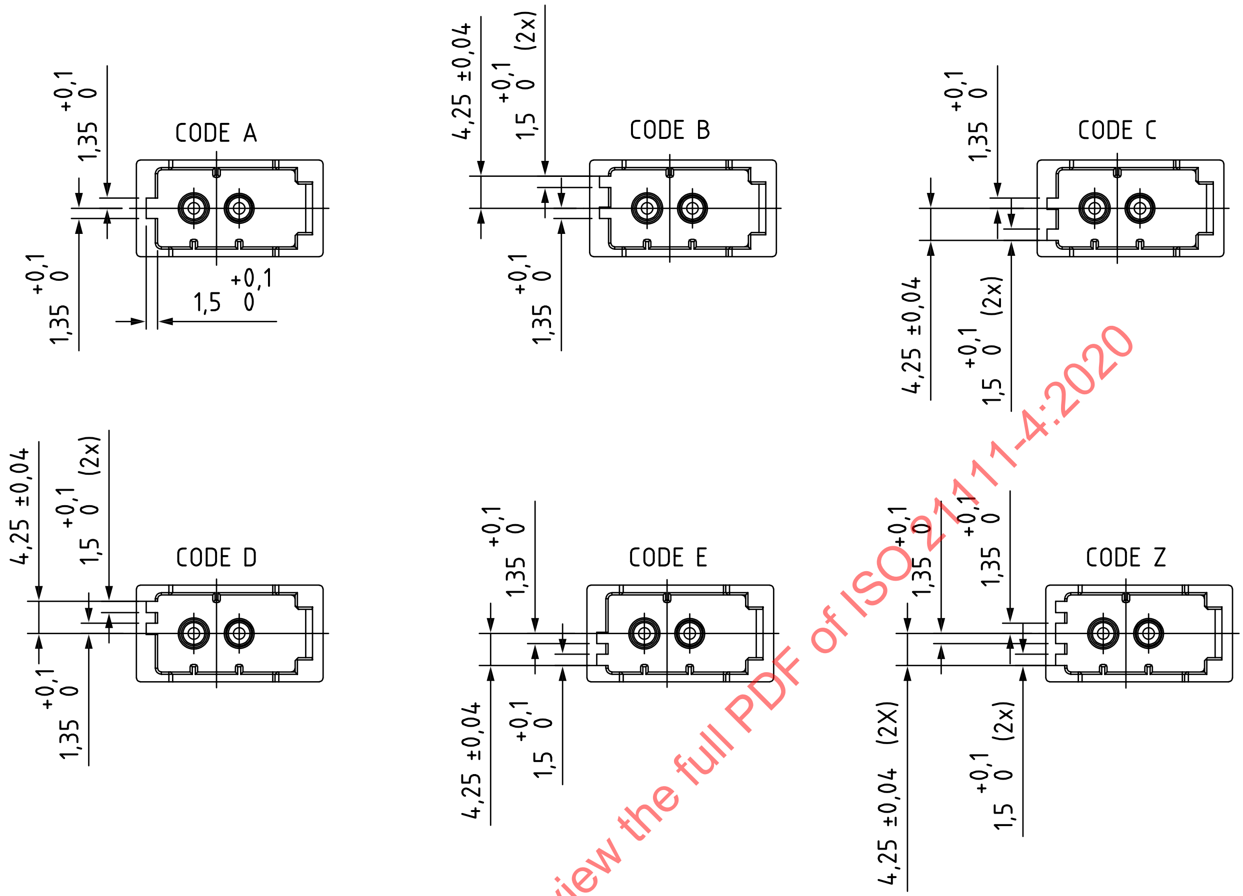


Figure 6 — Mechanical coding (type B)

6.3 Requirements of header connector

Table 1 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail. Requirements of optical and electrical characteristics are defined in Clause 9.

Table 1 — Requirements of header connector

Subclause	Requirement	Reference
6.4.1	High storage temperature exposure	ISO 8092-2 ISO 16750-1 ISO 16750-4 EIA/TIA 455-13A
6.4.2	Low storage temperature exposure	ISO 8092-2 ISO 16750-1 ISO 16750-4 EIA/TIA 455-13A

Table 1 *(continued)*

Subclause	Requirement	Reference
6.4.3	Operating temperature range	ISO 8092-2 ISO 16750-1 ISO 16750-4 EIA/TIA 455-13A ISO/IEC/IEEE 8802-3:2017/Amd 9

6.4 Evaluation

6.4.1 High storage temperature exposure

6.4.1.1 Purpose

Road vehicles are owned and operated in nearly all land regions of the earth. Significant variation in environmental conditions due to climatic environment, including diurnal and seasonal cycles, can therefore be expected. The durability test for high storage temperature is specified.

6.4.1.2 Test setup

The DUT for this durability test is a PCB with a header connector mounted on it. A programmable oven as defined in 9.5.2 is used to expose the DUT to the defined temperature.

6.4.1.3 Test methods

The header connector dimensions before the test are measured in accordance with EIA/TIA 455-13A. DUT is put into the programmable oven that shall be held at T_{max}. DUT is taken out of the programmable oven after being held for 96 h and held for 24 h at room temperature, and the same header connector dimensions shall be measured in the same manner as the initial measurement. An applicable test condition shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{max}) is defined in code K in ISO 16750-4:2010, Clause 4.

6.4.1.4 Requirement

Exposure test shall be performed at T_{max}. Header connector dimensions after durability test shall be within tolerances defined in Figures 3 to 6.

6.4.2 Low storage temperature exposure

6.4.2.1 Purpose

Road vehicles are owned and operated in nearly all land regions of the earth. Significant variation in environmental conditions due to climatic environment, including diurnal and seasonal cycles, can therefore be expected. The durability test for low storage temperature is specified.

6.4.2.2 Test setup

The DUT for this durability test is a PCB with a header connector mounted on it. A programmable oven as defined in 9.5.2 is used to expose the DUT to the defined temperature.

6.4.2.3 Test methods

The header connector dimensions before the test are measured in accordance with EIA/TIA 455-13A. DUT is put into the programmable oven that shall be held at T_{min}. DUT is taken out of the programmable oven after being held for 96 h and held for 24 h at room temperature, and the same header connector dimensions shall be measured in the same manner as the initial measurement. An applicable test condition shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{min}) is defined in code K in ISO 16750-4:2010, Clause 4.

6.4.2.4 Requirement

Exposure test shall be performed at T_{min}. Header connector dimensions after durability test shall be within tolerances defined in Figures 3 to 6.

6.4.3 Operating temperature range

6.4.3.1 Purpose

Road vehicles are owned and operated in nearly all land regions of the earth. Significant variation in environmental conditions due to climatic environment, including diurnal and seasonal cycles, can therefore be expected. Operating temperature range of a header connector is specified, and test method is defined.

6.4.3.2 Test setup

DUT for this test consist on a PCB with a header connector mounted and powered. Unless otherwise specified the operating mode of DUT is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5 test mode 3. A programmable oven as defined in 9.5.2 is used to expose the DUT to the defined temperature.

6.4.3.3 Test methods

The header connector dimensions before the test are measured in accordance with EIA/TIA 455-13A. The temperature of the programmable oven shall be raised until T_{max} and lowered until T_{min} with the temperature slope of 1 °C/min, and again increased back to room temperature with the temperature slope of 1 °C/min. An applicable test condition shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{min} and T_{max}) is defined in code K in ISO 16750-4:2010, Clause 4.

6.4.3.4 Requirement

Operating temperature test shall be performed at T_{min} and T_{max}. Channel type is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.7. Header connector dimensions after exposure test shall be within tolerances defined in Figures 3 or 4.

7 Cable connector

There are two types of cable connectors, cable plugs and cable sockets. The cable plug shall mate with either a header connector or a cable socket. Mechanical coding of cable plug and cable socket are defined in 7.1.2 and 7.2.2.

7.1 Cable plug

7.1.1 Dimension criteria

Two types of cable plug are defined.

Type A cable plug is defined in Figure 7 and type B cable plug is defined in Figure 8. MRP is used to determine a mechanical position when a cable plug and cable socket are mated. Additionally, ORP is used to determine an optical position for the efficient optical coupling performance.

— Type A

A type A cable plug shall comply with the dimensions and tolerances defined in Figure 7.

Dimensions in millimetres

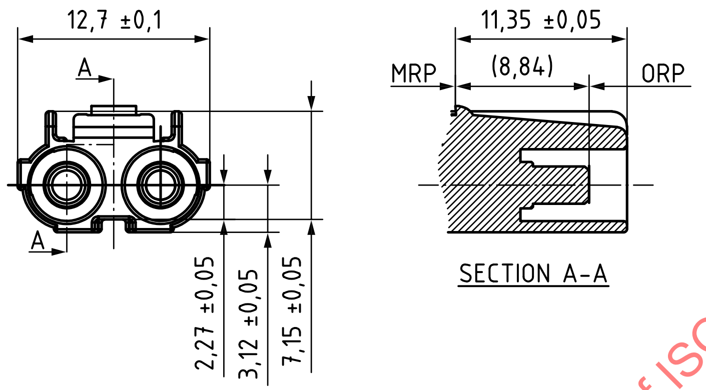


Figure 7 — Cable plug (type A)

— Type B

A type B cable plug shall comply with the dimensions and tolerances defined in Figure 8.

Dimensions in millimetres

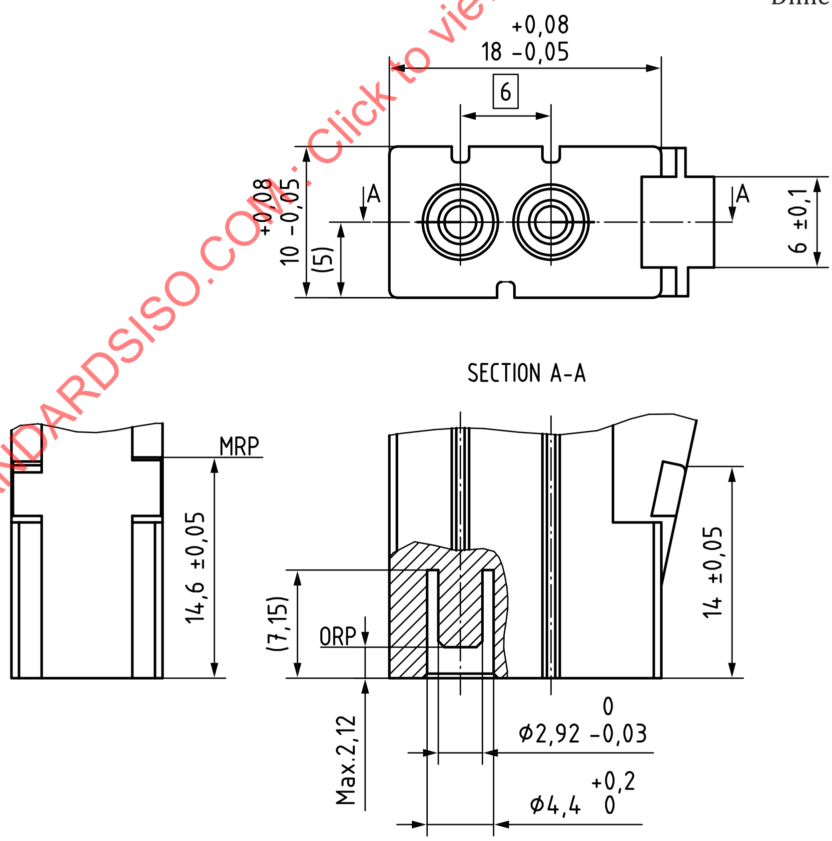


Figure 8 — Cable plug (type B)

7.1.2 Mechanical coding

Cable plug implements a mechanical coding that prevents possible wrong connection. Type A and type B cable plug mechanical coding are defined in 6.2.

7.2 Cable socket

7.2.1 Dimension criteria

Two types of cable socket are defined.

Type A cable socket is defined in Figure 9 and type B cable socket is defined in Figure 10. MRP is used to determine a mechanical position when a cable plug and cable socket are mated. Additionally, ORP is used to determine an optical position for the efficient optical coupling performance.

— Type A

A type A cable socket connector shall comply with the dimensions and tolerances defined in Figure 9.

Dimensions in millimetres

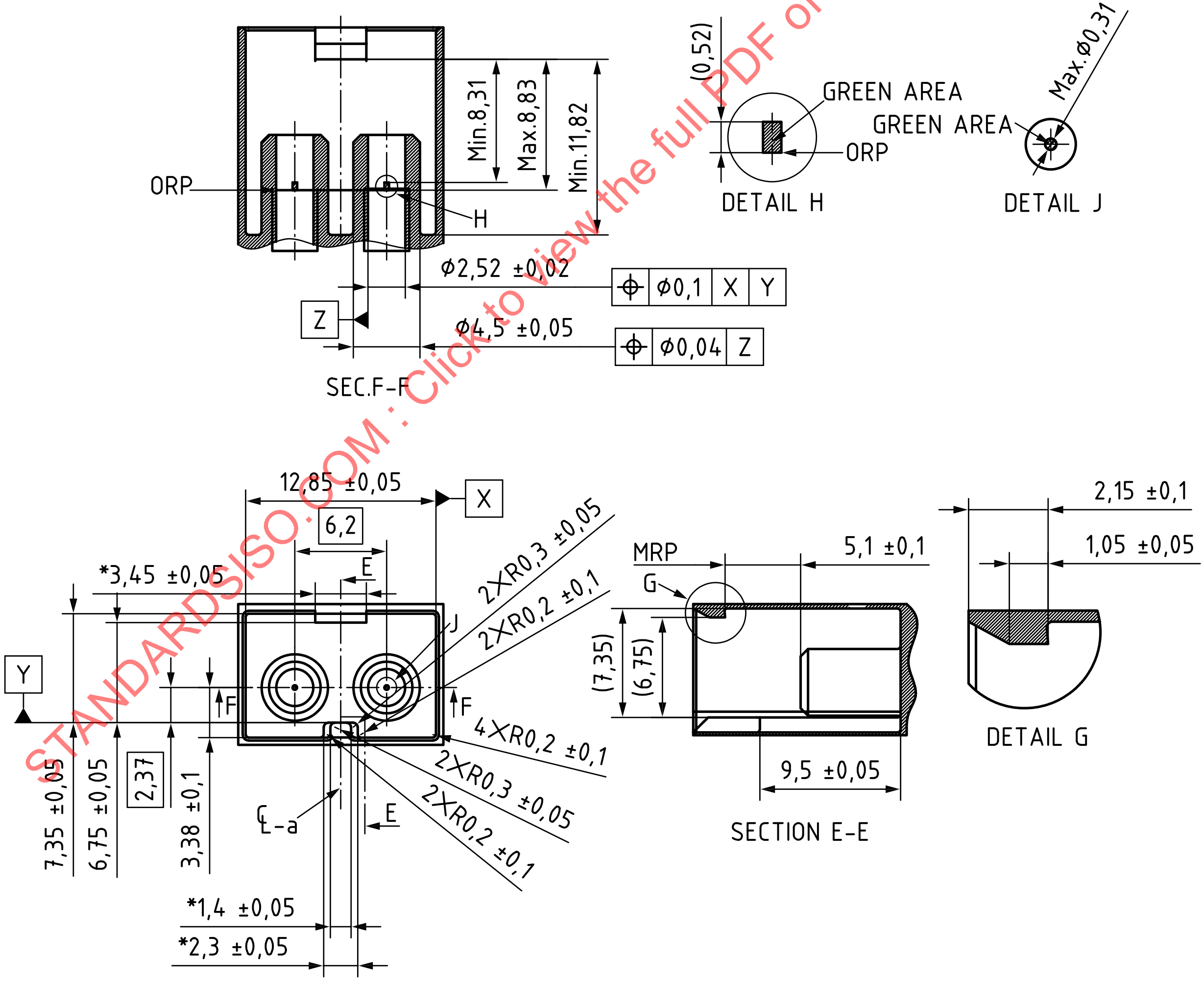
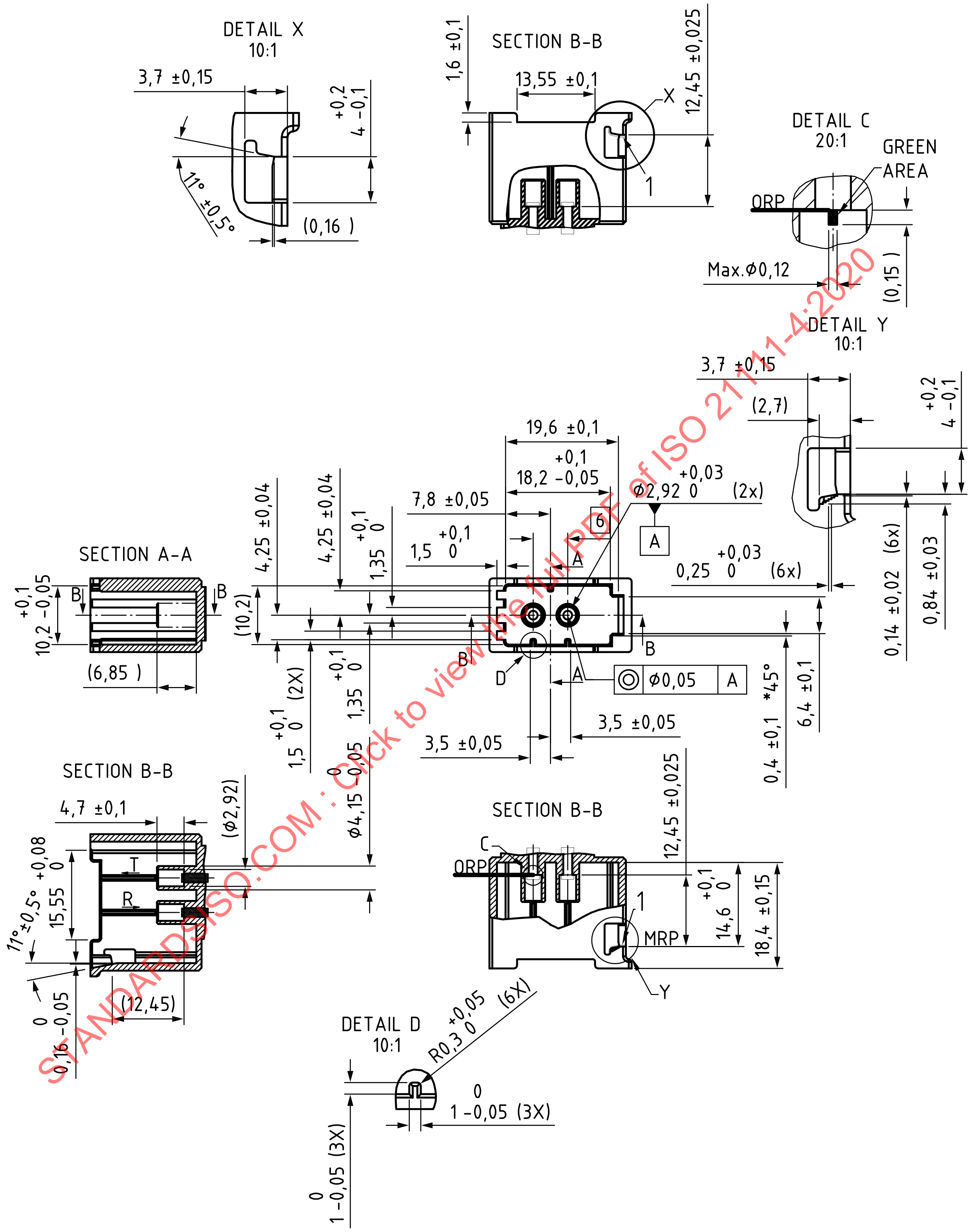


Figure 9 — Cable socket (type A)

— Type B

A type B cable socket connector shall comply with the dimensions and tolerances defined in Figure 10.

Dimensions in millimetres



Key

1 in this area no burr permitted, COD Z as shown

Figure 10 — Cable socket (type B)

7.2.2 Mechanical coding

Cable socket implements a mechanical coding that prevents possible wrong connection. Type A and type B cable socket mechanical coding are defined in 6.2.

7.3 Requirements of cable connector

Table 2 specifies the normative references that contain requirements and test methods that the optical connectors shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail. Optical and electrical requirements for optical connector are defined in Clause 9.

Table 2 — Requirements of optical connector

Subclause	Requirement	Reference
7.4.1	High storage temperature exposure	ISO 8092-2 EIA/TIA 455-13A
7.4.2	Low storage temperature exposure	ISO 8092-2 EIA/TIA 455-13A
7.4.3	Operation temperature range	ISO 8092-2 EIA/TIA 455-13A

7.4 Evaluation

7.4.1 High storage temperature exposure

7.4.1.1 Purpose

Road vehicles are owned and operated in nearly all land regions of the earth. Significant variation in environmental conditions due to climatic environment, including diurnal and seasonal cycles, can therefore be expected. A durability test for high storage temperature is specified.

7.4.1.2 Test setup

DUT is a part unit of the cable plug or the cable socket. An unmounted and unmated cable plug or an unmounted and unmated cable socket is put into a programmable oven.

7.4.1.3 Test methods

The cable plug or the cable socket dimensions before the test is measured in accordance with TIA 455-13A, the cable plug and the cable socket are put into the programmable oven that shall be held at T_{max}. The cable plug and the cable socket are taken out of the oven after being held for 96 h and held for 24 h at room temperature, and the dimensions of the connectors are measured in the same manner as the initial measurement. An applicable test shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{max}) is defined in code K in ISO 16750-4:2010, Clause 4.

7.4.1.4 Requirement

Durability test shall be performed at T_{max}. Optical connector dimensions after durability test shall be within tolerances defined in Figures 7 to 10.

7.4.2 Low storage temperature exposure

7.4.2.1 Purpose

Road vehicles are owned and operated in nearly all land regions of the earth. Significant variation in environmental conditions due to climatic environment, including diurnal and seasonal cycles, can therefore be expected. A durability test for low storage temperature is specified.

7.4.2.2 Test setup

DUT is a part unit of the cable plug or the cable socket. An unmounted and unmated cable plug or an unmounted and unmated cable socket is put into a programmable oven.

7.4.2.3 Test methods

The cable plug or the cable socket dimensions before the test is measured in accordance with TIA 455-13A, the cable plug and the cable socket are put into the programmable oven that shall be held at T_{min}. The cable plug and the cable socket are taken out of the oven after being held for 96 h and held for 24 h at room temperature, and the dimensions of the connectors are measured in the same manner as the initial measurement. An applicable test shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{min}) is defined in code K in ISO 16750-4:2010, Clause 4.

7.4.2.4 Requirement

Durability test shall be performed at T_{min}. Optical connector dimensions after durability test shall be within tolerances defined in Figures 7 to 10.

7.4.3 Operation temperature range (informative)

Both the cable plug and the cable socket are passive components. Therefore, it is not necessary to define the operating temperature if each component satisfies the definition of storage temperature.

8 POF and POF cable

8.1 POF

POF is defined as A4a.2 in IEC 60793-2-40:2015, Annex A.

8.2 Requirements of POF

Table 3 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail.

Table 3 — Requirements of POF

Subclause	Requirement	Reference
8.3.1	Cladding diameter	IEC 60793-1-20 IEC 60793-2-40
8.3.2	Numerical aperture	IEC 60793-1-43 IEC 60793-2-40 IEC 61300-3-53

Table 3 *(continued)*

Subclause	Requirement	Reference
8.3.3	Attenuation	IEC 60793-1-40 IEC 60793-2-40

8.3 Outline of POF

8.3.1 Cladding diameter

8.3.1.1 Purpose

The coupling performance of a fibre-optic connection is mainly determined by the alignment accuracy of the fibre. To allow for good match of the fibre to fibre and the MDI to fibre coupling the cladding diameter of the POF is within the specified limits.

8.3.1.2 Test setup

Test setup is defined in IEC 60793-1-20, Method B.

8.3.1.3 Test methods

The cladding diameter of POF is measured in accordance with IEC 60793-1-20, Method B. Mechanical diameter measurement technique using a micrometre calliper, or a laser micrometre can also be applicable to measure the cladding diameter.

8.3.1.4 Requirement

The cladding diameter of POF shall be 1 000 µm ± 45 µm.

8.3.2 Numerical aperture

8.3.2.1 Purpose

The numerical aperture (NA) of an optical fibre determines the acceptance angle at the fibre end face for light that can propagate in the optical fibre by total internal reflection. It is determined by the refractive index of the core and cladding of the fibre. Because the NA is crucial to the modal dispersion, the bandwidth and frequency response of the optical fibre are influenced. Therefore, the NA of POF is defined.

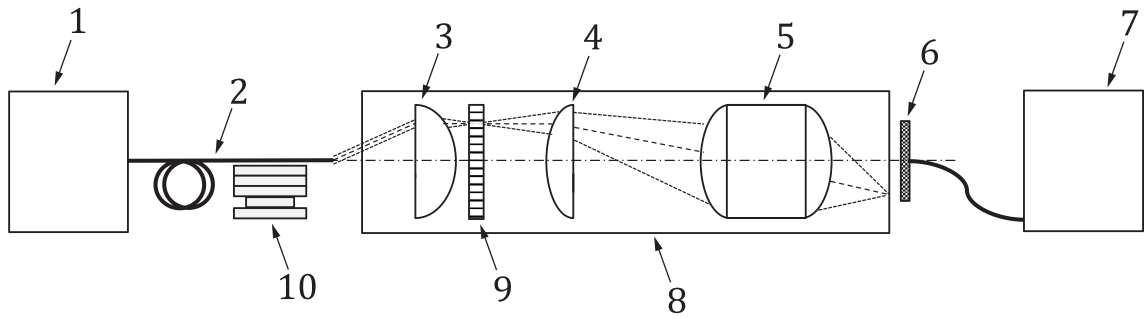
8.3.2.2 Test setup

Test setup is defined in IEC 60793-1-43.

8.3.2.3 Test methods

NA shall be measured in accordance with one of the following test methods:

— IEC 60793-1-43, Technique 3, or IEC 61300-3-53 with an FFP optical system as defined in Figure 11.



Key

1 light source
2 POF
3 *fθ* objective lens
4 field lens
5 relay lens
6 image sensor
7 FFP analyzer module
8 far field optical system
9 ND filter
10 micro positioner

Figure 11 — Far field optical system diagram

8.3.2.4 Requirement

NA shall be 0,53 ± 0,07.

8.3.3 Attenuation

8.3.3.1 Purpose

Attenuation of POF is specified because it is one of the key parameters that determine the maximum link length. Therefore, the attenuation of POF that adjusts to the link power budget defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-16 is provided.

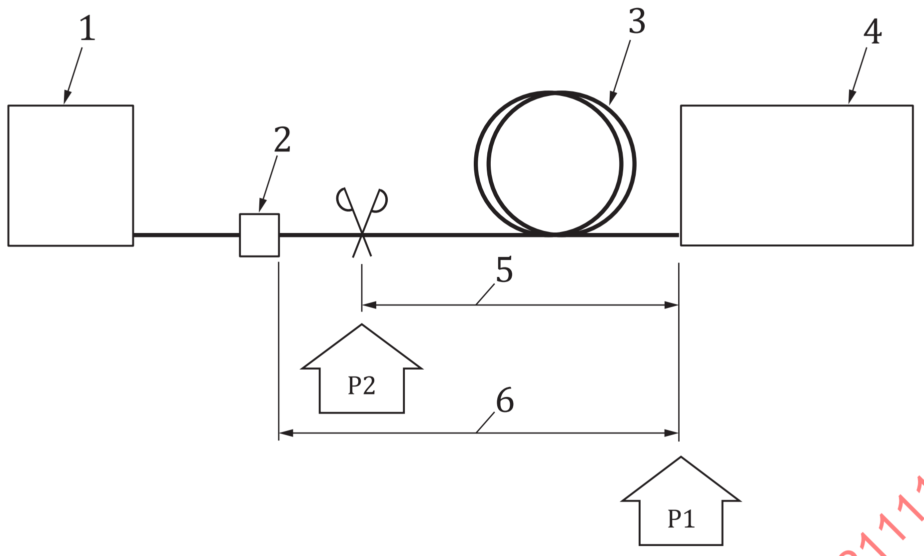
8.3.3.2 Test setup

DC light source defined in 9.5.1 is connected to the input of a 50 m optical fibre and the launch condition for attenuation measurement is the equilibrium mode distribution launch defined in IEC 60793-1-40. A spectrum analyser is connected to the output end face. The spectrum analyser is used to measure the optical power.

8.3.3.3 Test methods

Attenuation shall be measured in accordance with IEC 60793-1-40, Method A. The optical power at P1-point shall be measured firstly with the optical spectrum analyser. The optical fibre is cut at 40 m (P2-point) from the output end face (P1-point). See Figure 12.

The optical spectrum analyser measures the optical power as defined in IEC 60793-1-40 at P2-point. The difference between the optical power at P2-point and the optical power at P1-point is the inherent attenuation of 40 m POF.



Key

1 IEEE compliant DC light source
2 launch optics, equilibrium mode launch
3 POF
4 spectrum analyzer
5 cutting length of POF: 40 m
6 initial length of POF: 50 m
P1 optical output point of DUT
P2 optical output point of DUT after cut-back

Figure 12 — Attenuation measurement

Optical power (P1, P2) at 650 nm is measured. Attenuation of POF is calculated by Formula (1).

$$A_p = \frac{P2 - P1}{40} \tag{1}$$

where

A_p is the attenuation (dB) of 1 m POF;

P1 is the optical power (dBm) output after 50 m POF;

P2 is the optical power (dBm) output after 10 m POF.

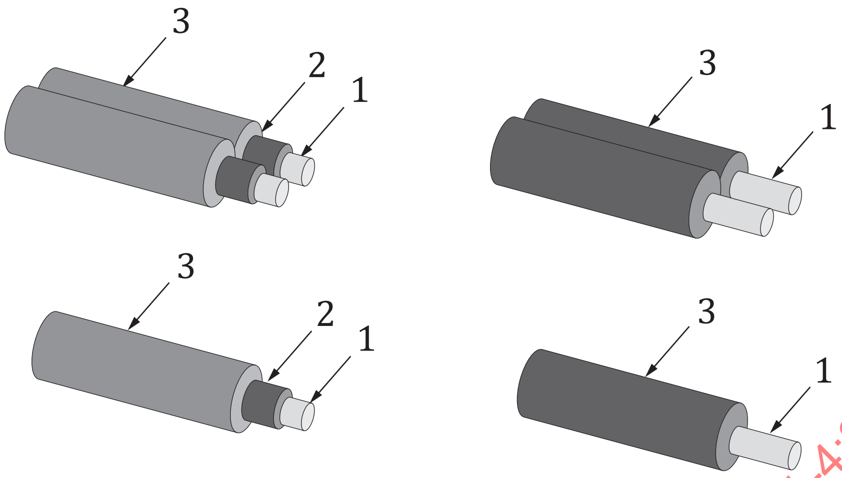
8.3.3.4 Requirement

The attenuation of POF shall be 0,2 dB/m or less at the wavelength of 650 nm.

8.4 POF cable

The jacket of a POF cable shall have the equivalent mechanical and environmental characteristics as wiring cable as specified in ISO 16750-1. Thus, tough and flame-resistant jacketing materials shall be used.

There are two types of jacketing for POF cable. Single jacketed POF cable is shown in right drawing of Figure 13. Double jacketed POF cable is shown in the left drawing of Figure 13.



Key

1 POF

2 inner jacket

3 outer jacket

Figure 13 — POF cable structure (informative)

8.5 Requirements of POF cable

Table 4 specifies the normative references that contain requirements and test methods that the optical cables shall also comply with in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail.

Table 4 — Requirements of POF cable

Subclause	Requirement	Reference
8.6.1	High storage temperature exposure	IEC 60793-1-51 ISO 16750-4
8.6.2	Low storage temperature exposure	IEC 60793-1-51 ISO 16750-4
8.6.3	Operation temperature range	IEC 60793-1-51
8.6.4	Minimum bending radius (temporarily allowable bending radius)	IEC 60794-1-47
8.6.5	Maximum bending attenuation	IEC 60794-1-47
8.6.6	Maximum tensile strength	IEC 60794-1-21 IEC 60794-2-41
8.6.7	Crush	IEC 60793-1-40 IEC 60794-1-21
8.6.8	Edge impact	IEC 60793-1-40 IEC 60794-1-21
8.6.9	Static torsion	IEC 60793-1-40 IEC 60794-1-21
8.6.10	Resistance to flame propagation	ISO 6722-1

8.6 Evaluation

8.6.1 High storage temperature exposure

8.6.1.1 Purpose

Optical harnesses are required to provide stable performance under the vehicle environment. The initial performance of POF cable is required to maintain after being held at T_{max} for a long time.

8.6.1.2 Test setup

The 50 m POF cable is put into the programmable oven. 5 m at each end is taken out to be connected to the test equipment. One end face of the 5 m POF cable is connected to the output of a DC light source defined in 9.5.1 that has 650 nm ± 15 nm centre wavelength, and the other end face of the 5 m POF cable is connected to the input of an optical power meter set at 650 nm centre wavelength. Before the programmable oven is operated, optical power output after a 50 m POF is measured as the initial value.

8.6.1.3 Test methods

The optical power is measured after heating for 1 000 h at T_{max}. An applicable test condition shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{max}) is defined in code K in ISO 16750-4:2010, Clause 4. The maximum difference between the optical power while testing and the initial value is the additional attenuation by temperature stress.

8.6.1.4 Requirement

The maximum optical power decrease of a 40 m POF cable under standard atmospheric conditions (as defined in IEC 61300-1) shall be defined as 0,5 dB.

8.6.2 Low storage temperature exposure

8.6.2.1 Purpose

Optical harnesses are required to provide stable performance under the vehicle environment. The initial performance of POF cable is required to maintain after being held at T_{min} for a long time.

8.6.2.2 Test setup

The 50 m POF cable is put into the programmable oven. 5 m at each end is taken out to be connected to the test equipment. One end face of the 5 m POF cable is connected to the output of a DC light source defined in 9.5.1 that has 650 nm ± 15 nm centre wavelength, and the other end face of the 5 m POF cable is connected to the input of an optical power meter set at 650 nm centre wavelength. Before the programmable oven is operated, optical power output after a 50 m POF is measured as the initial value.

8.6.2.3 Test methods

The optical power is monitored while continuously cooling for 1 000 h at T_{min}. An applicable test condition shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{min}) is defined in code K in ISO 16750-4:2010, Clause 4. The maximum difference between the optical power while testing and the initial value is the additional attenuation by temperature stress.

8.6.2.4 Requirement

The maximum optical power decrease of a 40 m POF cable under standard atmospheric conditions (as defined in IEC 61300-1) shall be defined as 0,5 dB maximum while testing.

8.6.3 Operation temperature range

POF cable is a passive component. Therefore, it is not necessary to define the operating temperature if POF cable satisfies the definition of high storage temperature and low storage temperature.

8.6.4 Minimum bending radius

8.6.4.1 Purpose

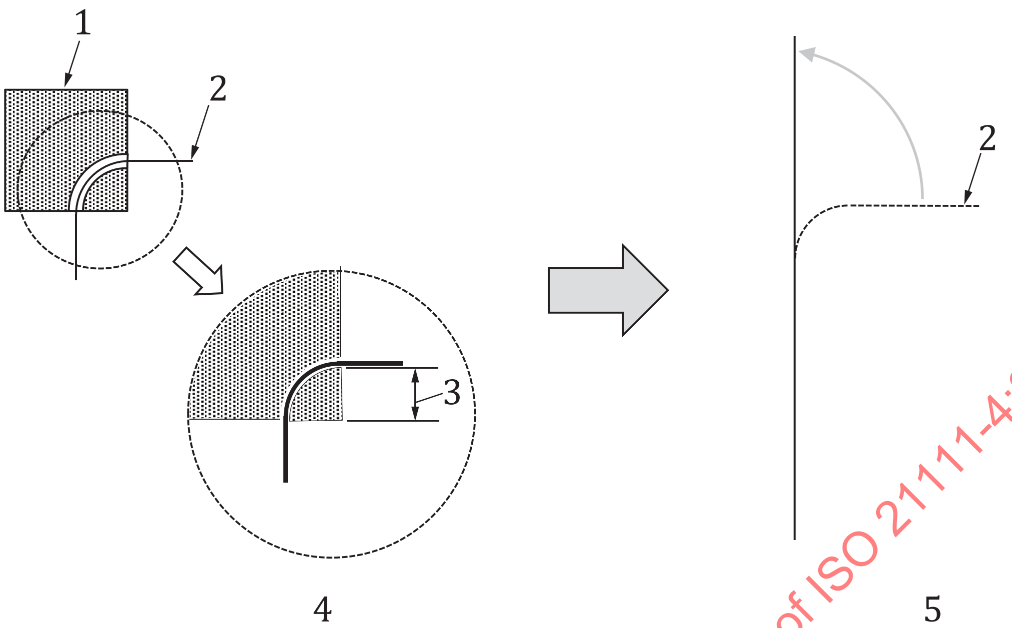
When a POF cable is bent in an excessively small radius, some irreversible deterioration can be generated at the bent portion and the transmitted optical power could be attenuated. Optical harnesses are often randomly bent during transportation or assembly into the vehicle. To avoid link performance deterioration by excessive cable bending, a minimum bending radius is defined.

8.6.4.2 Test setup

A POF cable with a length of 5 m is defined as DUT for this test. One end face of the DUT is connected with the launch optics. The other end face of the DUT is connected to the input of an optical power meter set at 650 nm centre wavelength. Use mode scrambler with equilibrium mode for the launch optics. The distance from the mode scrambler to the bent position is defined as 1 m.

8.6.4.3 Test methods

The optical power at the output of the cable shall be measured before placing the cable under test into the bending jig guide. The measured value is defined as the "initial value". The cable under test should be carefully set in the guide of a bending jig that has a 10 mm-radius groove and hold it for 24 h. The optical power at the output of the cable shall be measured after 1 min of the test (see Figure 14). The measured value is defined as "released value". The difference between the initial value and the released value is defined as "change in the attenuation".



Key

1 square jig for bent

2 POF cable

3 bent radius: 10 mm, angle: 90°

4 step 1: bend with square jig

5 step 2: release from the bend stress

Figure 14 — Release after bent test

8.6.4.4 Requirement

Change in the attenuation shall not exceed 0,2 dB when measured 1 min after test is finished.

8.6.5 Maximum bending attenuation

8.6.5.1 Purpose

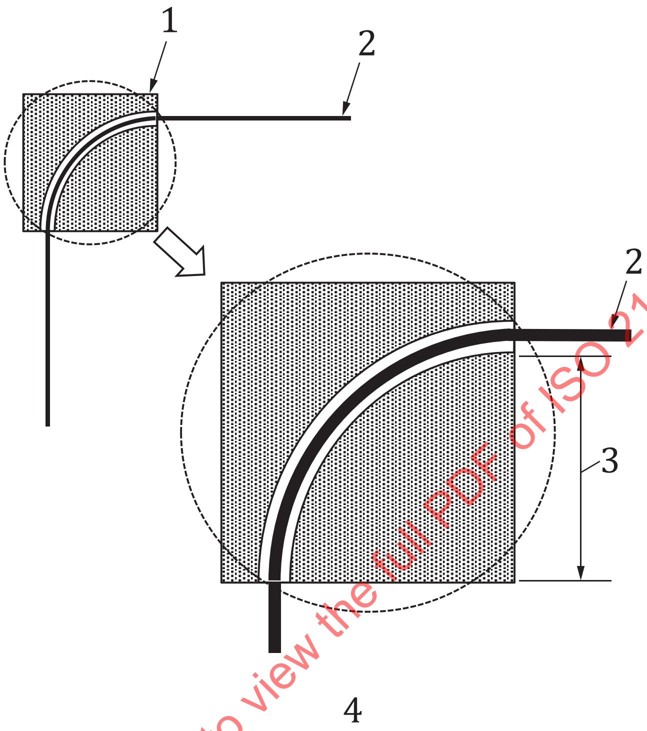
The propagation modes of some optical signals are changed, when the POF cable is bent. If the condition for total internal reflection is exceeded the respective modes enter the leaking mode. These modes are lost for the signal propagation and become the bending attenuation. Depending on their position in the vehicle body after assembly, POF cables in a harness are bent in the same manner as any other wire harness cable. To be able to calculate the expected losses of an installed POF-link the maximum bending attenuation is defined.

8.6.5.2 Test setup

A POF cable with a length of 5 m is defined as DUT for this test. One end face of the DUT is connected with the launch optics. The other end face of the DUT is connected to the input of an optical power meter set at 650 nm centre wavelength. Use mode scrambler with equilibrium mode for the launch optics. The distance from the mode scrambler to the bent position is defined as 1 m.

8.6.5.3 Test methods

The optical power at the output of the cable is measured before performing the bending test with jigs and the measured value is defined as the initial value. The cable under test shall be carefully set in the guide of a 90° bending jig that has a 25 mm radius groove. The optical power at the output of the cable being held for a minute is measured. The bending attenuation is the difference of the optical power before and after bending (see Figure 15). See IEC 60794-1-47 for further details.



Key

1 square jig for bent

2 POF cable

3 bent radius: 25 mm, angle: 90°

4 keep the bent shape with square jig

Figure 15 — Bent test

8.6.5.4 Requirement

The additional attenuation due to bending shall not exceed 0,5 dB.

8.6.6 Tensile strength

8.6.6.1 Purpose

POF cables used in the vehicle are routed in the same way as the typical wire harness. For this reason, the tensile strength requirement for a POF cable is equal than the requirements for an electric wire used for automobile.

8.6.6.2 Test setup

A tensile strength tester that has the load-cell of 200 N and movable-stage of 100 mm/min is prepared. DUT is just POF cable. DUT is set in a tensile strength tester at room temperature of +25 °C. The opposed wire clamps are set in the tensile strength tester with the distance of 100 mm to 200 mm. DUT is set to be pulled by the opposed wire clamps.

8.6.6.3 Test methods

DUT is pulled at a pulling speed of 100 mm/min., the load to DUT is read out as the tensile strength at the moment of 5 % elongation.

8.6.6.4 Requirement

The minimum tensile strength for 5 % elongation of a single or double jacket simplex POF cable (see 8.4) shall be 56 N. The minimum tensile load for 5 % elongation of a single or double jacket duplex POF cable (see 8.4) shall be 112 N.

8.6.7 Crush

8.6.7.1 Purpose

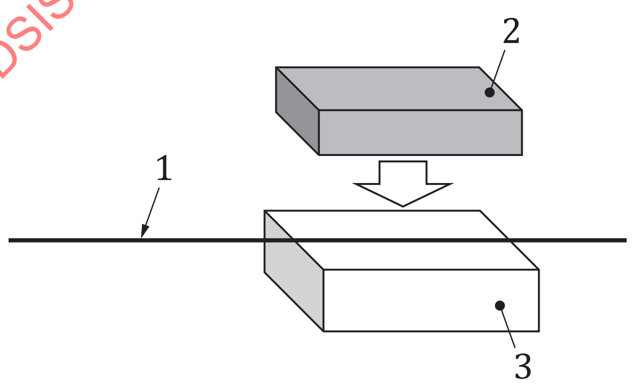
POF cables used in the vehicle might be subject to side pressure during cable routing and/or under assembled situation. Thus, it is required to define the upper limit value for attenuation increase due to this influence.

8.6.7.2 Test setup

A POF cable with a length of 5 m is defined as DUT for this test. One end face of the DUT is connected with the launch optics. The other end face of the DUT is connected to the input of an optical power meter set at 650 nm centre wavelength. The central part of POF cable is put on the base stage, and the weight jig is pressed from the upper side (see Figure 16). Use mode scrambler with equilibrium mode for the launch optics. The distance from the mode scrambler to crush position is defined as 1 m.

8.6.7.3 Test methods

The optical power at the output of the cable is measured before putting the crush load as the initial value. The crush load induced by a 105 kg weight jig is applied to the POF cable for three minutes. The transmission attenuation is measured one minute after the side pressure is released (see Figure 16). The test method shall follow the specification given in IEC 60793-1-21 for the edge of the weight jig. Increased attenuation is the difference of the optical power before and after crush test.



Key

1 POF cable

2 100 mm by 100 mm square, 105 kg weight jig

3 base stage that is larger than weight jig

Figure 16 — Cable crush test

8.6.7.4 Requirement

Increased attenuation of the POF cable measured 1 min after test ends shall be 0,2 dB or less.

8.6.8 Edge impact

8.6.8.1 Purpose

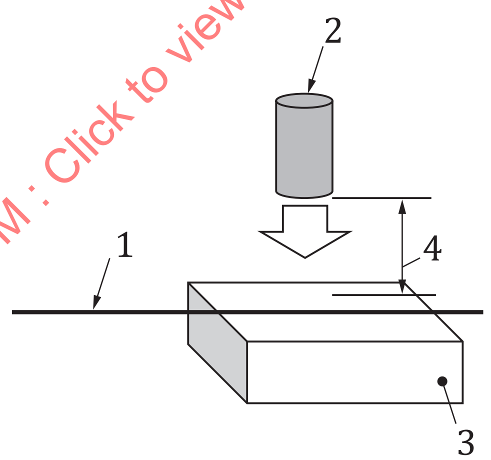
POF cables used in the vehicle might be subject to impact during cable routing. Thus, it is required to define the upper limit value of increased attenuation due to the impact force.

8.6.8.2 Test setup

A POF cable with a length of 5 m is defined as DUT for this test. One end face of the DUT is connected with the launch optics. The other end face of the DUT is connected to the input of an optical power meter set at 650 nm centre wavelength. The central part of POF cable is put on the base stage, and the impact jig is prepared to fall on the POF cable (see Figure 17). Use mode scrambler with equilibrium mode for the launch optics. The distance from the mode scrambler to edge impact position is defined as 1 m.

8.6.8.3 Test methods

The optical power at the output of the cable is measured before putting the impact load as the initial value. A metallic cylinder of 30 mm in the diameter and 1 kg in weight naturally dropped from the height of 50 mm on the POF cable, and the optical power is measured before and after the impact and the increased attenuation is calculated (see Figure 17). Test method shall follow the specification given in IEC 60793-1-21 for the edge of the impact jig. Increased attenuation is the difference of the optical power before and after impact test.



Key

1 POF cable

2 impact jig of a metallic cylinder of 30 mm in the diameter and 1 kg in weight

3 base stage that is larger than impact jig

4 height of fall: 50 mm

Figure 17 — Edge impact test

8.6.8.4 Requirement

Increased attenuation of the POF cable measured one minute after test ends shall be 0,2 dB or less.

8.6.9 Static torsion

8.6.9.1 Purpose

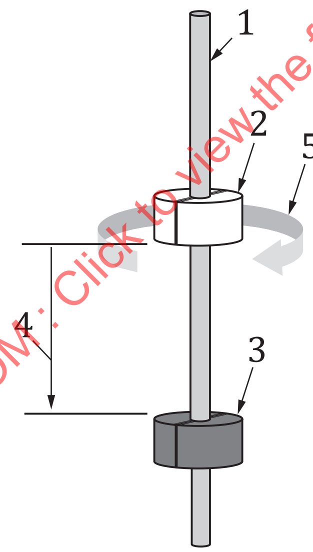
POF cables used in the vehicle might be subject to torsion during cable routing and/or under assembled situation. Thus, it is required to define the upper limit value of increased attenuation due to torsion.

8.6.9.2 Test setup

A POF cable with a length of 5 m is defined as DUT for this test. One end face of the DUT is connected with the launch optics. The other end face of the DUT is connected to the input of an optical power meter set at 650 nm centre wavelength. The POF cable is clamped to the fixed stage and the rotation stage for the static torsion test. Rotation stage shall be set between 1 m and 4 m from the launch optics. The distance between both stages is 50 mm. Use the mode scrambler with equilibrium mode for the launch optics. The distance from the launch optics to static torsion position is defined as 1 m.

8.6.9.3 Test methods

Before the DUT is twisted, optical power output after 5 m POF is measured as the initial value. POF cable attenuation is measured before twisting as the initial attenuation. Rotation stage is rotated to twist 180° in the section of 50 mm on POF cable under test. The attenuation in this situation and the initial attenuation are subtracted to obtain the increased attenuation (see Figure 18). The difference between the initial value and the optical power after twisting is the increased attenuation.



Key

1 POF cable
2 torsion jig: rotation stage
3 torsion jig: fixed stage
4 torsion range: 50 mm
5 torsion angle: 180°

Figure 18 — Static torsion test

8.6.9.4 Requirement

Increased attenuation of the POF cable that is measured after twisting-test shall be 0,2 dB or less.

8.6.10 Resistance to flame propagation

8.6.10.1 Purpose

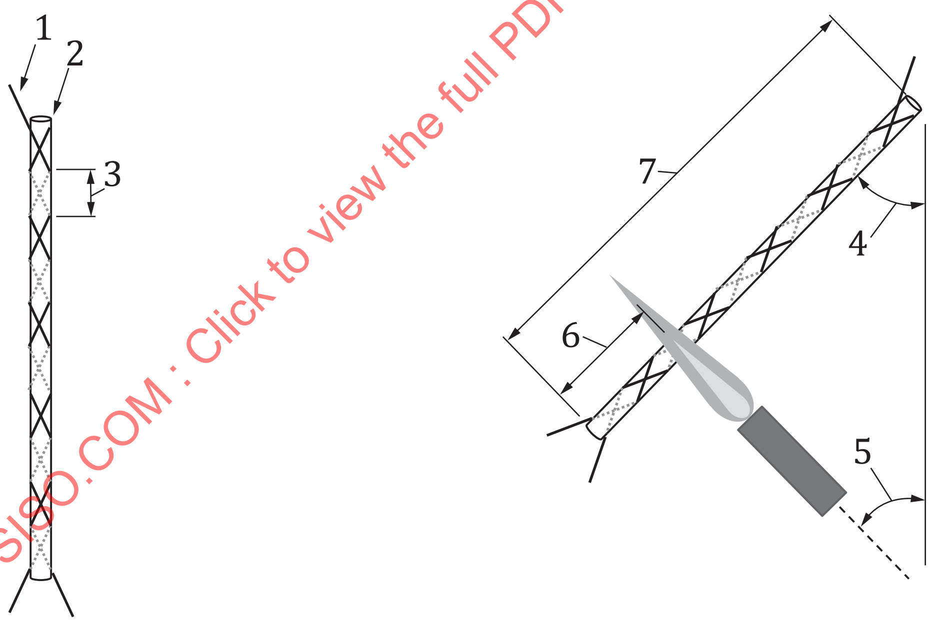
POF cables used in the vehicle are routed in the same way as the typical wire harness. For this reason, the flame resistance requirement for a POF cable is equal than the requirement for an electric wire used for automobile.

8.6.10.2 Test setup

A POF cable with a length of 600 mm ± 5 mm is fixed at 45° with respect to the horizontal direction at room temperature. The flame of a Bunsen burner is adjusted to the size of 50 mm inner flame and 100 mm outer flame. To prevent the self-extinction by the fusion, the test piece of the POF cable shall maintain the shape of DUT specified in Figure 19 a). To maintain the shape of DUT, POF cable is stabilized by one pair of copper wires supporting as defined in Figure 19 b).

8.6.10.3 Test methods

The POF cable is set 100 mm above the burner at 90° with respect to the inner flame of the burner. The POF cable is burned for 15 . The burner is removed after 15 s and the status of the POF cable after being ignited is chronologically monitored.



a) DUT with copper wires

b) Test image

Key

1 copper wire diameter for mesh supporter : (0,7 - 0,8) mm
2 POF cable
3 pitch of mesh for keeping an initial shape of DUT: 20 mm
4 tilt angle of the supported POF cable: 45°
5 tilt angle of the supported Bunsen burner: 45°
6 burning point from POF cable end: 100 mm
7 POF cable length for DUT: 600 mm

Figure 19 — Resistance to flame propagation test

8.6.10.4 Requirement

The flame at the DUT shall self-extinguish within 30 s after the flame of the burner is removed from the DUT.

9 Optical channel

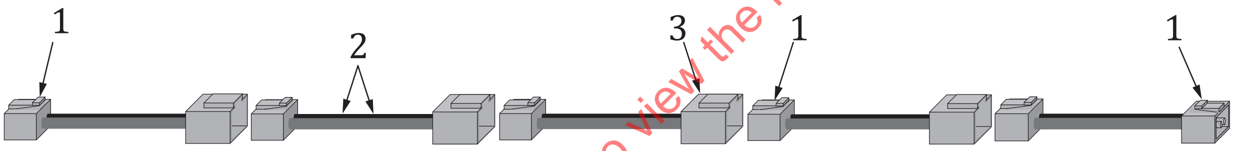
9.1 General

An optical channel is composed of an opposed optical PMD transceiver defined in 3.11 and an optical harness. The objective of an optical harness is to connect between the optical PMD transceivers by using one or more POF cables connected serially. The serial connection of POF cables is performed by an in-line system using in-line connector defined in 3.6.

9.2 Optical harness (informative)

The optical harness is divided into a lot of areas like the engine room, the instrument panel, the floor, the ceiling, the door and the trunk, etc., and a suitable design for each environment is enforced. After these electric harnesses are attached to the body, the portion of the harness in each area is connected with the in-line connector.

The number of in-line connectors in an optical harness is arbitrary when the total harness attenuation (A_H) is lower than the system power budget (P_B) defined in Annex A. For example, four in-line connectors can be inserted into a 15 m optical harness (see Figures 20 and 21).



Key

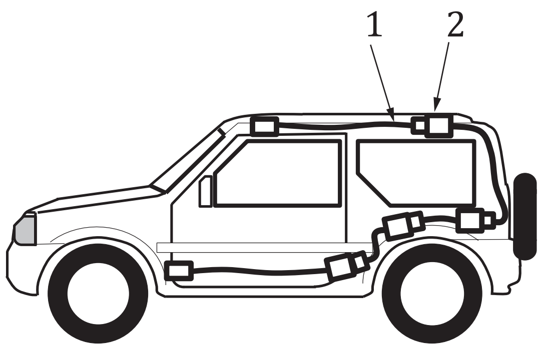
1 cable plug

2 POF cable

3 cable socket

1 and 3 in-line connector

Figure 20 — Optical harness with in-line connectors



Key

1 POF cable

2 in-line connector

Figure 21 — Optical harness layout image

9.3 Positions of test points

The test points as shown in Figure 22 are defined as the positions where the parameters provided by individual optical components are to be measured. Each test point is specified as follows.

— TP1: test point for electrical definitions of optical PMD transmitter that is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9.

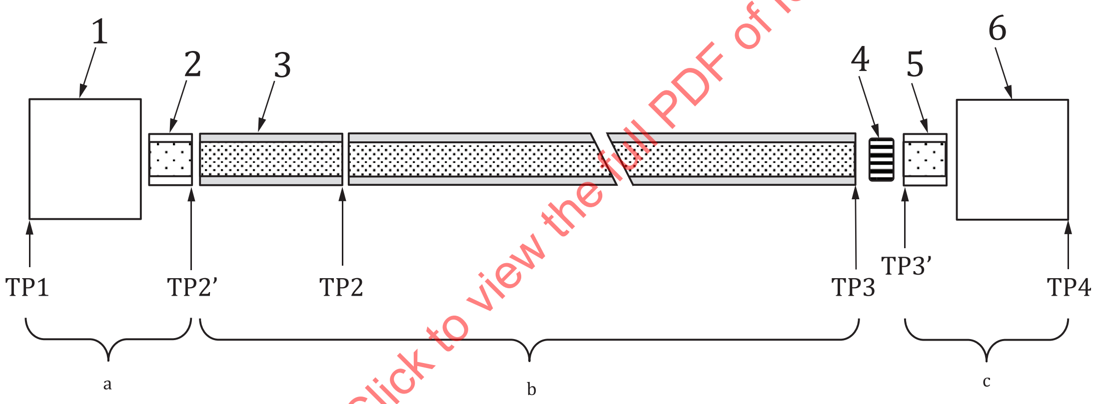
— TP2’: test point for optical definitions of optical PMD transmitter output that is defined in this subclause.

— TP2: test point for optical definitions of POF-end after 1 m from optical PMD transmitter that is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9.

— TP3: test point for optical definitions of POF harness-end that is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9.

— TP3’: test point for optical definitions of optical PMD receiver input that is defined in this subclause.

— TP4: test point for electrical definitions of optical PMD receiver that is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9.



Key

1 FOTx
2 waveguide
3 POF
4 mode filter (Annex B)
5 waveguide
6 FORx
a Optical PMD transmitter.
b POF cable.
c Optical PMD receiver.

Figure 22 — Position of test points

9.4 Requirements

9.4.1 Electrical characteristics

Table 5 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail.

Table 5 — Electrical characteristics

Subclause	Requirement	Reference
9.6.1	Optical PMD transmitter input electrical interface	ISO/IEC/IEEE 8802-3:2017/Amd 9
9.6.2	Optical PMD receiver output electrical interface	ISO/IEC/IEEE 8802-3:2017/Amd 9

9.4.2 Optical characteristics

Table 6 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail.

Table 6 — Optical characteristics

Subclause	Requirement	Reference
9.7.1	Minimum average output power at TP2	EIA/TIA 455-20A ISO/IEC/IEEE 8802-3:2017/Amd 9
9.7.2	Extinction ratio at TP2	EIA/TIA 455-34A ISO/IEC/IEEE 8802-3:2017/Amd 9
9.7.3	EAF profile at TP2	IEC 61300-3-53 ISO/IEC/IEEE 8802-3:2017/Amd 9
9.7.4	Minimum average output power at TP2'	EIA/TIA 455-20A ISO/IEC/IEEE 8802-3:2017/Amd 9
9.7.5	Minimum average output power at TP3	EIA/TIA 455-20A ISO/IEC/IEEE 8802-3:2017/Amd 9
9.7.6	Range of optical input power at TP3'	ISO/IEC/IEEE 8802-3:2017/Amd 9
9.7.7	Maximum coupling attenuation at optical in-line	EIA/TIA 455-34A IEC 60793-2-40

9.4.3 Physical characteristics

Table 7 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail.

Table 7 — Physical characteristics

Subclause	Requirement	Reference
9.8.1	Minimum retention force	ISO 8092-3 ANSI/EIA 364-13
9.8.2	Maximum insertion force	ISO 8092-2 ANSI/EIA 364-13
9.8.3	Maximum unlock and release force	ANSI/EIA 364-13
9.8.4	Durability of repeated mating/un-mating	IEC 60512-13-2
9.8.5	Maximum cable holding force	EIA 364-38A

9.4.4 Temperature environmental characteristics

Table 8 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail.

Table 8 — Temperature environmental characteristics

Subclause	Requirement	Reference
9.9.1	High storage temperature exposure	IEC 60793-1-51
9.9.2	Low storage temperature exposure	IEC 60793-1-51
9.9.3	High operation temperature exposure	IEC 60793-1-51
9.9.4	Low operation temperature exposure	IEC 60793-1-51

9.4.5 Combined environment examination

Table 9 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail. The following examinations are executed sequentially using one same DUT.

Table 9 — Combined environmental examination

Subclause	Requirement	Reference
9.10.3	Operation test after durability of mate/un-mate	EIA/TIA 455-21 ISO 16750-1
9.10.4	Operation test after high temperature exposure	ISO 16750-1 ISO 16750-4
9.10.5	Operation test after temperature and vibration	ISO 16750-1 ISO 16750-3
9.10.6	Operation test after heat shock	ISO 16750-1 ISO 16750-4
9.10.7	Operation test after humidity/temperature cycle procedure	ISO 16750-1 ISO 16750-4
9.10.8	Operation test after specific vibration profile	ISO 16750-1 ISO 16750-3

9.4.6 Specific environmental examination

Table 10 specifies the normative references that contain requirements and test methods that the optical components shall also comply in addition to the requirements and test methods defined in each subclause. In case that the result of a test method in the reference over the same parameter differs from the one defined in the subclause, the result in the reference shall prevail. DUT is prepared for individually, and the following examinations are executed individually.

Table 10 — Specific environmental examination

Subclause	Requirement	Reference
9.11.3	Operation test after specific physical impact	IEC 60028-2-27 ISO 16750-1

Table 10 *(continued)*

Subclause	Requirement	Reference
9.11.4	Operation test after chemical durability procedure	ISO 16750-1 ISO 16750-5
9.11.5	Operation test after Noxious gas exposure	IEC 60068-2-60
9.11.6	Operation test after specific dust condition exposure	ISO 16750-1 ISO 16750-4
9.11.7	Operation test after specific drop procedure	ISO 16750-1 ISO 16750-3

9.5 Methodology (informative)

9.5.1 Light source setup

Three kinds of light sources are prepared for the setup of each measurement.

a) IEEE compliant modulated light source:

Modulated light source is used for evaluation in operating mode 3.2 that is defined in ISO 16750-1. This light source is composed by an optical PMD transmitter that fulfils the optical characteristics defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-8. And an optical PMD transmitter is operated by test mode 3 that is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5.3.

b) IEEE compliant DC light source:

To determine the attenuation of some components or the change of the attenuation due to some conditions, a DC light source is used to measure the optical power at certain test points. This light source is composed by an optical PMD transmitter that fulfils the optical characteristics defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-8. And an optical PMD transmitter is operated by test mode 5 that is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5.3.

c) Applicable modulated LD light source:

This light source fulfils the optical characteristics defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-8 for an AOP output measured at TP2 of 1 dBm with the exception of the following optical characteristics:

— maximum relative intensity noise shall be lower than −131 dB/Hz;

— minimum extinction ratio shall be higher than 11 dB;

— minimum negative output droop shall be higher than −1,4 dB;

— minimum positive output droop shall be higher than −0,2 dB.

Measurement methods for transmitter optical characteristics are defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.6.4.

9.5.2 Excitation, test setup and measurement equipment

The test methods defined in this document require a controlled setting of physical variables and stimuli for the DUT. For these physical parameters a defined precision is required. The following list defines the recommended equipment and precision classified by the physical variable to be measured or set.

— Optical physical variable

Optical excitation and test setup equipment:

1) light source as defined in 9.5.1;
2) mode scrambler as defined in 3.9;
3) mode filter as defined in Annex B.

Test setup and measurement equipment:

1) FFP optical system as defined in IEC 61300-3-53;
2) optical sampling oscilloscope that is able to work with signals from DC to 1 GHz;
3) a set of an optical to electrical converter and a sampling oscilloscope with the same frequency range;
4) optical power meter that can measure average optical power from −35 dBm to +1,2 dBm;
5) detector of optical power meter has input window with sufficient diameter for detecting the optical signals that need to be measured.

— Electrical physical variable

Electrical excitation and test setup equipment:

1) function generator that is able to generate a voltage signal from 0,1 GHz to 1 GHz.

Test setup and measurement equipment:

1) sampling oscilloscope that is able to work with signals from DC to 1 GHz.

— Atmospheric physical variable

Test setup and measurement equipment:

1) programmable oven that can be controlled from −40 °C to +105 °C with a precision of ±1 °C;
2) standard temperature (and humidity) chamber.

— Mechanical physical variable

Test setup and measurement equipment:

1) tensile strength tester that can be measure strengths up to 200 N;
2) push-pull tester that can be measured up to 200 N;
3) jigs are defined as follows:
   — square jig for bent: see 8.6.4 and 8.6.5;
   — weight jig: see 8.6.7;
   — impact jig: see 8.6.8;
   — torsion jig: see 8.6.9;
   — ferrule guide: see 9.6.1 and 9.7.4;
   — pick-up cord: see 9.7.4.

9.5.3 Harness setup

When the optical harness is evaluated, it is recommended that the optical harness is kept in a shape similar to the actual assembly: locations to be bent, the number of bent locations, angle to twist, the number of twists, points to connect in-line and the number of in-line connections. It should be paid attention that the propagation mode might excessively change in the aforementioned points.

9.6 Evaluation (characteristics of photoelectric conversion)

9.6.1 Optical PMD transmitter input electrical interface

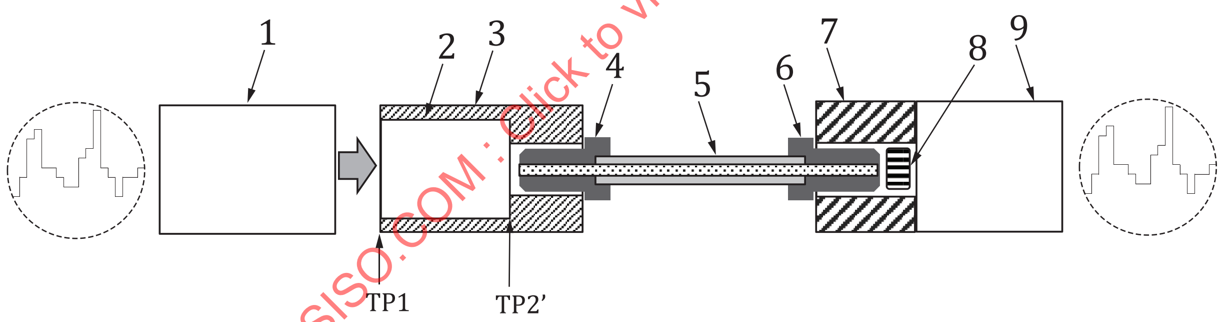
9.6.1.1 Purpose

The optical PMD transmitter converts the signal x(*n*) from the PMA through its input at TP1 into an optical signal at its output at TP2'. The electrical characteristics at TP1 are measured.

9.6.1.2 Test setup

As a complement of the test methods defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.6.4, a test setup that allows substituting the 1000BASE-H transceiver by the electrical model of Figure 23 is defined. The electrical model may be performed by a function generator that fulfils the specifications given in 9.6.1.4. The equivalent circuit of the function generator plus the connections to the optical PMD transmitter shall be equivalent to Figure 23 in all the frequency range from DC to at least 1 GHz.

In this test setup the function generator drives the optical PMD transmitter with electrical signals that may be equivalent to the ones generated by the 1000BASE-H transmitter when set in one of the test modes from 2 to 6 defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5. The test setup includes mode filter (see Annex B) and optical pick-up cord (see Figure 28). Mode filter is inserted between waveguide and the ferrule-end of optical pick-up cords. Mode filter serves as a mechanical fixture for coupling a fibre to the optical PMD transmitter while maintaining respective mode guidance. The output end of the optical pick-up cord is connected to the optical signal input terminal of the optical sampling oscilloscope (see Figure 23).



Key

1 function generator
2 optical PMD transmitter
3 transmitter side of header connector
4 ferrule
5 POF cable
6 ferrule
7 ferrule guide
8 mode filter (Annex B)
9 photo detector of optical sampling oscilloscope
TP1 electrical signal input
TP2' optical signal output

Figure 23 — Test setup for TP1 electrical interface measurement

9.6.1.3 Test methods

Complementary to the test methods defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.6.4, the test methods specified in this document shall use the test setup defined in 9.6.1.2.

9.6.1.4 Requirement

At TP1, electric signals shall be derived from the signal x(*n*) transmitted to the optical PMD transceiver. The signal x(*n*) is defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.3.3.1 and equation 115-22. The value of x(*n*) at each time shall be selected from the test modes 2 to 6 defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5.

To obtain the electrical signals at TP1 an electric model of the 1000BASE-H transmitter and of the optical PMD transmitter is defined in Figure 24:

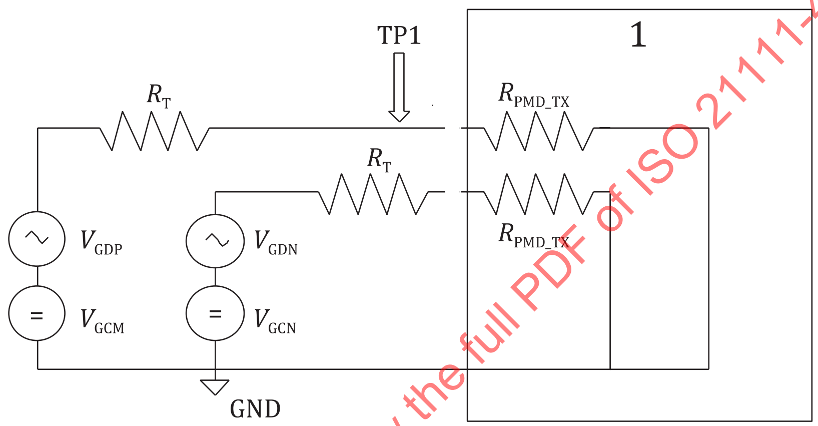


Figure 24 — 1000BASE-H transmitter electrical model and optical PMD transmitter model

V_{GDP} and V_{GDN} shall follow the relationship defined in Formulae (2) and (3) with the signal x(*n*):

$$V_{GDP} = \frac{I_{FS} R_T \mathrm{x}(n)}{2} \tag{2}$$

$$V_{GDN} = -\frac{I_{FS} R_T \mathrm{x}(n)}{2} \tag{3}$$

where $-1 \le \mathrm{x}(n) \le 1$.

On the other hand, the common mode V_{GCM} shall fulfil Formula (4):

$$V_{GCM} = \frac{I_{FS} R_T}{2} \tag{4}$$

R_T and I_{FS} are parameters that shall be provided by the 1000BASE-H transmitter component vendor indicating the minimum and maximum values that can take under operation ambient conditions.

R_{PMD} is a parameter that shall be provided by the optical PMD transmitter component vendor indicating the min and max values that can take under operation ambient conditions.

Once the values are given, the common and differential voltages at TP1 V_{com} and $V_{in\text{-}diff}$ are determined by the models defined in Figure 24. In Table 11, examples of voltages at TP1 are given for typical values of R_T, I_{FS} and R_{PMD}.

Table 11 — Interface at TP1 (informative)

Parameter	Symbol	Minimum	Typical	Maximum	Unit
1000BASE-H transceiver impedance to GND	R_T	—	50	—	Ohm
1000BASE-H transceiver full scale to current	I_{FS}	—	6	—	mA
PMD impedance to GND	R_{PMD}	46	50	54	Ohm
Common mode voltage at TP1	V_{com}	65	75	85	mV
Differential amplitude at TP1 (peak to peak)	$V_{in\text{-}diff}$	250	300	350	mV

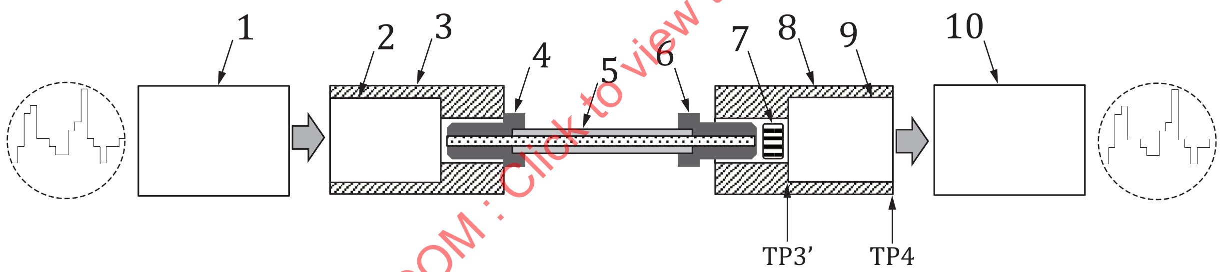
9.6.2 Optical PMD receiver output electrical interface

9.6.2.1 Purpose

The optical PMD receiver shall convert the optical signal received at TP3' into electrical signals at TP4. The electrical characteristics of TP4 are measured.

9.6.2.2 Test setup

TP3' is optically coupled to the optical input of the optical PMD receiver via a mode filter. Electrical signals output from the photoelectric converter are connected to the input terminal of the sampling oscilloscope (see Figure 25). Impedance R_T shall be connected to measure the V_n and V_p voltages as defined in Figure 26.



Key

1 function generator
2 optical PMD transmitter
3 transmitter side of header connector
4 ferrule
5 POF cable
6 ferrule
7 mode filter (Annex B)
8 receiver side of header connector
9 optical PMD receiver
10 sampling oscilloscope
TP3’ optical signal input
TP4 electrical signal output

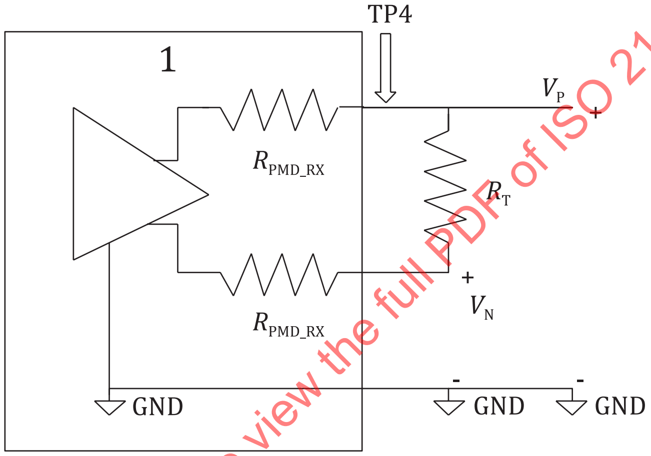
Figure 25 — Test setup for TP4 electrical interface measurement

9.6.2.3 Test methods

An electrical stimulus signal is to be provided at the signal input of the photoelectric converter (at TP1) in a way that the intensity of the optical signal at TP3' follows a sine wave with a frequency of 10 MHz and an extinction ratio between 10 dB and 16 dB. With this signal as the optical stimulus of the DUT, its electrical output is observed at TP4 with a sampling oscilloscope at TP4. The differential output pads of the optical PMD receiver (DUT) shall be terminated with the desired impedance R_T (see Figure 26). The voltages V_{com_TP4} and V_{out_diff} are measured.

9.6.2.4 Requirement

Optical signal input into TP3' is defined as a 10 MHz sine wave with an extinction ratio between 10 dB and 16 dB that is photoelectrically converted. Electrical signals are output from TP4. To obtain the electric signals at TP4, a model of the optical PMD receiver and a measurement procedure are defined in Figure 26:



Key

1 optical PMD receiver

Figure 26 — Optical PMD receiver model and measurement procedure

V_p and V_n are measured by terminating differentially the optical PMD receiver with an impedance of controlled value R_T. V_p and V_n shall be measured by using high impedance probes connected to a sampling oscilloscope that shall be able to simultaneously sample both probes to compute $V_{out\text{-}diff}$ and V_{com_TP4}. V_{com_TP4} is defined, instantaneously, as a function of V_p and V_n [see Formula (5)]:

$$V_{com\_TP4} = \frac{V_P + V_n}{2} \quad (5)$$

V_{out_diff} is defined, instantaneously, as a function of V_p and V_n [see Formula (6)]:

$$V_{out\_diff} = V_P - V_n \quad (6)$$

Optical PMD receiver output shall be differential and defined with a common mode voltage V_{com_TP4} and a differential amplitude $V_{out\text{-}diff}$.

R_{PMD}, V_{com_TP4} and V_{out_diff} are parameters that shall be provided by the optical PMD receiver component vendor indicating the minimum and maximum values of the parameters that can occur under ambient operation conditions. In Table 12, pass/fail criteria for the test methods that refers to TP4 in this document are defined. A pass result in the test for a component does not guarantee that the combination of the component and the 1000BASE-H transceiver fulfils the requirements for a reliable communication as defined in ISO/IEC/IEEE 8802-3:2017/Amd 9.

Table 12 — Interface pass/fail criteria at TP4

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Measurement procedure differential impedance	R_T	—	100	—	Ohm
Output PMD receiver impedance to GND	R_{PMD_RX}	46	50	54	Ohm
Common mode voltage at TP4	V_{com_TP4}	0,59	—	1,55	V
Differential amplitude at TP4 (peak to peak)	$V_{out\text{-}diff}$	120	—	350	mV

9.7 Evaluation (optical characteristics)

9.7.1 Minimum average output power at TP2

9.7.1.1 Purpose

To be able to design the optical communication system, the minimum average output power at TP2 is an important parameter. It is a reference value required to secure the reliability of the optical communication as it determines the minimum receivable optical power at TP3 for a given optical loss of a link.

9.7.1.2 Test setup

The DUT for this test is composed of the PMD transmitter connected with a 1 m POF cable by a cable plug. One end of the POF cable has a polished fibre end and the other cable end has the cable plug assembled. A function generator defined in 9.5.2 is used as the signal stimulus for the PMD transmitter. The electrical signals that drive the optical PMD transmitter shall be square wave of 16,25 MHz (ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5 test mode 3). The value of V_{com} and $V_{in\text{-}diff}$ shall fulfil the requirements given in 9.6.1.4. AOP shall be measured with an optical power meter that is corrected at 650 nm. The detector of the optical power meter shall have sufficient area in order to detect all the light emitted from TP2.

9.7.1.3 Test methods

POF cable is connected to the optical PMD transmitter that is operated with the condition defined in 9.7.1.2. The POF cable under evaluation test shall be set free from being bent at small radius, side pressure, and other stress factors. The AOP from the other end is measured with an optical power meter.

9.7.1.4 Requirement

The AOP measured at TP2 shall be within the limits defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-8 for 1000BASE-RHC corrected by a factor derived from the different test mode applied to measure AOP.

9.7.2 Extinction ratio at TP2

9.7.2.1 Purpose

The extinction ratio is a key factor to guarantee the quality of the optical PMD transmitter. Thus a limited allowable range for the extinction is defined.

9.7.2.2 Test setup

1 m of POF cable that has the cable plug assembled on the cable end and polished on the other cable end is prepared. DUT for this test method is composed by a PMD transmitter connected to the POF cable

with the cable plug assembled. A function generator and an optical PMD transmitter shown in 9.6.1 are used as the measurement light source. Electrical signals that drive the optical PMD transmitter shall be square wave of 16,25 MHz (ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5 test mode 3). The value of V_{com} and $V_{in\text{-}diff}$ shall fulfil the requirements given in 9.6.1.4.

9.7.2.3 Test methods

The POF cable is connected to the optical PMD transmitter and the other end is connected to an optical oscilloscope or an oscilloscope via optical/electrical converter to measure the extinction ratio. The POF cable under evaluation test shall be set free from being bent at small radius, side pressure, and other stress factors. Measurement methods of the ER shall be referred to ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.6.4.5.

9.7.2.4 Requirement

The ER measured at TP2 shall be within the limits defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-8 for 1000BASE-RHC.

9.7.3 EAF profile at TP2

9.7.3.1 Purpose

EAF of optical signals entering optical fibres is restricted to maintain the transmission bandwidth required for the entire defined length of optical harness.

9.7.3.2 Test setup

1 m of POF cable that has the cable plug assembled on the cable end and polished on the other cable end is prepared. DUT for this test method is composed by a PMD transmitter connected to the POF cable with the cable plug assembled. Electrical signals that drive the optical PMD transmitter shall be square wave of 16,25 MHz (ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5 test mode 3). EAF measuring equipment with $f\theta$ lens system that is defined in IEC 61300-3-53 is prepared. The measuring equipment is corrected at 650 nm wavelength, and it shall be able to detect all the emitted light from TP2. The optical fibre under evaluation test shall be set free from being bent at small radius, side pressure, and other stress factors.

9.7.3.3 Test methods

One end of a 1 m POF is connected to the optical PMD transmitter and the other end is connected to the input of the EAF measurement equipment. The EAF is measured as a function of the numerical aperture full angle.

9.7.3.4 Requirement

EAF at TP2 shall not exceed the lower limit defined in ISO/IEC/IEEE 8802-3:2017/Amd 9.

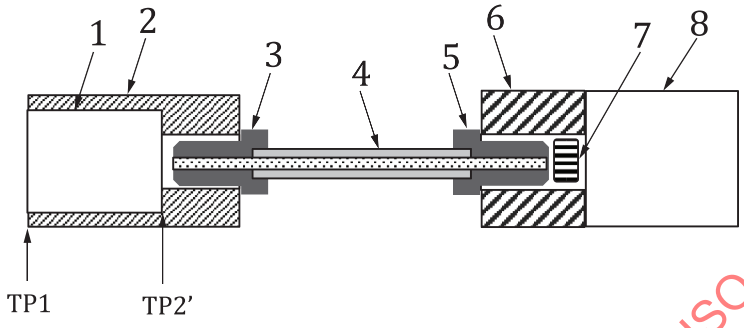
9.7.4 Minimum average output power at TP2’

9.7.4.1 Purpose

To be able to design the optical communication system, the minimum average output power at TP2’ is an important parameter. It is a reference value required to secure the reliability of the optical communication as it determines the minimum receivable optical power at TP3 for a given optical loss of a link.

9.7.4.2 Test setup

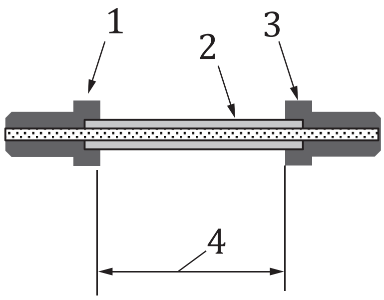
A function generator and optical PMD transmitter shown in 9.5.2 are used as the measurement light source. Electrical signals that drive the optical PMD transmitter shall be square wave of 16,25 MHz (ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5 test mode 3). The value of V_{com} and $V_{in\text{-}diff}$ shall fulfil the requirements given in 9.6.1.4. The output face of the optical PMD transmitter is positioned facing the input face of the mode filter connected with an optical pick-up cord with length fix to 100 mm and known attenuation. The output face of the optical pick-up cord (see Figure 28) is positioned facing to the photo detector of an optical power meter corrected at 650 nm (see Figure 27).



Key

1 optical PMD transmitter
2 transmitter side of header connector
3 ferrule
4 POF cable
5 ferrule
6 ferrule guide
7 mode filter (Annex B)
8 photo detector of the optical power meter
TP1 electrical signal input
TP2’ optical signal output

Figure 27 — Optical power pick-up system



Key

1 ferrule
2 POF cable (cladding diameter of POF: 1 mm; NA of POF: ≥0,5)
3 ferrule
4 cable length between ferrules: 100 mm

Figure 28 — Pick-up cord

9.7.4.3 Mode filter

Optical filter that eliminates higher order modes in order to suppress modal dispersion. A propagation mode necessary to maintain the bandwidth of POF is extracted by mode filter defined in Annex B.

9.7.4.4 Test methods

The AOP of optical signals on the output surface of the mode filter for optical coupling is measured with an optical power meter defined in 9.5.2.

9.7.4.5 Requirement

The AOP measured at TP2' shall be within the limits defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-8 for 1000BASE-RHC at TP2 decreased by 3,3 dB.

9.7.5 Minimum average output power at TP3

9.7.5.1 Purpose

To be able to design the optical communication system, the minimum average input power at TP3 is an important parameter. It is a reference value required to calculate for the maximum allowable loss of the optical link for a given minimum power at TP2/TP2'.

9.7.5.2 Test setup

POF cable with cable plug on the both ends is prepared as the DUT. Total length of POF cable and number of in-line shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, DUT is 15 m POF cable that includes 4 in-lines. A function generator and optical PMD transmitter shown in 9.5.2 are used as the measurement light source. Electrical signals that drive the optical PMD transmitter shall be square wave of 16,25 MHz (ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, 115.5 test mode 3). The value of V_{com} and $V_{in\text{-}diff}$ shall fulfil the requirements given in 9.6.1.4. POF cable with ferrules in both ends is prepared. One end of ferrule is connected with optical PMD transmitter and other end of ferrule (TP3) is connected with photo detector of optical power meter. AOP shall be measured with an optical power meter that is corrected at 650 nm. The detector of the optical power meter shall have sufficient area in order to detect all the light emitted from TP3. The optical fibre under test is set free from being bent at small radius, side pressure, and other stress factors.

9.7.5.3 Test methods

AOP at TP3 is measured with an optical power meter.

9.7.5.4 Requirement

The AOP measured at TP3 shall be within the limits defined in ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-10 for 1000BASE-RHC at TP3.

9.7.6 Range of optical input power at TP3'

9.7.6.1 Purpose

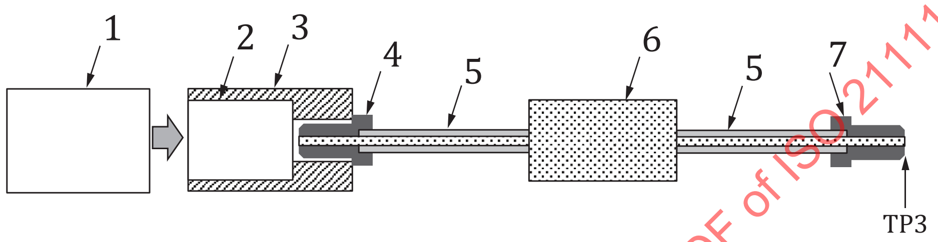
The optical input level to the optical PMD receiver greatly changes by the PMD transmitter's AOP, the design of the POF harness and the system operating condition. Therefore, optical PMD receiver should be able to output an accurate demodulated electrical signal at TP4 if applied with an optical signal at TP3 according to ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, Table 115-10.

9.7.6.2 Test setup

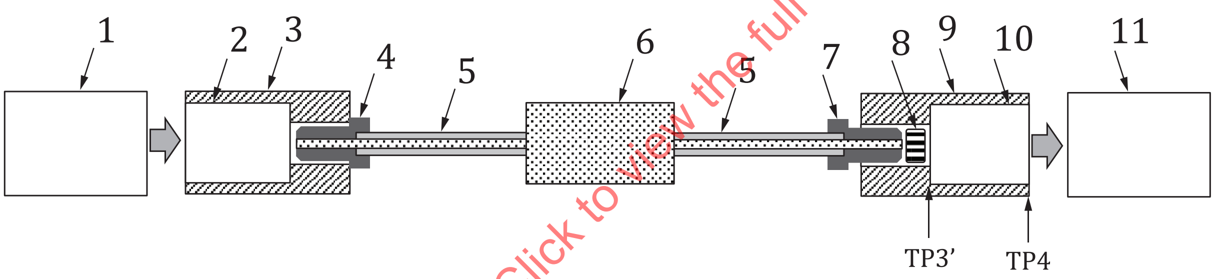
A function generator and modulated LD light source defined in 9.5.1 are used as the measurement light source. Electrical signals that drive the LD light source shall be sine wave of 10 MHz with extinction ratio between 10 dB and 16 dB. The system to provide the output of TP3 is prepared [see Figure 29 a)]. Each control point of the neutral density attenuator by which the output of TP3 becomes 1 dBm, −9 dBm, and −18,5 dBm respectively is confirmed. Optionally, additional control points may be set as the output of TP3 between 1 dBm and −18,5 dBm. The system to evaluate the optical PMD receiver is prepared [see Figure 29 b)].

9.7.6.3 Test methods

The electrical signal output V_{com_TP4} and $V_{out\text{-}diff}$ of TP4 are measured with the sampling oscilloscope with the input conditions at TP3 set to 1 dBm, −9 dBm, and −18,5 dBm respectively.



a) Output setting at TP3



b) Optical PMD receiver evaluation

Key

1 function generator
2 applicable modulated LD light source defined in 9.5.1
3 transmitter side of header connector
4 ferrule
5 POF cable
6 neutral density attenuator
7 ferrule
8 mode filter (Annex B)
9 receiver side of header connector
10 optical PMD receiver
11 sampling oscilloscope
TP3' optical signal input
TP4 electrical signal output

Figure 29 — Optical PMD receiver evaluation

9.7.6.4 Requirement

Electrical signal output at TP4 shall be within the limits defined in Table 11 for V_{com_TP4} and $V_{out\text{-}diff}$ according to the optical signal output from TP3 defined in ISO/IEC/ 8802-3:2017/Amd 9:2018, Table 115-10.

9.7.7 Maximum coupling attenuation at optical in-line

9.7.7.1 Purpose

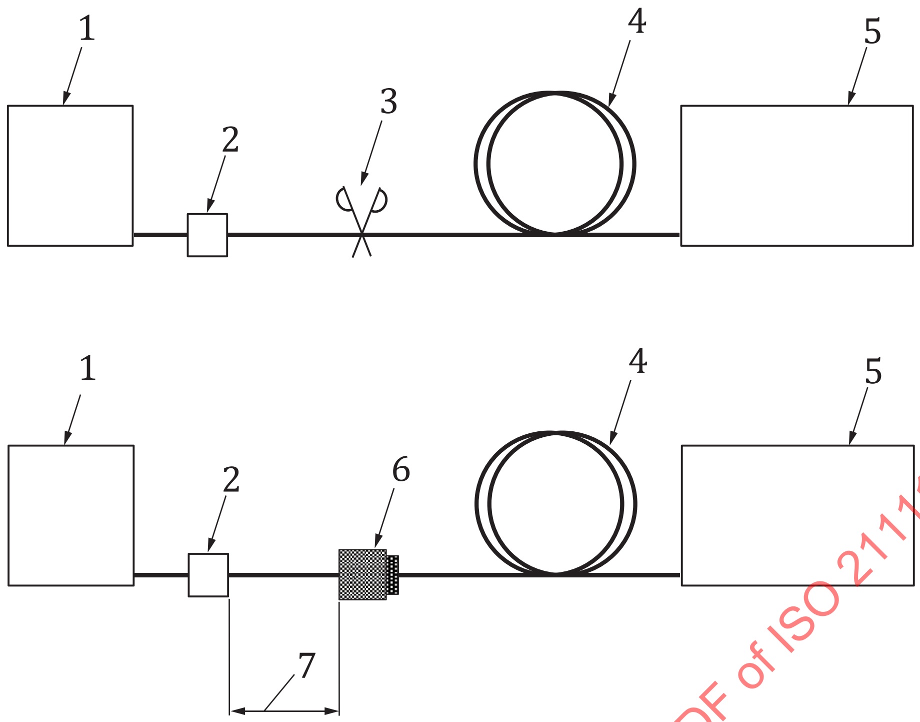
The optical in-line connector is a component of the optical harness to connect harness sections. The maximum attenuation of an in-line connector is required to calculate the total attenuation of the optical harness.

9.7.7.2 Test setup

The length of POF cable under test is defined to be 5 m. One end face of the 5 m POF cable is connected to the output of a mode scrambler after 1 m from DC light source that has 650 nm ± 15 nm centre wavelength, and the other end face of the 5 m POF cable is connected to the input of an optical power meter set at 650 nm centre wavelength.

9.7.7.3 Test methods

As initial value the optical power at the end of the 5 m test cable is read out. The POF cable is cut at 1 m from the mode scrambler, and a cable socket and a cable plug are attached to the opposing cut faces. The optical power of the 5 m POF cable with the inserted in-line connector is measured as the attenuated value. The difference between the initial optical power and the attenuated value is the insertion attenuation of the in-line connector (see Figure 30).



Key

1 DC light source
2 mode scrambler
3 cut point
4 POF cable
5 optical power meter
6 in-line connector
7 distance between mode scrambler and in-line: 1 000 mm

Figure 30 — In-line attenuation measurement

9.7.7.4 Requirement

The insertion attenuation per one in-line connector shall be 1,5 dB or less.

9.8 Evaluation (physical characteristics)

9.8.1 Minimum retention force

9.8.1.1 Purpose

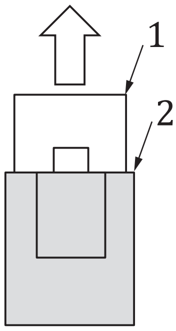
Unexpected pull forces during assembly of the optical harness into the vehicle or at the vehicle maintenance might result in a not fully mated connector. This situation would increase the coupling attenuation by the fibre to fibre distance change in the connector. Therefore, the performance of the lock mechanism of an optical connector is specified not to come off by unexpected force.

9.8.1.2 Test setup

DUT is composed by the mated cable plug and cable socket that are defined in Clause 7. DUT shall be operated mated and unmated repeatedly ten times as the pre-condition. The cable socket is clamped to the base stage with the holding jig, and the cable plug is clamped to the movable stage with the holding jig.

9.8.1.3 Test methods

The movable stage shall be moved away in the vertical direction from the base stage (see Figure 31). The tensile strength tester is operated under the designated operation criteria, and the retention force of the optical connector is measured when the lock mechanism is damaged by pulling at the speed of 50 mm/min.



Key

1 cable plug (clamped to the movable stage)

2 cable socket (clamped to the base stage)

Figure 31 — Retention force measurement

9.8.1.4 Requirement

The retention force of optical connectors shall be 100 N or stronger when the lock mechanism is damaged.

9.8.2 Maximum insertion force

9.8.2.1 Purpose

The insertion power is defined for the effort reduction in the connector mating work when an optical harness is assembled to the car.

9.8.2.2 Test setup

The test setup of the maximum insertion force measurement that is used to mate the connector plug to socket is defined in ANSI/EIA-364-13.

9.8.2.3 Test methods

The test method is defined in ANSI/EIA-364-13 as the particularity that shall be performed with the lock mechanism activated.

9.8.2.4 Requirement

The maximum insertion force shall be 44,1 N or lower when mating optical connectors at the speed of 50 mm/min.

9.8.3 Maximum unlock and release force

9.8.3.1 Purpose

The lock mechanism of optical connectors is required to be easily unlocked and released when optical harnesses are removed due to vehicle maintenance.

9.8.3.2 Test setup

ANSI/EIA-364-13 defines the load required to release the lock of vehicle connectors. This evaluation test shall be performed with the lock mechanism deactivated.

9.8.3.3 Test methods

ANSI/EIA-364-13 defines mating and unmating force test procedure for vehicle connectors. The pushing load of the latch lever generated when a connector begins to unmate is measured.

9.8.3.4 Requirement

The pushing load of the latch lever generated when the both POF connectors are released shall be 20 N or smaller when the lock mechanism of cable plug is pushed at the speed of 10 mm/min.

9.8.4 Durability of repeated mating and unmating

9.8.4.1 Purpose

Optical harnesses assembled in the vehicle are mated and unmated several times during vehicle maintenance such as the product inspection process. An evaluation test that mates/unmates cable plug and cable socket repeatedly is required to check whether or not the optical connector maintains its required performance after repeated mate and unmate actions.

9.8.4.2 Test setup

The DUT for this test method consists of a POF cable with an in-line connector at the centre. The total DUT length is 5 m. One end face of the 5 m POF cable is connected to the output of a mode scrambler after 1 m from DC light source that has 650 nm ± 15 nm centre wavelength, and the other end face of the 5 m POF cable is connected to input of an optical power meter set at 650 nm centre wavelength. After first mating of in-line connector (DUT) and prior to any unmating action, measure the initial output power of the mated DUT.

9.8.4.3 Test methods

The cable plug and socket of the in-line connector shall be mated and unmated repeatedly. The optical output power is measured after each plug cycle when the cable plug and socket are mated. The difference between the initial value and the optical output power after each mating cycle is calculated as the insertion attenuation change of in-line connector. The mate and unmate speed is not defined, because the mating of the plug and socket is done for the evaluation tests are typically performed manually.

9.8.4.4 Requirement

The cable plug does the mate and un-mate operation ten times repeatedly with the cable socket. The difference of the insertion attenuation after each mate and unmate operation shall be defined within +0,5 dB.

9.8.5 Maximum cable holding force

9.8.5.1 Purpose

Optical harnesses might be pulled by unexpected forces when they are assembled into the vehicle or vehicle maintenance is performed. The end of POF cable held in an optical connector is moved when the POF cable is pulled. In this case, the optical coupling attenuation between the end of POF cable and the opposite optics increases. To avoid this situation, the cable holding force of optical connector shall be defined.

9.8.5.2 Test setup

The POF cable with a cable plug or a cable socket assembled on one end is prepared. The cable plug or the cable socket is fixed with a holding jig set on the base stage of the tensile strength tester, and the POF cable is fixed with the holding jig set on the movable stage.

9.8.5.3 Test methods

The tensile strength test is performed at a pulling speed of 50 mm/min. The force generated when the POF cable is pulled from either the cable plug or the cable socket is measured.

9.8.5.4 Requirement

The cable-holding force shall be 110 N or stronger when the POF cable is pulled out from the cable plug or the cable socket by pulling with a speed of 50 mm/min.

9.9 Evaluation (temperature environmental characteristics)

9.9.1 High storage temperature exposure

9.9.1.1 Purpose

Optical harnesses are required to perform stable operation under the vehicle environment. Optical connectors in the optical harness are also required to maintain their optical performance even after being exposed for a long time to T_{max}.

9.9.1.2 Test setup

The DUT is composed of a POF cable of 3 m with a cable plug assembled on one end and a POF cable of 3 m with a cable socket assembled on one end mated. One end face of the 3 m POF cable is connected to the output of a mode scrambler after 1 m from DC light source that has a 650 nm ± 15 nm centre wavelength, and the other end face of the 3 m POF cable is connected to photo detector of an optical power meter set at 650 nm centre wavelength. The in-line connector of DUT is put into a programmable oven, and the ends of each POF cable are respectively connected to a DC light source and the optical power meter prepared outside of the oven.

9.9.1.3 Test methods

Optical power that comes from the DUT is measured before the heat operation as the initial value. After being held for 1 000 h at the designated temperature (T_{max}), the inside temperature is brought to the room temperature. Optical power that comes from the DUT is measured at room temperature (+25 °C). The increase of the attenuation in the in-line connector is obtained by subtracting the optical power before and after heating. An applicable test condition shall be agreed between supplier and vehicle manufacturer. Unless otherwise provided, designated temperature (T_{max}) is defined in code K in ISO 16750-4:2010, Clause 4.