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ISO 21111-8

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Road vehicles — In-vehicle Ethernet —

Part 8: Electrical 100-Mbit/s Ethernet transmission media, components and tests

Véhicules routiers — Ethernet embarqué —

Partie 8: Tests, composants et supports de transmission ethernet électriques à 100 Mbit/s

Reference number
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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 conforms with the Open Systems Interconnection (OSI) reference model specified in ISO/IEC 7498-1[1] and ISO/IEC 10731[2].

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 and the amendments, the document structure, type of physical entities, in-vehicle Ethernet specific functionalities, and so on.

ISO 21111-2[4] 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[5] 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.

ISO 21111-4[6] specifies the optical components requirements and test methods for 1-Gbit/s optical in-vehicle Ethernet.

ISO 21111-5[7] 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[8] 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 sublayer requirements and conformance test plan.

ISO 21111-7 [9] specifies the implementation for ISO/IEC/IEEE 8802-3, 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.

This document specifies the transmission media, the channel performance and the tests for an 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[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.

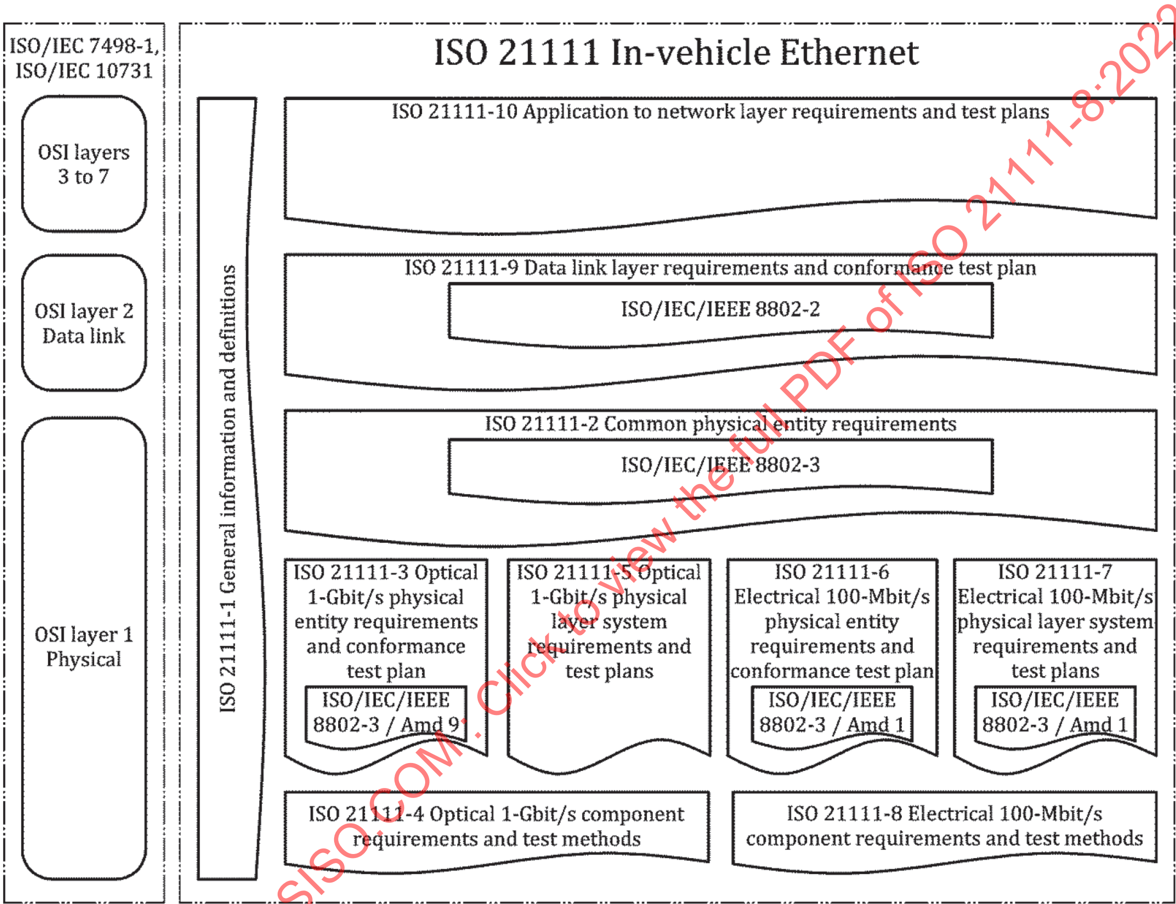


Figure 1 — In-vehicle Ethernet document reference according to the OSI model

Road vehicles — In-vehicle Ethernet —

Part 8:
Electrical 100-Mbit/s Ethernet transmission media, components and tests

1 Scope

This document defines various parameters to be tested for the communication channel between two Ethernet devices (e.g. ECUs for automotive application) and also for the transmission media including cables and connectors as a single component of which the communication channel consists. This document also specifies the general RF requirements for a physical layer communication channel for ISO/IEC/IEEE 8802-3. These requirements are related to signal integrity of the communication channel.

Test methods for electrical performances of the communication channel/link and cables and connectors are also specified in 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, *Telecommunications and exchange between information technology systems — Requirements for local and metropolitan area networks — Part 3: Standard for Ethernet*

ISO 19642-2, *Road vehicles — Automotive cables— Part 2: Test methods*

ISO 21111-1, *Road vehicles – In-vehicle Ethernet – Part 1: General information and definitionsIEC 60512-25(all parts), Connectors for electronic equipment – Tests and measurements*

IEC 60603-7-7:2010, *Connectors for electronic equipment - Part 7-7: Detail specification for 8-way, shielded, free and fixed connectors for data transmission with frequencies up to 600 MHz*

IEC 60512-25 (all parts), *Connectors for electronic equipment - Tests and measurements*

IEC 61935-1 (all parts), *Specification for the testing of balanced and coaxial information technology cabling - Part 1: Installed balanced cabling as specified in ISO/IEC 11801-1 and related standards*

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 terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
Ethernet data cable
single twisted pair cable that can transmit 100BASE-T1 Ethernet signals

Note 1 to entry: This is specified in Reference [11].

3.2
power sum alien near end crosstalk loss
PSANEXT

$$PSANEXT(f)_N = -10\log_{10}\sum_{j=1}^{m} 10^{\frac{-ANEXT(f)_{N_j}}{10}}$$

where

$PSANEXT$	is the PSANEXT;
f	is the frequency;
j	is the disturbing signals;
N	is the disturbed signal;
m	is the number of disturbing pairs.
α_{ANEXT}	is the ANEXT.

Note 1 to entry: Power sum alien near end crosstalk loss is expressed in dB.

3.3
power sum attenuation to alien crosstalk ratio far end
PSAACRF

$$PSAACRF(f)_N = -10\log_{10}\sum_{j=1}^{m} 10^{\frac{-AACRF(f)_{N_j}}{10}}$$

$$AACRF(f)_{Nj} = AFEXT(f)_{Nj} - IL(f)_N$$

where

$PSAACRF$	is the PSAACRF;
f	is the frequency;
j	is the disturbing signals;
N	is the disturbed signal;
m	is the number of disturbing pairs;
$AACRF$	is the AACRF;
$AFEXT$	is the AFEXT
IL	is the IL

Note 1 to entry: power sum attenuation to alien crosstalk ratio far end is expressed in dB.

4 Abbreviated terms

AACRF	alien attenuation to crosstalk ratio far-end
AFEXT	alien far end crosstalk loss
AFEXTDC	alien far end cross conversion loss common to differential
AFEXTDS	alien far end cross conversion loss single ended to differential
ANEXT	alien near end crosstalk loss
ANEXTDC	alien near end cross conversion loss common to differential
ANEXTDS	alien near end cross conversion loss single ended to differential
CC	communication channel
CIDM	characteristic impedance differential mode
CUT	cable under test
DUT	device under test
ECU	electronic control unit
ES	environment system
GND	ground
IL	insertion loss
LCL	longitudinal conversion loss
LCTL	longitudinal conversion transmission loss
MDI	media dependent interface
PCB	printed circuit board
PSANEXT	power sum alien far end crosstalk loss
PSAACRF	power sum power-sum alien attenuation to crosstalk ratio far-end
RL	return loss
RT	room temperature
SMA	sub miniature type A
SCC	standalone communication channel
S-Parameter	scattering parameter
TDR	time domain reflectometry
VNA	vector network analyser
WCC	whole communication channel

5 Communication channel/link

5.1 General

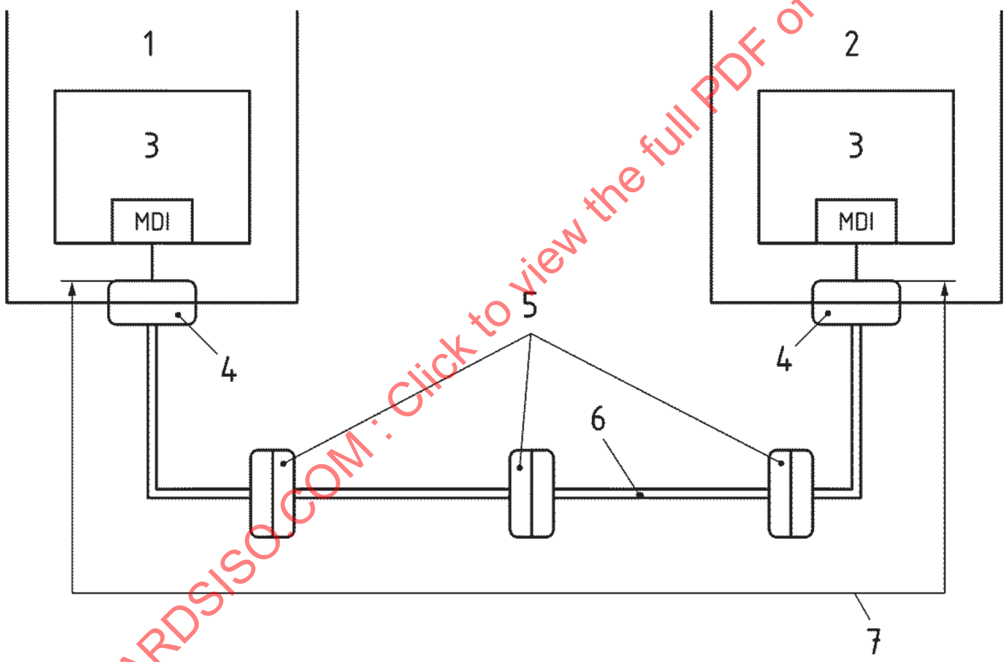
5.1.1 Definition of communication channel

This clause specifies the general RF requirements for a physical layer communication channel according to Figure 2, which shall conform with ISO/IEC/IEEE 8802-3 (100BASE-T1) for in-vehicle Ethernet applications.

The maximum length of WCC is not defined. It depends on the characteristics of each single component. These components should be chosen to achieve a typical length of 15 m and in maximum 4 inline connectors for car applications.

The combination of channel length and maximum inline connections shall be decided in accordance with the compliance with the channel RF performance specification specified in this document.

Connectors and cables which are applied to the communication channel shall fulfil at least electrical requirements (e.g. Open Alliance TC2 100 baseT1 specification[11]).



Key

1 device 1
2 device 2
3 physical entity
4 device connector
5 inline connector
6 cable
7 communication channel

Figure 2 — Definition of communication channel

NOTE The number of inline connections in Figure 2 is an example.

5.1.2 Operating temperature

The communication channel requirements are valid within the temperature range of the intended application. In general, the communication channel is used in between -40 °C and 105 °C. In some applications, an operating temperature of 85 °C, 100 °C, or 125 °C is required.

5.1.3 RF parameters

For all parts of the communication channel, the RF requirements are defined in terms of the following RF and S-parameter (see Table 1).

Table 1 — Definitions for RF and S - parameter

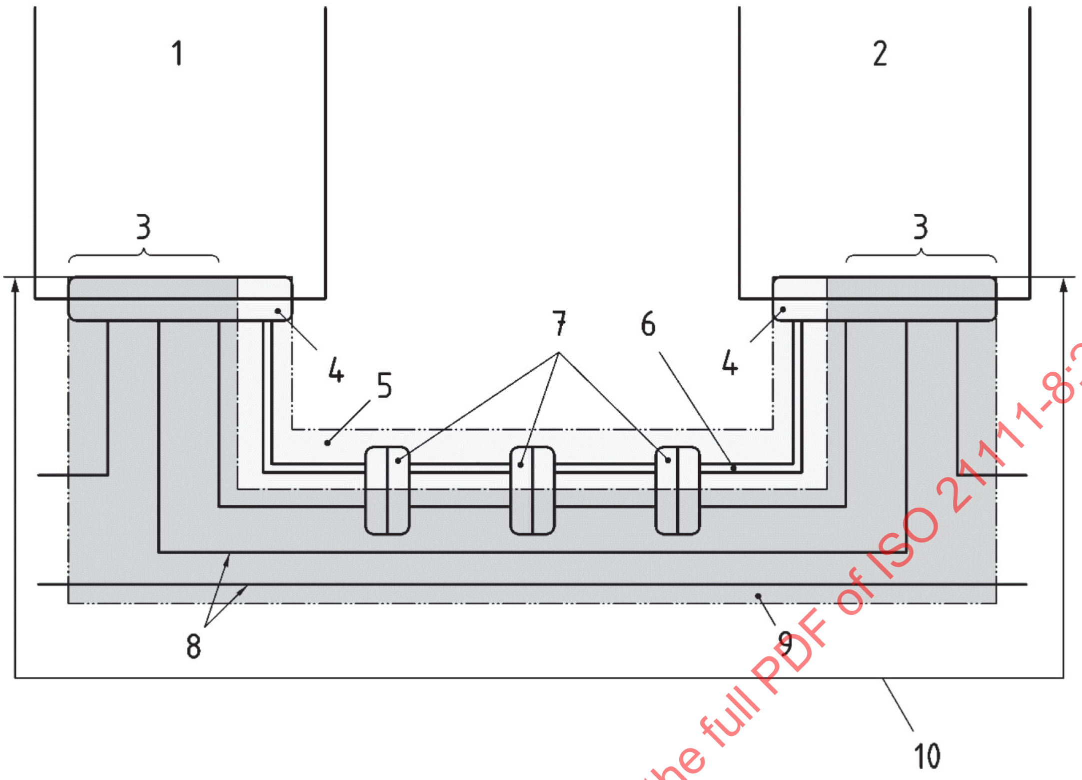
Item	Parameter
Impedance	
CIDM	Z_{RF}
Single channel characteristics (port 1, 2)	
RL	S_{dd11}, S_{dd22}
IL	S_{dd21}
LCL	S_{dc11}, S_{dc22}
LCTL	S_{dc12} , S_{dc21}
Cross talk single channel and other signals (channels/port 3 to port x)	
ANEXT	S_{dd31}, S_{ddx1}
AFEXT	S_{dd32}, S_{ddx2}
PSANEXT[a]	N/A
PSAACRF[b]	N/A
ANEXTDC	S_{dc31}, S_{dcx1}
ANEXTDS	S_{ds31}, S_{dsx1}
AFEXTDC	S_{dc32}, S_{dcx2}
AFEXTDS	S_{ds32}, S_{dsx2}

Note In principle, the limits for S-parameter are valid in the frequency range 1 MHz ≤ f ≤ 66 MHz. For LCL, LCTL, AFEXTDC, AFEXTDS, ANEXTDC, and ANEXTDS limits are valid up to f = 200 MHz.

[a] See 3.2.

[b] See 3.3.

5.1.4 Definition of whole communication channel



Key

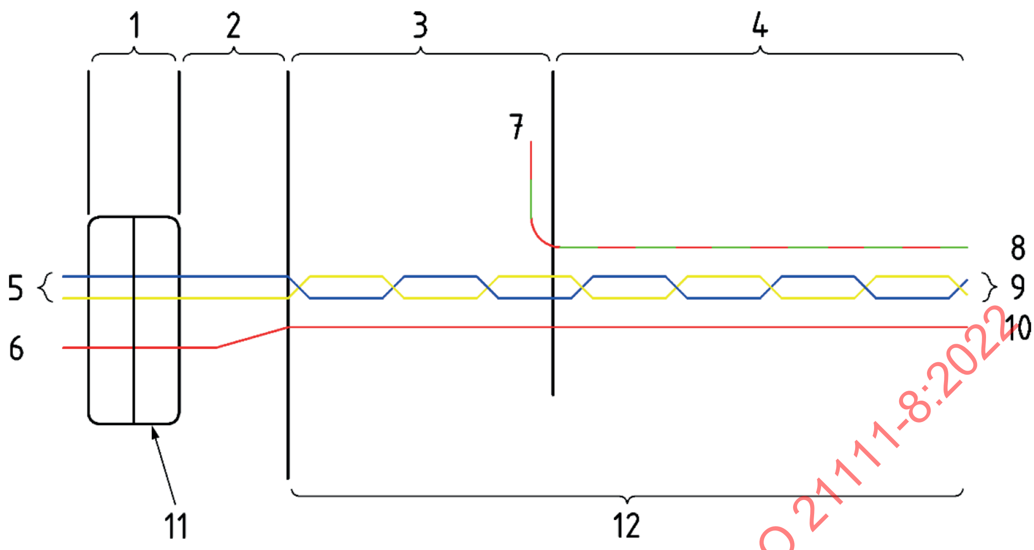
1 device 1
2 device 2
3 power, signals, and other system
4 device connector
5 SCC
6 ethernet data cable
7 inline connector
8 cable other system
9 ES
10 WCC

Figure 3 — Definition of whole communication channel

In a practical system, the communication channel which transmits Ethernet signals is not discrete, but coexists with power lines and control signal lines other than Ethernet signals in the wiring harness bundle. Considering this condition, the whole communication channel (WCC) is defined in Figure 3. Therefore, the communication channel is always subjected to electromagnetic interaction. Hereafter, the communication channel, which is dedicated to transmit Ethernet signals, is defined as standalone communication channel (SCC) and a cabling system which is not for Ethernet signals is defined as an environmental system (ES).

5.1.5 Definition of coupling zone

Electromagnetic interaction between ES and SCC are separated into four different zones (Figure 4).



Key

1 zone 1
2 zone 2
3 zone 3
4 zone 4
5 port 1
6 port 3A
7 port 3B
8 port 4B (line without noise)
9 port 2 (100BASE-T1 channel)
10 port 4A (line with noise)
1 connector
12. wiring harness/cable bundle

Figure 4 — Zone concept for electromagnetic interaction between ES and SCC

Table 2 defines four coupling zones. Examples of the dominant disturbing source and related S-parameter at each zone are shown in Table 2.

For evaluation the WCC, it should be tested as a complete system including all zones. For analysis and optimization or evaluation of single components of WCC, the zone should be tested separately

Table 2 — Coupling zone definitions

Zone	Interaction / cross talk to differential mode port 1 / port 2 (SCC)	Dominant disturbing source (if present)	Related S-parameter (exemplary)
1	Multi-pin connector	Line(s) with high common mode noise	Port 3A: S_{dc13A} (S_{ds13A})
2	Connecting area connector – cable - untwist region outside connector (valid for ECU connector and inline connector)	Line(s) with high common mode noise	Port 3A: S_{dc13A} (S_{ds13A})
Depending on the application configuration, the WCC will contain of a combination or a subset of the defined zones.			

Table 2 *(continued)*

Zone	Interaction / cross talk to differential mode port 1 / port 2 (SCC)	Dominant disturbing source (if present)	Related S-parameter (exemplary)
3	Connecting area connector – cable - twist region outside connector	Line(s) with high common mode noise	Port 3A: S_{dc13A} (S_{ds13A})
4	Cable bundle wiring harness	Line(s) without common mode noise and other communication lines	Port 3A: S_{dc13A} (S_{ds13A}) Port 3B: S_{dd13B} Port 4B: S_{dd14B}
Depending on the application configuration, the WCC will contain of a combination or a subset of the defined zones.			

5.2 Specification of single channel charactoristics for SCC, cable and connector

5.2.1 Specification of SCC in WCC configuration including assembly

For the evaluation of the complete channel implementation, the requirements for WCC shall be applied. To be able to setup a compliant 100BASE-T1 channel implementation, the cables and connectors that fulfil the respective requirements should be used. Please refer to ISO/IEC/IEEE 8802-3:2021,96.7 for a detailed specification.

The SCC for testing the complete WCC shall comply with the specification in Table 3.

Table 3 — Specification of SCC for WCC

Parameters		Specification	Test reference
CIDM	Z_{RF}	100 Ω ± 10 % [c d]	IEC 62153-1-1
IL[e]	S_{dd21}[a]	1 MHz: ≤ 1,0 dB 10 MHz: ≤ 2,6 dB 33 MHz: ≤ 4,9 dB 66 MHz: ≤ 7,2 dB	IEC 61935-1
RL	S_{dd11}, S_{dd22}[b]	1 MHz: ≥ 18,0 dB 20 MHz: ≥ 18,0 dB 66 MHz: ≥ 12,8 dB	
LCL LCTL	S_{dc11}, S_{dc22}[b] S_{dc21}, S_{dc12}[b]	1 MHz: ≥ 43,0 dB 33 MHz ≥ 43,0 dB 50 MHz: ≥ 39,4 dB 200 MHz: ≥ 27,3 dB	

[a] Logarithmic scale for loss value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

[b] Linear scale for loss value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

[c] Measurement is done at systems rise time of 700 ps.

[d] Actual measurements are corrected with use of a proper correction method. Annex B shows the information of the correction method. The specification is valid for the corrected value $CIDM_{corrected}(t)$. Both actual measurements $CIDM_{measured}(t)$ and corrected values $CIDM_{corrected}(t)$ shall be plotted in the same graph.

[e] Because of the deviation between IL at room temperature and temperature dependent IL of the used cable, the limit is valid for the corrected IL according to 6.3.3.5.

5.2.2 Specification of the cable in SCC

The cables used in SCC shall fulfil the cable electrical requirements (e.g. Open Alliance TC2 100baseT1 specification[11]).

5.2.3 Specification of the connector in SCC

Table 4 specifies the connectors used in SCC.

Table 4 — Connector specification in SCC

Parameters		Specification	Test reference
Intra pair skew	$T_{intra\_pair\_x}$	None [c]	IEC 60512-25-4
CIDM	Z_{RF}	100 Ω ± 10 % [d]	IEC 60512-25-7
IL	S_{dd21} [b]	1 MHz: ≤ 0,025 dB 10 MHz: ≤ 0,038 dB 33 MHz: ≤ 0,05 dB 66 MHz: ≤ 0,075 dB	IEC 60512-25-2
RL	S_{dd11}, S_{dd22} [a]	1 MHz: ≥ 38,0 dB 33 MHz: ≥ 38,0 dB 66 MHz: ≥ 30,5 dB	IEC 60512-25-5
LCL LCTL	S_{dc11}, S_{dc22} [a] S_{dc21}, S_{dc12} [a]	1 MHz: ≥ 46,0 dB 50 MHz: ≥ 46,0 dB 200 MHz: ≥ 34,0 dB	IEC 60603-7-7

[a] Linear scale for loss value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

[b] Logarithmic scale for loss value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

[c] No limit, the measurement result may be used for compensation of connector propagation delay skew at the layout of ECU.

[d] Measurement is done at systems rise time of 700 ps.

5.3 Specification related to the electromagnetic interaction between SCC and ES

5.3.1 Specification of the connector

The connectors used in WCC shall comply with the specification in Table 5.

Table 5 — Specification of alien cross talk for the connector

Parameters		Specification	Test reference
ANEXT/AFEXT	S_{dd31}, S_{ddx1}, S_{dd32}, S_{ddx2} [a]	1 MHz: ≥ 70,4 dB 16 MHz: ≥ 46,3 dB 33 MHz: ≥ 40,0 dB 66 MHz: ≥ 34,0 dB	IEC 60512-25-1

[a] Linear scale for cross talk value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

Table 5 *(continued)*

Parameters		Specification	Test reference
Cross talk mode conversion [a] ANEXTDC/ANEXTDS AFEXTDC/ANFEXTDS	S_{dc31}, S_{dcx1}, S_{ds31}, S_{dsx1} [a] S_{dC32}, S_{dcx2}, S_{ds32}, S_{dsx2} [a]	1 MHz: ≥ 46,0 dB 50 MHz: ≥ 46,0 dB 100 MHz: ≥ 40,0 dB 200 MHz: ≥ 34,0 dB	IEC 60603-7-7

[a] Linear scale for cross talk value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

5.3.2 Specification of SCC in WCC including assembly

The SCC for testing the complete WCC shall comply with the specification in Table 6.

Table 6 — Specification of SCC in WCC

Parameters		Specification	Test reference
PSANEXT [b, c]		1 MHz: ≥ 51,5 dB 100 MHz: ≥ 31,5 dB	IEC 61935-1
PSAACR-F [b, c]		1 MHz: ≥ 56,5 dB 100 MHz: ≥ 16,5 dB	
Cross talk mode conversion [a] ANEXTDC/ANEXTDS AFEXTDC/ANFEXTDS	S_{dc31}, S_{dcx1}, S_{ds31}, S_{dsx1} [a] S_{dC32}, S_{dcx2}, S_{ds32}, S_{dsx2} [a]	1 MHz: ≥ 43,0 dB 50 MHz: ≥ 43,0 dB 100 MHz: ≥ 39,4 dB 200 MHz: ≥ 27,3 dB	IEC 61935-1-1

[a] Linear scale for cross talk value (dB) axis and linear interpolation for limit value at logarithmic scale of frequency (MHz) axis are applied.

[b] This specification is valid for any WCC. To compare WCC with specific cables and connector types a four-around-one test setup according to Annex C may be used.

[c] The parameter is specified in ISO/IEC/IEEE 8802-3.

6 Test methods

6.1 Apparatus

6.1.1 Test equipment

A vector network analyser (VNA) and a time domain reflectometer (TDR) in combination with a test fixture with the parameters specified in Table 7 shall be used.

Table 7 — Requirements for test apparatuses

Measurement	Apparatus	Requirements	
Mixed mode S-parameter	VNA	Type of apparatus	4 ports vector network analyser
		System impedance	50 Ω
		Frequency range	0,3 – 1 000 MHz
		Test fixture	See Annex A for an example.

Table 7 *(continued)*

Measurement	Apparatus	Requirements	
Characteristic Impedance (CIDM)	TDR	Type of apparatus	2 channel differential mode
		System impedance	50 Ω (single ended)/100 Ω differential mode
		Rise time	Pulse generator: ≤ 25 ps internal (≤ 100 ps at test fixture) Analyser: no filter/700 ps internally adjustable (used digital filter characteristic of test apparatus)
		Test fixture	See Annex A for an example.

6.1.2 Precautions for VNA

Test operators shall take the following precautions for VNA according to IEC 61935-1.

1) The reference plane of the calibration shall coincide with the measurement reference plane. If it is not the case, the magnitude of the deviation shall be determined.

2) Consistent resistor loads shall be used for each pair of conductors throughout the test sequence.

3) The alignment of the cable under test shall be chosen as defined for the single tests and it shall be fixed throughout the test sequence.

4) Sharp bends and restrains for the cable under test shall be avoided throughout the test sequence to prevent cable and adapter discontinuities.

5) Coaxial cable, balanced cable and traces of the circuit on the test fixture shall be kept as short as possible to minimize resonance and parasitic effects.

6) Overload conditions of the network analyser shall be avoided.

6.1.3 VNA setting parameter

Test operators shall set the VNA parameters as shown in Tables 8 and 9.

Table 8 — VNA settings for S-parameter

Parameter	Setting
Sweep f_{start}	300 kHz
Sweep f_{stop}	1 GHz
Sweep type	Logarithmic
Sweep points	1 600
Output power	≥ -10 dBm
Measurement bandwidth	≤ 500 Hz
Logic port impedance differential mode	100 Ω
Logic port impedance common mode	200 Ω
Data calibration kit (VNA)	Use an appropriate calibration kit. (The calibration kit shall be identified in the test report.)

Table 8 *(continued)*

Parameter	Setting
Averaging function	Single time measurement* Note: A multiple-averaging setting can be used along with the recording of the actual averaging time used.
Smoothing function	Deactivated

Table 9 — VNA settings for impedance

Parameter	Value
Rise time	700 ps
Sweep f_{Start}	700 kHz
Sweep f_{Stop}	1,4 GHz
Sweep type	Linear
Sweep points	2 000
Filtering	Hann window or similar window
TDR Type	Step
Output power	Minimum -10 dBm
Measurement bandwidth	≤ 500 Hz
Port reference impedances	50 Ω single ended port impedances (This results in 100 Ω differential mode reference impedance after conversion to mixed mode parameters.)
Data calibration kit (VNA)	Use an appropriate calibration kit. (The calibration kit shall be identified in the test report.)
Averaging function	Single time measurement* NOTE A multiple-averaging setting may be used along with the recording of the actual averaging time used.
Smoothing function	Deactivated

6.2 Procedure

6.2.1 Cable

All tests shall be operated according to ISO 19642-2. See also Reference [11].

6.2.2 Connector

6.2.2.1 General

All tests shall be operated according to IEC 60512-25 series and IEC 60603-7-7.

If the connector under test has more than two conducting pins, all pairs of pins which are used for a part of SCC of 100BASE-T1 shall be tested. Cross talk in between pins in SCC and all other pins in the connector shall be tested, unless otherwise specified.

6.2.2.2 Test setup

The terminal of the connector under test shall be crimped firmly as recommended on the conductors out of circuit board of the test fixture.

6.2.2.3 Test temperature

Unless otherwise agreed between the supplier and the customer, the measurements shall be operated in the room temperature defined as 23 ± 5 °C, 25-75 % RH, in addition, at -40 °C and at either of 85 °C, 100 °C, or 125 °C.

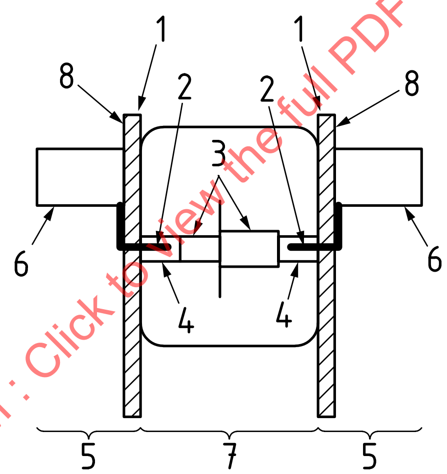
6.2.2.4 Test fixture

The test fixture shall comply with IEC 60512–25-1. An example is shown in A.1. The test fixture shall be low attenuation, high symmetry between the two differential lines of the pair and match to 50 Ω of single-ended impedance.

The connector test fixture shall provide an optimal connection of connector terminals with the measurement equipment. In order to avoid parasitic effects at the test fixture, a printed circuit board should be used with impedance-controlled traces (which should be as short as possible) and RF board connectors. Please see A.1 for a detailed picture.

Regardless of either device connector or inline connector, the measurement reference plane is defined at the geometrical boundary electrical contact system of the connector, as shown in Figure 5.

The measurement reference plane may be moved to the RF connector on the test fixture, if the electrical characteristics of the test fixture are calibrated and corrected for measurement.



Key

1 measurement reference plane
2 conductor
3 termincal
4 crimp
5 test fixture
6 RF connector (SMA)
7 connector (DUT)
8 PCB

Figure 5 — Measurement reference plane on the test fixture (connector)

6.2.3 WCC

6.2.3.1 General

The test of WCC shall be done in accordance with the test procedures specified in 6.3.1 and 6.3.2. For testing the complete WCC, all cables and connectors to be used in the WCC shall be in IUT (implementation under test).

6.2.3.2 Test setup

Untwisted zone (zone 1 and 2 in Figure 4 and Table 2) shall be configured in the same manner as mass production. All interactions between SCC and ES according to Table 2 shall be included into the test setup.

For testing the complete WCC with taking actual implementation into account, the following setup may be recommended. Please see an example in Figure 6.

— All components in WCC are installed on an insulation support with $\varepsilon_r \leq 1{,}4$ and 10 ± 0,5 mm thickness over larger 1 m × 2 m dimension ground reference plane.

— Ground reference plane overlaps all components of the test configuration within minimum 30 mm (3 times height over reference ground plane).

— The distance between all components in the WCC is not smaller than 30 mm (3 times height over reference ground plane).

— For small WCC configuration, the cable is routed in a straight way.

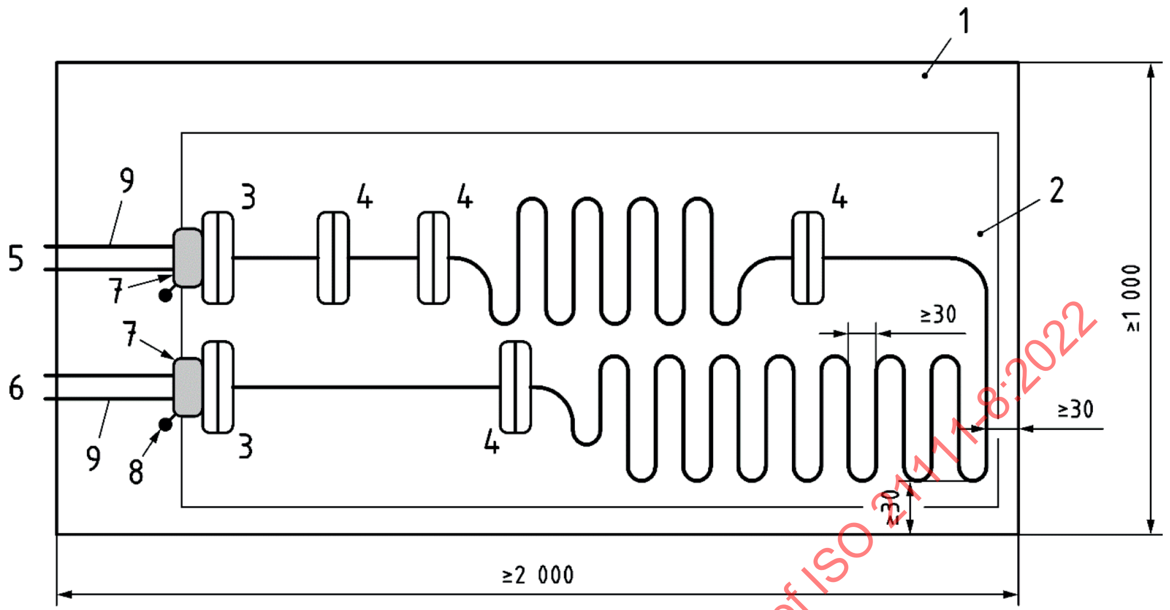
— For large WCC configuration, the cable segment is arranged as a meander between the connectors to avoid parasitic coupling.

— The minimum bending radius of the cable shall not be smaller than the minimum bending radius specified in the relevant cable specification.

— The orientation and direction of devices and inline connectors are kept horizontal to ground reference plane.

— The ground reference of the test fixture is connected to the ground reference plane with low impedance.

Dimensions in mm



Key

1 ground plane
2 insulation support
3 ECU connector
4 inline connector
5 port 1
6 port 2
7 test fixture
8 GND connection test fixture
9 cable to VNA/TDR

Figure 6 — An example of the WCC test setup

6.2.3.3 Test temperature

The test of WCC is operated at room temperature of 23 ± 5 °C, 25-75 % RH.

6.2.3.4 Test fixture

The measurement reference plane is defined at the geometrical boundary electrical contact system of the device connector at both ends of WCC, as shown in Figure 7 and Figure 5.

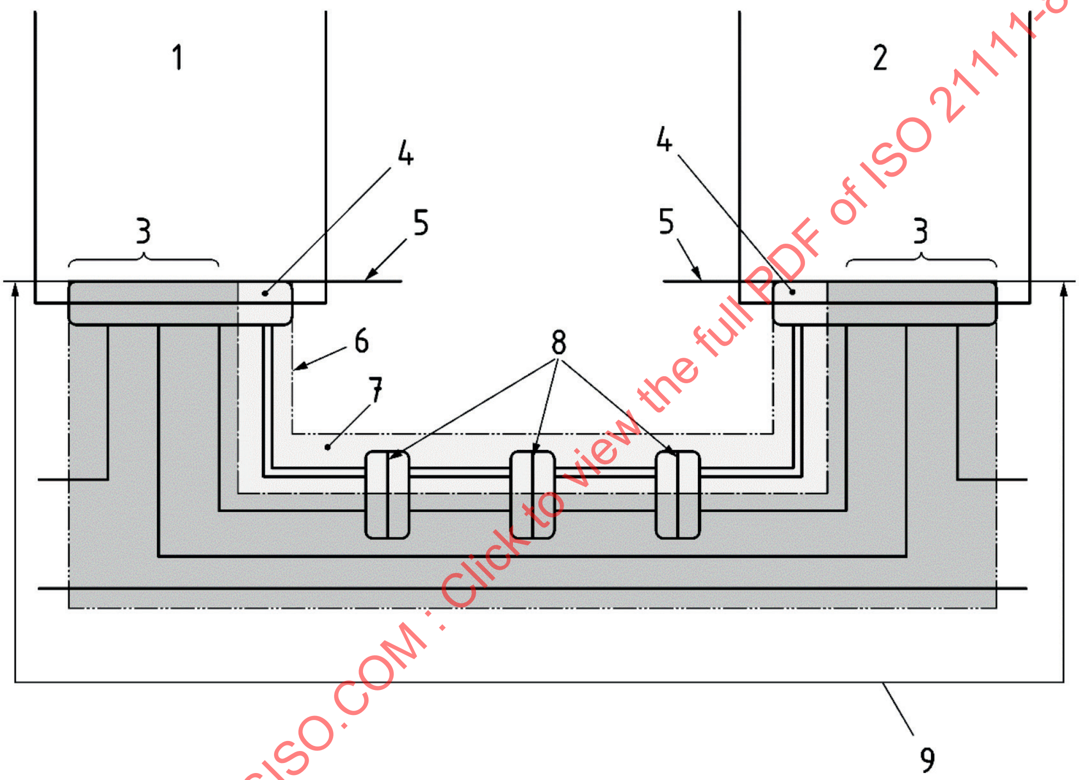
6.2.3.5 Correction of test results

The test results of WCC shall be corrected by using the temperature dependent IL performance of the cable at fixed frequencies of f = 1 MHz, 10 MHz, 16 MHz, 33 MHz, and 66 MHz. The correction formula is as given in Formula (1)

$$IL_{wcc\_max\ temp} = IL_{wcc\_RT} + (IL_{cable\_max\ temp/m} - IL_{cable\_RT/m}) * l \qquad (1)$$

where

$IL_{wcc\_max\ temp}$	is the value insertion loss for measured WCC configuration at maximum temperature;
IL_{wcc_RT}	is the value insertion loss for measured WCC configuration at RT;
$IL_{cable\_max\ temp/m}$	is the value insertion loss per meter for measured cable at maximum temperature;
$IL_{cable\_RT/m}$	is the value insertion loss per meter for measured cable at RT;
l	is the length of measured WCC configuration.



Key
1 device 1
2 device 2
3 [ES] power signals, and other system
4 device connector
5 measurement reference plane
6 SCC
7 wiring harness/cable bundle
8 inline connector
9 WCC

Figure 7 — An example of the WCC test setup

6.3 Test results

The test results shall be reported. Reporting contents should include the following items:

- date and time of test,
- identification of DUTs (e.g. product numbers and serial numbers of cables and connectors under test),
- test condition (e.g. temperature, humidity, cleanness),
- detailed test setup,
- results of S-parameter:
  - actual measurement values in dB with the pass/fail criteria,
  - a chart against the logarithmic frequency up to 1 000 MHz,
- results of TDR measurement:
  - differential impedance values in Ω with the pass/fail criteria,
  - charts of actual measurement values and corrected values (see Annex B for the information of the correction method):
    - linear time scale in ns in X-axis,
    - additional linear length scale in m in X-axis.

  NOTE The length is calculated using 2/3 of c_0 or real phase velocity of cable/connector and correction of two-way of pulse propagation. Where, c_0 is the velocity of light transmission in the vaccum space.

Annex A
(informative)

Extended test setup definitions

A.1 Connector fixture

Figure A.1 shows a detailed example of the test fixture.

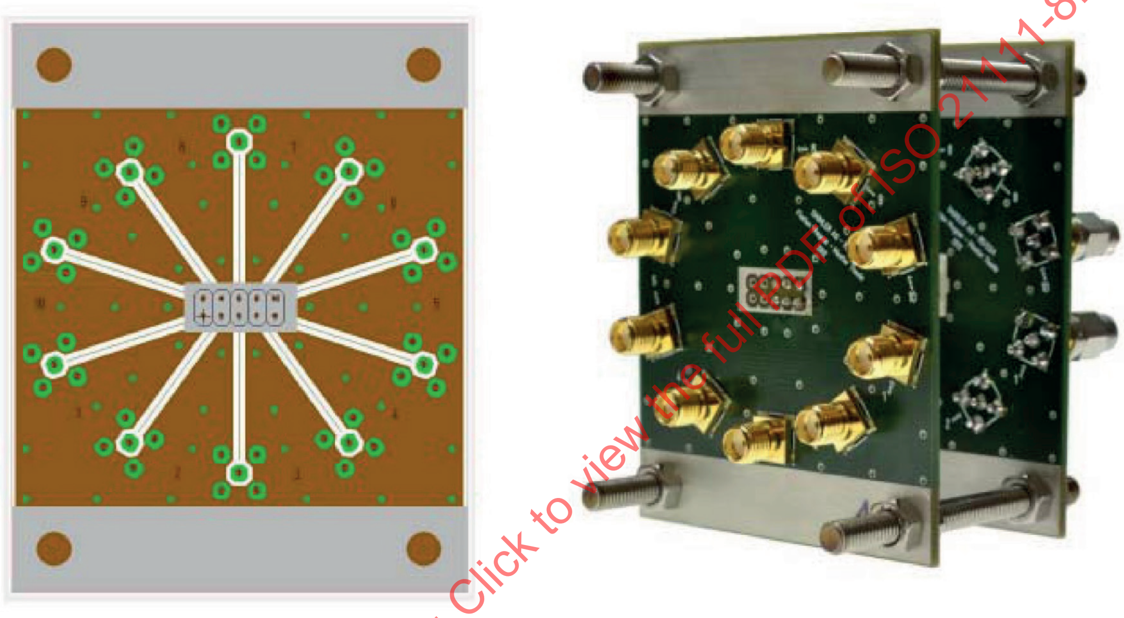


Figure A.1 — Example of the test fixture of connectors