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Road vehicles — Automotive cables —

Part 12: Dimensions and requirements for unscreened twisted pair RF cables with a specified analogue bandwidth up to 1 GHz

Véhicules routiers — Câbles automobiles —

Partie 12: Dimensions et exigences pour les câbles RF en paire torsadée non blindés de bande passante analogique spécifiée jusqu'à 1 GHz

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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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 19642 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

This document has been added to existing standards in the ISO 19642 series. It was prepared following a joint resolution to improve the general structure of the ISO Automotive Electric Cable standards. This new structure adds more clarity and, by defining a new standard family, opens up the standard for future amendments.

Many other standards currently refer to ISO 6722-1, ISO 6722-2 and ISO 14572. Therefore, these standards will stay valid at least until the next scheduled systematic review and will be replaced later on by the ISO 19642 series.

For new automotive cable projects customers and suppliers are advised on using the ISO 19642 series.

Road vehicles — Automotive cables —

Part 12: Dimensions and requirements for unscreened twisted pair RF cables with a specified analogue bandwidth up to 1 GHz

WARNING — The use of this document may involve hazardous materials, operations, and equipment. This document does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this document to establish appropriate safety practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This document specifies the dimensions and requirements for unscreened single twisted pair RF cables with a specified analogue bandwidth up to 1 GHz intended for use in road vehicle applications where the nominal system voltage is 30 V a.c. or 60 V d.c.

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 19642-1, *Road vehicles — Automotive cables — Part 1: Terminology and design guidelines*

ISO 19642-2:—[1)], *Road vehicles — Automotive cables — Part 2: Test methods*

ISO 19642-3, *Road vehicles — Automotive cables — Part 3: Dimensions and requirements for 30 V a.c. or 60 V d.c. single core copper conductor cables*

ISO 21111-8:2022, *Road vehicles — In-vehicle Ethernet — Part 8: Electrical 100-Mbit/s Ethernet transmission media, components and tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19642-1 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/

4 Specifications

4.1 General test conditions

The test conditions of ISO 19642-2 shall apply. The descriptions of the tests are found in ISO 19642-2. This document only contains requirements and specific remarks. The cables shall be submitted to the tests as specified in Clause 7.

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The single cores of the UTP cable shall meet the requirements of ISO 19642-3. Dimensions and conductor definitions may be different, but shall be documented in the test report.

If suppliers and customers agree upon modifications or changes to the methods and requirements, it is required that all the changes and modifications are clearly documented.

NOTE The clause numbers in this document are aligned with the clause numbers in ISO 19642-2. Test clause numbers not needed in this document are identified as “Test is not required” or “Test is not possible”.

4.2 Safety concerns

See the “Warning" at the beginning of this document.

4.3 Voltage rating

The voltage rating is established by the rating of the cores 30 V a.c. or 60 V d.c.

4.4 Temperature classes

The temperature class rating is established by the rating(s) of the core and sheath. The rating of the cable shall be equal to the lowest rating of the core and sheath. For details on temperature classes, see ISO 19642-1.

4.5 Cable construction

For detailed information on preferred constructions please refer to Table 9 and Table 10. Other constructions and materials are permissible when agreed between customer and supplier.

4.5.1 Single Cores

4.5.1.1 Conductor

4.5.1.1.1 Conductor material

For conductor materials see ISO 19642-3 and for additional materials see Table 1.

Table 1 — Additional permissible conductor materials

Specification	Conductor material
CEN/TS 13388	Copper magnesium alloy (CuMg02)
	Copper silver alloy (CuAg01)
	Copper tin alloy (CuSn03)
ASTM B452	Copper clad steel (CCS)
ASTM B105	Copper alloy

4.5.1.1.2 Conductor construction

For conductor construction of the core see ISO 19642-3 and Table 9 and Table 10.

4.5.1.1.3 Maximum conductor outside diameter

For conductor construction requirements of preferred cable types, refer to Table 9 and Table 10. If possible, use maximum conductor outside diameter values as specified in ISO 19642-3.

4.5.1.2 Insulation material

The material used shall be documented in the supplier data sheet.

4.5.1.3 Maximum outside diameter of the single cores

The maximum and minimum diameter of the single cores depend upon the specified impedance and may not follow the specifications according to ISO 19642-3. If different, outside diameters and minimal wall thickness shall be documented in the supplier data sheet.

4.5.2 Twisted pair

4.5.2.1 Lay length

The lay length shall be documented in the supplier data sheet.

4.5.2.2 Diameter of twisted pair

For JUTP cables the diameter of the twisted pair is referenced as inner diameter of sheath.

4.5.3 Separator

If a separator is used, it shall be documented in the supplier data sheet. The description shall contain information about type of material, e.g. PP foil, PETP foil, powder, etc.

4.5.4 Sheath

4.5.4.1 Sheath material

The sheath material shall be a flame retardant polymer compound or an intrinsically non-flammable polymer. The material used shall be documented in the supplier data sheet.

4.5.4.2 Sheath thickness

For sheathed cables, different sheath thicknesses are allowed per this document.

For new constructions it is recommended to define the thickness of the sheath according to ISO 19642-1:—[2)], Annex A.

4.6 Cable designators

For the definition of the cable designators see Table 2.

For reference numbers of preferred cable types refer to Table 9 and Table 10.

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Table 2 — Cable designator description

Designator	Valid entries	Comment
construction	UTP	unshielded twisted pair cable **without** a sheath
	JUTP	Jacketed unshielded twisted pair cable **with** a sheath
delimiter	-	
impedance	100, 120, ...	nominal value of the differential RF cable impedance
delimiter	-	
reference #	1, 2, 3, ...	up to 3-digit reference number to identify similar cable types
version	a	lower case version designator to differentiate between similar constructions
delimiter	white space	delimiter
# of cores	2x	2x for pair
CSA of cores	0,13	cross sectional area of cores [mm^2]

EXAMPLE JUTP-100 -11a 2x0,13.

4.7 Representative cable elements testing

When a test is required, all combinations of different cable elements shall meet the appropriate requirements. However, if testing of representative cable elements is permitted, compliance for cables with different dimensions, but with the same insulation and sheath compound, may be demonstrated by testing samples of the cable with the thinnest sheath wall thickness only. For all other cables a reduced test procedure is acceptable. The remaining mandatory tests for initial certification shall be performed following Tables 4 to 7.

4.8 Reference and requirements for the tests

All tests are defined in ISO 19642-2. This document only contains requirements and specific remarks.

4.9 General remark on requirements

Requirements for preferred unscreened single pair RF cable types are specified in Table 9 and Table 10. The requirements for other unscreened single pair RF cable types shall be as agreed between customer and supplier.

5 Requirements for the cable's dielectric cores

5.1 General

The cable's dielectric cores shall be tested according to ISO 19642-2 at the cable temperature class rating. Tests on the dielectric cable cores in JUTP cables shall be performed according to Table 4.

For any UTP cable the cores shall meet all requirements of ISO 19642-3, dimensions may be different but shall be identified in the test report.

NOTE For preferred cable types refer to Table 9 and Table 10.

5.2 Dimensional tests

5.2.1 Cable outside diameter

The dielectric core outside diameter shall meet the required tolerances in Table 9 and Table 10.

5.2.2 Insulation thickness

The insulation thickness shall be checked and documented against the supplier datasheet.

5.2.3 Conductor diameter

No single value shall be outside the required tolerances in Table 9 and Table 10.

5.2.4 Cross sectional area (CSA)

No single value shall be outside the required tolerances in Table 9 and Table 10.

5.2.5 In-process cable outside diameter

In-process cable outside diameter monitoring is mandatory. No single value shall be outside the required tolerances in Table 9 and Table 10.

5.3 Electrical tests

5.3.1 Conductor resistance

No single value shall be outside the required tolerances in Table 9 and Table 10. The conductor resistance in Table 9 and Table 10 includes the twisting loss. For determination of maximum conductor resistance refer to the design guidelines in ISO 19642-1:—, A.5.

5.3.2 Determination of temperature coefficients

Test is not required.

5.3.3 Withstand voltage

5.3.3.1 Test voltage

After applying the test voltage of 1 kV a.c. for 30 min, no ramp up of the voltage is required.

5.3.3.2 Requirement

Breakdown shall not occur.

5.3.4 Withstand voltage after environmental testing

5.3.4.1 Test voltage

The test voltage is 1 kV a.c., hold for 1 min.

5.3.4.2 Requirement

Breakdown shall not occur.

5.3.5 Insulation faults

All cores shall be subjected to the inline insulation faults test during the extrusion process.

5.3.5.1 Test voltage

The test voltage is 1 kV a.c.

5.3.5.2 Requirement

Breakdown shall not occur.

5.3.6 Insulation volume resistivity

The value shall be ≥ 1×10^9 Ω·× mm.

5.4 Mechanical tests

5.4.1 Strip force

The measured force shall be within the values as agreed between customer and supplier.

5.4.2 Abrasion

Test is not required.

5.4.3 Breaking force of the finished cable

Test is not required.

5.4.4 Cyclic bending

Test is not required.

5.4.5 Flexibility

Test is not required.

5.5 Environmental tests

5.5.1 Test specimen preparation and winding tests

Test is not required.

5.5.2 Long term heat ageing, 3 000 h, at temperature class rating

Test is not required.

5.5.3 Short term heat ageing, 240 h at temperature class rating +25 K

Test is not required.

5.5.4 Thermal overload, 6 h at temperature class rating + 50 K

Test is not required.

5.5.5 Pressure test at high temperature

If no conductor is visible, perform a withstand voltage after environmental testing as given in 5.3.4. During 5.3.3.2 a withstand voltage after environmental testing breakdown shall not occur.

5.5.6 Shrinkage by heat

The maximum shrinkage shall not exceed 2 mm from either end.

5.5.7 Low temperature winding

After winding, no conductor shall be visible. During 5.3.3.2 a withstand voltage after environmental testing breakdown shall not occur.

5.5.8 Cold impact

Test is not required.

5.5.9 Temperature and humidity cycling

Test is not required.

5.5.10 Resistance to hot water

Test is not required.

5.5.11 Resistance to liquid chemicals

Test is not required.

5.5.12 Durability of cable marking

Test is not required.

5.5.13 Stress cracking resistance

Test is not required.

5.5.14 Resistance to ozone

Test is not required.

5.5.15 Resistance to flame propagation

Test is not required.

6 Requirements for the finished UTP or JUTP cables

6.1 General

The cables shall be tested per ISO 19642-2 according to their temperature class rating. UTP cables shall be submitted to the tests as specified in Table 5. JUTP cables shall be submitted to the tests as specified in Table 6. Tests according to Table 5 are not required for JUTP cables.

6.2 Dimensional tests

6.2.1 Cable outside diameter for JUTP cables

Measure the following parameters if applicable:

— outside diameter of twisted cores;

— outside diameter of sheath.

No single value shall be greater than the maximum value in Table 10.

6.2.2 Ovality of sheath for JUTP cables

Ovality shall be < 10 %.

NOTE Sheath ovality can be different after handling due to mechanical deformation.

6.2.3 Thickness of sheath for JUTP cables

No single value shall be less than the minimum value in Table 10.

6.2.4 In-process cable outside diameter for JUTP cables

In-process cable outside diameter monitoring is mandatory.

No single value shall be greater than the maximum value in Table 10.

6.2.5 Lay length

The lay length shall be checked and documented against the supplier datasheet.

6.3 Electrical tests

6.3.1 Electrical continuity

The indicator shall show continuity.

6.3.2 Withstand voltage at final inspection

Breakdown shall not occur between core(s) when applying a test voltage of 1 kV a.c. or d.c. to be measured at the end of the test specimen for a minimum of 3 s.

6.3.3 Screening effectiveness

Test is not possible.

6.3.4 Sheath fault on screened cables

Test is not possible.

6.3.5 General information on electrical test setups of unscreened balanced cables

Perform the low and high frequency tests using the test setups defined in 8.2.

6.3.5.1 Test set ups for unscreened balanced cables

For long time ageing no special test setup is defined. RF parameters are measured at the start and after the end of the ageing only. RF tests where a ground reference is needed shall use test setup 3 or 4.

6.3.6 General information on low frequency electrical tests

Information is not provided in this edition.

6.3.7 Resistance unbalance

Test is not possible.

6.3.8 Capacitance

6.3.8.1 General information

Information is not provided in this edition.

6.3.8.2 Samples

Information is not provided in this edition.

6.3.8.3 Mutual capacitance

If applicable, no single value shall fall outside the tolerances specified in Table 9 and Table 10.

This property is also used for the calculation of the characteristic impedance according to 6.3.12.

6.3.9 Inductance

Test is not required.

6.3.10 General information on radio frequency (RF) electrical tests

Submit a new cable, which was not subjected to any prior environmental stress, to the RF tests in Table 7. Test the cable again after applied stresses according to the requirements in Table 8 and subsequent environmental test descriptions. The measurements shall be performed at room temperature. At least three samples shall be measured for this test.

If not otherwise defined the test shall be performed with a start frequency of 10 MHz and a stop frequency of 120 % of the analogue bandwidth defined for the cable types in Table 9 and Table 10.

6.3.11 Velocity of propagation

6.3.11.1 General

Perform the tests for unbalanced cables following ISO 19642-2:—[3], 6.3.11.1.2.

6.3.11.2 Phase velocity $v_p(f)$ of propagation

If applicable, no single value shall fall outside the tolerances specified in 8.2. This property is also used for the calculation of the characteristic impedance according to 6.3.12.

6.3.11.3 Group velocity $v_g(f)$ of propagation

Test is not required.

6.3.11.4 Intra-pair skew for symmetrical data transmission

Test is not required.

6.3.11.5 In-pair skew for symmetrical data transmission

Test is not required.

6.3.11.6 Propagation delay

If applicable, no single value shall fall outside the tolerances specified in 8.2.

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6.3.12 Characteristic impedance in frequency domain (CIF)

6.3.12.1 Unbalanced cables (CICMF)

Test is not possible.

6.3.12.2 Balanced cables (CIDMF)

This test gives an overview of the impedance of the cable depicted over the applied frequency but no information on the impedance at different lengths from the input into the cable. This is the preferred method. If applicable, no single value shall fall outside the tolerances specified in 8.2.

6.3.13 Characteristic impedance in time domain (CIT)

6.3.13.1 Unbalanced cables (CICMT)

Test is not possible.

6.3.13.2 Balanced cables (CIDMT)

This test gives an overview of the impedance of the cable depicted over the length of the sample but no information on the influence of different frequencies. If applicable, no single value in the evaluation window shall fall outside the tolerances specified in 8.2. The difference of the results on the new cable and on the cable after stresses must not be greater than the related tolerances in Table 9 and Table 10.

6.3.14 Insertion loss, IL

6.3.14.1 Unbalanced cables

Test is not possible.

6.3.14.2 Balanced cables

If applicable, no single value shall fall outside the tolerances specified in 8.2.

6.3.15 Return loss, RL

6.3.15.1 Unbalanced cables

Test is not possible.

6.3.15.2 Balanced cables

If applicable, no single value shall fall outside the tolerances specified in 8.2.

6.3.16 Unbalance attenuations

If applicable, no single value shall fall outside the tolerances specified in 8.2.

6.4 Mechanical tests

6.4.1 Strip force of sheath

The undisturbed section of the sheath shall be able to be removed from the interior cores. The requirement for this test shall be established by agreement between customer and supplier.

6.4.2 Cyclic bending

The requirement for this test shall be established by agreement between customer and supplier.

6.4.3 Flexibility

The requirement for this test shall be established by agreement between customer and supplier.

6.4.4 Cyclic bending test for RF cables

The requirement for this test shall be established by agreement between customer and supplier.

6.4.5 Dynamic bending tests for RF cables

Test is not required.

6.4.6 Test for assessment of minimum bending radius

Test is not required.

6.4.7 Strip force of screen

Test is not possible.

6.4.8 Abrasion test of sheath

This test is only possible for JUTP cables. The requirement for this test shall be established by agreement between customer and supplier.

6.5 Environmental tests

6.5.1 Test specimen preparation and winding tests

ISO 19642-2:—, 6.5.1 describes the mandrel sizes used for preparation of specimens in different subsequent environmental tests. It also describes the winding tests used to detect defects caused by environmental stresses.

6.5.2 Long term heat ageing, 3 000 h at temperature class rating

6.5.2.1 Ageing of test specimens

Prepare 3 test specimens of 600 mm length. Further referenced as “600 mm test specimens”.

Prepare 3 test specimens of 10 m length. Further referenced as “10 m test specimens”.

Place all test specimens in the oven for 3 000 h at temperature class rating.

6.5.2.2 Winding test

After the winding test according to 6.5.1 the 600 mm test specimens shall show no signs of cracks. If no cracks are observed perform the procedure given in 6.3.2. Breakdown shall not occur.

6.5.2.3 Additional RF tests as specified in 8.2

— Take initial measurement at RT.

— After the 3 000 h heat ageing and measurement, ramp down to RT and condition for a minimum of 4 hours, then take measurement.

6.5.3 Short term heat ageing, 240 h at temperature class rating + 25 °C

After the winding test according to 6.5.1 the test specimen shall show no signs of cracks. If no cracks are observed perform the procedure given in 6.3.2. Breakdown shall not occur.

6.5.4 Thermal overload, 6 h at temperature class rating + 50 °C

Test is not required.

6.5.5 Pressure test at high temperature

The thickness within the area of the indentation shall not be less than 40 % of the mean of the other two values.

6.5.6 Shrinkage by heat of sheath

The requirement for this test shall be established by agreement between customer and supplier.

6.5.7 Low temperature winding

The test specimen shall show no signs of cracks. During the withstand voltage at final inspection given in 6.3.2 breakdown shall not occur.

6.5.8 Cold impact

Perform the test with a mass of the hammer according to Table 3. The test specimen shall show no signs of cracks. During the withstand voltage at final inspection given in 6.3.2 breakdown shall not occur.

Table 3 — Cold impact

Cable outside diameter (*D*), [mm]	**Mass of the hammer,** [g]
$D < 2,5$	100
$2,5 \leq D < 4,5$	150
$D \geq 4,5$	200

6.5.9 Temperature and humidity cycling

The test specimen shall show no signs of cracks.

6.5.10 Resistance to liquid chemicals

The test specimen shall show no signs of cracks. Other requirements shall be as agreed between customer and supplier.

6.5.11 Durability of sheath marking

The requirement for this test shall be established by agreement between customer and supplier.

6.5.12 Resistance to ozone

The requirement for this test shall be established by agreement between customer and supplier.

6.5.12.1 Requirement

The visual examination of the sheath shall show no cracks.

6.5.13 Artificial weathering

The need to perform this test shall be established by agreement between customer and supplier.

6.5.13.1 Requirement

After exposure to the artificial weathering, the elongation of the conditioned test specimen shall not be less than 50 % of the unconditioned specimen measured value.

6.5.14 Resistance to flame propagation

Any combustion flame of insulating or sheath material shall extinguish within 70 s from the end of ignition and a minimum of 50 mm of insulation and sheath at the top of the test specimen shall remain unburnt. All five specimens shall pass the test.

7 Test overview tables

7.1 Test table for single cores

Tests shall be performed on cores taken from cable production after the core extrusion process, but before the subsequent production processes (twisting of cores, sheath extrusion, etc.).

For any UTP cable the cores shall meet all requirements of ISO 19642-3, dimensions may be different but shall be identified in the test report.

Table 4 — Tests on UTP cable cores

Test description		Mandatory			If required[c]	
		In process[a]	Initial certification	Periodic[b]	Initial certification	Periodic[b]
5.2.1	Cable outside diameter	–	X	X	–	–
5.2.2	Insulation thickness	–	X	X	–	–
5.2.3	Conductor diameter	–	–	–	X	X
5.2.4	Cross sectional area (CSA)	–	–	–	X	X
5.2.5	In-process cable outside diameter	X	–	–	–	–
5.3.1	Conductor resistance	–	X	X	–	–
5.3.3	Withstand voltage[d]	–	X	X	–	–
5.3.5	Insulation faults	X	–	–	–	–
5.3.6	Insulation volume resistivity[d]	–	–	–	X	X
5.4.1	Strip force	–	–	–	X	X
5.5.5	Pressure test at high temperature	–	X	X	–	–
5.5.6	Shrinkage by heat	–	X	X	–	–

Key

X test shall be performed according to ISO 19642-2

– test is not required

[a] A test made on the entire cable lot during or after manufacture.

[b] The frequency of periodic testing shall be established by agreement between customer and supplier.

[c] The usage of "If required" tests shall be established by agreement between customer and supplier.

[d] It is to be completed on pre-manufactured cores of the same production lot.

7.2 Test tables for finished cables

Table 5 — Tests on UTP finished cables

Test description		Mandatory			If required[c]	
		In process[a]	Initial certification	Periodic[b]	Initial certification	Periodic[b]
5.2.1	Cable outside diameter	–	X	X	–	–
6.2.5	Lay length [d]		X			
6.3.1	Electrical continuity	X	–	–	–	–
6.3.2	Withstand voltage at final inspection	X	–	–	–	–
6.4.2	Cyclic bending	–	–	–	X	–
6.4.3	Flexibility	–	–	–	X	–
6.4.4	Cyclic bending test for RF cables	–	–	–	X	–
6.5.2	Long term heat ageing, 3 000 h at temperature class rating[e]	–	X	–	–	–
6.5.3	Short term heat ageing, 240 h at temperature class rating + 25 °C	–	X	X	–	–
6.5.7	Low temperature winding	–	X	X	–	–
6.5.9	Temperature and humidity cycling[e]	–	–	–	X	–
6.5.14	Resistance to flame propagation	–	X	X	–	–

Key

X test shall be performed according to ISO 19642-2

– test is not required

[a] A test made on entire cable length during or after manufacture.

[b] The frequency of periodic testing shall be established by agreement between customer and supplier.

[c] The usage of "If required" tests shall be established by agreement between customer and supplier.

[d] It is to be documented in supplier data sheet and the test report.

[e] Compliance of a cable family made of the same insulation compound may be demonstrated by testing the sample of the cable family with the smallest insulation wall thickness only.

Table 6 — Tests on JUTP finished cables

Test description		Mandatory			If required [c]	
		In process [a]	Initial certification	Periodic [b]	Initial certification	Periodic [b]
6.2.1	Cable outside diameter	–	X	X	–	–
6.2.2	Ovality of sheath	–	–	–	X	X
6.2.3	Thickness of sheath	–	X	X	–	–
6.2.4	In-process cable outside diameter for JUTP cables	X	–	–	–	–
6.2.5	Lay length [d]		X			
6.3.1	Electrical continuity	–	X	X	–	–
6.3.2	Withstand voltage at final inspection	X	X	X	–	–
6.4.1	Strip force of sheath	–	–	–	X	X
6.4.2	Cyclic bending	–	–	–	X	–
6.4.3	Flexibility	–	–	–	X	–
6.4.4	Cyclic bending test for RF cables	–	–	–	X	–
6.4.8	Abrasion test of sheath	–	–	–	X	–
6.5.2	Long term heat ageing, 3 000 h at temperature class rating[e]	–	X	–	–	–
6.5.3	Short term heat ageing, 240 h at temperature class rating + 25 °C	–	X	X	–	–
6.5.5	Pressure test at high temperature	–	X	X	–	–
6.5.6	Shrinkage by heat of sheath	–	X	X	–	–
6.5.7	Low temperature winding	–	X	X	–	–
6.5.8	Cold impact	–	–	–	X	X
6.5.9	Temperature and humidity cycling[e]	–	–	–	X	–
6.5.10	Resistance to liquid chemicals[e]	–	X	–	–	–
6.5.11	Durability of sheath marking[e]	–	–	–	X	X
6.5.12	Resistance to ozone[e]	–	–	–	X	–
6.5.13	Artificial weathering[e]	–	–	–	X	–
6.5.14	Resistance to flame propagation	–	X	X	–	–

Key

X test shall be performed according to ISO 19642-2

– test is not required

[a] A test made on entire cable length during or after manufacture.

[b] The frequency of periodic testing shall be established by agreement between customer and supplier.

[c] The usage of "If required" tests shall be established by agreement between customer and supplier.

[d] It is to be documented in supplier data sheet and the test report.

[e] Compliance of a cable family made of the same insulation and sheath compound may be demonstrated by testing the sample of the cable family with the smallest sheath wall thickness only.

Table 7 — RF tests

Test description		Mandatory			If required[c]	
		Final inspection test[d, h]	Initial certification	Periodic[g]	Initial certification	Periodic[g]
6.3.8.3	Mutual capacitance	b	a	–	–	–
6.3.11.2	Phase velocity $v_p(f)$ of propagation	b	a	–	–	–
6.3.11.6	Propagation delay	–	b	–	b	b
6.3.12.2	Characteristic impedance in frequency domain (CIDMF)	b	b	–	–	–
6.3.13.2	Characteristic impedance in time domain (CIDMT)[e, f]	–	b	–	–	–
6.3.14	Insertion loss, IL	b	b	–	–	–
6.3.15	Return loss, RL	b	b	–	–	–
6.3.16	Unbalance attenuations	–	b	b	–	–

Key

– test is not required

a It is mandatory for documentation in supplier data sheet and test report.

b It is mandatory if specified in 8.1 or 8.2.

c The usage of "If required" tests shall be established by agreement between customer and supplier.

d For final inspection tests, use the limit values according 8.2.

e It is to be followed in related tests.

f For information only.

g The frequency of periodic testing shall be established by agreement between customer and supplier.

h Performed on a sample with a length of 10 m from each batch/lot.

Table 8 — RF tests to be performed after stress tests

RF test to be performed, according to key	LCL	LCTL	VP[a]	PD[a]	CIDMF	CIDMT	IL	RL
6.4.4 Cyclic bending test for RF cables	X	X	–	–	–	X	–	–
6.5.2 Long term heat ageing, 3 000 h at temperature class rating	–	–	X	X	X	–	X	X

Key	Test description	according to
LCL	Longitudinal conversion loss	6.3.16
LCTL	Longitudinal conversion transmission loss	6.3.16
VP	Phase velocity, $v_p(f)$, of propagation	6.3.11.2
PD	Propagation delay	6.3.11.6
CIDMF	Characteristic impedance differential mode frequency domain	6.3.12.2
CIDMT	Characteristic impedance differential mode time domain	6.3.13.2
IL	Insertion loss	6.3.14
RL	Return loss	6.3.15

a Either VP or PD has to be performed, in case of dispute VP is the referee method.

8 Cable types

8.1 Cable parameters

Table 9 — Parameters of preferred UTP cable types

Cable designator		UTP-100-1a 2x0,35	UTP-120-2a 2x0,13	UTP-120-3a 2x0,35
Characteristic impedance	Ω	100	120	120
Analogue bandwidth	MHz	66 100	100 20	100 20
Applicable for standard		100BASE-T1 FlexRay	CAN FD CAN	CAN FD CAN
Temperature class rating	°C	100 125	125	125
ISO conductor size	mm^2	0,35	0,13	0,35
Material		a	a	a
Number of strands		7	7	7
Maximum strand diameter	mm	0,26	0,16	0,26
Maximum conductor diameter	mm	0,9	0,5	0,9
Maximum conductor resistance	mΩ/m	55,5	175	55,5
Dielectric material		a	a	a
Maximum dielectric core outside diameter	mm	1,3	1,05	1,6
Lay length of twisted cores	mm	a	a	a
Maximum mutual capacitance	pF/m	a	a	a

[a] It is to be documented in supplier data sheet.

Table 10 — Parameters of preferred JUTP cable types

Cable designator		JUTP-100-1a 2x0,13	JUTP-100-1b 2x0,13	JUTP-100-2a 2x0,13	JUTP-100-2b 2x0,13	JUTP-100-2c 2x0,13	JUTP-100-2d 2x0,13	JUTP-100-3a 2x0,35	JUTP-120-4a 2x0,13	JUTP-120-5a 2x0,35
Characteristic impedance	Ω	100	100	100	100	100	100	100	120	120
Analogue bandwidth	MHz	600 66 100	600 66 100	600 66 100	600 66 100	600 66 100	600 66 100	600 66 100	100 20	100 20
Applicable for standard		1000BASE-T1 100BASE-T1 FlexRay	1000BASE-T1 100BASE-T1 FlexRay	1000BASE-T1 100BASE-T1 FlexRay	1000BASE-T1 100BASE-T1 FlexRay	1000BASE-T1 100BASE-T1 FlexRay	1000BASE-T1 100BASE-T1 FlexRay	1000BASE-T1 100BASE-T1 FlexRay	CAN FD CAN	CAN FD CAN
Temperature class rating	°C	85 100	85 100	100	85 100/125	85 100	85 100	100/125	100 125	125
ISO conductor size	mm^2	0,13	0,13	0,13	0,13	0,13	0,13	0,35	0,13	0,35
Conductor material		a	a	a	a	a	a	a	a	a
Number of strands		7	7	7	7	7	7	7	7	7
Maximum strand diameter	mm	0,17	compressed conductor	0,16	0,16	0,17	compressed conductor	0,26	0,16	0,26
Maximum conductor diameter	mm	0,55	0,55	0,55	0,55	0,55	0,55	0,9	0,55	0,9
Maximum conductor resistance	mΩ/m	210	210	180	140	210	210	55,5	180	55,5
Dielectric material		a	a	a	a	a	a	a	a	a
Maximum dielectric core outside diameter	mm	0,95	0,95	0,9	0,9	0,95	0,95	1,42	1,05	1,8/1,95
Lay length of twisted cores	mm	a	a	a	a	a	a	a	a	a
Separator material		a	a	a	a	a	a	a	a	a
Sheath material		a	a	a	a	a	a	a	a	a
Minimum thickness of sheath	mm	0,28	0,28	0,53	0,53	0,45	0,49	0,51	0,46	0,32/0,45
Maximum outside cable diameter	mm	2,7	2,7	3,5	3,5	3,5	3,5	4,3	3,4	4,5/5,2
Maximum mutual capacitance	pF/m	a	a	a	a	a	a	a	a	a

[a] It is to be documented in supplier data sheet.

8.2 Application requirements

The following requirements shall be met for the untested cable at RT.

Using cables of the same production run measure RF parameters at temperature class rating according to Table 7 and after performing the tests according to Table 8. Document the percentage of the changes in relation to the values at room temperature in the test report.

8.2.1 CAN

The detailed electrical requirements for CAN are defined in Table 11.

Measurement frequency range 300 kHz to 20 MHz.

Table 11 — Electrical requirements for CAN

Mutual capacitance	pF/m	max.	100
Characteristic impedance (CIDMF)	Ω		90 - 140
Velocity of propagation, % of velocity of light	%	min.	55

8.2.2 CAN FD

The detailed electrical requirements for CAN FD are defined in Table 12.

Measurement frequency range 1 MHz to 100 MHz.

Table 12 — Electrical requirements for CAN FD

Mutual capacitance	pF/m	max.	60
Characteristic impedance (CIDMF)	Ω		110 - 140
Insertion loss, IL	dB/m	min.	$\mathrm{IL}(f) \leq \begin{cases} 0{,}061\ \mathrm{MHz} < f < 4\ \mathrm{MHz} \\ 0{,}214\ \mathrm{MHz} \leq f \leq 50\ \mathrm{MHz} \end{cases}$
Unbalance attenuations TCL, TCTL	dB	min.	$\begin{cases} \mathrm{TCL}(f), \\ \mathrm{TCTL}(f) \end{cases} \geq \begin{cases} 25 & 1\ \mathrm{MHz} \leq f < 50\ \mathrm{MHz} \\ 15 & 50\ \mathrm{MHz} \leq f \leq 100\ \mathrm{MHz} \end{cases}$
Velocity of propagation, % of velocity of light	%	min.	55

8.2.3 FlexRay

The detailed electrical requirements for FlexRay are defined in Table 13.

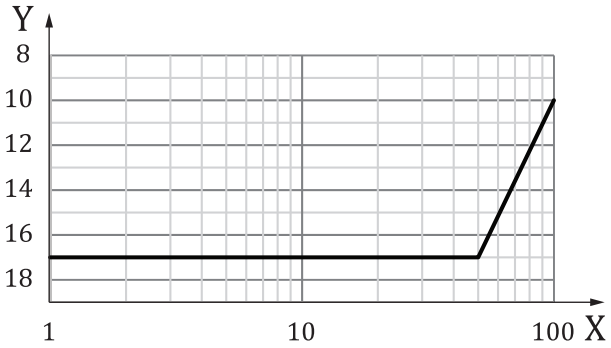
Measurement frequency range 1 MHz to 100 MHz.

Table 13 — Electrical requirements for FlexRay

Mutual capacitance	pF/m	max.	65
Characteristic impedance (CIDMF)	Ω		80 - 110
Return loss, RL	dB	min.	$\mathrm{RL}(f) \geq \begin{cases} 17 & 1\ \mathrm{MHz} \leq f < 50\ \mathrm{MHz} \\ 17 - 23{,}25 \cdot \log_{10}\left(\frac{f}{50}\right) & 50\ \mathrm{MHz} \leq f \leq 100\ \mathrm{MHz} \end{cases}$
Insertion loss, IL	dB/m	max.	$= 0{,}005\ 88 \cdot f + 0{,}029\ 9 \cdot \sqrt{f} - 0{,}034\ 2 / \sqrt{f}$
Velocity of propagation, % of velocity of light	%	min.	50

8.2.3.1 Return loss

For a graphic representation of return loss limit please refer to Figure 1.



Key

X f [MHz]
Y RL [dB]

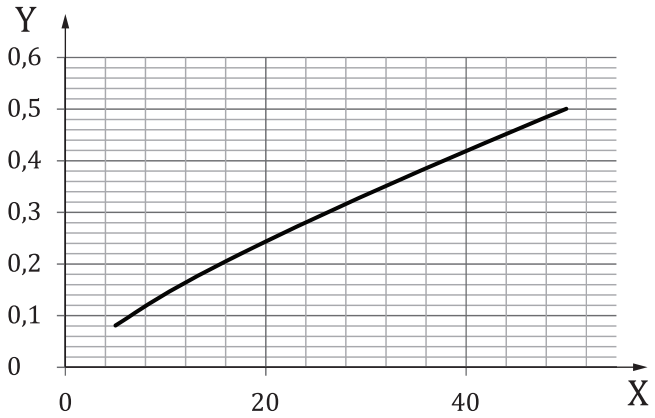
Figure 1 — FlexRay, return loss limit

8.2.3.2 Insertion loss

For a table of selected frequency points see Table 14. For a graphic representation please refer to Figure 2.

Table 14 — Flexray, insertion loss limit

f in [MHz]	IL in [dB/m] at 20 °C
5	0,081
10	0,14
15	0,20
20	0,24
25	0,29
30	0,33
35	0,38
40	0,42
45	0,46
50	0,50



Key

X f [MHz]

Y IL [dB/m]

Figure 2 — FlexRay, insertion loss limit

8.2.4 100BASE-T1 Ethernet

The detailed application specific electrical requirements below must be fulfilled by the cable.

The detailed electrical requirements for the whole 100BASE-T1 Ethernet channel are described in ISO 21111-8 and are not part of the cable test.

All measurements against the limits in Table 15 shall be performed on a cable at room temperature. Additionally, tests are performed at -40 °C and the temperature class rating. They are performed on test setup 3 or 4. Document the percentage of the changes in relation to the values at room temperature in the test report.

Perform the additional tests after 3 000 h test according to 6.5.2.3.

All frequency dependent RF Data shall be documented following the diagram figures in 8.2.4.2.

Table 15 — RF parameters 100BASE-T1 Ethernet

RF parameters	Unit	Tolerance	Requirement
Characteristic impedance (CIDMF or CIDMT)	Ω	± 10	100
Return loss, RL	dB	min.	$RL(f) \geq \begin{cases} 20 & 1\ \text{MHz} \leq f < 20\ \text{MHz} \\ 20 - 10 \cdot \log_{10}\left(\frac{f}{20}\right) & 20\ \text{MHz} \leq f \leq 66\ \text{MHz} \end{cases}$
Insertion loss, IL [b]	dB/m	max.	$IL_{10\,m}(f) < \frac{1}{10}\left(0{,}018\ 1 \cdot f + 0{,}688 \cdot \sqrt{f} + \frac{0{,}191}{\sqrt{f}}\right)$ $IL_{15\,m}(f) < \frac{1}{15}\left(0{,}018\ 1 \cdot f + 0{,}688 \cdot \sqrt{f} + \frac{0{,}191}{\sqrt{f}}\right)$ for $1\ \text{MHz} \leq f \leq 66\ \text{MHz}$

[a] Due to the reciprocity of the system LCL (S_{dc11}) and TCL (S_{cd11}) give almost identical results, the same holds true for LCTL (S_{dc21}) and TCTL (S_{cd21}). For validation purposes only LCL and LCTL measurement shall be performed.

[b] Limit values fulfil the requirements of ISO 21111-8. By use of these formulae smooth curves are obtained between the reference points too.

Table 15 *(continued)*

RF parameters	Unit	Toler-ance	Requirement
LCL (S_{dc11}) [a] LCTL (S_{dc21}) [a]	dB	min.	$\begin{cases} \mathrm{LCL}(f) \\ \mathrm{LCTL}(f) \end{cases} \geq \begin{cases} 46 & 1\ \mathrm{MHz} \leq f < 50\ \mathrm{MHz} \\ 46 - 20 \cdot \log_{10}\left(\frac{f}{50}\right) & 50\ \mathrm{MHz} \leq f \leq 200\ \mathrm{MHz} \end{cases}$
[a] Due to the reciprocity of the system LCL (S_{dc11}) and TCL (S_{cd11}) give almost identical results, the same holds true for LCTL (S_{dc21}) and TCTL (S_{cd21}). For validation purposes only LCL and LCTL measurement shall be performed. [b] Limit values fulfil the requirements of ISO 21111-8. By use of these formulae smooth curves are obtained between the reference points too.			

8.2.4.1 Test setup

All low and high frequency tests are performed on 10 m samples using test set up 3 according to 6.3.5.1.

Use TDR and VNA settings in accordance with to ISO 21111-8:2022, 6.1.1, 6.1.2 and 6.1.3.

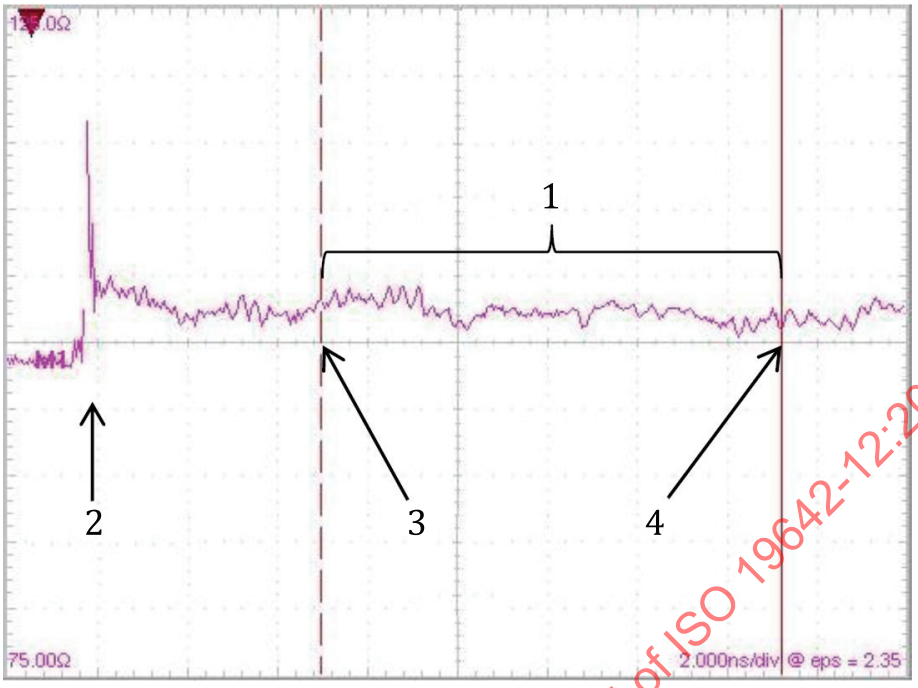
8.2.4.2 Tests

8.2.4.2.1 Characteristic impedance

The characteristic impedance in differential mode is alternatively measured as:

— CIDMF in frequency domain is measured in according to 6.3.12.2, or

— CIDMT in time domain is measured according to 6.3.13.2 in the evaluation window according to Figure 3. If not otherwise defined, use a TDR with a rise-time set to a maximum value of 700 ps.



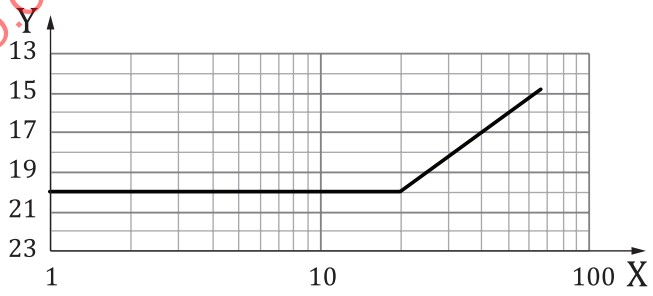
Key

1 evaluation window
2 L = 0 m
3 L= 0,5 m
4 L = 1,5 m

Figure 3 — Evaluation window for CIDMT

8.2.4.2.2 Return loss

The return loss RL is measured according to 6.3.15.2. For a graphic representation please refer to Figure 4.



Key

X f [MHz]
Y RL [dB]

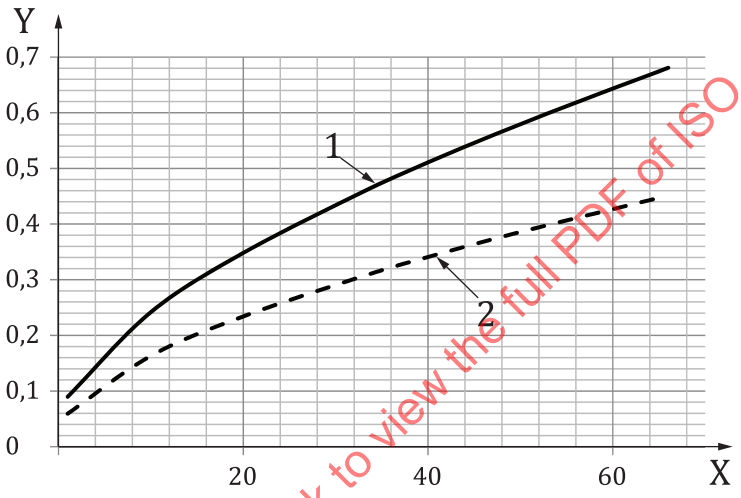
Figure 4 — 100BASE-T1 Ethernet, return loss limit

8.2.4.2.3 Insertion loss

The insertion loss IL is measured according to 6.3.14. For a table of selected frequency points see Table 16. For a graphic representation please refer to Figure 5.

Table 16 — 100BASE-T1 Ethernet, insertion loss limits

	Max. cable length, in [m]	
frequency, *f*	10 m cable	15 m cable
in [MHz]	IL at 20 °C, [dB/m]	
1	0,09	0,06
10	0,24	0,16
20	0,35	0,23
33	0,46	0,31
40	0,51	0,34
50	0,58	0,39
66	0,68	0,45



Key

X *f* [MHz]
Y IL [dB/m]
1 10 m cable
2 15 m cable

Figure 5 — 100BASE-T1 Ethernet, insertion loss limits

8.2.4.2.4 Unbalance attenuations

The unbalance attenuations LCL and LCTL are measured according to 6.3.16. For a graphic representation please refer to Figure 6.