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TECHNICAL REPORT

Information technology – Generic cabling for customer premises – Part 9902: End-to-end link configurations

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CONTENTS

INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES –

Part 9902: End-to-end link configurations

FOREWORD

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ISO/IEC TR 11801-9902, which is a Technical Report, was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This Technical Report has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all currently available parts of the ISO/IEC 11801 series, under the general title *Information technology — Generic cabling for customer premises*, can be found on the IEC website.

INTRODUCTION

One major difference between a standard generic cabling installation and an industrial cabling as also other application areas of cabling is how it is installed. In these areas it is common practice to deploy cabling channels constructed from one or more cords as described in Annex B and Annex C of ISO/IEC 11801-3:—[1]. In addition, the cords are field terminated rather than pre-terminated into plugs elsewhere. As a result, these cords might have problems associated with the termination process which are not identified during channel verification testing in accordance with ISO/IEC 11801-1 since such testing excludes the free connectors at the end of the channel.

This Technical Report provides definitions for, and examples of, such cabling implementations, described as end-to-end (E2E) links. It also provides performance specifications to support Class D and Class E balanced cabling channels of ISO/IEC 11801-1 which include the impact of the terminating connectors that may be used for performance verification using the test method of ISO/IEC 14763-4.

1 Under preparation. Stage at the time of publication: ISO/IEC FDIS 11801-3:2017.

INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES –

Part 9902: End-to-end link configurations

1 Scope

This part of ISO/IEC 11801, which is a Technical Report, provides definitions for, and examples of, cabling implementations described as end-to-end (E2E) links.

In addition, this document provides performance specifications to support Class D and Class E balanced cabling channels of ISO/IEC 11801-1. These specifications amend those channel specifications of ISO/IEC 11801-1 by including the impact of the free connectors in accordance with the interfaces specified in ISO/IEC 11801-3 used to terminate the E2E link.

Test methods are provided in ISO/IEC 14763-4.

End-to-end link configurations can include any type of connection.

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 11801-1[2], *Information technology – Generic cabling for customer premises – Part 1: General requirements*

ISO/IEC 11801-3[3], *Information technology – Generic cabling for customer premises – Part 3: Industrial premises*

ISO/IEC 14763-4[4], *Information technology – Implementation and operation of customer premises cabling – Part 4: Measurement of end-to-end (E2E)-links*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 11801-1, ISO/IEC 11801-3 and the following apply.

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2 Under preparation. Stage at the time of publication: ISO/IEC FDIS 11801-1:2017.

3 Under preparation. Stage at the time of publication: ISO/IEC FDIS 11801-3:2017.

4 Under preparation. Stage at the time of publication: ISO/IEC CDV 14763-4:2017.

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

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

3.1.1
end-to-end link
end-to-end transmission path formed by structured cabling based on passive components including the portion of the end connection that is attached to the link and the portion of the end connection that is attached to the end equipment

3.1.2
fixed connector
connector for attachment to a rigid surface

3.1.3
free connector
connector for attachment to a free end

3.1.4
bulkhead connection
connection that serves as an interconnection point located through an enclosure wall

3.1.5
segment
cabling between connectors of an end-to-end link

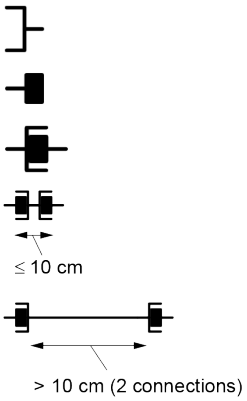
3.2 Abbreviated terms

For the purposes of this document, the abbreviations given in ISO/IEC 11801-1, ISO/IEC 11801-3 and the following apply.

B	bulkhead connection
C	connection
CP	consolidation point
E2E	end-to-end
ffs	for further study
L1	length of E2E-link
TI	test interface

3.3 Symbols

For the purposes of this document, the symbols given in ISO/IEC 11801-1, ISO/IEC 11801-3 and the following apply.



The symbols shown in Figure 1 define the number of connections in all E2E links.

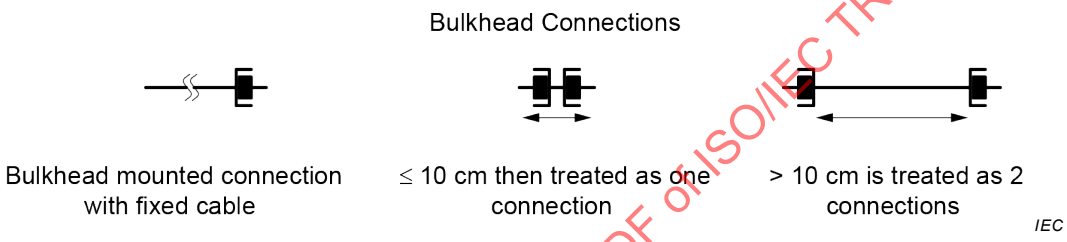


Figure 1 – Symbols for bulkhead connections

NOTE Bulkhead mounted connections with fixed cable can have a variable length to accommodate the installation with in the cabinet.

Bulkhead connector assemblies can consist of one plug jack assembly with a cable attached or two back-to-back jacks meeting the distance specifications defined by IEC 61918 for a specific transmission class.

4 Specifications

The specifications for an end-to-end link include the following.

a) The configurations and structure should meet the specifications outlined in Clause 5.

b) The interfaces to the cabling should meet the specifications of ISO/IEC 11801-1 or ISO/IEC 11801-3 with respect to mating interfaces and performance.

c) Connecting hardware at other places in the cabling structure should meet the performance specifications specified in ISO/IEC 11801-1.

d) Installation should be performed in accordance with IEC 61918 and ISO/IEC 14763-2.

e) The E2E links should meet the specifications of Clause 6.

f) Performance testing to the specifications of Clause 6 should be used to provide assurance of installed cabling to determine its capacity to support the applications described by IEC 61918 and ISO/IEC 11801-1.

g) The performance of end-to-end link as specified in Clause 6 should support the channel specifications specified in ISO/IEC 11801-1. Performance can be achieved by one of the following when the additional connections are included in the test results:

   1) an E2E link design and implementation ensuring that the prescribed transmission performance is met;

   2) attachment of appropriate components to a permanent link or CP link meeting the prescribed performance class of ISO/IEC 11801-1;

3) using compatible cabling components that meet the specifications of ISO/IEC 11801-3 and ISO/IEC 11801-1.

5 Examples of end-to-end link configurations

There are multiple configurations of E2E links that are identified by the number of mated connections in the configuration including those at the ends of the E2E link. This document describes two-, three-, four-, five-, and six-connection E2E links as illustrated in Figure 2 to Figure 9.

Annex A provides information regarding CP cords.

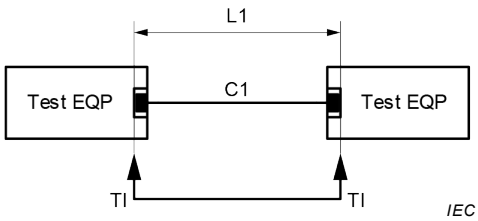


Figure 2 – One-segment, two-connections, E2E link

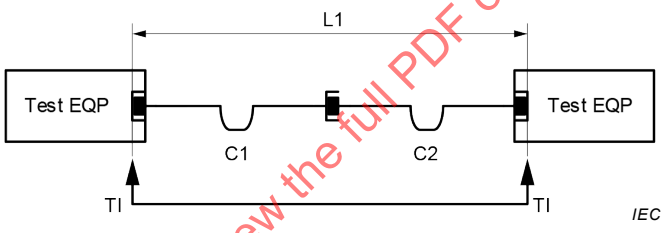


Figure 3 – Two-segments, three-connections, E2E link

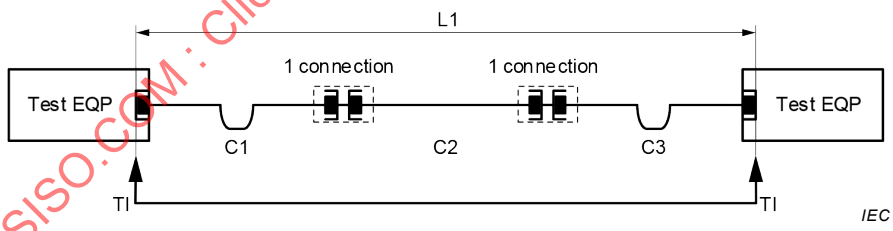


Figure 4 – Three-segments, one-connection bulkheads, four-connections, E2E link

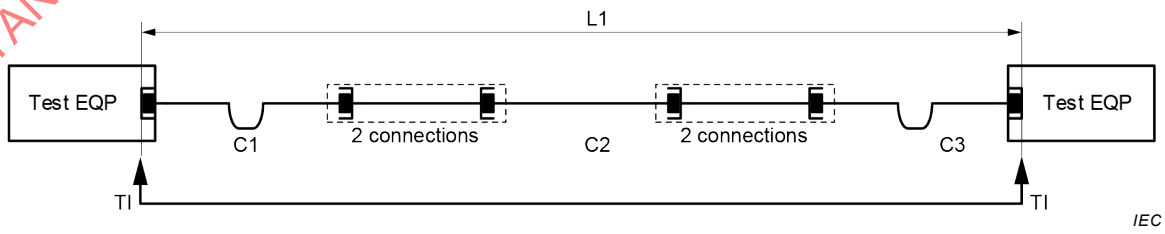


Figure 5 – Three-segments, six-connections, E2E link

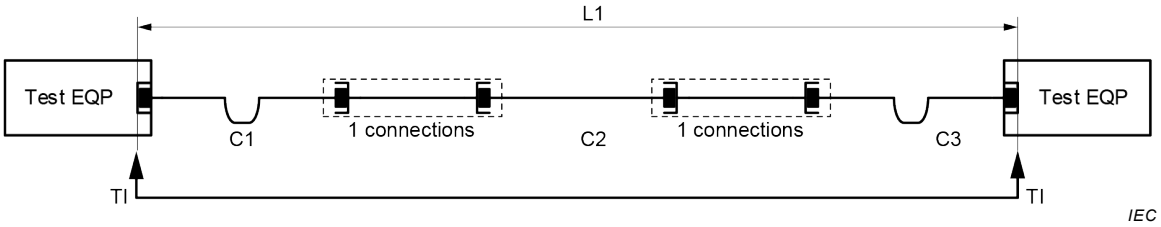


Figure 6 – Three-segments, four-connections, E2E link

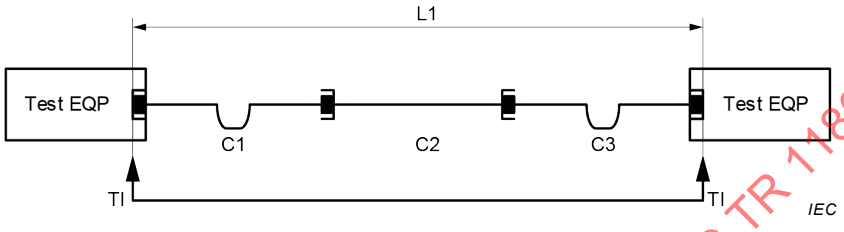


Figure 7 – Three-segments, four-connections, E2E link

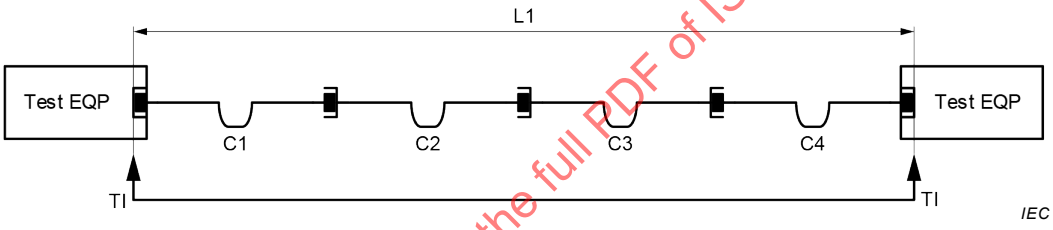


Figure 8 – Four-segments, five-connections, E2E link

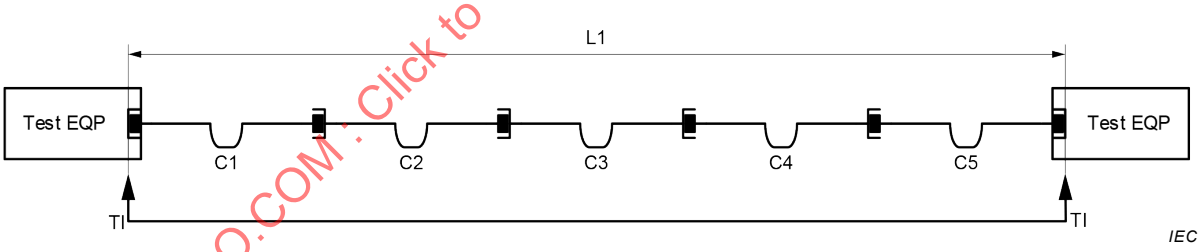


Figure 9 – Five-segments, six-connections, E2E link

6 Performance specifications when using end-to-end link limits

6.1 General

The performance specifications of 6.3 are based on the number of connections comprising the E2E link. These specifications are based on the modelling techniques described in ISO/IEC TR 11801-9903 using the balanced cabling components of Category 5 and Category 6 of ISO/IEC 11801-1 to provide the specification for Class D and Class E, respectively.

The worst case limits of 6.2 show the values calculated using the formulae of 6.3 to 6.8 for six connections as in Figure 4 and Figure 5.

The specifications for two- and three-connection E2E links are based on the two- and three-connection permanent link specifications of ISO/IEC 11801-1.

The specifications for four-, five- and six-connection E2E links are based on the matrix model of ISO/IEC TR 11801-9903. For these E2E links the model was used to examine the difference between traditional channels and a similar topology of E2E links. This difference was then added to the channel limits provided by ISO/IEC 11801-1 to provide the E2E link limits.

In 6.2 the limits for the E2E links for Class D and Class E are provided.

6.2 Worst case limits

Table 1 and Table 2 contain the worst case limits for E2E links containing six connections for Class D and Class E, respectively. The tables summarize the values in 6.3 to 6.8. 6.9 to 6.15 contain additional parameters and limits.

Table 1 – Worst case Class D E2E link performance at key frequencies

Frequency MHz	IL dB	RL dB	NEXT dB	PSNEXT dB	ACRF dB	PSACRF dB
1	4,00	16,73	63,29	60,29	56,28	53,28
4	4,69	16,69	53,51	50,51	44,24	41,24
10	7,40	16,61	46,88	43,88	36,28	33,28
20	10,56	16,47	41,73	38,73	30,26	27,26
30	13,04	14,58	38,64	35,64	26,74	23,74
40	15,17	13,20	36,39	33,39	24,24	21,24
50	17,08	12,10	34,62	31,62	22,30	19,30
60	18,83	11,18	33,14	30,14	20,72	17,72
70	20,45	10,38	31,87	28,87	19,38	16,38
80	21,98	9,67	30,74	27,74	18,22	15,22
90	23,43	9,03	29,73	26,73	17,20	14,20
100	24,82	8,44	28,82	25,82	16,28	13,28

Table 2 – Worst case Class E E2E link performance at key frequencies

Frequency MHz	IL dB	RL dB	NEXT dB	PSNEXT dB	ACRF dB	PSACRF dB
1	4,00	18,45	65,00	65,00	62,80	59,80
4	4,26	18,43	63,01	60,51	50,76	47,76
10	6,68	18,40	56,49	53,91	42,80	39,80
20	9,50	16,83	51,45	48,79	36,78	33,78
30	11,70	15,89	48,43	45,73	33,25	30,25
40	13,60	15,20	46,26	43,52	30,76	27,76
50	15,29	14,17	44,54	41,77	28,82	25,82
60	16,83	13,32	43,11	40,33	27,23	24,23
70	18,27	12,59	41,89	39,08	25,89	22,89
80	19,61	11,95	40,81	37,99	24,74	21,74
90	20,89	11,38	39,85	37,02	23,71	20,71
100	22,11	10,87	38,98	36,13	22,80	19,80
150	27,56	8,81	35,50	32,60	19,28	16,28
200	32,29	7,26	32,88	29,95	16,78	13,78
250	36,57	6,00	30,73	27,77	14,84	11,84

6.3 Insertion loss limits

Table 3 and Table 4 contain the insertion loss limits for Class D and Class E E2E links, respectively.

Table 3 – Class D E2E link insertion loss limits

Connections	Maximum Class D E2E link insertion loss dB
2	$\left(\frac{L}{100}\right)\cdot\left(1{,}9108\cdot\sqrt{f}+0{,}0222\cdot f+\frac{0{,}2}{\sqrt{f}}\right)+\left(2\cdot 0{,}04\cdot\sqrt{f}\right)$
3	$\left(\frac{L}{100}\right)\cdot\left(1{,}9108\cdot\sqrt{f}+0{,}0222\cdot f+\frac{0{,}2}{\sqrt{f}}\right)+\left(3\cdot 0{,}04\cdot\sqrt{f}\right)$
4	$(1{,}05)\cdot\left(1{,}9108\cdot\sqrt{f}+0{,}0222\cdot f+\frac{0{,}2}{\sqrt{f}}\right)+\left(4\cdot 0{,}04\cdot\sqrt{f}\right)$
5	$(1{,}05)\cdot\left(1{,}9108\cdot\sqrt{f}+0{,}0222\cdot f+\frac{0{,}2}{\sqrt{f}}\right)+\left(5\cdot 0{,}04\cdot\sqrt{f}\right)$
6	$(1{,}05)\cdot\left(1{,}9108\cdot\sqrt{f}+0{,}0222\cdot f+\frac{0{,}2}{\sqrt{f}}\right)+\left(6\cdot 0{,}04\cdot\sqrt{f}\right)$
NOTE 1 To align with ISO/IEC 11801-1 permanent link specifications, the maximum length for one- and two-segment E2E links is 90 m. NOTE 2 Calculated values less than 4 dB revert to 4 dB.	

Table 4 – Class E E2E link insertion loss limits

Connections	Maximum Class E E2E link insertion loss dB
2	$\left(\frac{L}{100}\right)\cdot\left(1{,}82\cdot\sqrt{f}+0{,}0169\cdot f+\frac{0{,}25}{\sqrt{f}}\right)+\left(2\cdot 0{,}02\cdot\sqrt{f}\right)$
3	$\left(\frac{L}{100}\right)\cdot\left(1{,}82\cdot\sqrt{f}+0{,}0169\cdot f+\frac{0{,}25}{\sqrt{f}}\right)+\left(3\cdot 0{,}02\cdot\sqrt{f}\right)$
4	$(1{,}05)\cdot\left(1{,}82\cdot\sqrt{f}+0{,}0169\cdot f+\frac{0{,}25}{\sqrt{f}}\right)+\left(4\cdot 0{,}02\cdot\sqrt{f}\right)$
5	$(1{,}05)\cdot\left(1{,}82\cdot\sqrt{f}+0{,}0169\cdot f+\frac{0{,}25}{\sqrt{f}}\right)+\left(5\cdot 0{,}02\cdot\sqrt{f}\right)$
6	$(1{,}05)\cdot\left(1{,}82\cdot\sqrt{f}+0{,}0169\cdot f+\frac{0{,}25}{\sqrt{f}}\right)+\left(6\cdot 0{,}02\cdot\sqrt{f}\right)$
NOTE 1 To align with ISO/IEC 11801-1 permanent link specifications, the maximum length for one- and two-segment E2E links is 90 m. NOTE 2 Calculated values less than 4 dB revert to 4 dB.	

6.4 Return loss

Table 5 and Table 6 contain the return loss limits for Class D and Class E E2E links, respectively.

Table 5 – Class D E2E link return loss limits

Connections	Minimum Class D E2E link return loss dB	
2	$1 \le f \le 20$	19
	$20 < f \le 100$	$32 - 10\cdot\log(f)$
3	$1 \le f \le 20$	19
	$20 < f \le 100$	$32 - 10\cdot\log(f)$
4	$1 \le f \le 20$	$17-\left(0{,}41+\left(0{,}88\cdot\left(\frac{f-1}{99}\right)\right)\right)$
	$20 < f \le 100$	$30-10\cdot\log(f)-\left(0{,}41+\left(0{,}88\cdot\left(\frac{f-1}{99}\right)\right)\right)$
5	$1 \le f \le 20$	$17-\left(0{,}33+\left(1{,}08\cdot\left(\frac{f-1}{99}\right)\right)\right)$
	$20 < f \le 100$	$30-10\cdot\log(f)-\left(0{,}33+\left(1{,}08\cdot\left(\frac{f-1}{99}\right)\right)\right)$
6	$1 \le f \le 20$	$17-\left(0{,}27+\left(1{,}29\cdot\left(\frac{f-1}{99}\right)\right)\right)$
	$20 < f \le 100$	$30-10\cdot\log(f)-\left(0{,}27+\left(1{,}29\cdot\left(\frac{f-1}{99}\right)\right)\right)$

Table 6 – Class E E2E link return loss limits

Connections	Minimum Class E E2E link return loss dB	
2	$1 \le f \le 10$	21
	$10 < f \le 40$	$26 - 5 \cdot \log(f)$
	$40 < f \le 250$	$34 - 10 \cdot \log(f)$
3	$1 \le f \le 10$	21
	$10 < f \le 40$	$26 - 5 \cdot \log(f)$
	$40 < f \le 250$	$34 - 10 \cdot \log(f)$
4	$1 \le f \le 10$	$19 - \left(0{,}7 + \left(1{,}21 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
	$10 < f \le 40$	$24 - 5 \cdot \log(f) - \left(0{,}7 + \left(1{,}21 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
	$40 < f \le 250$	$32 - 10 \cdot \log(f) - \left(0{,}7 + \left(1{,}21 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
5	$1 \le f \le 10$	$19 - \left(0{,}57 + \left(1{,}48 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
	$10 < f \le 40$	$24 - 5 \cdot \log(f) - \left(0{,}57 + \left(1{,}48 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
	$40 < f \le 250$	$32 - 10 \cdot \log(f) - \left(0{,}57 + \left(1{,}48 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
6	$1 \le f \le 10$	$19 - \left(0{,}55 + \left(1{,}47 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
	$10 < f \le 40$	$24 - 5 \cdot \log(f) - \left(0{,}55 + \left(1{,}47 \cdot \left(\frac{f-1}{249}\right)\right)\right)$
	$40 < f \le 250$	$32 - 10 \cdot \log(f) - \left(0{,}55 + \left(1{,}47 \cdot \left(\frac{f-1}{249}\right)\right)\right)$

6.5 NEXT limits

Table 7 and Table 8 contain the NEXT limits for Class D and Class E E2E links, respectively.

Table 7 – Class D E2E link NEXT limits

Connections	Minimum Class D E2E link NEXT dB
2	$-20 \cdot \log\left(10^{\frac{65,3-15\cdot\log(f)}{-20}} + 10^{\frac{83-20\cdot\log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{65,3-15\cdot\log(f)}{-20}} + 10^{\frac{83-20\cdot\log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{65,3-15\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{83-20\cdot\log(f)}{-20}}\right)\right) - \left(0,34 \cdot \left(\frac{f-1}{99}\right)\right)$
5	$\left(-20 \cdot \log\left(10^{\frac{65,3-15\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{83-20\cdot\log(f)}{-20}}\right)\right) - \left(0,8 \cdot \left(\frac{f-1}{99}\right)\right)$
6	$\left(-20 \cdot \log\left(10^{\frac{65,3-15\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{83-20\cdot\log(f)}{-20}}\right)\right) - \left(1,26 \cdot \left(\frac{f-1}{99}\right)\right)$
NOTE Calculated values greater than 65 dB revert to 65 dB.	

Table 8 – Class E E2E link NEXT limits

Connections	Minimum Class E E2E link NEXT dB
2	$-20 \cdot \log\left(10^{\frac{74,3-15\cdot\log(f)}{-20}} + 10^{\frac{94-20\cdot\log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{74,3-15\cdot\log(f)}{-20}} + 10^{\frac{94-20\cdot\log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{74,3-15\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{94-20\cdot\log(f)}{-20}}\right)\right) - \left(1,42 \cdot \left(\frac{f-1}{249}\right)\right)$
5	$\left(-20 \cdot \log\left(10^{\frac{74,3-15\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{94-20\cdot\log(f)}{-20}}\right)\right) - \left(2,07 \cdot \left(\frac{f-1}{249}\right)\right)$
6	$\left(-20 \cdot \log\left(10^{\frac{74,3-15\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{94-20\cdot\log(f)}{-20}}\right)\right) - \left(2,38 \cdot \left(\frac{f-1}{249}\right)\right)$
NOTE Calculated values greater than 65 dB revert to 65 dB.	

6.6 PSNEXT limits

Table 9 and Table 10 contain the PSNEXT limits for Class D and Class E E2E links, respectively.

Table 9 – Class D E2E link PSNEXT limits

Connections	Minimum Class D E2E link PSNEXT dB
2	$-20 \cdot \log\left(10^{\frac{62,3-15 \cdot \log(f)}{-20}} + 10^{\frac{80-20 \cdot \log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{62,3-15 \cdot \log(f)}{-20}} + 10^{\frac{80-20 \cdot \log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{62,3-15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{80-20 \cdot \log(f)}{-20}}\right)\right) - \left(0,34 \cdot \left(\frac{f-1}{99}\right)\right)$
5	$\left(-20 \cdot \log\left(10^{\frac{62,3-15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{80-20 \cdot \log(f)}{-20}}\right)\right) - \left(0,8 \cdot \left(\frac{f-1}{99}\right)\right)$
6	$\left(-20 \cdot \log\left(10^{\frac{62,3-15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{80-20 \cdot \log(f)}{-20}}\right)\right) - \left(1,26 \cdot \left(\frac{f-1}{99}\right)\right)$
In cases where measured insertion loss is less than 4 dB, the pass/fail limits for PSNEXT should not apply.	

Table 10 – Class E E2E link PSNEXT limits

Connections	Minimum Class E E2E link PSNEXT dB
2	$-20 \cdot \log\left(10^{\frac{72,3-15 \cdot \log(f)}{-20}} + 10^{\frac{90-20 \cdot \log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{72,3-15 \cdot \log(f)}{-20}} + 10^{\frac{90-20 \cdot \log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{72,3-15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{90-20 \cdot \log(f)}{-20}}\right)\right) - \left(1,42 \cdot \left(\frac{f-1}{249}\right)\right)$
5	$\left(-20 \cdot \log\left(10^{\frac{72,3-15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{90-20 \cdot \log(f)}{-20}}\right)\right) - \left(2,07 \cdot \left(\frac{f-1}{249}\right)\right)$
6	$\left(-20 \cdot \log\left(10^{\frac{72,3-15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{90-20 \cdot \log(f)}{-20}}\right)\right) - \left(2,38 \cdot \left(\frac{f-1}{249}\right)\right)$

6.7 ACR-F Limits

Table 11 and Table 12 contain the ACR-F limits for Class D and Class E E2E links, respectively.

Table 11 – Class D E2E Link ACR-F limits

Connections	Minimum Class D E2E Link ACR-F dB
2	$-20 \cdot \log\left(10^{\frac{63,8-20\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{75,1-20\cdot\log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{63,8-20\cdot\log(f)}{-20}} + 3 \cdot 10^{\frac{75,1-20\cdot\log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{63,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{75,1-20\cdot\log(f)}{-20}}\right)\right) + 0,13$
5	$\left(-20 \cdot \log\left(10^{\frac{63,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{75,1-20\cdot\log(f)}{-20}}\right)\right) - 0,81$
6	$\left(-20 \cdot \log\left(10^{\frac{63,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{75,1-20\cdot\log(f)}{-20}}\right)\right) + 1,12$
ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.	

Table 12 –Class E E2E Link ACR-F limits

Connections	Minimum Class E E2E Link ACR-F dB
2	$-20 \cdot \log\left(10^{\frac{67,8-20\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{83,1-20\cdot\log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{67,8-20\cdot\log(f)}{-20}} + 3 \cdot 10^{\frac{83,1-20\cdot\log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{67,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{83,1-20\cdot\log(f)}{-20}}\right)\right) - 0,09$
5	$\left(-20 \cdot \log\left(10^{\frac{67,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{80,1-20\cdot\log(f)}{-20}}\right)\right) - 0,36$
6	$\left(-20 \cdot \log\left(10^{\frac{67,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{83,1-20\cdot\log(f)}{-20}}\right)\right) - 0,46$
ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.	

6.8 PSACR-F

Table 13 and Table 14 contain the PSACR-F limits for Class D and Class E E2E links, respectively.

Table 13 – Class D E2E link PSACR-F limits

Connections	Minimum Class D E2E link PSACR-F dB
2	$-20 \cdot \log\left(10^{\frac{60,8-20\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{72,1-20\cdot\log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{60,8-20\cdot\log(f)}{-20}} + 3 \cdot 10^{\frac{72,1-20\cdot\log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{60,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{72,1-20\cdot\log(f)}{-20}}\right)\right) \mp 0,13$
5	$\left(-20 \cdot \log\left(10^{\frac{60,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{72,1-20\cdot\log(f)}{-20}}\right)\right) - 0,81$
6	$\left(-20 \cdot \log\left(10^{\frac{60,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{72,1-20\cdot\log(f)}{-20}}\right)\right) - 1,12$

Table 14 – Class E E2E link PSACR-F limits

Connections	Minimum Class E E2E link PSACR-F dB
2	$-20 \cdot \log\left(10^{\frac{64,8-20\cdot\log(f)}{-20}} + 2 \cdot 10^{\frac{80,1-20\cdot\log(f)}{-20}}\right)$
3	$-20 \cdot \log\left(10^{\frac{64,8-20\cdot\log(f)}{-20}} + 3 \cdot 10^{\frac{80,1-20\cdot\log(f)}{-20}}\right)$
4	$\left(-20 \cdot \log\left(10^{\frac{64,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{80,1-20\cdot\log(f)}{-20}}\right)\right) - 0,09$
5	$\left(-20 \cdot \log\left(10^{\frac{64,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{80,1-20\cdot\log(f)}{-20}}\right)\right) - 0,36$
6	$\left(-20 \cdot \log\left(10^{\frac{64,8-20\cdot\log(f)}{-20}} + 4 \cdot 10^{\frac{80,1-20\cdot\log(f)}{-20}}\right)\right) - 0,46$
NOTE Calculated values greater than 62 dB revert to 62 dB	

6.9 TCL specifications

Table 15 contains the TCL limits for Class D and Class E E2E links for unscreened cabling.

Table 15 – E2E link TCL

Class	Frequency MHz	Minimum E2E link TCL dB [a]		
		E_1	E_2	E_3
Class D	$1 \le f \le 30$ $30 \le f \le 100$	53 − 15log(f) 60,4 − 20log(f)	63 − 15log(f) 70,4 − 20log(f)	73 − 15log(f) 80,4 − 20log(f)
Class E	$1 \le f \le 30$ $30 \le f \le 250$	53 − 15log(f) 60,4 − 20log(f)	63 − 15log(f) 70,4 − 20log(f)	73 − 15log(f) 80,4 − 20log(f)
[a] TCL at frequencies that correspond to calculated values of greater than 40 dB revert to 40 dB.				

NOTE TCL specifications apply to all E2E links.

6.10 ELTCTL specifications

Table 16 contains the ELTCTL limits for Class D and Class E E2E links for unscreened cabling.

Table 16 – E2E link segment ELTCTL

Class	Frequency MHz	Minimum E2E link segment ELTCTL [a] dB		
		E_1	E_2	E_3
Class D	$1 \le f \le 30$	30 − 20log(f)	40 − 20log(f)	50 − 20log(f)
Class E	$1 \le f \le 30$	30 − 20log(f)	40 − 20log(f)	50 − 20log(f)
[a] ELTCTL at frequencies that correspond to calculated values of greater than 40 dB revert to 40 dB.				

6.11 Coupling attenuation specifications

Table 17 contains the coupling attenuation limits for Class D and Class E E2E links for screened cabling.

Table 17 – Minimum E2E link coupling attenuation

Class	Frequency MHz	Minimum E2E link coupling atenuation dB		
		E_1	E_2	E_3
Class D	$1 \le f \le 30$	40	50	60
	$1 \le f \le 100$	80 − 20log(f)	90 − 20log(f)	90 − 20log(f)
Class E	$1 \le f \le 30$	40	50	60
	$1 \le f \le 100$	80 − 20log(f)	90 − 20log(f)	90 − 20log(f)

6.12 DC loop resistance

Table 18 contains the DCLR limits for Class D and Class E E2E.

Table 18 – E2E link segment DC loop resistance

Class	Maximum DC E2E link segment loop resistance per pair for n connections in link = (2 thru 6) + 2 Ω
D and E	$\left(\frac{L}{100}\right) \cdot 21 + (n \cdot 0{,}4)$
DC loop resistance is length scaled up to a maximum length of 100 m.	

6.13 Propagation delay

Table 19 contains the maximum propagation delay limits for Class D and Class E E2E links.

Table 19 – E2E link delay

Class	Frequency	Maximum E2E link delay for n connections in link = (2 thru 6) ns
D	$1 \le f \le 100$	$\left(\frac{L}{100}\right) \cdot (0{,}534 + 0{,}036 \cdot \sqrt{f}) + (n \cdot 0{,}0025)$
E	$1 \le f \le 250$	$\left(\frac{L}{100}\right) \cdot (0{,}534 + 0{,}036 \cdot \sqrt{f}) + (n \cdot 0{,}0025)$

6.14 Delay skew

Table 20 contains the delay skew limits for Class D and Class E E2E links. The delay skew is length dependent.

Table 20 – E2E link delay skew

Class	Maximum E2E link delay for n connections in link = (2 thru 6) ns
D and E	$\left(\frac{L}{100}\right) \cdot 0{,}045 + (n \cdot 0{,}00125)$

6.15 DC resistance unbalance within a pair

Table 21 contains the DC resistance unbalance limits for a Class D and Class E E2E link.

Table 21 – E2E link DC resistance unbalance

Class	Maximum E2E link DC resistance unbalance ns
D and E	DC resistance unbalance < (the greater of 3 % or $(n \cdot 0{,}05)$) [a]
[a] n is the number of connections in the E2E link.	

7 E2E link performance

7.1 General

Performance testing can be undertaken either:

a) in a laboratory, where E2E links contain cabling components in a specific design configuration; or

b) in the field, after installation, using field test equipment. This testing is independent from any specifications for acceptance testing and is specified as explained in ISO/IEC 14763-2 and IEC 61918.

Performance testing of both kinds may be performed by independent or third party organizations in order to give greater guarantees of compliance. Reference testing is also known as type testing.

7.2 Reference performance testing

This testing is performed on a sample of installed cabling in a laboratory where an assessment against the conformance criteria of ISO/IEC TR 11801-9902 is required. The assessment documentation should include details of the number of channels or links tested, test evaluation criteria, supplier's declarations and certification, laboratory accreditation and calibration certification.

This testing can also be used for the comparison of measurements performed with laboratory and field test instruments:

a) assessing cabling models in a laboratory environment;

b) assessing parameters that cannot be tested in an installation.

7.3 Installation performance testing

This testing is performed in accordance with Clause 8, on a complete installation of cabling in the field where an assessment against the conformance criteria of an ISO/IEC 11801 series standard is required.

7.4 Installation performance testing of E2E links

Testing to determine performance with the specifications of Clause 5 is optional. Testing should be performed in the following cases:

a) E2E links with lengths exceeding, or having more components than, those specified in reference implementations of the cabling design documents;

b) E2E links using components whose transmission performance is lower than those described in ISO/IEC 11801-1;

c) E2E links created by adding more than one cord to either end of a link meeting the specifications of ISO/IEC 11801-1;

d) evaluation of cabling to determine its capacity to support a certain group of applications;

e) confirmation of performance of cabling designed in accordance with the reference.

Table 22 contains the test regime for reference performance and installation performance.

Table 22 – Test regime for reference performance and installation performance – Balanced cabling of Classes D to E

Transmission parameter [a]	Reference performance testing	Installation performance testing
Return loss	N	N
Insertion loss	N	N
Pair-to-pair NEXT	N	N
PS NEXT	C	C
Pair-to-pair ACR-N	C	C
PS ACR-N	C	C
Pair-to-pair ACR-F	N	N
PS ACR-F	C	C
Direct current (DC) loop resistance	N	N
Direct current (DC) resistance unbalance within pairs	N	I
Direct current (DC) resistance unbalance between pairs	N	I
Propagation delay	N	N
Delay skew	N	N
Unbalance attenuation, near-end (TCL)	N	I
Unbalance attenuation, far-end (ELTCTL)	N	I
Coupling attenuation	N	I
PS ANEXT	N	N_S
PS ANEXT$_{avg}$	C	C
PS AACR-F	N	N_S
PS AACR-F$_{avg}$	C	C
Wire-map	N	N
Continuity: • signal conductors; • screen conductors (if present); • short circuits; • open circuits.	N	N
Length [b]	I	I

Symbols used in this table:

C is the calculated value;

I is the informative (optional) testing;

N is the normative (100 %) testing, if not met by design;

N_S is the normative (sampled) testing, if not met by design. The sample size to be tested should be in accordance with ISO/IEC 14763-2.

NOTE The term “met by design” refers to a specification which can be met by the selection of appropriate materials and installation techniques.

[a] Only those parameters specified for each Class of cabling need to be tested.

[b] Length is not a pass/fail criterion.

8 Testing of end-to-end links

Refer to ISO/IEC 14763-4 for testing of E2E links.