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Connectors for electronic equipment –

Part 3-109:
Detail specification for two-part cable to board connector for high speed data application in a harsh industrial environment – Protection rate IP67 according to IEC 60529

PUBLICLY AVAILABLE SPECIFICATION

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

Reference number
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FOREWORD

A PAS is a technical specification not fulfilling the requirements for a standard, but made available to the public.

IEC-PAS 61076-3-109 has been processed by subcommittee 48B: Connectors, of IEC technical committee 48: Electromechanical components and mechanical structures for electronic equipment.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:

Draft PAS	Report on voting
48B/1106/PAS	48B/1121/RVD

Following publication of this PAS, the technical committee or subcommittee concerned will investigate the possibility of transforming the PAS into an International Standard.

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CONNECTORS FOR ELECTRONIC EQUIPMENT –

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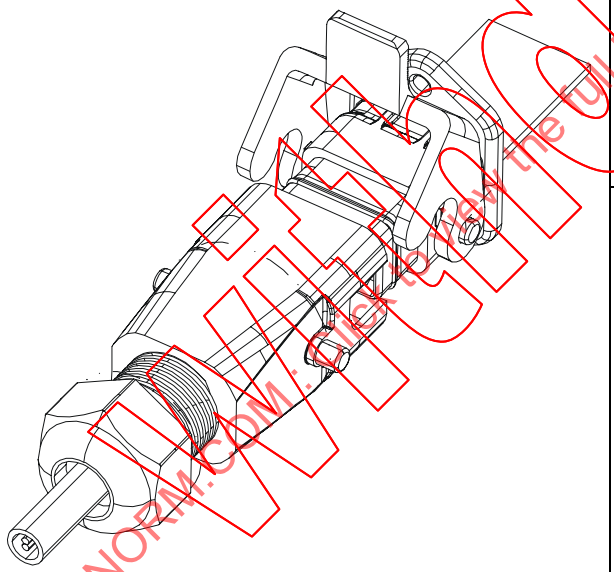
IEC SC 48B: LF Connectors Specification available from: IEC Central Office or from the addresses shown on the inside cover. Electronic components of assessed quality in accordance with: GENERIC SPECIFICATION IEC 61076-1 First edition 1995	**IEC-PAS 61076-3-109** Page 7 of 62 pages
See for dimensions 	Detail specification for two-part cable to board connector used in: – high speed data application up to 600 MHz. – harsh industrial environment – protective housing with robust locking latch and cable gland. – protection rate IP67 according to IEC 60529 – 2 and 4 balanced shielded contact pairs (4 and 8 contacts) – optional 2 unshielded pre-leading contacts Performance level (PL):1, 2, 3

1 General

1.1 Scope

This PAS establishes an uniform specification and type testing requirements for 4- to 10-pole connectors, containing 2 or 4 balanced shielded pairs for frequencies up to 600 MHz and optional 2 unshielded contacts for lower frequencies or power line interconnections.
The mounting footprint of the fixed connector to a cabinet is compatible to a widely used industrial standard connector for industrial power and signal interconnection (Han 3A).
The purpose of this connector is to provide solutions for increasing data rates and to establish highest reliability interconnection under harsh environmental conditions for high speed data transmission in industrial environments to, for instance Industrial Gigabit Ethernet 1000BaseT applications.

1.2 Recommended method of mounting

The free connector (cable connector) is provided with moulded contact-cavities for each balanced shielded or unshielded contact pair, terminated to the signal line of the cable with insulation piercing terminations and solderless shielding clamp contacts to the cable braid.
The contact inserts are mounted in a rigid housing with locking levers for achieving IP67 protection degree.
Appropriate cable has to be selected and professional harnessing workmanship to be secured.
The fixed connector (board connectors) is provided with moulded contact-cavities for each balanced shielded or unshielded contact pair, terminated to a printed board by surface mount termination.
The contact insert is fixed to the board by press-in pivots. After the soldering process the assembly is mounted in the cabinet and the fixed connector housing with an appropriated seal is adjusted over the contact insets and mounted to the outside surface of the electronic cabinet to achieve IP 67 protection degree.

1.3 Ratings and characteristics

Rated voltage:

Material group	Pollution degree	Rated voltage (V)
I, II, IIIa/b	1	400
II, IIIa/b	2	63
II, IIIa/b	3	25
NOTE Reference is made to "Table 4 – Minimum creepage and clearance distances of this specification, and Table 4 of IEC 60664-1 listing the relation between creepage distances, pollution degree and material groups versus voltages r.m.s.		

Table 1 – Rated voltage

Current rating: All contacts:
2 A at 70 °C applied on each contact of the shielded balanced pair and the unshielded contacts

Insulation resistance: 10^6 MΩ min.

Shielding: to achieve high speed performance as detailed in 4.2.6 to 4.2.14.

Degree of Protection: IP67 in accordance with IEC 60529.

Climatic category: PL1: 55/125/56
PL2: 55/125/21
PL3: 25/100/00

1.4 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Public Available Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-1-am1:1992, *Amendment No.1*

IEC 60352-6:1997, *Solderless connections - Part 6: Insulation piercing connections – General requirements, test methods and practical guidance*

IEC 60512-1:1994, *Electromechanical components for electronic equipment – Basic testing procedures and measuring methods – Part 1: General*

IEC 60512-2:1985, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 2: General examination, electrical continuity and contact resistance tests, insulation tests and voltage stress tests*

IEC 60512-2-am1:1994, *Amendment No.1*

IEC 60512-3:1976, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 3: Current-carrying capacity tests*

IEC 60512-4:1976, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 4: Dynamic stress tests*

IEC 60512-5:1992, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 5: Impact tests (free components), static load tests (fixed components), endurance tests and overload tests*

IEC 60512-6:1984, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 6: Climatic tests and soldering tests*

IEC 60512-7:1993, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 7: Mechanical operating tests and sealing tests*

IEC 60512-8:1993, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 8: Connector tests (mechanical) and mechanical tests on contacts and terminations*

IEC 60512-9:1992, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 9: Miscellaneous tests*

IEC 60512-11-1: 1995, *Electromechanical components for electronic equipment - Basic testing procedures and measuring methods – Part 11: Climatic tests – Section 1: Test 11a: Climatic sequence*

IEC 60512-11-14: 1996, *Electromechanical components for electronic equipment - Basic testing procedures and measuring methods – Part 11: Climatic tests – Section 14: Test 11p: Flowing single gas corrosion test*

IEC 60529:1989, *Degree of protection provided by enclosures (IP Code)*

IEC 60664-1:1992: *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

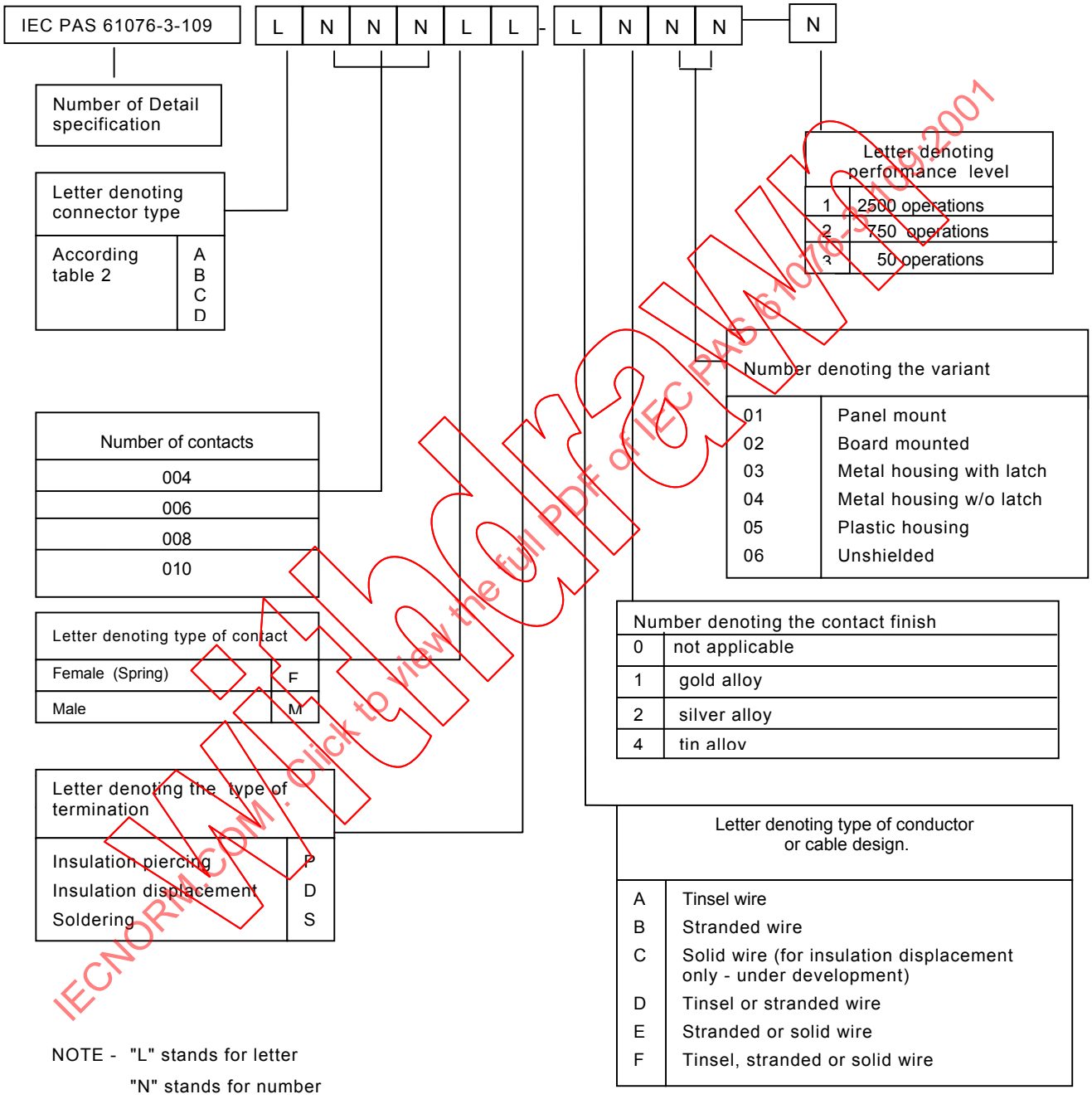
ISO 1302: 1992, *Technical drawings – Method of indicating surface texture*

2 Marking

Marking of the connector and the package shall be in accordance with 2.6 of IEC 61076-1.

2.1 IEC type designation

Connectors, according to this PAS shall be designated by the following system:



NOTE - "L" stands for letter
"N" stands for number

3 Dimensional information

3.1 General

All dimensions are in millimetres. The shape of the connector may deviate from those given in the following drawings as long as the specified dimensions are maintained.

3.2 Isometric view and common feature

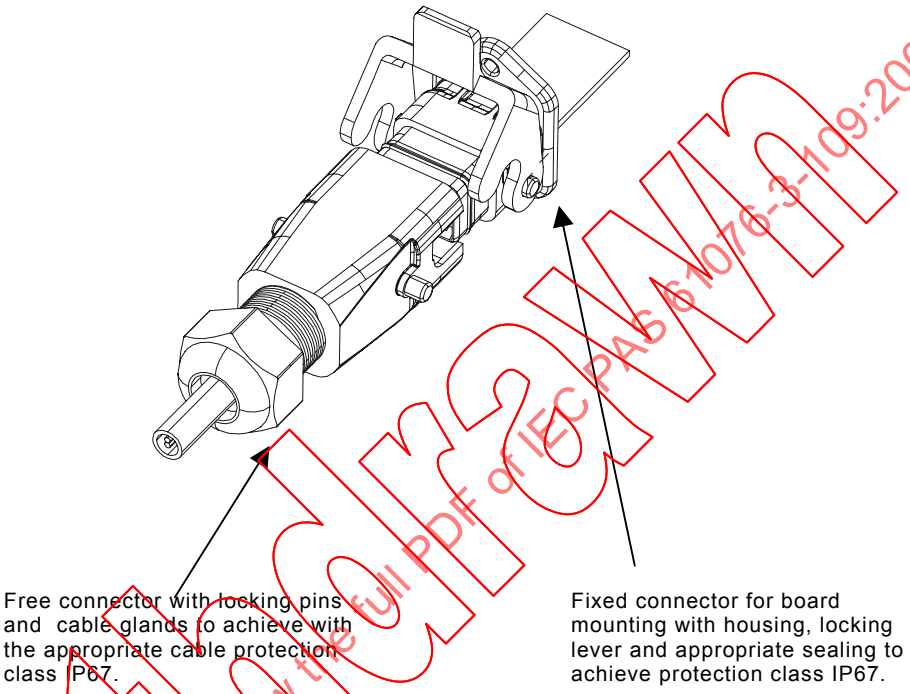


Figure 1 – Isometric view of fixed and free connector.

3.3 Mating information

The design of the housing, the shielding and the insulator body prevent mismating. The housing and the shielding mate before the contacts. The connector is fully mated when the locking lever on the free connector is engaged with the locking pins of the fixed connector.

3.3.1 Contact arrangement for fixed and free connector

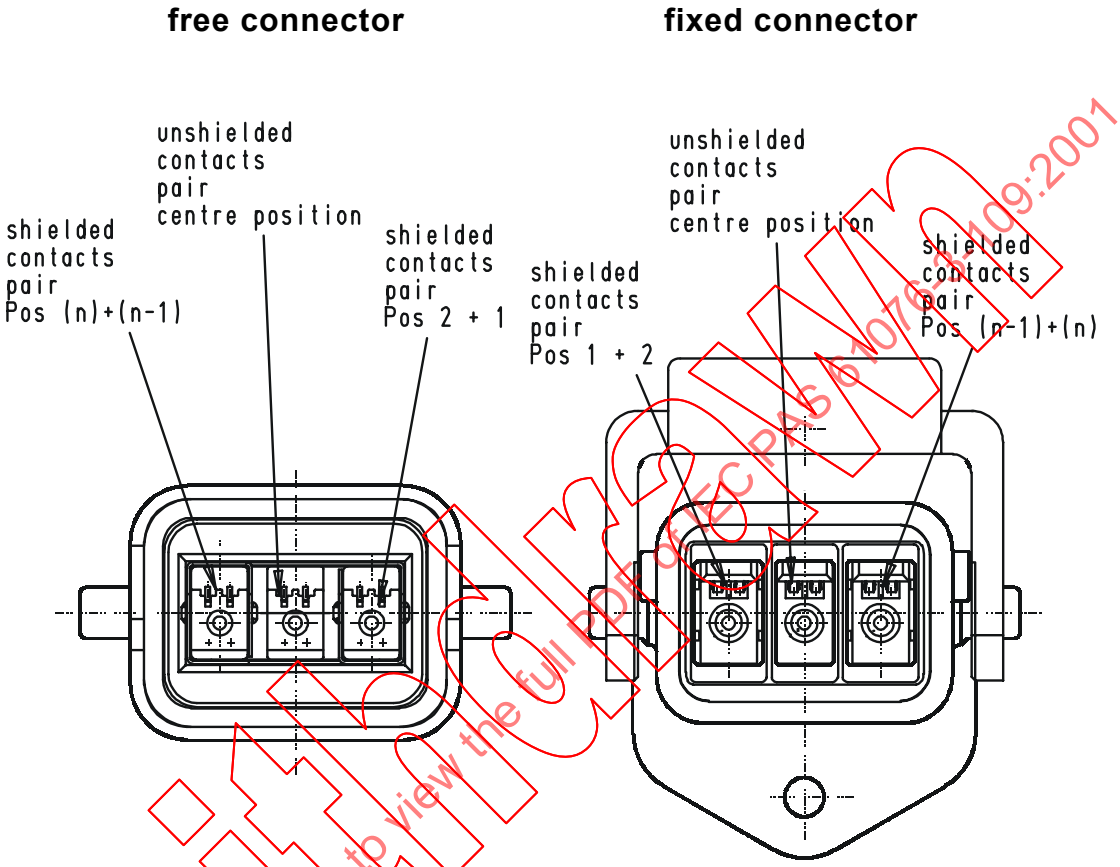


Figure 2 – Contact arrangement, mating side of free and fixed connectors.

Table 2 – Contact arrangement

Connector type	Numbers of contacts n	Positon of shielded contacts	Position of un-shielded contacts
A	4	1,2,3,4	
B	6	1,2,5,6	3,4
C	8	1,2,3..8	
D	10	1,2,3,4, 7…10	5,6

3.4 Fixed connector

3.4.1 Dimensions

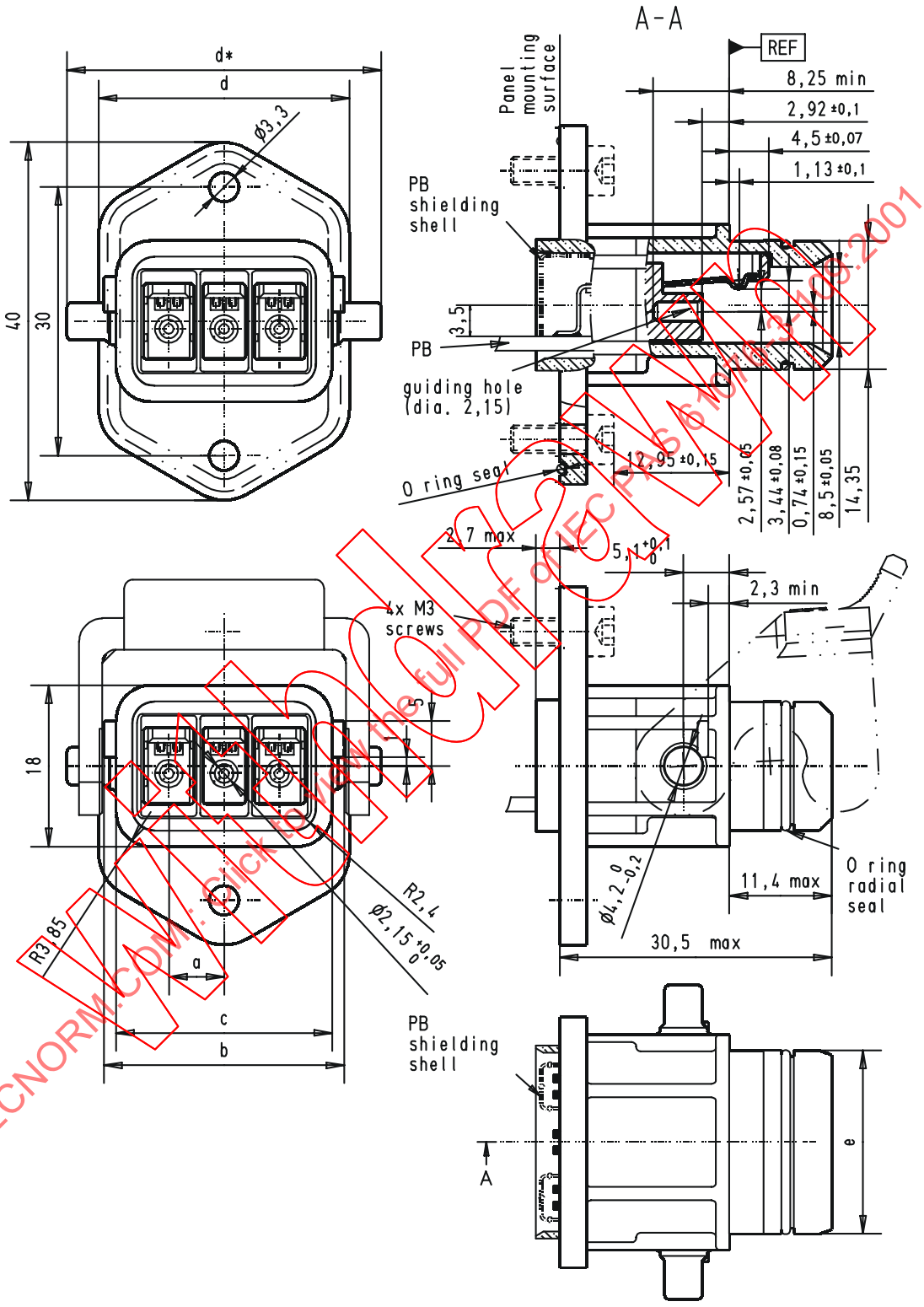


Figure 3 – Fixed connector with housing, shielding, insulation body and contacts.

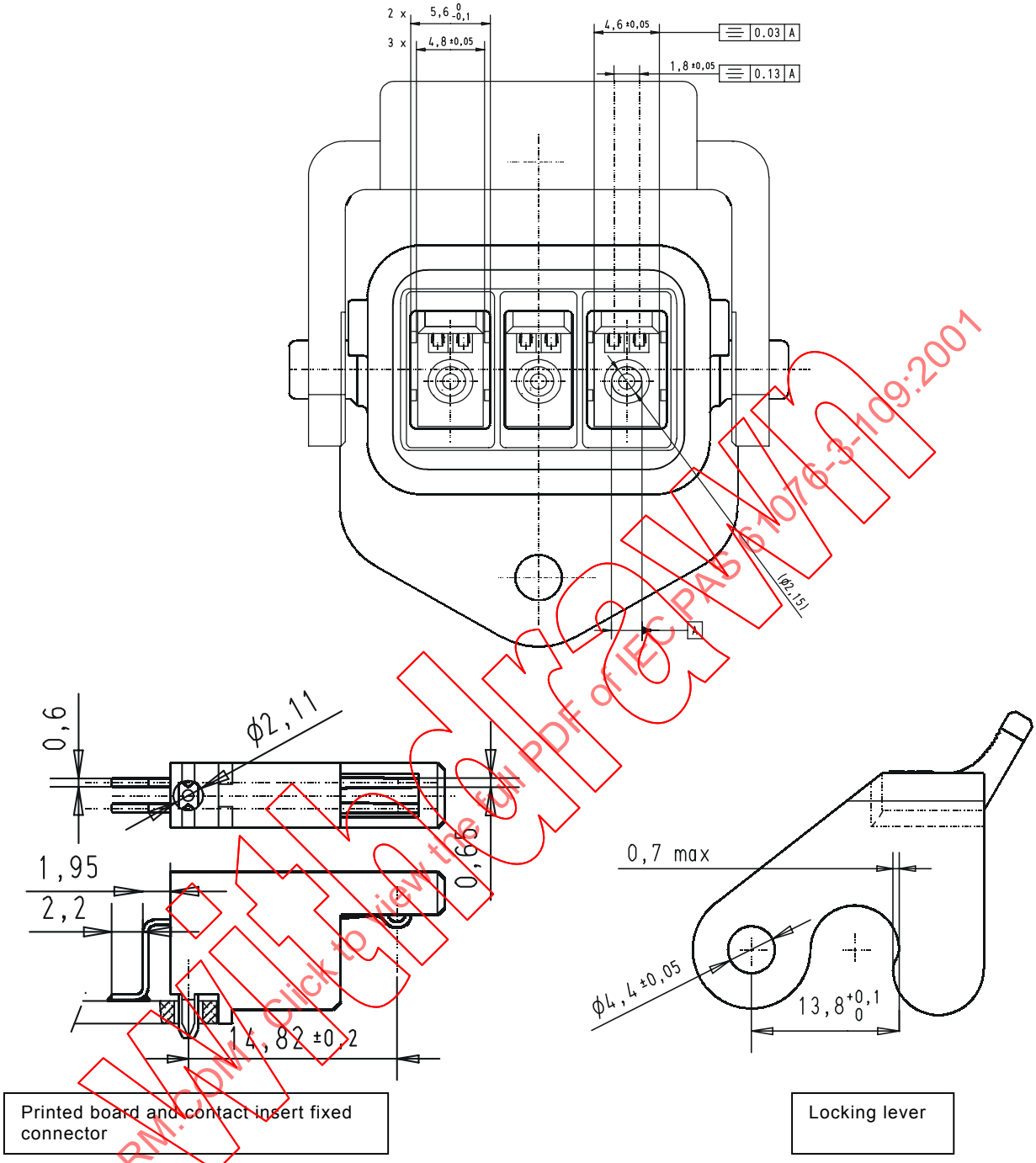


Figure 3 (cont.) – Fixed connector with housing, shielding, insulation body and contacts

NOTE Dimension a to e see table 3

Table 3 – Dimensions fixed connector

Connector type	Number of contacts	Dimensions					
		a	b	c	d	d*	e
A	4	3,3	21,0	18,3	22,2	21,9	14,65
B	6	6,2	26,8	24,1	28	27,7	20,45
C	8	3,3 / 9,9	34,2	31,5	35,4	35,1	27,85
D	10	6,6 / 12,8	40,0	37,3	41,2	40,9	33,65

3.4.2 Terminations

The preferred termination design for the fixed connector is surface mountable solder terminations for solder past reflow process.

3.5 Free connector

3.5.1 Dimensions

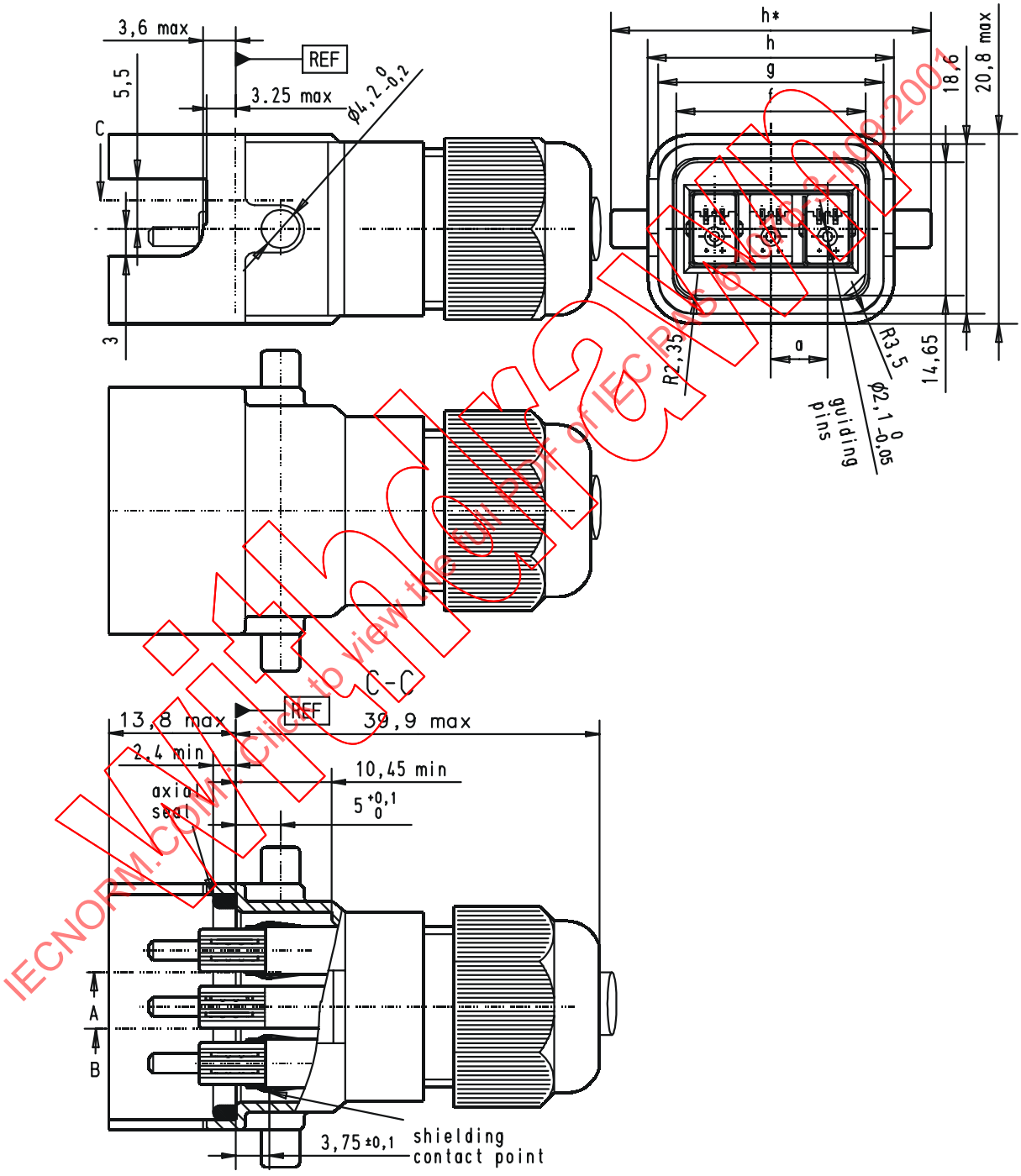


Figure 4 – Free connector with housing, shielding, insulation body and contacts

NOTE Dimension a, f, g, h and h* see table 4

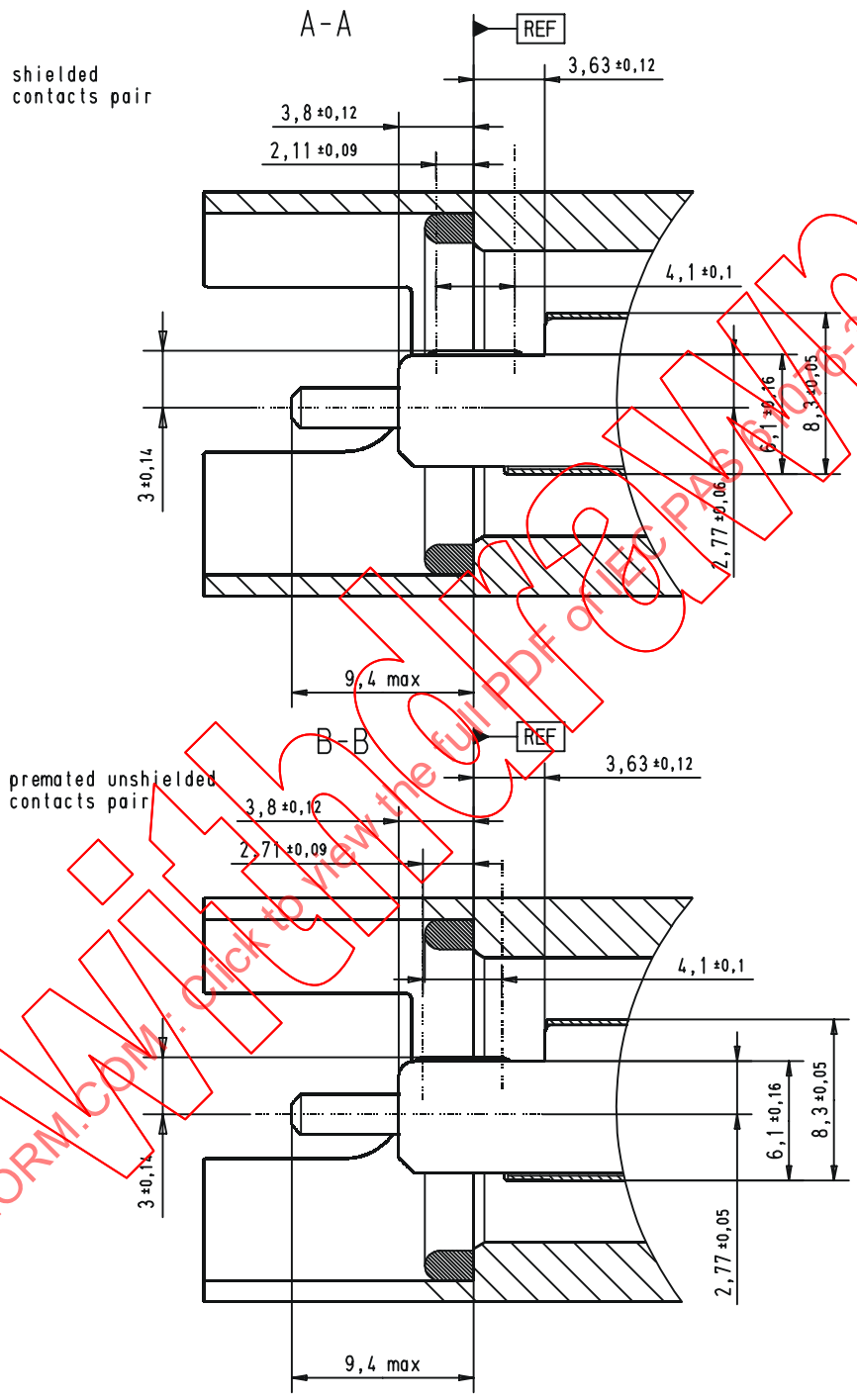


Figure 4 (cont.) – Free connector with housing, shielding, insulation body and contacts

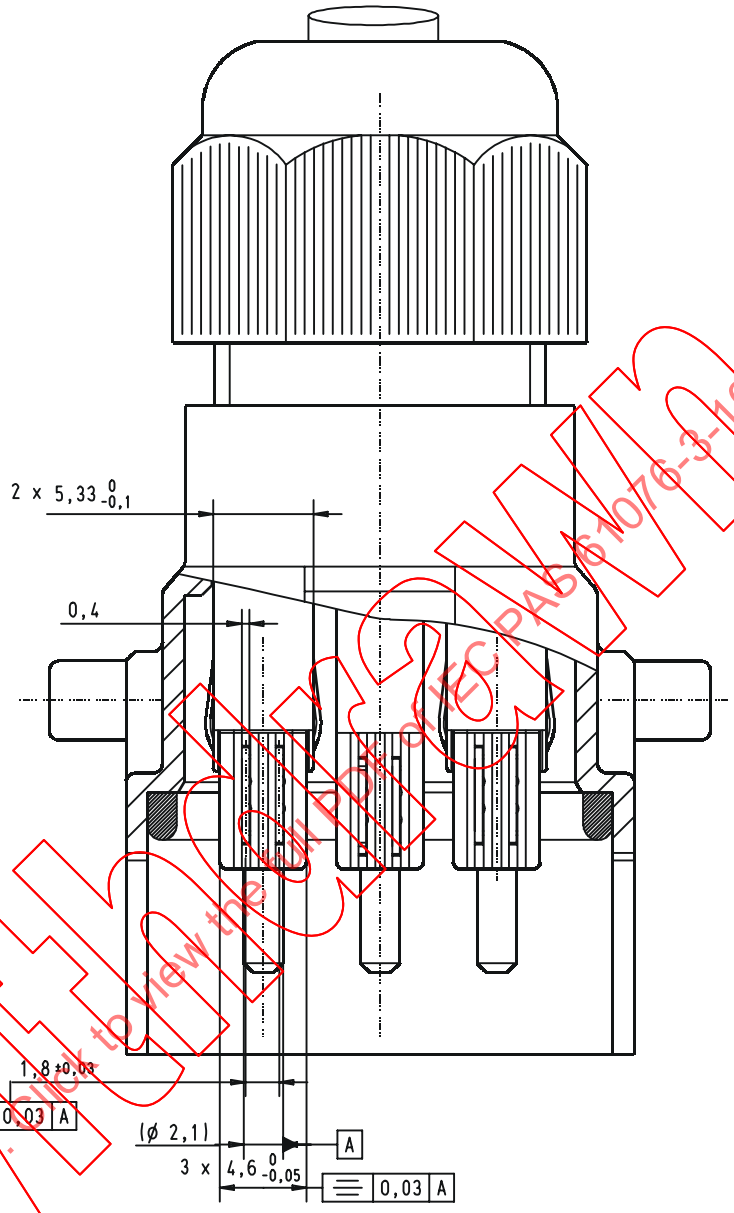


Figure 4 (cont.) – Free connector with housing, shielding, insulation body and contacts

Table 4 – Dimensions free connector

Connector type	Number of contacts	Dimensions				
		a	f	g	h	h*
A	4	3,3	14,95	18,9	21,2	29,3
B	6	6,2	20,75	24,7	27,0	35,1
C	8	3,3 / 9,9	28,15	32,1	34,4	42,5
D	10	6,6 / 12,8	33,95	37,9	40,2	48,3

3.5.2 Terminations

The preferred termination design for the free connector is insulation piercing connection according to IEC 60352-6 for termination of signal contact to tinsel or stranded wires. (Insulation displacement connection to stranded or solid wires under development). Termination between outer cable shield and connector shielding by solder-less shielding clamp contacts to the cable braid.

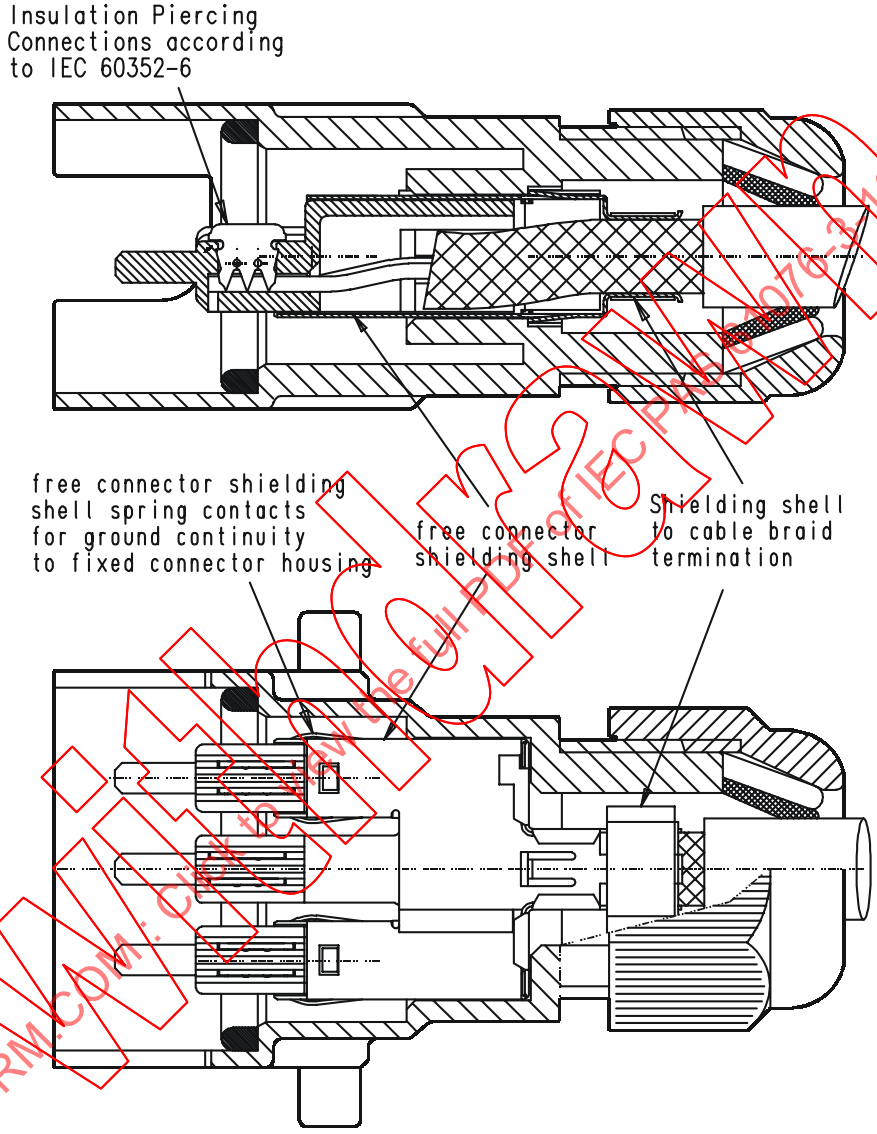


Figure 5 – Free connector termination information

3.6 Mounting information for fixed connector

3.6.1 Printed boards

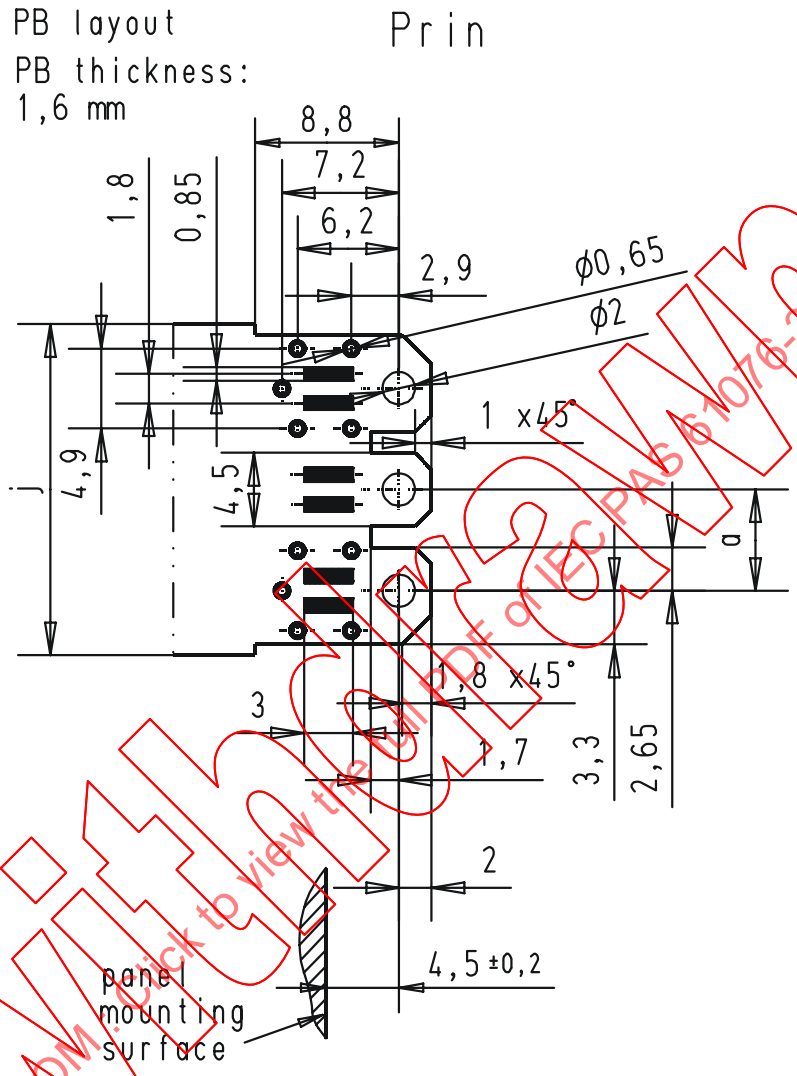


Figure 6 – Board layout for fixed connector

3.6.2 Mounting information for housing to panel

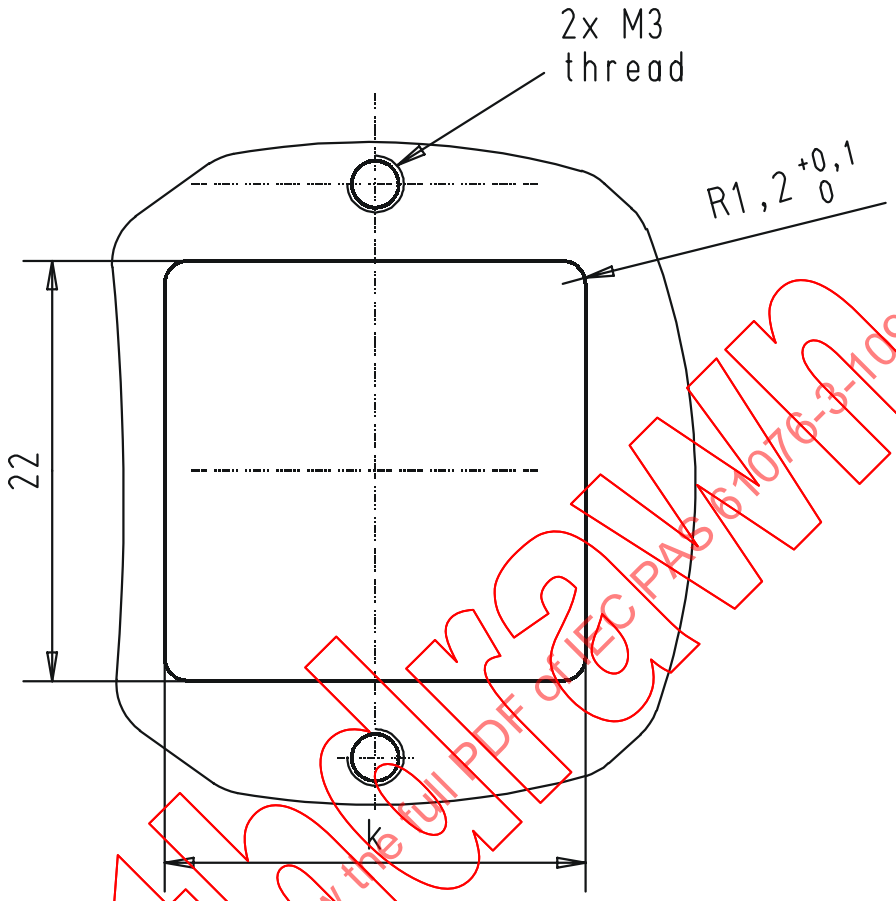


Figure 7 – panel cut out

Table 5 – Mounting information for fixed connector

Connector type	Number of contacts	Dimensions		
		b	j	k
A	4	14,7	14,5	16,0
B	6	20,5	20,3	22,0
C	8	27,9	27,7	29,5
D	10	33,7	33,5	35,0

3.7 Termination information for free connector

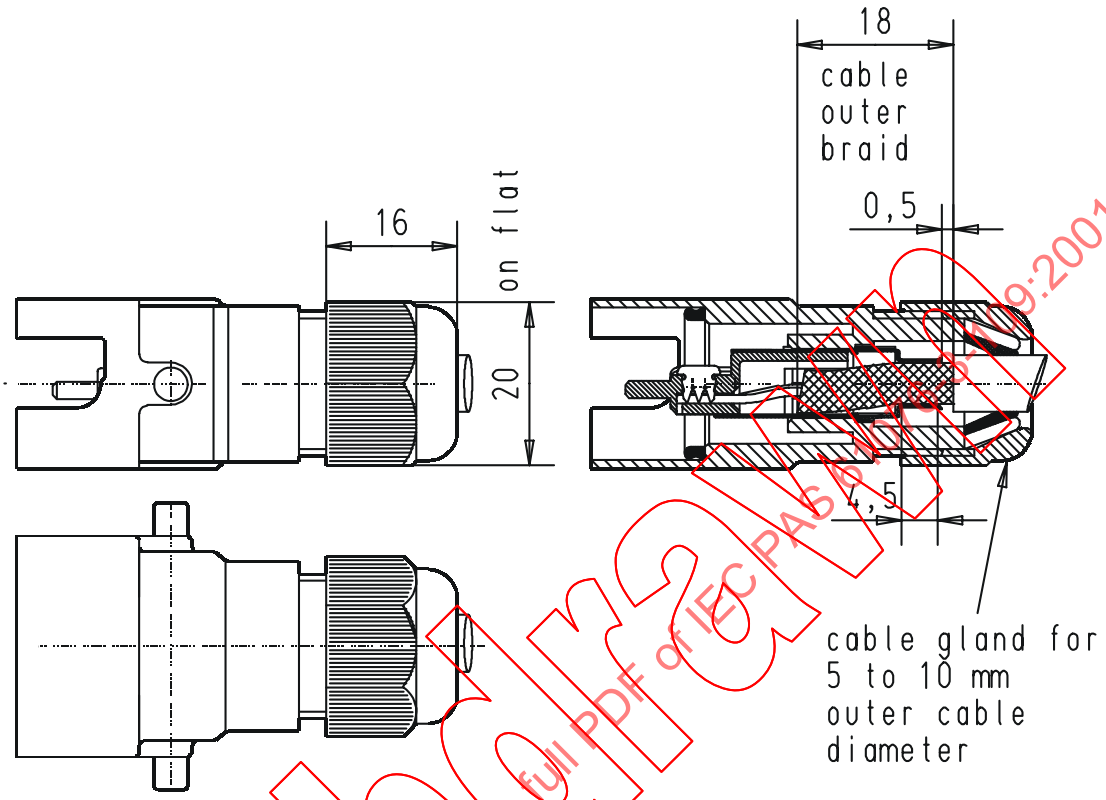


Figure 8 – Termination free connector

3.8 Locking mechanism

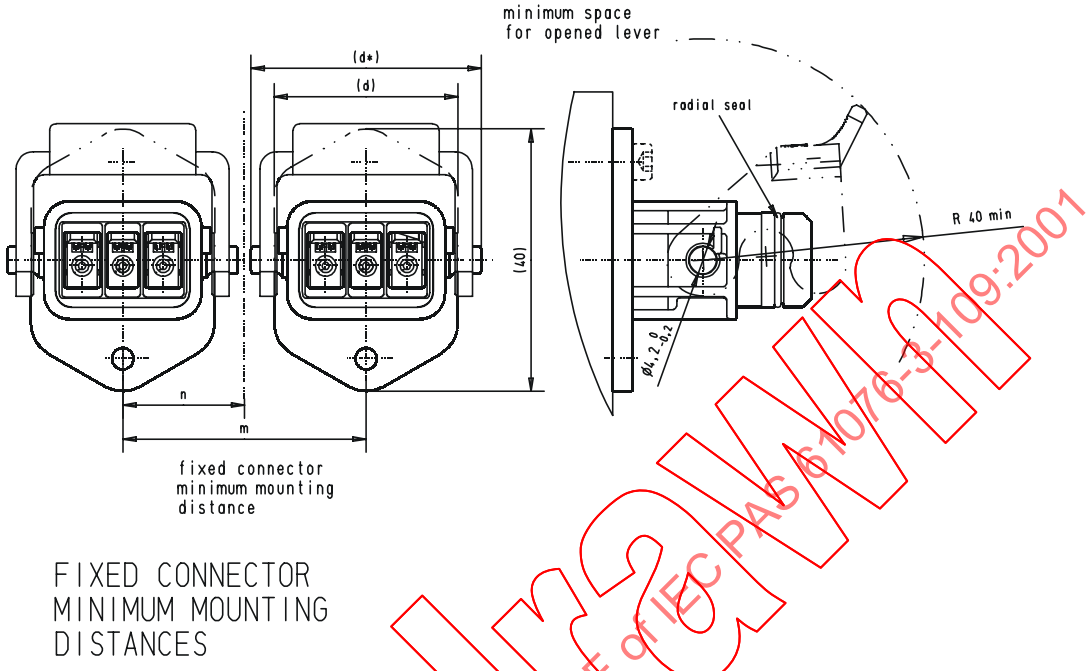


Figure 9 – Locking mechanism

Table 6 – Locking mechanism - minimum mounting distance

Connector type	Number of contacts	Dimensions	
		m	n
A	4	22,8	11,4
B	6	28,6	14,3
C	8	36,0	18,0
D	10	41,8	20,9

3.9 Gauges

3.9.1 Sizing gauges and retention force gauges

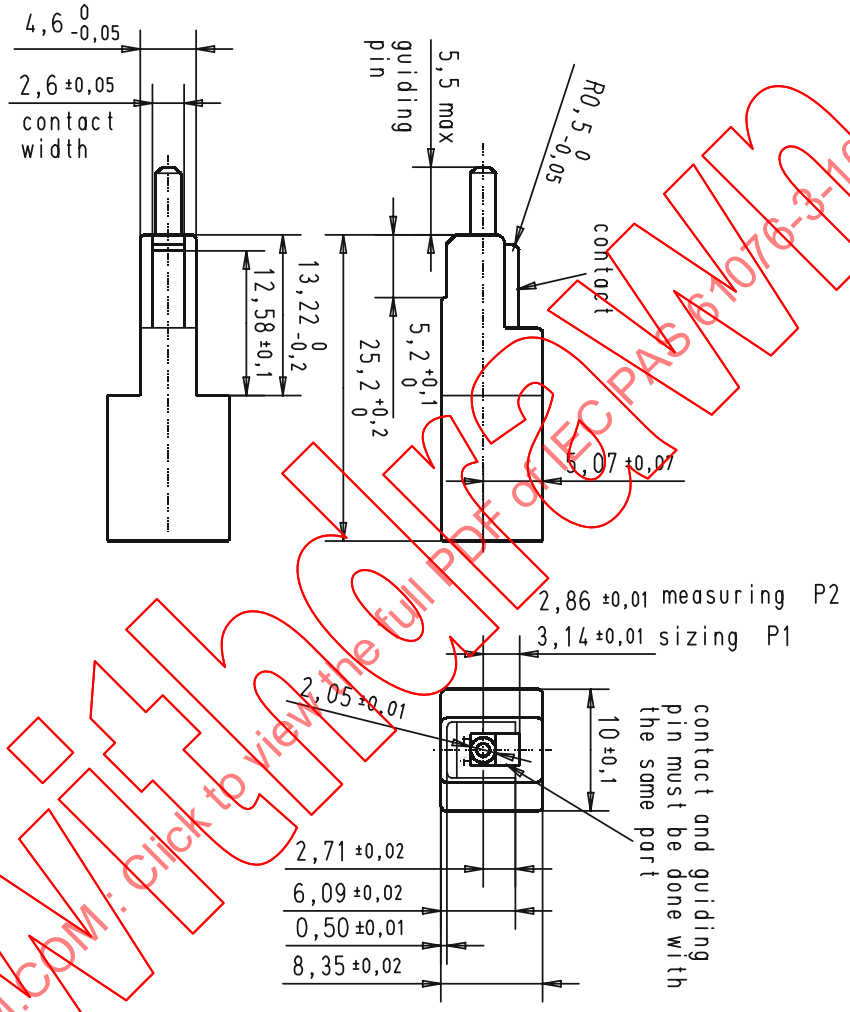


Figure 10 – Sizing and retention force gauge

3.9.2 Locking mechanism gauges

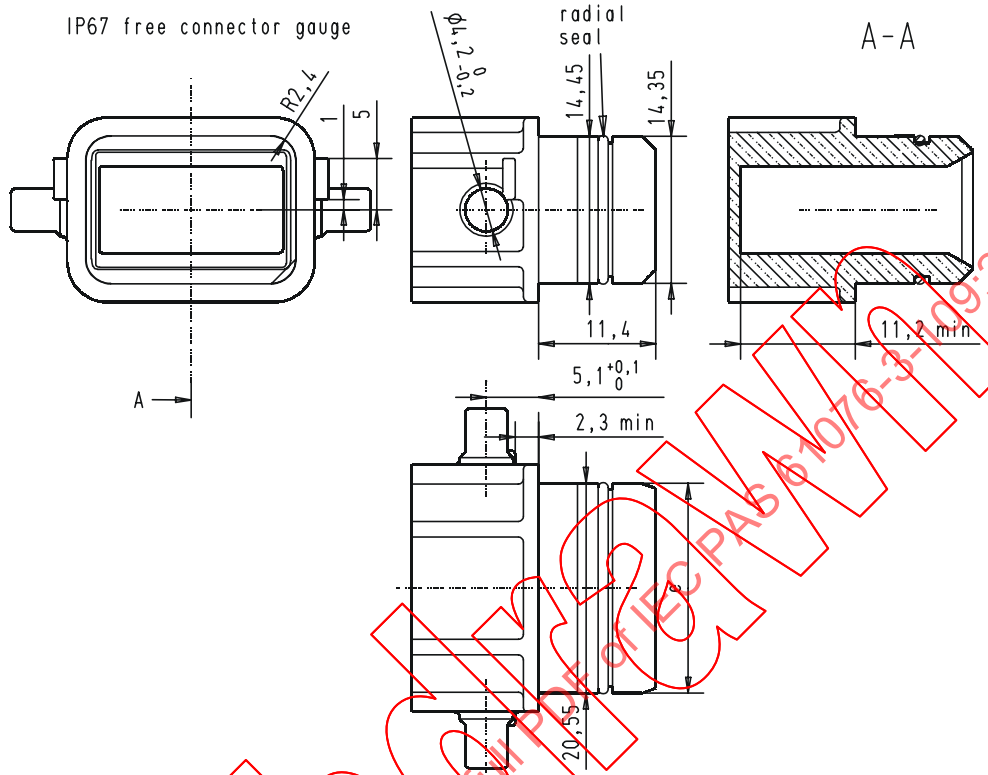


Figure 11 – Gauge for IP67 protection test of free connector,

(Locking lever assembled to free connector for testing,
for additional dimensions, see Figure 3 and Table 3)

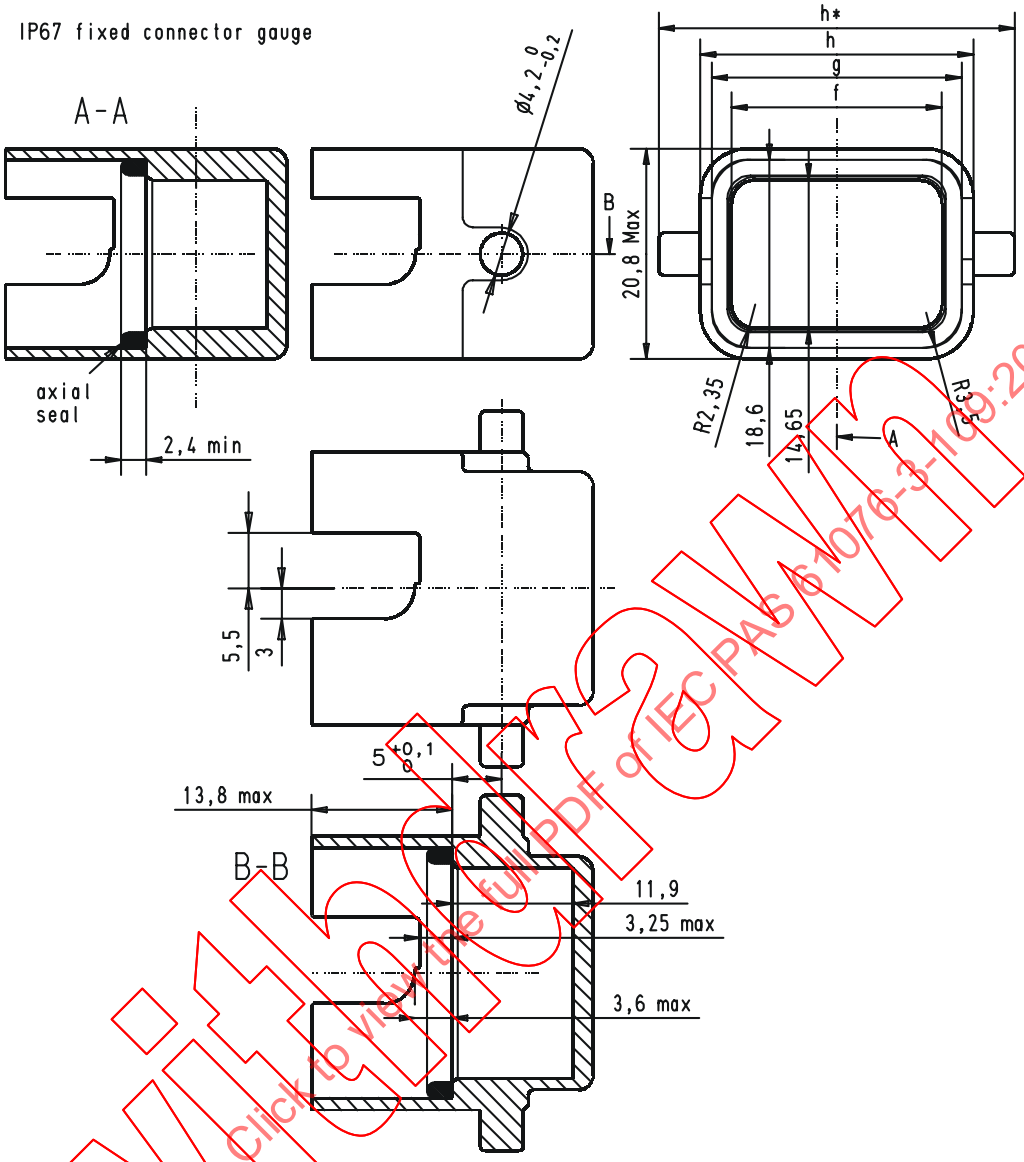


Figure 12 – Gauge for IP67 protection test of fixed connector

(Locking lever assembled to fixed connector for testing,
for additional dimensions, see Figure 4 and Table 4)

4 Characteristics

4.1 Climatic category

Table 7 – Climatic category

Performance level	Climatic category	Category temperature		Damp heat, steady state		Days
		Lower °C	Upper °C	Temperature °C	Relative humidity	
1	25/125/56	–25	125	40	93 %	56
2	25/125/21	–25	125	40	93 %	21
3	25/85/00	–25	85	Not applicable		

4.2 Electrical

4.2.1 Creepage and clearance distances

The permissible operating voltages depend on the applicable or specified requirements, see table 1. Therefore, the clearance and creepage distances are given as operating characteristics. In practice, reductions in creepage or clearance distances may occur due to the conductive pattern of the printed board or the wiring used and shall duly be taken into account.

Table 8 – Minimum creepage and clearance distances

Connector type	Minimum distance between contacts and chassis		Minimum distance between adjacent contacts	
	Creepage mm	Clearance mm	Creepage mm	Clearance mm
Mated	1,25	0,8	1,25	0,8

4.2.2 Voltage proof

Conditions: IEC 60512-2, test 4a
Standard atmospheric conditions, Mated connectors
All variants:
1 500 V d.c. or a.c. peak contact to contact
test points according to 5.1.3 and Figure 16
1 500 V d.c. or a.c. peak, contact to test panel or shield.

4.2.3 Current-carrying capacity

Conditions: IEC 60512-3, test 5b
Standard atmospheric conditions
All contacts: 2 A at 70 °C.

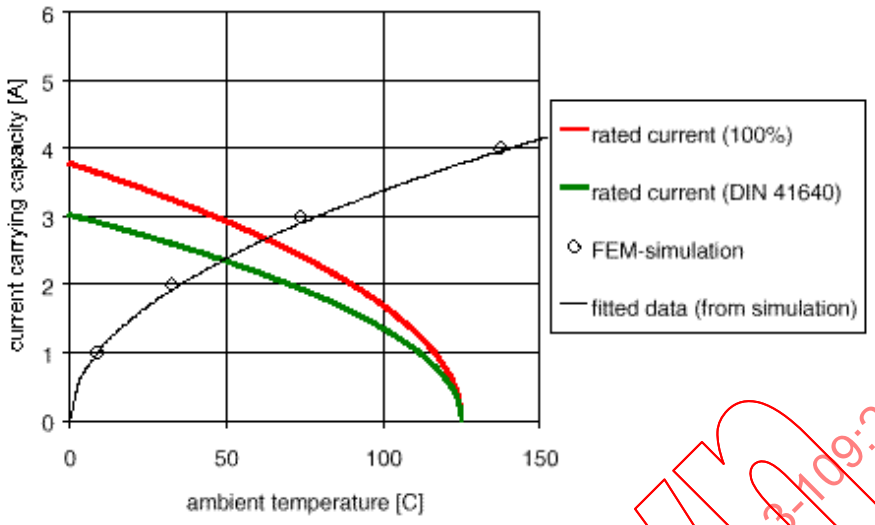


Figure 13 – Current-carrying capacity

4.2.4 Contact resistance

Conditions: IEC 60512-2, test 2a
Standard atmospheric conditions
Mated connectors, contact resistance = 20 mΩ max.
Test points according to 5.1.1 and Figure 14.

4.2.5 Insulation resistance

Conditions: IEC 60512-2, test 3a, method A
Standard atmospheric conditions
Test voltage 100 V ± 15 V d.c. Mated connectors
between contacts and between contacts shield and housing: 500 MΩ min.
Test points according to 5.1.3 and Figure 16.

4.2.6 Insertion loss

Conditions: Annex B, Insertion loss
IEC 60512-25-2 Ed. 1.0 (Attenuation/Insertion loss)
Mated connector, all pairs of shielded contacts:

All shielded lines: $\leq 0{,}02 \times \sqrt{f}$ (rounded to superior 0,1 dB).

4.2.7 Return loss

Conditions: Annex C, Return loss
IEC 60512-25-5 Ed. 1.0
Mated connectors, all pairs of shielded contacts
All shielded lines: 64 – 20 log(f) dB up to 600 MHz, but not >30 dB.

4.2.8 Propagation delay

Conditions: IEC 60512-25-4
Mated connectors, all pairs of shielded contacts

All shielded lines: ≤2,5 ns.

4.2.9 Delay skew

Conditions: IEC 60512-25-4
Mated connectors, all pairs of shielded contacts

All shielded lines: ≤ 1,25 ns.

4.2.10 NEXT loss

Conditions: Annex D, Near end cross talk (NEXT)
IEC 60512-25-1 Ed. 1.0
Mated connectors, between all combinations of 2 pairs of shielded contacts
All shielded lines: 102,4 – 15 log (f) up to 600 MHz but not >80 dB.

4.2.11 FEXT loss

Conditions: Annex E, Far end cross talk (FEXT)
IEC 60512-25-1 Ed. 1.0
Mated connectors, between all combinations of 2 pairs of shielded contacts
All shielded lines: 90 – 15 log (f) up to 600 MHz but not >60 dB.

4.2.12 Longitudinal conversion loss (balanced)

Conditions: Annex F, Longitudinal Conversion Loss (LCL)
Mated connectors, all pairs of shielded contacts
All shielded lines: 26 – 20 log (f/100) up to 80 MHz f.f.s (for future specification)

4.2.13 Coupling attenuation

Conditions: Annex H Coupling attenuation
IEC 60512-25-2
Mated connectors, all pairs of shielded contacts

All shielded contacts: ≥80 dB for frequency range 30 MHz ≤ f ≤ 100 MHz

≥ 80 – 20 log (f/100) dB, for frequency range 100 MHz < f ≤ 1000 MHz f.f.s (for future specification)

NOTE Coupling attenuation requirement is assumed to be fulfilled when the transfer impedance requirement is met an the full bandwidth. Coupling attenuation should only be performed on cable assemblies.

4.2.14 Transfer impedance

Conditions: Annex G, Transfer impedance
IEC 60512-23-7 Mated connectors, all pairs of shielded contacts
0,1 ohm from 1 MHz to 10 MHz
0,01 × $f_{(MHz)}$ Ohm from 10 MHz to 80 MHz
The values from 80 MHz to 600 MHz are f.f.s (for future specification).

4.3 Mechanical

4.3.1 Mechanical operation

Conditions: IEC 60512-5, test 9a
Standard atmospheric conditions
Maximum speed of operation: 10 mm/s
Rest: 5 s min (unmated)

PL 1: 2 500 operations
PL 2: 750 operations
PL 3: 50 operations

4.3.2 Insertion and withdrawal forces

Conditions: IEC 60512-7, test 13b
Standard atmospheric conditions
Maximum speed 10 mm/min
Total insertion / withdrawal force: 4 poles: max 6 N / 6 poles: max 7 N
8 poles: max 8 N / 10 poles: max 9 N

4.3.3 Degree of protection:

IP67 according to IEC 60529 in mated and locked position.

4.3.4 Vibration (sinusoidal)

Conditions: IEC 60512-4, test 6d
Standard atmospheric conditions, Mated connectors
The fixed connector shall be rigidly installed in a suitable fixture
and the cable of the cable connector shall be fully installed and rigidly mounted to the vibration fixture 100 mm after the cable outlet.

Table 9 – Vibration severity

Performance level	Severity
1	10 Hz to 2 000 Hz and 1,5 mm or 20 g
2	10 Hz to 500 Hz and 0,35 mm or 5 g
3	Not applicable

5 Test schedule

5.1 General

This test schedule shows all tests and the order in which they shall be carried out as well as the requirements to be met. An "X" in the column "Requirements" of the following tables indicates that the test or conditioning shall be applied. Unless otherwise specified, mated sets of connectors shall be tested. Care shall be taken to keep a particular combination of connectors together during the complete test sequence, i.e. when non-mating is necessary for a certain test, the same connectors as before shall be mated for the subsequent tests. In the following text, a mated set of connectors is called a "specimen". When the initial tests have been completed, all the specimens are divided up according to the test groups. Before testing commences, the connectors shall have been stored for at least 24 h in the non-inserted state under normal climatic conditions for testing as per IEC 60068-1. The following specimens are necessary for the entire inspection and test sequence according to the style and number of poles.

Table 10 – Number of specimens

Connector type	Number of connectors	Number of specimens																							
		Initial test group			Test groups																				
		P			AP			BP			CP			HP			JP								
		Performance levels																							
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
A,B, C,D	24 18 10	24	18	10	6	4	4	8	4	4	4	4	-	4	4	4	2	2	2						

5.1.1 Arrangement for contact resistance measurement:

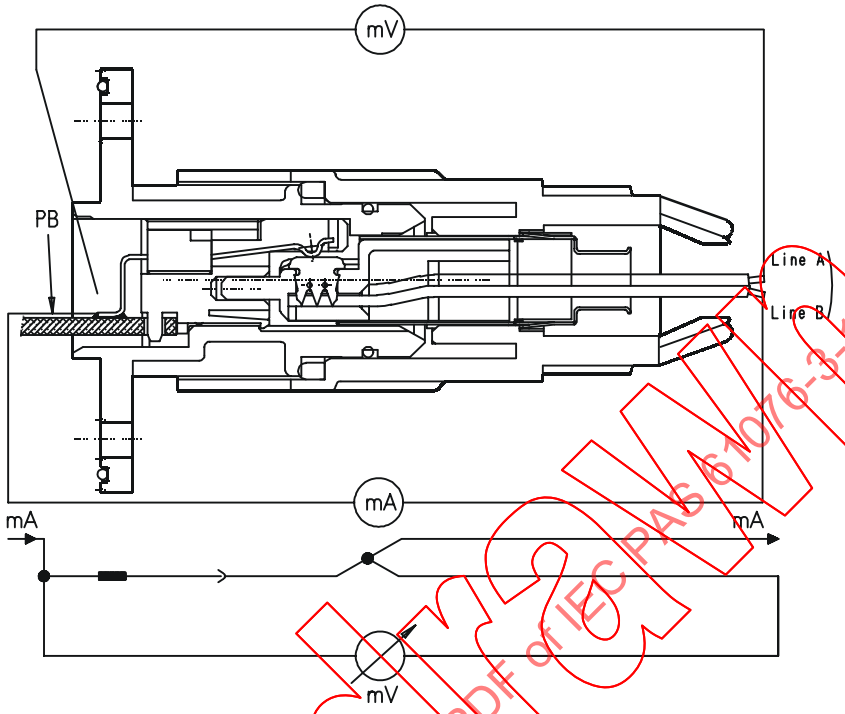


Figure 14 – Measuring points

5.1.2 Arrangement for dynamic stress tests

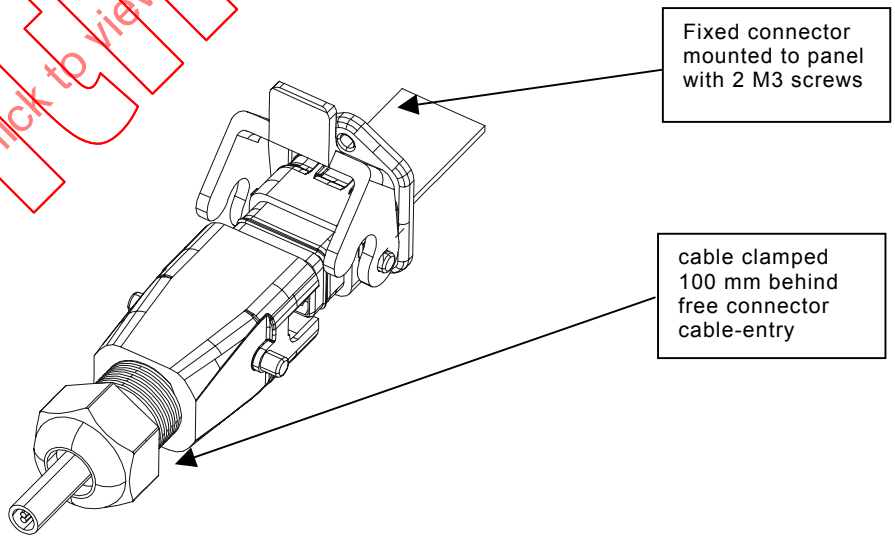


Figure 15 – Arrangement for dynamic stress test

5.1.3 Wiring arrangement for insulation resistance, voltage proof and polarisation voltage during damp heat test

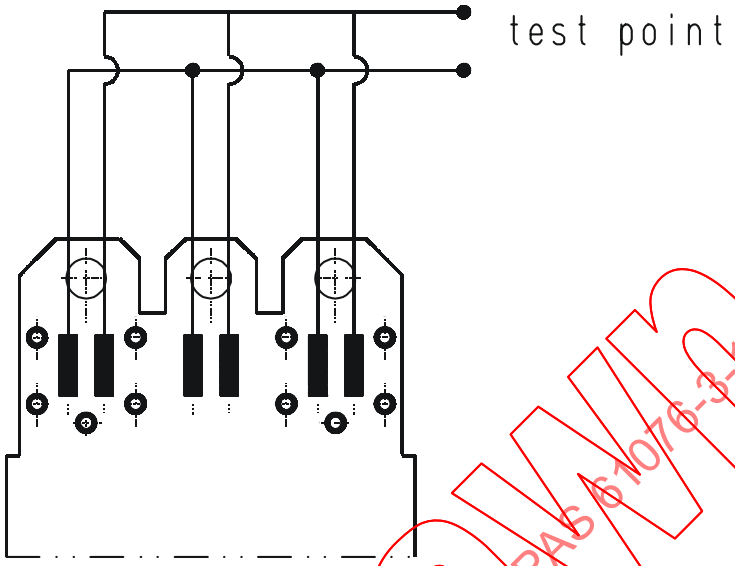


Figure 16 – Wiring arrangement for connector type B
(other types to be arranged accordingly).

5.1.4 Arrangement for high speed data transmission measurement

See Annex A for general requirements for the measurement set-up and Annex I for Termination of balun.

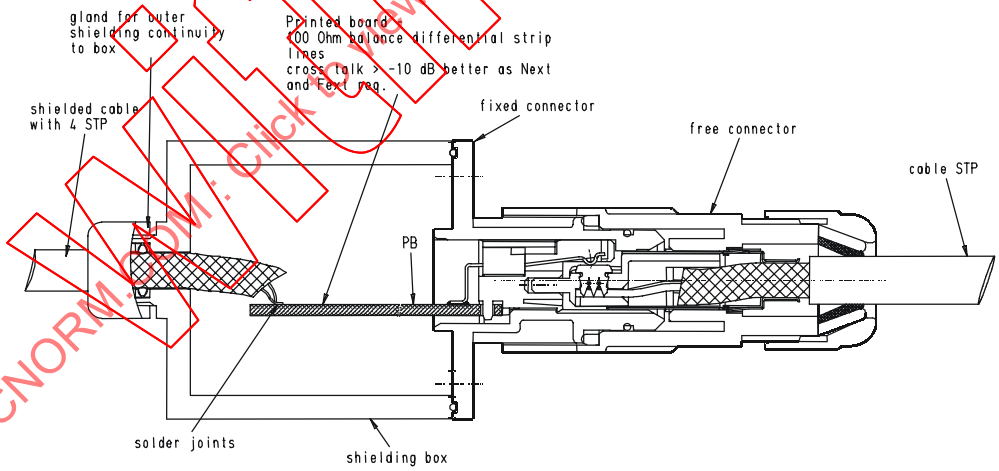


Figure 17 – Test set-up for high speed data transmission measurement

5.2 Test schedule tables

5.2.1 Test group P – Preliminary

All specimens shall be subjected to the following tests in sequence:

Test phase	Test			Measurement to be performed			Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.	PL	
P1	General examination		Unmated connectors	Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation
				Dimensional examination	1b	1 2 3	The dimensions shall comply with those specified in clause 3 including creepage and clearance distances as specified in Table 8
P2	Polarizing method	13e	Force to be applied: 100 N				It shall be possible to correctly align and mate the free connector to the fixed connector It shall be not possible to mate the connector in any other than the correct manner
P3			Connection points: according to 4.2.4 and Figure 14 incl. shielding	Contact resistance - Millivolt level method	2a	1 2 3	Shielded and un-shielded contacts: 20 mΩ max. Shielding: 50 mΩ max.
P4			Test voltage 100 V ± 15 V d.c. Method A Contact/contact Contact/shield Contact/housing	Insulation resistance	3a	1 2	500 MΩ min.
						3	500 MΩ min.
P5			Test voltage: 1500 V acc. 4.2.2 Contact/contact Contact/shield Contact/ housing	Voltage proof	4a	1 2 3	No breakdown or flashover

The specimens shall be divided into five groups. All connectors in each group shall undergo the tests specified for the relevant group.

5.2.2 Test group AP – Dynamic /climatic

Test phase	Test			Measurement to be performed		PL	Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.		Title
AP1	Gauge retention force	16e	Method A Fixed connector only Sizing with P1 and Measuring with P2 acc. to 3.9.1			1 2 3	0,15 N min
AP2	Insertion and withdrawal force	13b	Acc. 4.3.2			1 2 3	4 pole: max 6N 6 pole: max 7N 8 pole: max 8N 10 pole: max 9N
AP 3.1	Solderability	12a				1 2 3	Insertion depth tbd Wetted test area tbd.
AP 3.2	Resistance to solder heat	12d?	Fixed connector only to be applied to reflow soldering			1 2 3	There shall be no defect that would impair normal operation
AP 3A	Gauge retention force	16e	Fixed connector only Gauge P2 acc. to 3.7.1			1 2 3	0,15 N min
AP 4				Voltage proof	4a		No breakdown or flashover
AP 5 AP 6							Not applicable
AP 7	Vibration	6d	acc. 4.3.4 20 min/sweep 12 sweep/axes Three axes (12 h total)	Contact disturbance	2e	1 2	Monitor all contacts in series 100 mA for a discontinuity of 1μs max.
AP 8	Shock	6c	20 g/11 ms, 3 times in both direction of each axis	Contact disturbance		1 2	Monitor all contacts in series 100 mA for a discontinuity of 1μs max.
AP 9							Not applicable
AP 10	Rapid change of temperature	11d	Mated connectors unloaded 30 min exposure five cycles –25 °C to +125 °C. Recovery time :2 h			1 2	
AP 10.1			Test voltage 100 V ± 15 V d.c. Method A Contact/contact Contact/shield Contact/housing	Insulation resistance	3a	1 2	500 MΩ min.
AP 10.2			Test voltage: 1 500 V acc. 4.2.2 Contact/contact Contact/shield Contact/ housing	Voltage proof	4a	1 2 3	No breakdown or flashover
AP 10.3				Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation

5.2.2 Test group AP (continued)

Test phase	Test			Measurement to be performed		PL	Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.		Title
AP 11	Climatic sequence	11a	Mated unloaded				
AP 11.1	Dry heat	11j	Temperature 125 °C 85 °C			1 2 3	96 h
AP 11.2	Damp heat cyclic first cycle	11m	Upper temperature 55 °C one cycle, variant 2, Recovery time: 2h Ambient room temperature			1 2	
AP 11.3	Cold	11j	Temperature –25 °C			1 2 3	4 h
AP 11.4							Not applicable
AP 11.5	Damp heat cyclic remaining cycle	11m	Upper temperature 55 °C five cycles as in AP 11.2			1 2	
			Connection points: according to 4.2.4 and Figure 14 Shielding	Contact resistance - Millivolt level method	2a	1 2 3	Shielded and un-shielded contacts: 20 mΩ max. Shielding: 50 mΩ max.
			Test voltage 100 V ± 15 V d.c. Method A Contact/contact Contact/shield Contact/housing	Insulation resistance	3a	1 2	500 MΩ min.
			Test voltage: 1 500 V acc. 4.2.2 Contact/contact Contact/shield Contact/ housing	Voltage proof	4a	1 2 3	No breakdown or flashover
AP 12.1	Insertion and withdrawal force	13b	Acc. 4.3.2			1 2 3	10 N max.
AP 12.2			Unmated Connector	Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation

5.2.3 Test group BP – Mechanical endurance

Test phase	Test			Measurement to be performed		PL	Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.		Title
BP 1	Gauge retention force	16e	Method A Fixed connector only Sizing P1and Measuring P2 acc. to 3.9.1			1 2 3	0,15 N min
BP 2	Mechanical operations	9a	Acc.4.3.1			1 2 3	1250 375 25
BP 3	Flowing mixed gas corrosion	11-7	4 days half the samples mated and unmated			1 2	
BP 4			Connection points: according to 4.2.4 and Figure 14 incl. Shielding	Contact resistance - Millivolt level method	2a	1 2 3	Shielded and un-shielded contacts: 20 mΩ max. Shielding: 50 mΩ max.
BP 5	Mechanical operations	9a	Acc.4.3.1			1 2 3	1250 375 25
BP 6			Connection points: according to 4.2.4 and Figure 14 incl. Shielding	Contact resistance - Millivolt level method	2a	1 2 3	Shielded and un-shielded contacts: 20 mΩ max. Shielding: 50 mΩ max.
BP 7			Test voltage 100 V ± 15 V d.c. Method A Contact/contact Contact/shield Contact/housing	Insulation resistance	3a	1 2 3	500 MΩ min.
BP 8			Test voltage: 1500 V acc. 4.2.2 Contact/contact Contact/shield Contact/housing	Voltage proof	4a	1 2 3	No breakdown or flashover
BP 9				Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation

5.2.4 Test group CP – Moisture

Test phase	Test			Measurement to be performed		PL	Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.		Title
CP1	Damp heat steady state	11c	Polarising voltage: 60 V d.c. Recovery time: 2 h			1 2	56 days 21 days
			Test voltage 100 V ± 15 V d.c. Method A Contact/contact Contact/shield Contact/housing	Insulation resistance	3a	1 2	500 MΩ min.
			Test voltage: 1500V acc. 4.2.2 Contact/contact Contact/shield Contact/ housing	Voltage proof	4a	1 2	No breakdown or flashover
			Connection points: according to 4.2.4 and Figure 14 incl. Shielding	Contact resistance Millivolt level method	2a	1 2	Shielded and un-shielded contacts: 20 mΩ max. Shielding: 50 mΩ max.
			Acc. 4.3.2	Insertion and withdrawal force	13b	1 2	4 pole: max 6N 6 pole: max 7N 8 pole: max 8N 10 pole:max 9N
				Visual examination	1a	1 2	There shall be no defect that would impair normal operation

5.2.5 Test group GP – Connections

Test program Piercing acc. IEC 60352-6

5.2.6 Test group HP - Mechanical resistivity

Test phase	Test			Measurement to be performed		PL	Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.		Title
HP 1.1	Cable-clamp resistance to cable pull (tensile)	17c	For free connector with cable clamp Applied tensile force: Tbd			1 2 3	Permissible displacement with cable-clamp: tbd
HP 1.2	Cable-clamp resistance to cable torsion	17d	For free connector with cable clamp Applied torque: Tbd			1 2 3	Permissible angle of displacement: (Tbd. 45°)
HP 2			Unmated connector	Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation
HP 3	Locking and unlocking torque		Test applied with mounted connector			1 2 3	Torque 10 Nm max.
HP 4			Unmated connector	Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation
HP 5	Mechanical strength impact	7b	For free connector, Drop height. (Tbd 500 ± 10 mm)			1 2 3	
HP 6			Unmated connector	Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation
HP 7	Degree of protection		Test shall be applied by usage of minimum gauge acc. 3.7.2			1 2 3	Degree of protection IP67 acc. to IEC 60529
HP 8	Protection against access to hazardous parts		IPxxB Unmated Connector			1 2 3	Protection against access with a test finger acc. to 15.2 of IEC 60529
HP 9			Unmated connectors	Visual examination	1a	1 2 3	There shall be no defect that would impair normal operation

5.2.7 Test group JP – High speed data transmission measurements.

Test phase	Test			Measurement to be performed		PL	Requirements
	Title	IEC 60512 Test No.	Severity or condition of test	Title	IEC 60512 Test No.		Title
JP 1			Annex B	Insertion loss	25-2	1 2 3	See clause 4.2.6 and note 4, 6, 7
JP 2			Annex C	Return loss	25-5		See clause 4.2.7 and note 2, 6, 7
JP 3			For information	Propagation delay	25-4		See clause 4.2.8
JP 4			For information	Skew	25-4		See clause 4.2.9
JP 5			Annex D	NEXT loss	25-1		See clause 4.2.10 and note 1, 6, 7
JP 6			Annex E	FEXT loss	25-1		See clause 4.2.11 and note 3, 6, 7
JP 7			Annex F	Longitudinal conversion loss (balanced)	u.c.		See clause 4.2.12 and note 5, 6, 7
JP 8			Annex H	Coupling attenuation	25-2		See clause 4.2.13 and note 6, 7
JP 9			Annex G	Transfer impedance	23-7		See clause 4.2.14 and note 6, 7

1) NEXT loss at frequencies that correspond to calculated values of greater then 80 dB shall revert to a minimum requirement of 80 dB.
2) Return loss at frequencies that correspond to calculated values of greater then 30 dB shall revert to a minimum requirement of 30 dB.
3) FEXT loss at frequencies that correspond to calculated values of greater then 60 dB shall revert to a minimum requirement of 60 dB.
4) Attenuation at frequencies that correspond to calculated values of less than 0,1 dB shall revert to a requirement of 0,1 dB maximum.
5) Balance at frequencies that correspond to calculated values of greater then 40 dB shall revert to a minimum requirement of 40 dB.
6) All transmission results shall report worst case overall for the corresponding pair or pair combination after testing the ten samples.
7) All measurements to be performed on mated connectors.

Annex A
(normative)

General requirements for the measurement set-up

A.1 Test instrumentation

These electrical test procedures require the use of a vector network analyser. The analyser should have the capability of full two port calibrations. The analyser shall cover the frequency range of 1 MHz to 1 GHz at least.
At least 2 test baluns are required in order to perform measurements with balanced symmetrical signals. The requirements for the baluns are given in clause A.4.
Reference loads and cables are needed for the calibration of the set-up. Requirements for the reference components are given in clause A.5.1 and A.5.2 respectively.
Termination loads are needed for termination of pairs, used and unused, which are not terminated by the test baluns. Requirements for the termination loads are given in clause A.6.
A test adapter (triaxial test set) is needed for the transfer impedance measurements. Reference to requirements for this set-up is given in annex G.
An absorbing clamp and ferrite absorbers are needed for the coupling attenuation measurements. The requirements for these items are given in clause H.2.

A.2 Coaxial cables and test leads for network analysers

Coaxial cable assemblies between network analyser and baluns should be as short as possible. (It is recommended that they do not exceed 60 cm each).
The baluns shall be electrically bonded to a common ground plane. For crosstalk measurements a test fixture may be used, in order to reduce residual crosstalk (see annex G).
Balanced test leads and associated connecting hardware to connect between the test equipment and the connector under test shall be taken from components that meet or exceed the requirements for the relevant category. Balanced test leads shall be limited to maximum 7 cm between each balun and the reference plane of the connector under test. Pairs shall remain twisted from the baluns to where connections are made.

A.3 Measurement precautions

To assure a high degree of reliability for transmission measurements, the following precautions are required:
1) Consistent and stable balun and resistor loads shall be used for each pair throughout the test sequence.
2) Cable and adapter discontinuities, as introduced by physical flexing, sharp bends and restraints shall be avoided before, during and after the tests.
3) The relative spacing of conductors in the pairs shall be preserved throughout the tests to the greatest extent possible.
4) The balance of the cables is maintained to the greatest extent possible by consistent conductor lengths and pair twisting to the point of load.
5) The sensitivity to set-up variations for these measurements at high frequencies demands attention to details for both the measurement equipment and the procedures.

A.4 Balun requirements

The baluns may be balun transformers or 180° hybrids with attenuators to improve matching if needed (see figure A.1).

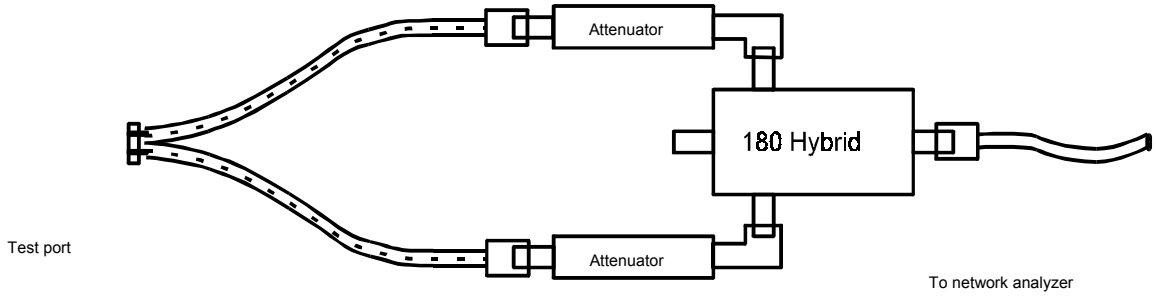


Figure A.1 – 180° hybrid used as a balun.

The specifications for the baluns apply for the whole frequency range for which they are used. Baluns shall be RFI shielded and shall comply with the specifications listed in table A.1.

Table A.1 – Test balun performance characteristics

Parameter	Requirement at test frequencies up to 250 MHz	Requirement at test frequencies above 250 MHz
Impedance, primary	Matched to applied network analyzer	
Impedance, secondary 100	100 Ω	
Insertion loss	10 dB maximum	
Return loss secondary	14 dB minimum	
Return loss common mode with common mode termination [1]	10 dB minimum	
Return loss Common mode without common mode termination [1]	1 dB maximum	NA
Longitudinal balance [2]	50 dB	NA
Common mode rejection [3]	50 dB	40 dB
Output signal balance [3]	50 dB	40 dB
Power rating	0,1 W	

Notes: NA: not applicable

[1] Measured by connecting the balanced output terminals together and measuring the return loss. The nominal primary impedance shall terminate the primary input terminal.

[2] Applicable for baluns, which are used for balance measurements. Measured from primary input terminal to common mode terminal when secondary balanced terminal is terminated with 100 Ω.

[3] Measured according to ITU-T (formerly CCITT recommendations G.117 and O.9).

A.5 Reference components for calibration.

A.5.1 Reference loads for calibration

To perform a one or two-port calibration of the test equipment, a short circuit, an open circuit and a reference load is required. These devices shall be used to obtain a calibration at the reference plane.

The reference load shall be calibrated against a calibration reference, which shall be a 50 Ω load, traceable to an international reference standard. Two 100 Ω reference loads in parallel shall be calibrated against the calibration reference. The reference loads for calibration shall be placed in a N type connector according to IEC 60169-16, meant for panel mounting, which

is machined flat on the back side (see figure A.2). The loads shall be fixed to the flat side of the connector, distributed evenly around the centre conductor. A network analyser shall be calibrated, one port full calibration, with the calibration reference. Thereafter the return loss of the reference loads for calibration shall be measured. The verified return loss shall be >46 dB at frequencies up to 100 MHz and >40 dB at frequencies above 100 MHz and up to the limit for which the measurements are to be carried out.

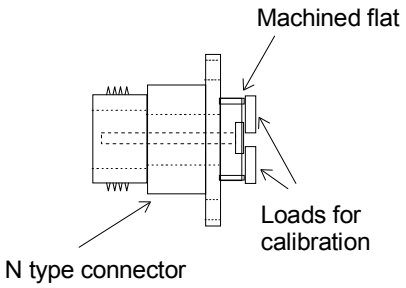


Figure A.2 – Calibration of reference loads

A.5.2 Reference cables for calibration

As a minimum, reference cable that is used to perform calibration of the test set-up shall satisfy the requirement of the same category according to IEC 61156 as the category of the connector. The reference cable shall be a length of horizontal cable for which the sheath is preserved. One of the pairs of the reference cable is used for the calibrations. The total length of reference cable shall be according to the length of the measurement cables as outlined in the calibration procedures for the various tests. Both ends of the reference cable must be well prepared, so that the twisting is maintained up to the test ports

A.6 Termination loads for termination of conductor pairs

During measurement, conductor pairs of the measurement cables for the connector under test shall be terminated according to the specified test set-up with impedance matching loads. For pairs under test this is provided by the test instrumentation at one or both ends. For pairs not under test or not connected to test instrumentation, resistor loads or terminated baluns shall be applied. For differential mode only terminations, only resistor loads are allowed[1] .
The nominal differential mode impedance of the termination shall be 100 Ω. The nominal common mode impedance shall be 50 Ω ± 25 Ω.

NOTE- The exact value of the common mode impedance is not critical for most measurements. Normally a value of 75 Ω is used for unscreened connectors while a value of 25Ω is used for screened connectors.

Resistor loads shall use resistors specified for ±1 % accuracy at d.c. and have a return loss greater than 40 – 10 log(f) where f is the frequency in megahertz[2] . For pairs connected to a balun, common mode load is implemented by applying a load at the common mode terminal (centre tap)of the balun. The impedance of the load is equal to the common mode impedance. For a balun without a common mode terminal (centre tap is not accessible), the requirement for common mode return loss shall be complied with by inserting a balanced attenuator between the balun and the connector pair. Guidance on how this is done is shown annex I. For pairs connected to resistor loads, common mode load is implemented by the Y configuration shown in figure A.3.

[1] Unpredictable stray capacitance's in baluns causes resonance's at high frequencies, if they are used as terminations, when the common mode terminal is open.
[2] Return loss of terminations are measured with a network analyser connected to one balun, which is calibrated (full one port calibration) using the reference loads (clause 2.5.1).

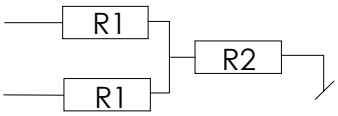


Figure A.3 – Resistor load

where

$$R_1 = \frac{R_{dif}}{2}$$

and

$$R_2 = R_{com} - \frac{R_{dif}}{4}$$

where:

R_{diff} is the differential mode impedance (Ω);
R_{com} is the common mode impedance (Ω).

The two resistors R_1 shall be matched to within 0,5 %. The termination shall be implemented at a small printed circuit board with surface mount resistors. The layout for the resistors R1 shall be symmetrical.
The common mode termination points for all pairs shall be connected to the ground plane.

A.7 Termination of screens

If the connector under test is screened, screened measurement cables shall be applied. The screen or screens of these cables shall be fixed to the ground plane as close as possible to the measurement baluns.

A.8 Test specimen and reference planes

The test specimen is a mated pair of relevant connectors. The electrical reference plane for the test specimen is the point at which the cable sheath enters the connector (the back end of the connector), or the point, at which the internal geometry of the cable is no longer maintained, whichever is farther from the connector (see figure A.4). This definition applies to both ends of the test specimen.

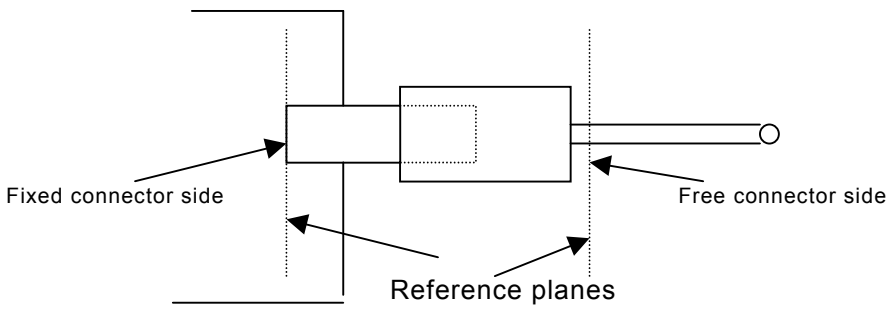


Figure A.4 – Definition of reference planes

Annex B
(normative)

Insertion loss [3)]

B.1 Object

The object of this test is to measure the insertion loss, which is defined as the additional attenuation that is provided by a pair of mated connectors inserted in a communication cable.

B.2 Test method

Insertion loss is evaluated by measuring the scattering parameters, S_{21}, of all the conductor pairs.

B.3 Tests set-up.

The test set-up consists of a network analyzer and two baluns as defined in annex A.
It is not needed to terminate the unused pairs.

B.4 Procedure.

B.4.1 Calibration.

A full 2-port calibration shall be performed at the reference plane. This is performed by applying a maximum length of 14 cm reference cable between the terminals of the baluns and perform the transmission calibration measurement. Then a maximum length of 7 cm reference cables are connected to the terminals of the two baluns (see figure B.1). The total length of these cables shall be equal to the length of the reference cable used for transmission calibrations. At the end of these reference cables the reflection calibrations are performed by applying open, short and load terminations.

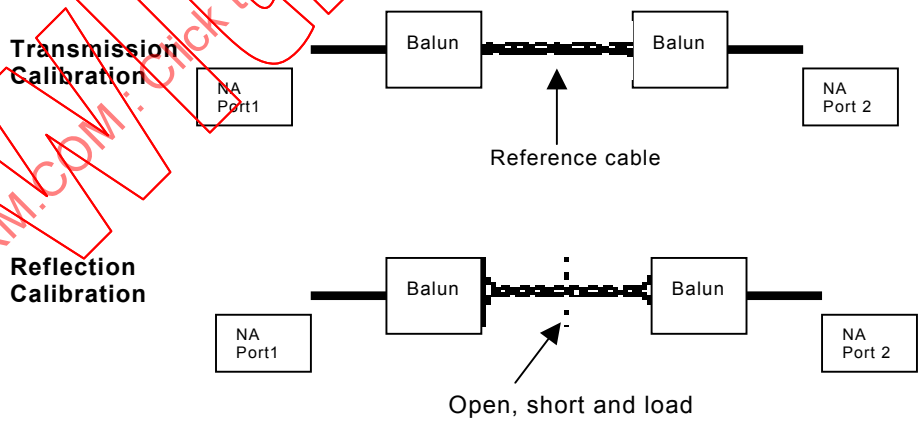


Figure B.1 - Calibration

B.4.2 Measurement.

The test specimen shall be terminated with measurement cables at both ends. The length of measurement cables shall be equal to the length of the reference cables used for reflection calibrations. The measurement cables shall be the cable types for which the connector is intended. A S_{21} measurement shall be performed.

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[3] Often referred to as attenuation.

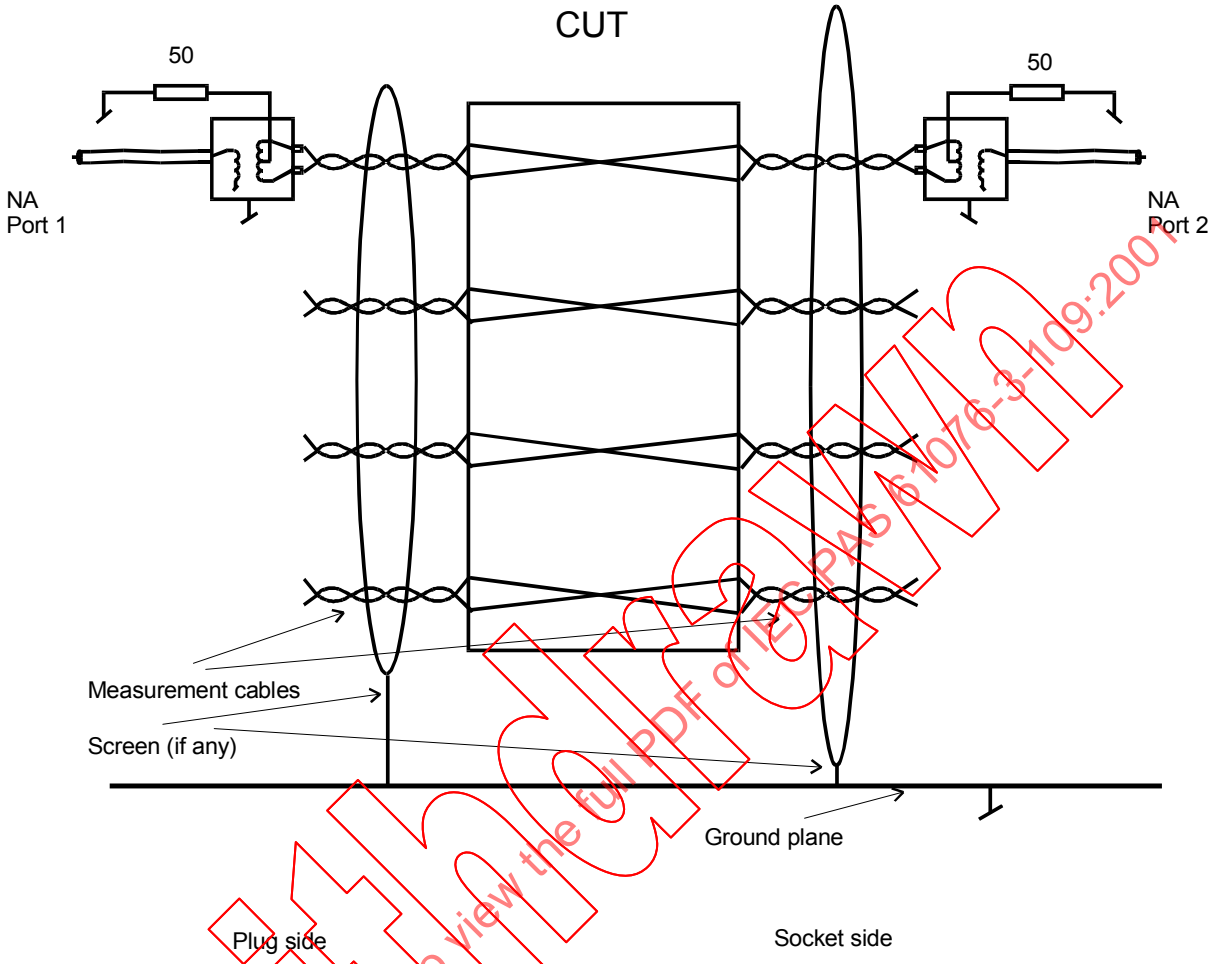

Figure B.2 – Measuring set-up

B.5 Test report

The measured results shall be reported in graphical or table format with the specification limits shown on the graphs or in the table at the same frequencies as specified in the relevant detail specification.
Results for all pairs shall be reported. It shall be explicitly noted if the measured results exceed the test limits.

B.6 Accuracy

The accuracy shall be within ±0,05 dB

Annex C
(normative)

Return loss

C.1 Object

The object of this test is to measure the return loss of a mated connector pair at the two reference planes.

C.2 Test method

Return loss is measured by measuring the scattering parameters, S_{11} and S_{22} of all the conductor pairs.

NOTE As a connector is a low loss device the return loss of the two sides are nearly equal.

C.3 Test set-up

The test set-up is as described in Annex A.

C.4 Procedure

C.4.1 Calibration

Calibration shall be performed as described in clause B.4.1.

C.4.2 Measurement

The test specimen shall be terminated with measurement cables at both ends. The length of measurement cables shall be equal to the length of the reference cables used for reflection calibrations. The measurement cables shall be the cable types for which the connector is intended. S_{11} and S_{22} measurements shall be carried out for each of the pairs.

C.5 Test report

The measured results shall be reported in graphical or table format with the specification limits shown on the graphs or in the table at the same frequencies as specified in the relevant detail specification.
Results for all pairs shall be reported. It shall be explicitly noted if the measured results exceed the test limits.

C.6 Accuracy

The return loss of the load for calibration is verified to be greater than 46 dB up to 100 MHz and greater than 40 dB at higher frequencies. The uncertainty of the connection between the connector under test and the baluns are expected to deteriorate the return loss of the set-up (effectively the directional bridge implemented by the test set-up) by 6 dB. The accuracy of the return loss measurements is then equivalent with measurements performed by a directional bridge with a directivity of 40 dB and 34 dB. The accuracy (uncertainty band) is tabled in table C.1.

Table C.1 – Uncertainty band of return loss measurement at frequencies below 100 MHz

Measured RL	10	12	15	18	20	22	25	28	30
Lower uncertainty limit	-0,3	-0,3	-0,5	-0,7	-0,8	-1,0	-1,4	-1,9	-2,4
Higher uncertainty limit	+0,3	+0,4	+0,5	+0,7	+0,9	+1,2	+1,7	+2,5	+3,3

Annex D
(normative)

Near end cross talk (NEXT)

D.1 Object

The object of this test procedure is to measure the magnitude of the electric and magnetic coupling between driven (disturbing) and quiet (disturbed) pairs of a mated connector pair.

D.2 Test method

Near end crosstalk is evaluated by measuring the scattering parameters, S21, of the possible conductor pair combinations at one end of the mated connector, while the other end of the pairs are terminated.

D.3 Test set-up

The test set-up consists of two baluns and a network analyser as defined in annex A. A figure of the set-up, which also shows the termination principles, is shown in figures D.1 and D.2.

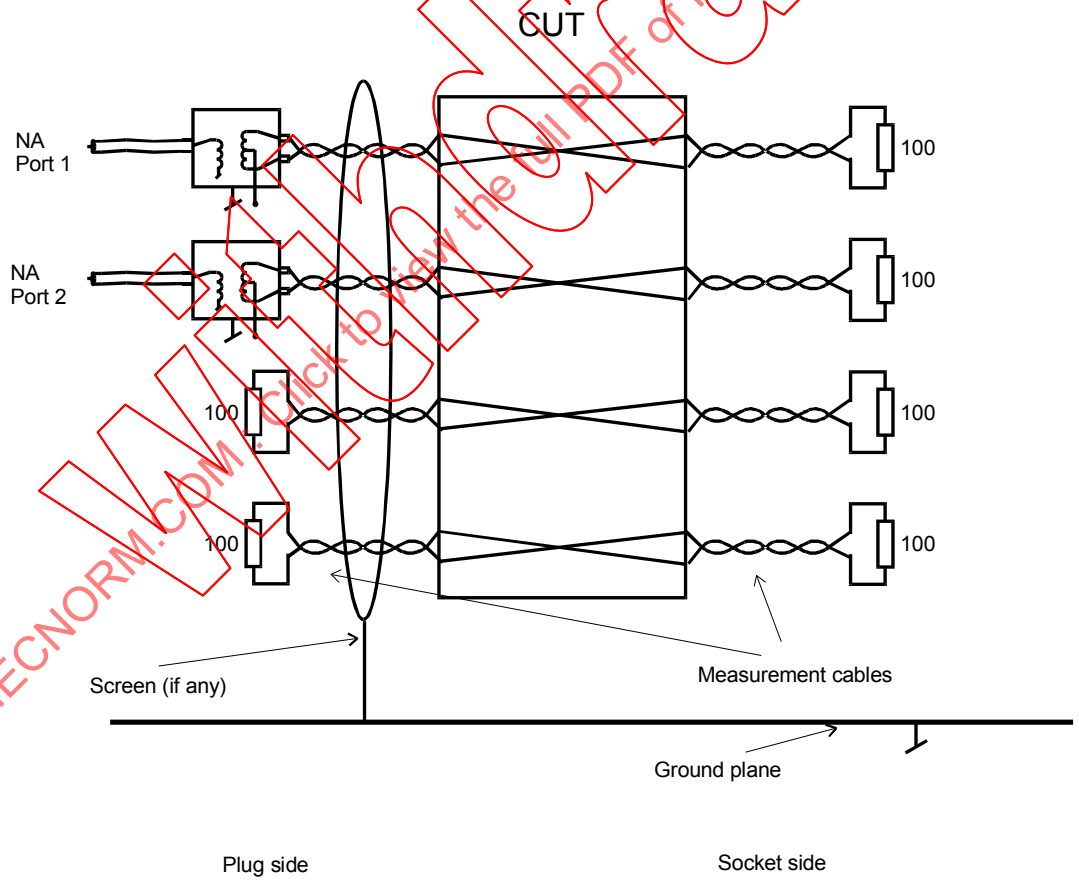

Figure D.1 – NEXT measurement differential mode only terminations

(Passive terminations must be resistor terminations)

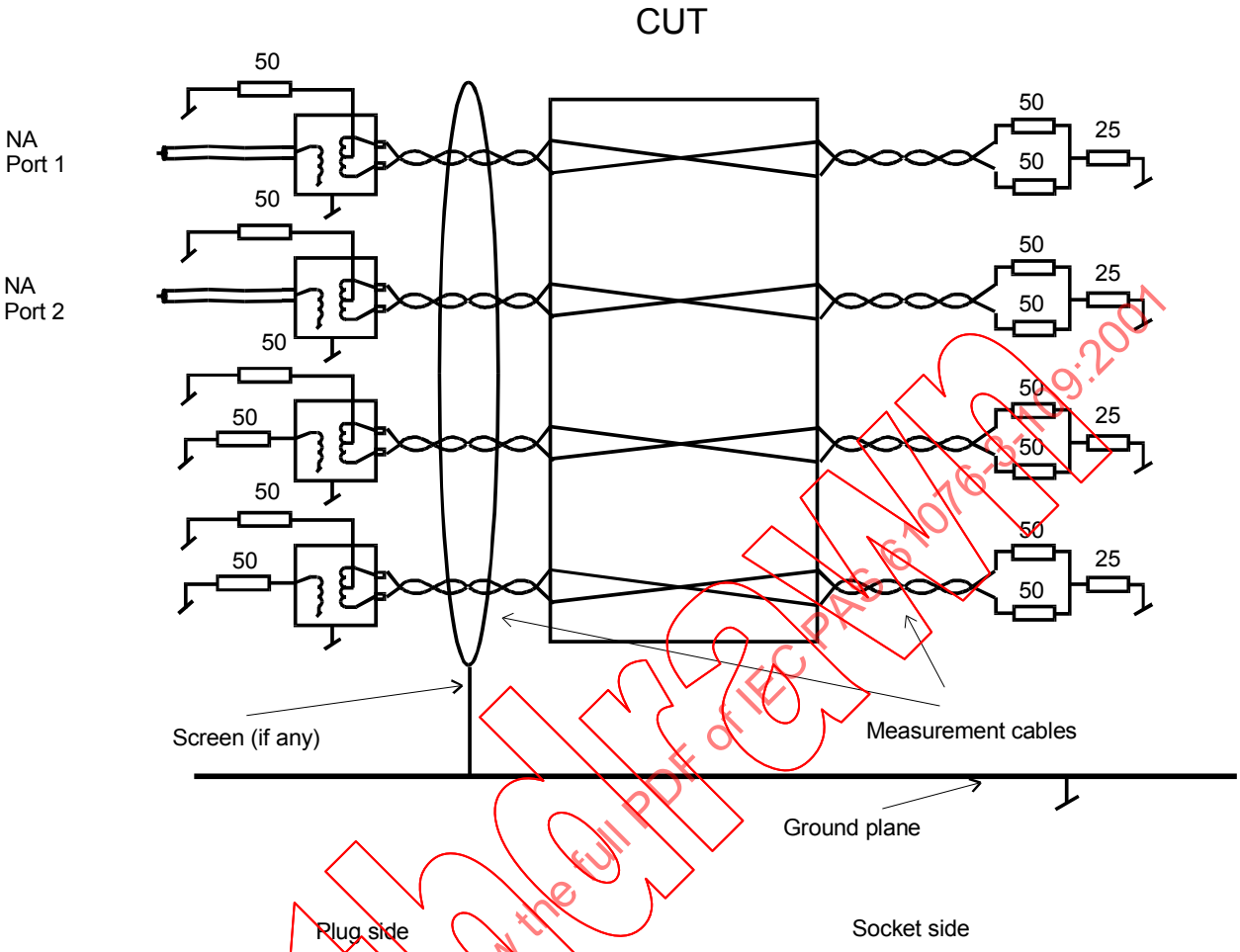

Figure D.2 – NEXT measurement differential and common mode termination.

(Passive terminations may be either balun or resistor terminations)

D.4 Procedure

D.4.1 Calibration

A through calibration shall be applied as a minimum. Full two port calibrations is recommended in order to enhance the measurement accuracy.

D.4.2 Establishment of noise floor

The noise floor of the set-up shall be measured. The level of the noise floor is determined by white noise, which may be reduced by increasing the test power and by reducing the bandwidth of the network analyser, and by residual crosstalk between the test baluns. The noise floor shall be measured by terminating the baluns with resistors and perform a S21 measurement. The noise floor shall be 20 dB lower than any specified limit for the crosstalk. If the measured value is closer to the noise floor than 10 dB, this shall be reported.

NOTE For high crosstalk values, it may be needed to screen the terminating resistors.

D.4.3 Measurement

Connect the disturbing pair of the CUT to the signal source and the disturbed pair to the receiver port. Terminate according to figure D.1 and figure D.2. It is recommended that the socket be terminated with short separated pairs without jacket. Test all possible pair combinations [4] and record the results.
The CUT shall be tested in the following configurations:
1. With differential mode terminations only. (This is not requested for category 7 connectors, and the requirement will be removed for all categories if experience show that a requirement for balance can replace this requirement.)
2. With differential and common mode terminations.
The measurements have to be performed from both ends of the mated connector. As a connector is a low loss devise near-end cross talk values from the two ends are nearly equal.

D.5 Test report

The measured results shall be reported in graphical or table format with the specification limits shown on the graphs or in the table at the same frequencies as specified in the relevant detail specification.
Results for all pairs shall be reported. It shall be explicitly noted if the measured results exceed the test limits.

D.6 Accuracy

The accuracy shall be better than ±1 dB at measurements up to 60 dB and ±2 dB at measurements up to 85 dB.

[4] There are 6 different combinations of near-end crosstalk in a four-pair connector from each side, which gives atotal of 12 measurements for each kind of termination method.

Annex E
(normative)

Far end cross talk (FEXT)

E.1 Object

The object of this test procedure is to measure the magnitude of the electric and magnetic coupling between driven (disturbing) and quiet (disturbed) pairs of a mated connector pair.

E.2 Test method

Far end crosstalk is evaluated by measuring the scattering parameters, S_{21}, of the possible conductor pair combinations at one end of the mated connector, to the other end.

E.3 Test set-up

The test set-up consists of two baluns and a network analyser as defined in annex A. A figure of the set-up, which also shows the termination principles, is shown in figures E.1 and E.2.

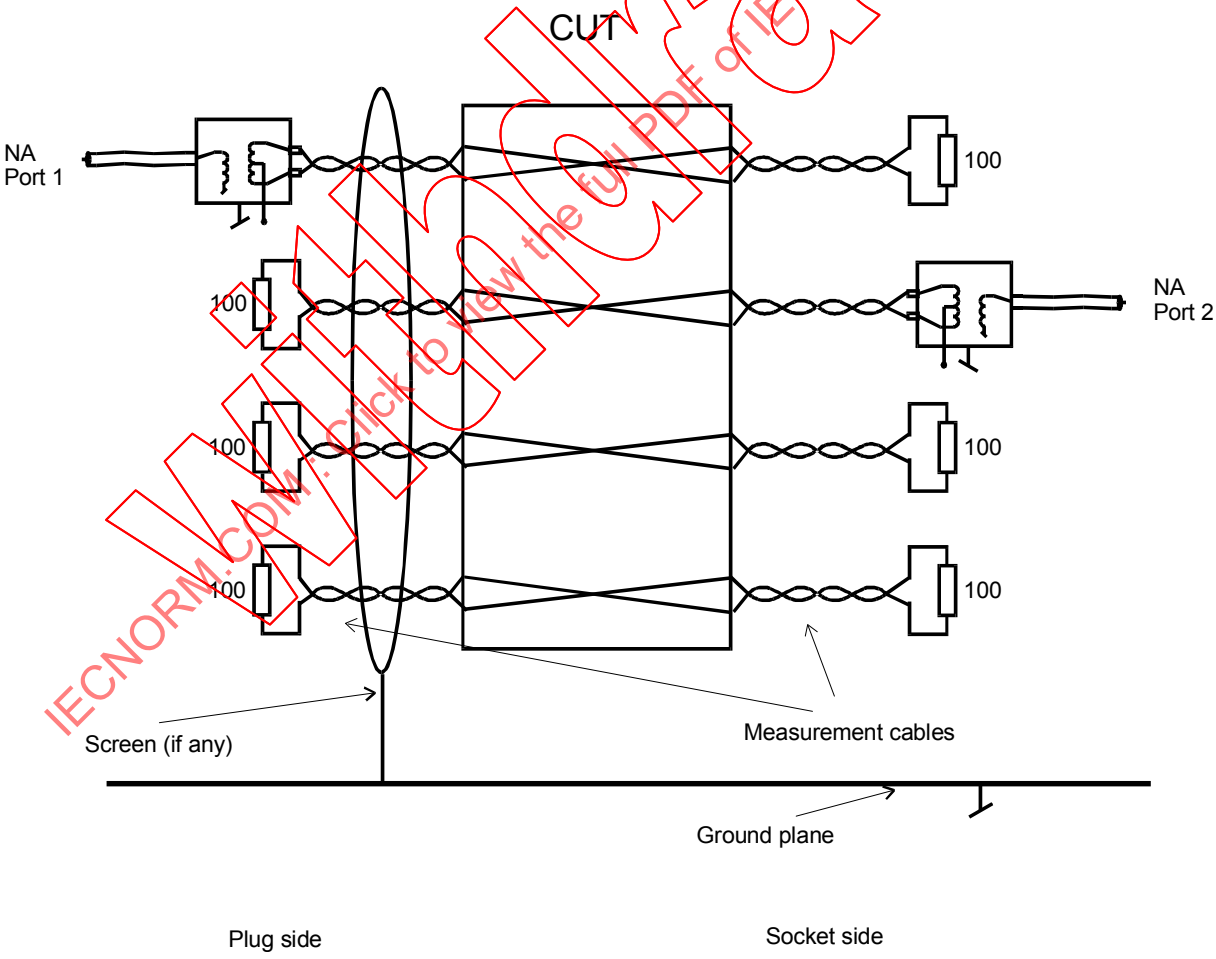

Figure E.1 - FEXT measurement differential mode only terminations

(Passive terminations must be resistor terminations)

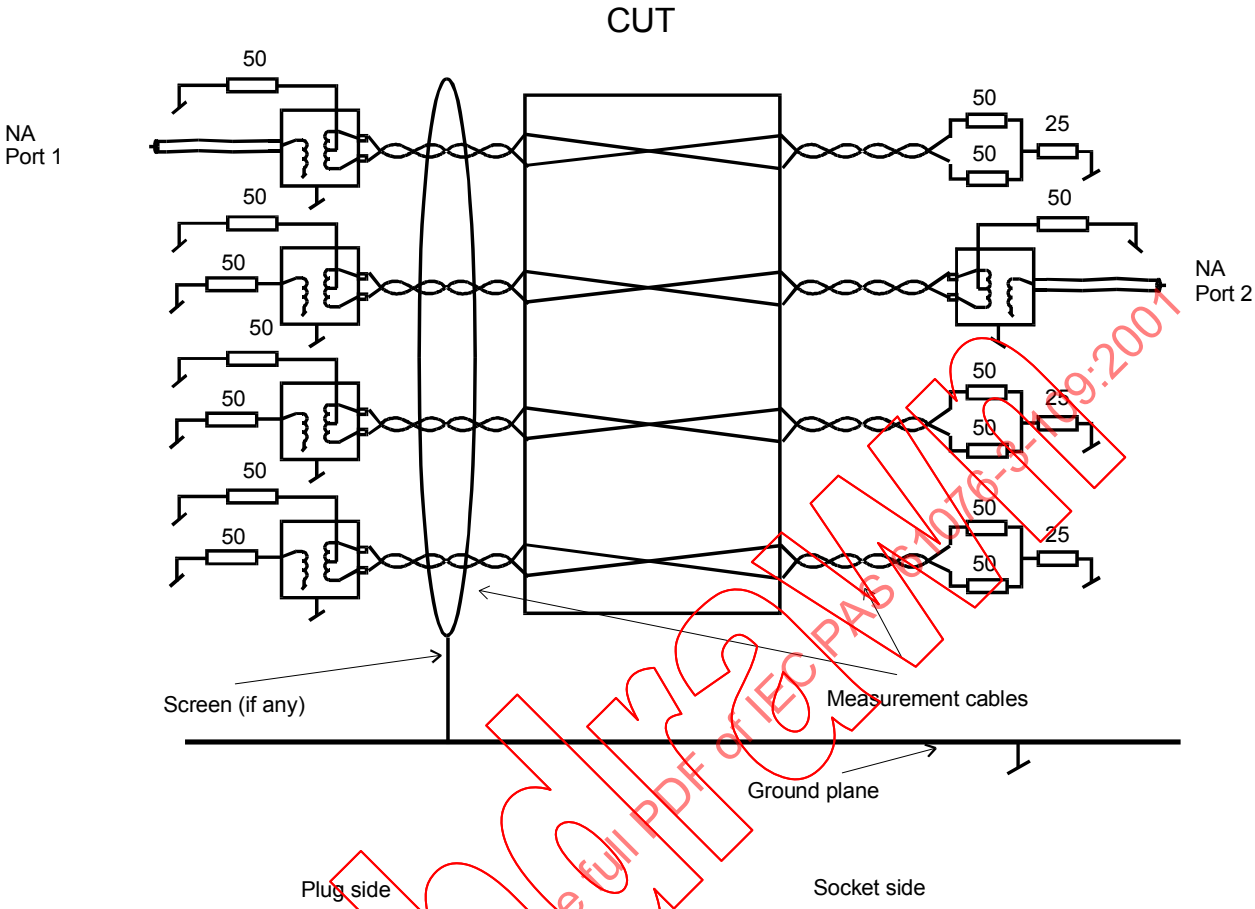

Figure E.2 - FEXT measurement differential and common mode terminations

(Passive terminations may be either balun or resistor terminations.)

E.4 Procedure

E.4.1 Calibration

Calibration is performed as shown in clause D.4.1.

E.4.2 Establishment of noise floor

The noise floor of the set-up is established as shown in clause D.4.2.