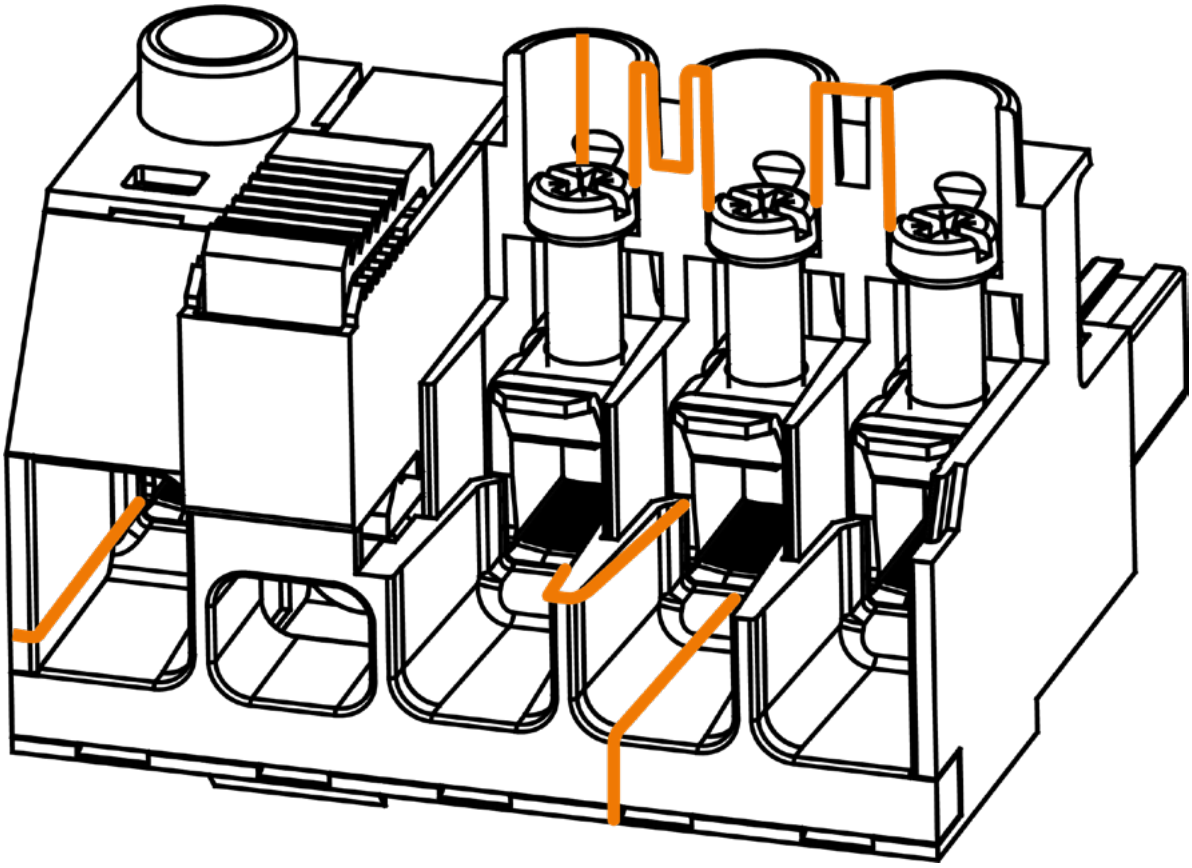
Weidmüller

Measurement of clearance and creepage distances according to VDE / IEC and UL

Technical information



Design of clearance and creepage distances in electrical equipment

General:
Since April 1997 the sising of clearance and creepage distances has been covered by DIN VDE 0110 part 1 "Insulation coordination for electrical equipment in low-voltage systems".

DIN VDE 0110 part 1 contains the modified edition of IEC Report 664-1 (see also IEC 664-1/Oct 1992). The design data resulting from these provisions is – if applicable – specified in this catalogue for each product.

Table 1: Rated impulse withstand voltages for electrical equipment

Rated voltage of power supply system*) in V		Rated impulse withstand voltage in kV			
Three-phase systems	Single-phase systems with neutral point	Electrical equipment at the supply point of the installation **(Overvoltage category IV)**	Electrical equipment as part of the permanent installation **(Overvoltage category III)**	Electrical equipment to be connected to the permanent installation **(Overvoltage category II)**	Specially protected electrical equipment **(Overvoltage category I)**
	120 to 240	4,00	2,50	1,50	0,80
230/400 277/480		6,00	4,00	2,50	1,50
400/690		8,00	6,00	4,00	2,50
1000		Values depend on the particular project or, if no values are available, the values above for 400/690 V can be used.			

*) to IEC 38

Category I is valid for specially rated equipment.

Category II is valid for technical committees responsible for electrical equipment specified for connecting to the mains power supply.

Category III is valid for technical committees responsible for installation materials, and for some specific technical committees.

Category IV is valid for power supply companies and particular projects.

Table 2a: Minimum clearances to VDE 0110-1/Apr 1997

Rated impulse withstand volt. in KV	Minimum clearance distances in mm for sites up to 2000 m above sea level									
	Case A (inhomogeneous field)					Case B (homogeneous field)				
	Pollution severity					Pollution severity				
	1	2	1)	3	4	1	2	1)	3	4
0,33	0,01			0,80	1,60	0,01	0,20		0,80	1,60
0,40	0,02		0,10			0,02		0,10		
0,50	0,04	0,20				0,04				
0,60	0,06		0,12			0,06		0,12		
0,80	0,10					0,10				
1,00	0,15		0,20			0,15		0,20		
1,20	0,25	0,25				0,20				
1,50	0,50	0,25				0,30	0,30			
2,00	1,00	1,00		1,00		0,45	0,45			
2,50	1,50	1,50		1,50		0,60	0,60			
3,00	2,00	2,00		2,00	2,00	0,80	0,80			
4,00	3,00	3,00		3,00	3,00	1,20	1,20		1,20	
5,00	4,00	4,00		4,00	4,00	1,50	1,50		1,50	
6,00	5,50	5,50		5,50	5,50	2,00	2,00		2,00	2,00
8,00	8,00	8,00		8,00	8,00	3,00	3,00		3,00	3,00
10,00	11,00	11,00		11,00	11,00	3,50	3,50		3,50	3,50
12,00	14,00	14,00		14,00	14,00	4,50	4,50		4,50	4,50
15,00	18,00	18,00		18,00	18,00	5,50	5,50		5,50	5,50

1) Pollution severity 2 is split for impulse voltages up to 1.00 kV (case A) or 1.20 kV (case B).
These values apply for printed circuits but deviate from those in IEC Report 664.

Dimensioning of clearance and creepage distances to VDE 0110/Apr 1997 (IEC Report 664-1) "Insulation coordination for electrical equipment in low-voltage systems"

The provisions for insulation coordination result in the following relationships for dimensioning of clearance and creepage distances:

- **Clearances** are dimensioned according to the anticipated **overvoltages** taking into account the ratings of the **overvoltage protection precautions** in use and the anticipated environmental conditions taking into account the protective measures taken to prevent **pollution**.

- **Creepage distances** are dimensioned according to the **operating voltage** and the anticipated environmental conditions taking into account the **insulating materials** used and the protective measures taken to prevent **pollution**.

Dimensioning of clearances

Decisive for the dimensioning of clearances are the **rated impulse withstand voltages** shown in table 1, which are derived from the **overvoltage category** and the **phase-to-earth** voltage depending on the rated mains voltage (taking into account all types of supply systems).

The minimum clearances (up to site altitudes of 2000 m above mean sea level) are determined from table 2a based on the **rated impulse withstand voltage** and the **pollution severity.**

Note: Clearances that do not comply with case A must be subjected to an impulse withstand voltage test (see table 2a, footnote 1).

The **pollution severity categories** are as follows:

Pollution severity category 1:
No pollution, or only dry, non-conductive pollution that has no influence.

Pollution severity category 2:
Non-conductive pollution only; occasional condensation may cause temporary conductivity.

Pollution severity category 3:
Conductive pollution, or dry, non-conductive pollution that is liable to be rendered conductive through condensation.

Pollution severity category 4:
Contamination results in constant conductivity, e.g. caused by conductive dust, rain or snow.

The following aspects apply to the **overvoltage categories** in accordance with the German standard DIN VDE 0110-1:

Electrical equipment fed directly from the low-voltage mains
Specification of a specific overvoltage category shall be based on the following:

– Equipment of *overvoltage category I* is equipment that is intended to be connected to the permanent electrical installation of a building. Measures to limit transient overvoltages to the specific level are taken outside the equipment, either in the permanent installation or between the permanent installation and the equipment.

– Equipment of *overvoltage category II* is equipment to be connected to the permanent electrical installation of a building.

Note: Examples of such equipment are household appliances, portable tools and similar loads.

– Equipment of *overvoltage category III* is equipment that is part of the permanent electrical installation and other equipment where a higher degree of availability is expected.

Note: Examples of such equipment are distribution boards, circuit-breakers, wiring systems (IEV 826-06-01, including cables, busbars, junction boxes, switches, power sockets) in the permanent installation, and equipment for industrial use and some other equipment, e.g. stationary motors with permanent connections to the permanent installation.

– Equipment of *overvoltage category IV* is for use at or in the proximity of the incoming supply point of the electrical installations of buildings upstream of the main distribution board.

Table 3a: Single-phase 2- or 3-wire AC or DC systems

Rated voltage of the power supply (mains)*)	Voltages for table 4	
	For insulation phase-to-phase 1)	For insulation phase-to-earth 1)
	All systems	3-wire systems, neutr. point earthing
V	V	V
12,5	12,5	–
24	25	–
25		
30	32	–
42		
48	50	–
50**)		
60	63	–
30–60	63	32
100**)	100	–
110	125	–
120		
150**)	160	–
220	250	–
110–220	250	125
120–240		
300**)	320	–
220–440	500	250
600**)	630	–
480–960	1000	500
1000**)	1000	–

1) Phase-to-earth insulation levels for unearthed or impedance-earthed systems are equal to those of phase-to-phase because the operating voltage to earth of any phase can, in practice, reach full phase-to-phase voltage. This is because the actual voltage to earth is determined by the insulation resistance and capacitive reactance of each phase to earth; thus, a low (but acceptable) insulation resistance of one phase can earth it and raise the other two to full phase-to-phase voltage to earth.

*) It is assumed that the rated voltage of the electrical equipment is not lower than the nominal voltage of the power supply.

**) Because of the common changes, the meaning of the ** symbol has not been used in table 1; i.e. the / symbol indicates a 4-wire 3-phase distribution system. The lower value is the phase-to-neutral voltage, while the higher value is the phase-to-phase voltage. Where only one value is indicated, it refers to 3-wire, 3-phase systems and specifies the value phase-to-phase. The values given in table 1 are still taken into account in tables 3a and 3b by the ** symbol.

Table 3b: 3-phase 3- or 4-wire AC systems

Rated voltage of the power supply (mains)*)	Voltages for table 4		
	For insulation phase-to-phase 1)	For insulation phase-to-earth 1)	
	All systems	3-phase 4-wire systems with earthed neutral wire2)	3-phase 3-wire systems unearthed1) or phase-earthed
V	V	V	V
60	63	32	63
110/120/127	125	80	125
150**)	160	–	160
208	200	125	200
220/230/240	250	160	250
300**)	320	–	320
380/400/415	400	250	400
440	500	250	500
480/500	500	320	500
575	630	400	630
600**)	630	–	630
660/690	630	400	630
720/830	800	500	800
960	1000	630	1000
1000**)	1000	–	1000

1) Phase-to-earth insulation levels for unearthed or impedance-earthed systems are equal to those of phase-to-phase because the operating voltage to earth of any phase can, in practice, reach full phase-to-phase voltage. This is because the actual voltage to earth is determined by the insulation resistance and capacitive reactance of each phase to earth; thus, a low (but acceptable) insulation resistance of one phase can earth it and raise the other two to full phase-to-phase voltage to earth.

2) For electrical equipment for use in both 3-phase 4-wire and 3-phase 3-wire supplies, earthed and unearthed, use the values for 3-wire systems only.

*) It is assumed that the rated voltage of the electrical equipment is not lower than the nominal voltage of the power supply.

**) Because of the common changes, the meaning of the ** symbol has not been used in table 1; i.e. the / symbol indicates a 4-wire 3-phase distribution system. The lower value is the phase-to-neutral voltage, while the higher value is the phase-to-phase voltage. Where only one value is indicated, it refers to 3-wire, 3-phase systems and specifies the value phase-to-phase. The values given in table 1 are still taken into account in tables 3a and 3b by the ** symbol.

Note: Examples of such equipment are electricity meters, circuit-breakers and ripple control units.

Note on application of pollution severity and overvoltage categories

The pollution severity and rated impulse withstand voltage derived from the overvoltage category are each specified in this catalogue and are product-related.
In principle, the dimensioning of clearance and creepage distances, and the resulting specification of ratings for electromechanical products (terminal blocks, terminal strips, PCB terminals/ connectors) is based on pollution severity 3 and overvoltage category III considering all types of systems.

Dimensioning of creepage distances

Decisive for dimensioning of creepage distances are the rated voltages derived from the **system voltages** of the power supply for the respective **type of supply system** in conjunction with the **pollution severity** (classification, see "Clearances") and the **insulating material** used.
Taking into account tables 3a and 3b and the CTI (Comparative Tracking Index) of the insulating material, the minimum creepage distances are determined from table 4.

The insulating materials are subdivided into four groups according to their CTI (Comparative Tracking Index):

Insulating material	
I	600 ≤ CTI
II	400 ≤ CTI < 600
III a	175 ≤ CTI < 400
III b	100 ≤ CTI < 175

Table 4: Minimum creepage distances

Rated voltage U_{eff} or $U_{=}$ in V	Creepage distance in mm											
	Printed circuits		Other electrical equipment	Pollution severity								
	Pollution severity			2			3			4		
	1	2	1									
	Insulating mat.	Insulating mat.	Insulating mat.	Insulating material group			Insulating material group			Insulating material group		
	2)	3)	2)	I	II	III	I	II	III 4)	I	II	III 4)
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00	1,60	1,60	1,60
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05	1,60	1,60	1,60
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10	1,60	1,60	1,60
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20	1,60	1,60	1,60
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25	1,70	1,70	1,70
32	0,025	0,04	0,14	0,53	0,53	0,53	1,30	1,30	1,30	1,80	1,80	1,80
40	0,025	0,04	0,16	0,56	0,80	1,10	1,40	1,60	1,80	1,90	2,40	3,00
50	0,025	0,04	0,18	0,60	0,85	1,20	1,50	1,70	1,90	2,00	2,50	3,20
63	0,040	0,63	0,20	0,63	0,90	1,25	1,60	1,80	2,00	2,10	2,60	3,40
80	0,063	0,10	0,22	0,67	0,95	1,30	1,70	1,90	2,10	2,20	2,80	3,60
100	0,10	0,16	0,25	0,71	1,00	1,40	1,80	2,00	2,20	2,40	3,00	3,80
125	0,16	0,25	0,28	0,75	1,05	1,50	1,90	2,10	2,40	2,50	3,20	4,00
160	0,25	0,40	0,32	0,80	1,10	1,60	2,00	2,20	2,50	3,20	4,00	5,00
200	0,40	0,63	0,42	1,00	1,40	2,00	2,50	2,80	3,20	4,00	5,00	6,30
250	0,56	1,00	0,56	1,25	1,80	2,50	3,20	3,60	4,00	5,00	6,30	8,00
320	0,75	1,60	0,75	1,60	2,20	3,20	4,00	4,50	5,00	6,30	8,00	10,00
400	1,00	2,00	1,00	2,00	2,80	4,00	5,00	5,60	6,30	8,00	10,00	12,50
500	1,30	2,50	1,30	2,50	3,60	5,00	6,30	7,10	8,00	10,00	12,50	16,00
630	1,80	3,20	1,80	3,20	4,50	6,30	8,00	9,00	10,00	12,50	16,00	20,00
800	2,40	4,00	2,40	4,00	5,60	8,00	10,00	11,00	12,50	16,00	20,00	25,00
1000	3,20	5,00	3,20	5,00	7,10	10,00	12,50	14,00	16,00	20,00	25,00	32,00

2) Insulating materials I, II, IIIa, IIIb

3) Insulating materials I, II, IIIa

4) Creepage distances are not determined in this range.
Insulation group IIIb is generally not recommended for pollution severity 3 with voltages > 630 V, and is never recommended for pollution severity 4.

The comparative tracking index must be determined according to DIN IEC 112/VDE 0303 part 1 on the basis of specially prepared samples with test solution A.

Slots are taken into account in the measurement of creepage distances when their minimum width x is dimensioned according to the following table:

Pollution-severity	Minimum width x mm
1	0,25
2	1,0
3	1,5
4	2,5

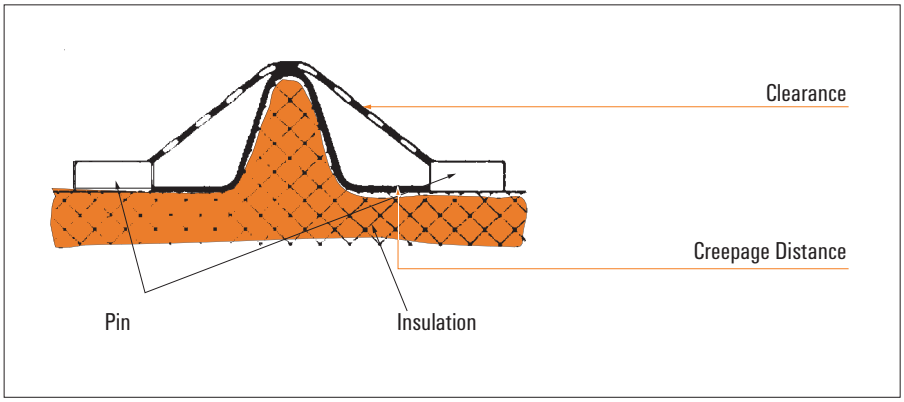
If the associated clearance is less than 3 mm, the minimum slot width can be reduced to 1/3 of the clearance.

Clearance and creepage distances

The maximum voltage to be applied to the connector depends on the distance between two connections.

Two distances have to be taken in account:

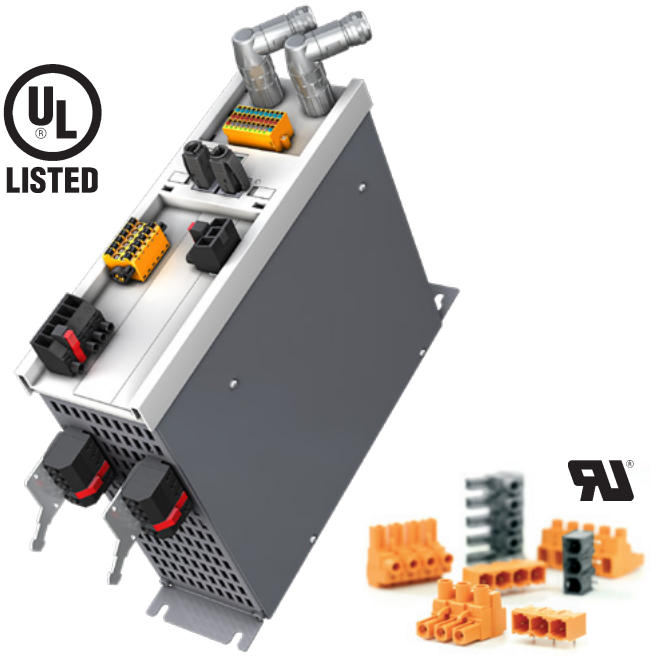
- Clearance = shortest distance between two conductive parts (in air)
- Creepage distance = distance along surface



Measurement of clearance and creepage distances according to UL

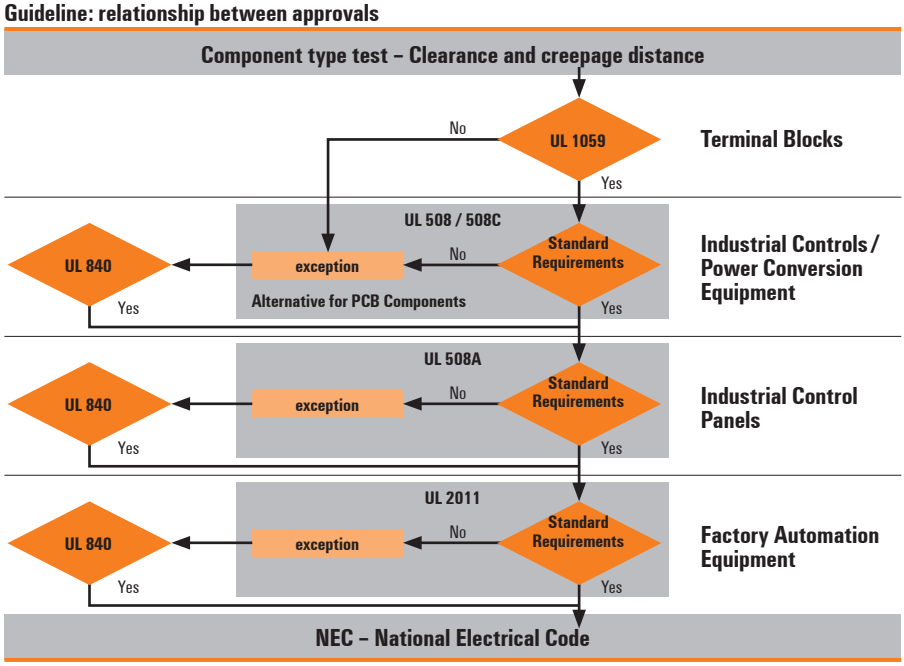
The UL standard distinguishes between listed devices and registered components. So a component, such as a terminal, is the smallest product unit and, unlike a device, is not given a UL listing, but is registered. Components may be used as passive elements. In turn, a device consists of certified components which form a unit. It is an end product and designed for use as an active component. There are also different standards and test marks for devices and components, irrespective of where they are used.

UL therefore sets different requirements for components and devices. Device connectivity components are subject to standard UL 1059, which is the accepted safety standard for terminal blocks and also applies to modular terminal blocks and plug-in connectors. Both are recognised as individual components in accordance with UL 1059.
In the final application, the components are then assessed and approved in conjunction with a device.



There is also device approval in line with UL 61800-5-1: the standard for Adjustable Speed Electrical Power Drive Systems -Part 5-1: Safety Requirements - Electrical, Thermal and Energy" which applies to controlled power electronics drives.

Guideline: relationship between approvals



White Paper UL:
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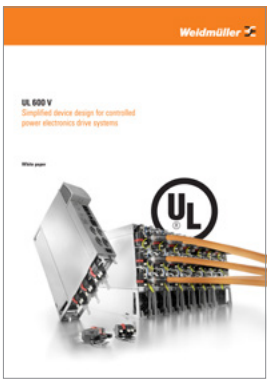
We share our expertise: Find out detailed information and interesting facts about trend topics in the field of device connectivity in our Whitepaper section.



The diagram below shows the approach or procedure for UL approvals from the component to the installation of a production system.

Components - Plug-in connector - Terminal	**Product standard** - PLC - Frequency converter	**Application standard** for industrial control cabinets	**Factory automation** for industrial control cabinets	**Installation of production systems**
				
UL 1059 Component approval for connection systems	**UL 508** Standard for industrial switching devices **UL 61800-5-1** Standard for controlled drive systems	**UL 508A** Standard for switchgears	**UL 2011** Standard for equipment in factories	**NEC** Mandatory American safety standard for electrical installations

The UL 1059 standard distinguishes application groups for connection systems, i.e. for terminals and plug-in connectors, and gives a dedicated description of the requirements for clearance and creepage distances. Industrial requirements are specified for „Use Group" C and/or D.

Application	Description	Potential involved in volts	Clearance distance (mm)	Creepage distance (mm)
A	Operating elements, consoles, etc.	150 300 600	12.7 19.1 25.4	19.1 31.8 50.8
B	Commercial devices, including Office and Electronic Data processing equipment, etc.	150 300 600	1.6 2.4 9.5	1.6 2.4 12.7
C	Industrial, general	150 300 600	3.2 6.4 9.5	6.4 9.5 12.7
D	Industrial, devices having limited ratings	300 600	1.6 4.8	3.2 9.5
E	Connection technology for the 600 V...1500 V voltage range	601 – 1000 1001 – 1500	14 17.8	21.6 30.5
F	Industrial Applications and equipment in accordance with UL 508, 508 C, 840	51 – 1500	As defined in the device standard	As defined in the device standard

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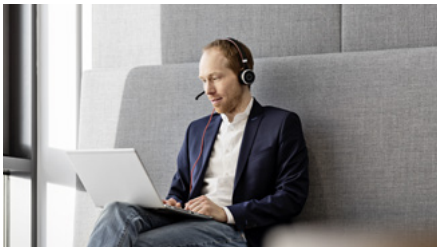

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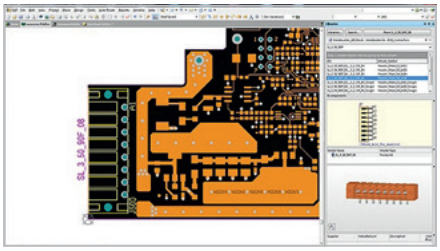

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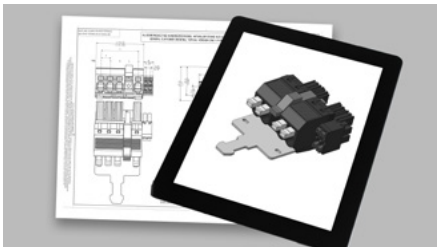

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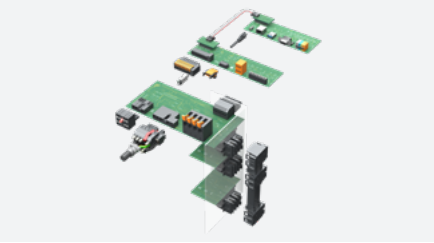

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