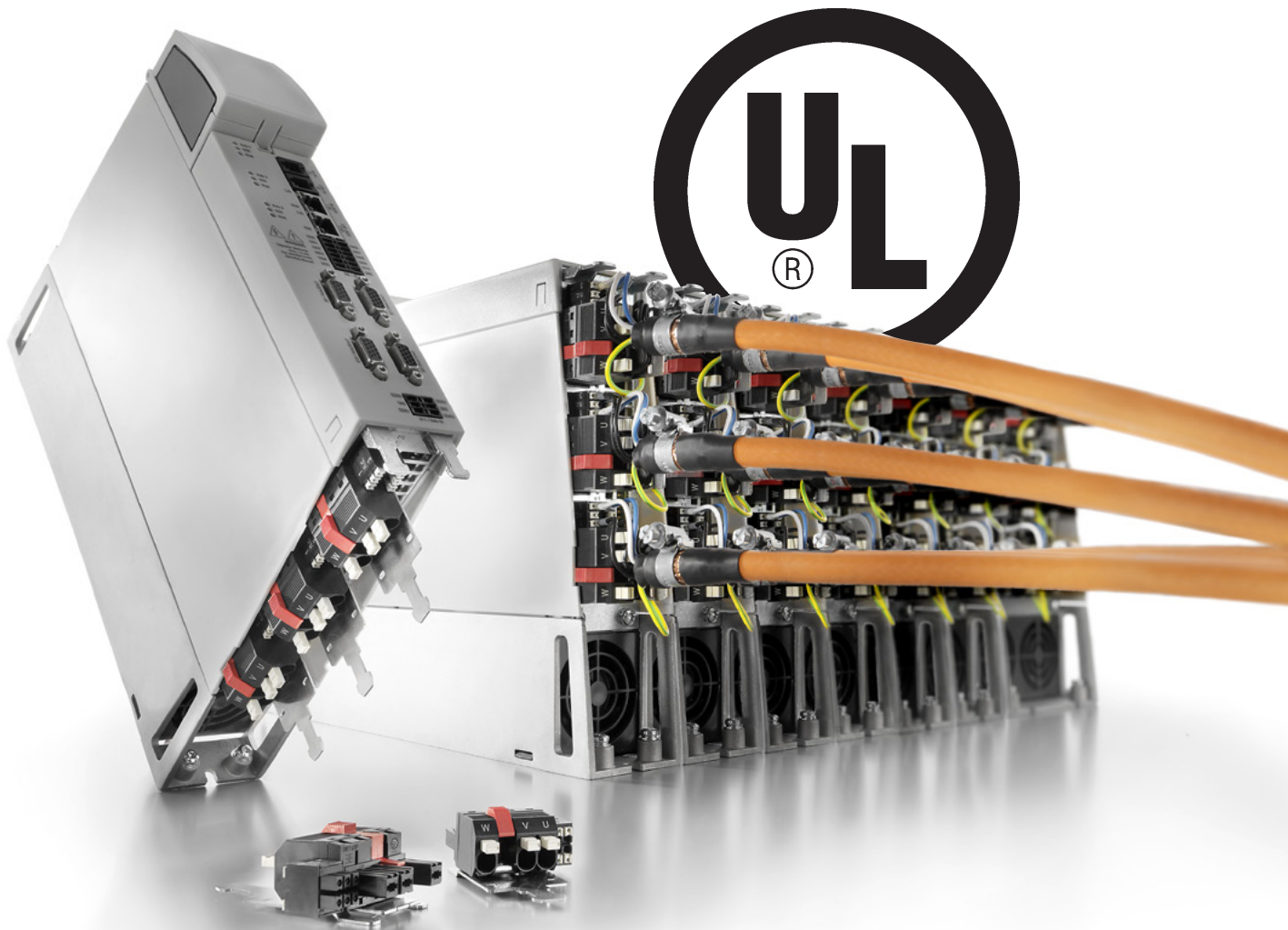


UL 600 V

Simplified device design for controlled
power electronics drive systems

White paper



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1. Introduction

UL 600 V

Simplified device design for controlled power electronics drive systems

The leading global organisations for the certification of product safety are Underwriters Laboratories (UL) based in Northbrook, Illinois, and the International Electrotechnical Commission (IEC) based in Ghent. All products must be certified in accordance with the local applicable standards for the market in a given country. This means that IEC standards apply in Europe and large areas of the world, whilst UL standards apply in the USA. There are some substantial differences between the standards, which makes global product approval more difficult. In general, the requirements for UL are stricter than those for the IEC.

So when developing devices, it is not only a question of considering the IEC standards, but also those required by UL. The approach is also important since it would be unwise to proceed with development based on European standards and then submit the device to UL for approval. This is because subsequent alterations to the device would lead to increased development and approval costs. So it is recommended that UL standards are considered from the very start of the development phase.

Seamless testing and certification results in quick device approval. So it is very much advised to find out at the component selection stage whether the relevant components already have UL registration.

As an option, components can be subject to simplified device approval. This allows, for example, the selection of more compact components for device design. The UL standard makes a distinction between field and factory wiring. Field wiring includes, for example, plugs with cables or cables to connect field components with external wiring involved. Factory wiring would be, for example, a connection strip or box for fitting into a device. The attachment and wiring or even soldering by the manufacturer of the device is internal, i.e. inside the device.

2. Certification of product safety

For components and devices in accordance with UL

IEC and UL are considered as the two major global organisations for the testing and certification of product safety.



2.1. IEC – International Electrotechnical Commission

The IEC describes the safety requirements of a device used in the field. The technical details for the design implementation of the safety requirements are the responsibility of the manufacturer.

*International organisation for standardisation in electrical engineering and electronics



2.2. UL – Underwriters Laboratories

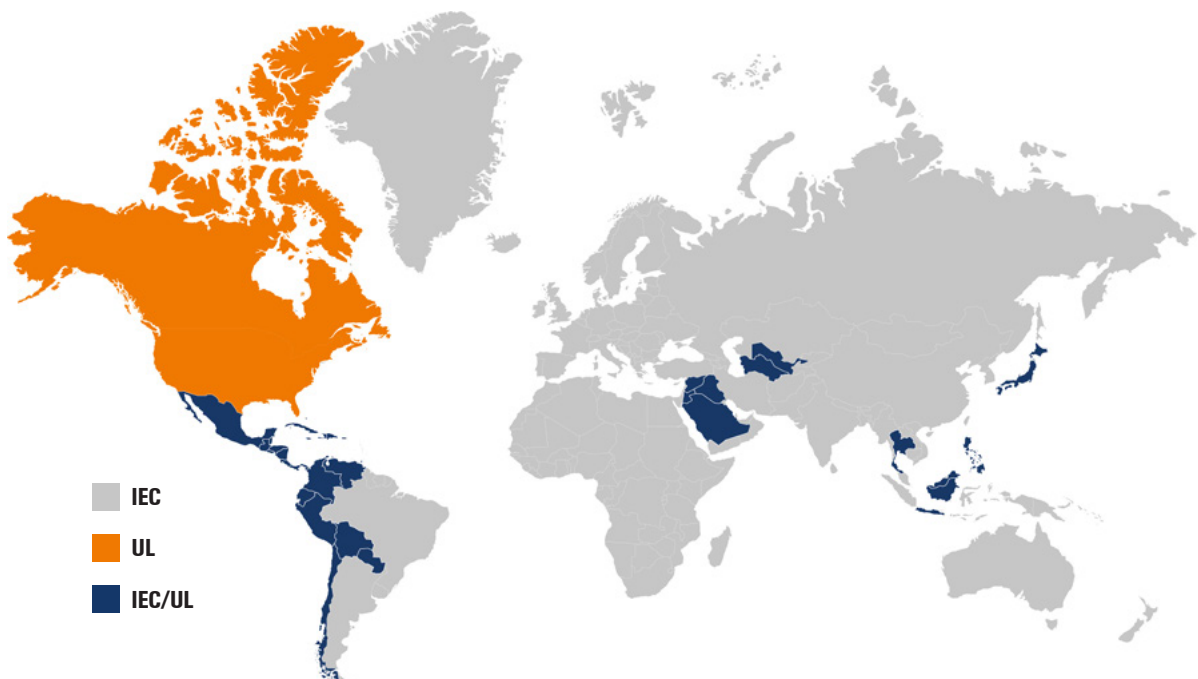
UL defines stricter approval criteria based on the tougher product liability laws in the USA. These approval criteria must be fulfilled by all products on the one hand and all process steps on the other. This also applies to product design, production, application, installation and extends as far as operation.

*Leading, independent American organisation which tests and certifies products with respect to their safety

2.3. TTIP – Transatlantic Trade and Investment Partnership

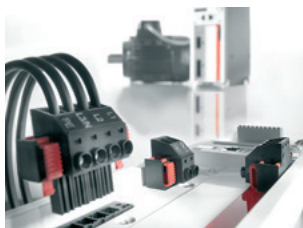
As things currently stand, the Transatlantic free trade agreement allows no exceptions, which means that product safety will continue to be an important aspect of trade relations.

*Transatlantic Trade and Investment Partnership



In the example considered here, UL 600 V, the UL makes a distinction between two test marks for simplified device design of controlled power electronics drive systems.

Firstly, there are registered components: these are used in a device and are considered the smallest available unit. They can be built into the panel as passive components, these include, for example, printed circuit boards and terminals.

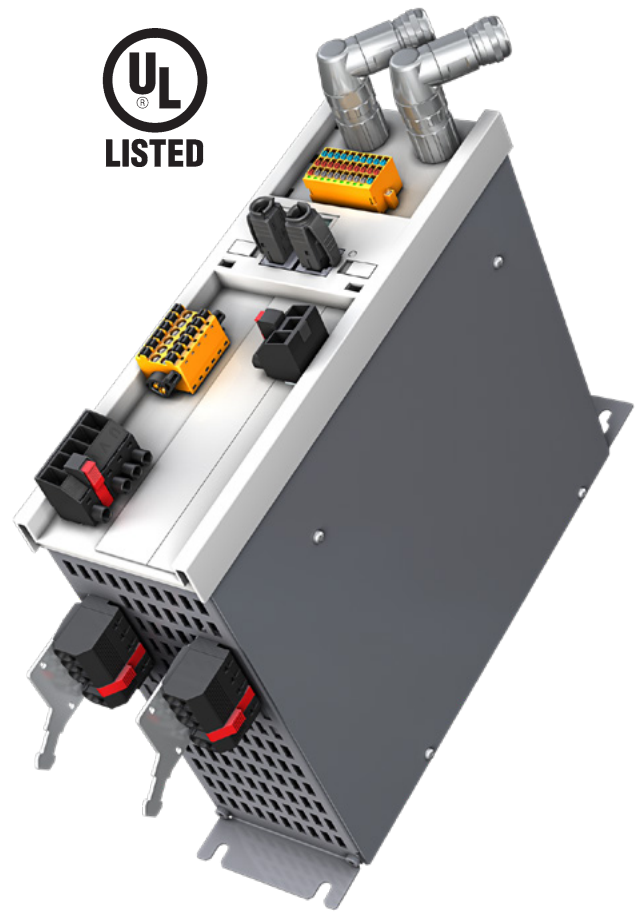
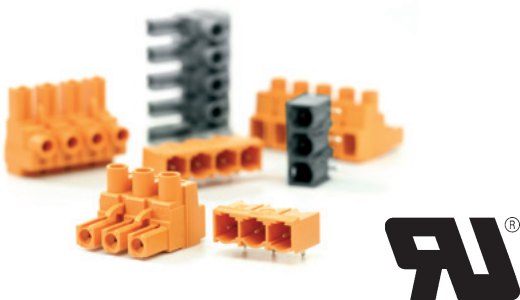


Secondly, there are listed devices: these consist of registered components, with operational devices most relevant in this instance. As active components, they can be installed in control cabinets or built into the device as printed circuit boards or terminals.

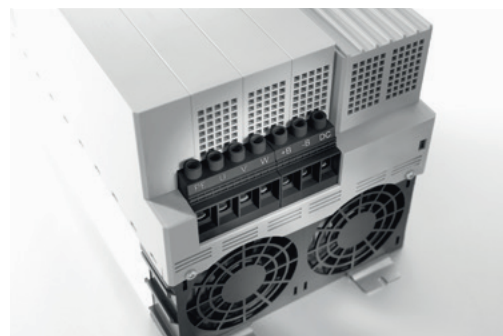
3. Different requirements For components and devices

The UL standard therefore 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.

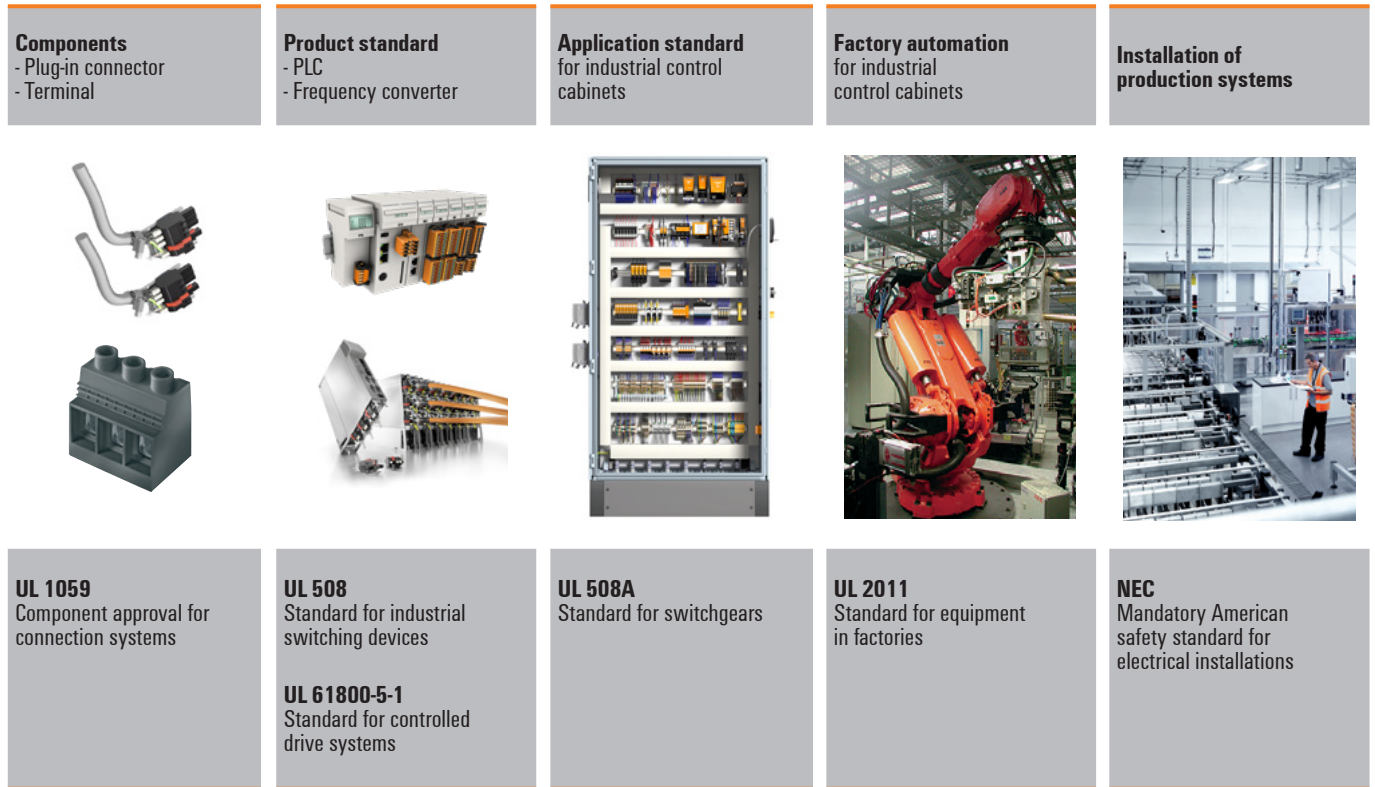
UL therefore sets different requirements for components and devices. Device connectivity components are subject to standard UL 1059, which is the accepted safety standard for terminal blocks and also applies to modular terminal blocks and plug-in connectors. Both are recognised as individual components 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.

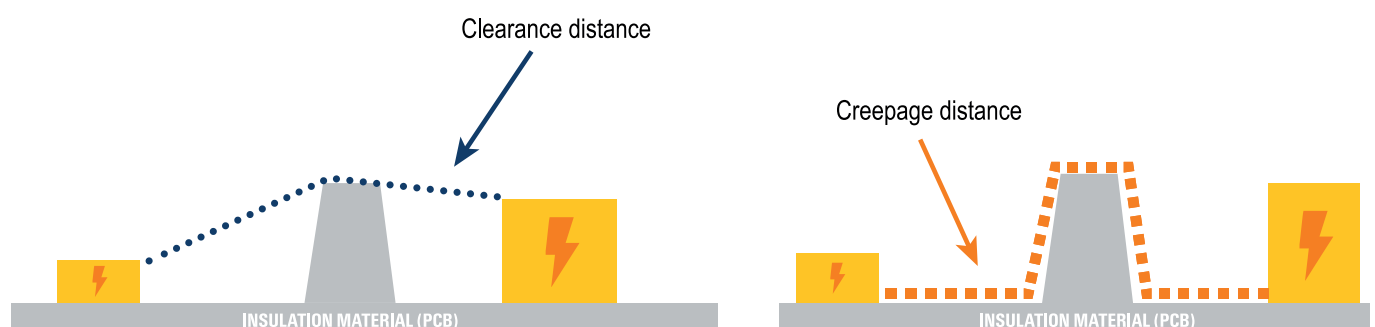


The diagram below shows the approach or procedure for UL approvals from the component to the installation of a production system.



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)
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

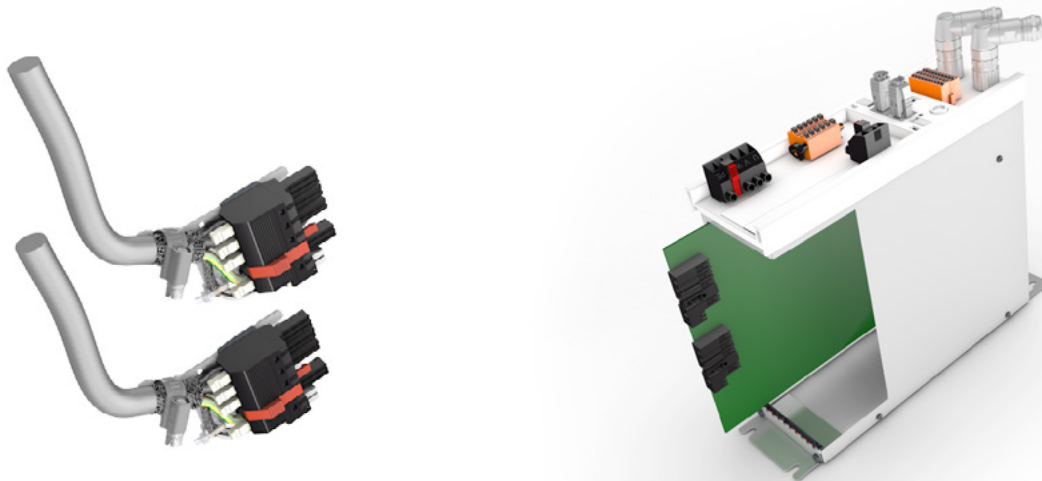


4. Systematic procedures

When selecting components for devices in accordance with UL

At the same time, the UL standard makes an essential distinction between field and factory wiring. Field wiring includes plugs with cables or cables for connecting field components, i.e. all wiring is external.

Note: this is not a mandatory requirement. Plugs in accordance with UL 1059 can be approved for factory wiring only, which means the rotation test and extraction test are not required.



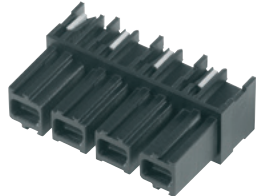
For factory wiring, the connection strip or terminal is designed for installation in a device. This means that the fixing and wiring or even the soldering by the manufacturer of the device occurs internally, i.e. inside the device.

The selection of components, such as plug-in connectors and male headers, is based on the manufacturer information, which must be specified in accordance with UL 1059. One example, the requirements are: rated voltage 600 V, rated current 35 A max. and UseGroup C (industrial application). In the ideal scenario, both components should meet the requirements specified. However, if only the plug-in connector meets the requirements and the male header does not, then approval is not possible.

Field wiring



Factory Wiring

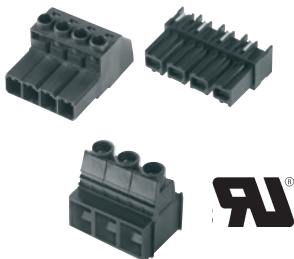


The clearance and creepage distance normally help the plug to meet the requirements for 600 V

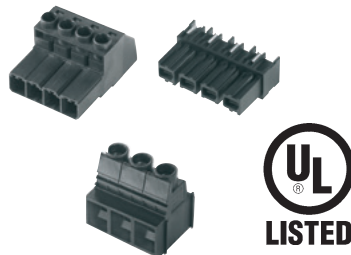
The clearance and creepage distance do not help the male header to meet the requirements for 600 V

In this case, the components can be approved as a device in accordance with the requirements for a device, i.e. device approval applies instead of component approval. A component can be approved in accordance with device norm UL 61800-5-1 if the necessary requirements are fulfilled. So different clearance and creepage distances allow for UL 600 V component usage.

Component approval



Device approval



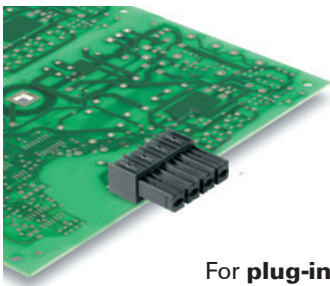
Approval of the components in accordance with UL 1059

Inspection of the components for the controlled drives in accordance with the UL 61800-5-1 device standard

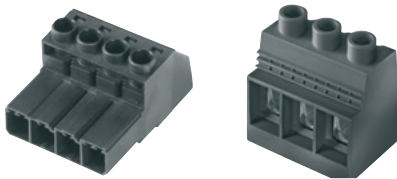
5. Effectiveness of device approval

For components in accordance with UL 61800-5-1

For device approval in accordance with UL 61800-5-1, various requirements must be fulfilled. For printed circuit board headers, evidence of the requisite clearance and creepage distances must be provided in the form of measurements.



For **plug-in connectors** and **PCB terminal blocks**, the connection system must feature splice protection and the requisite clearance and creepage distances must be evidenced by means of measurements.



But a consideration based on UL 61800-5-1 alone does not lead to a component listing!

5.1. Systematic procedures when selecting components for devices in accordance with UL 600V

As mentioned above, the essential principle is that, because the rules for UL certification are stricter than those for certification based on IEC standards, products should be developed to meet UL standards from the outset. By the same token, products which already have UL registration take priority.

Underwriters Laboratories (UL) advertise a service on their official website (<http://ul.com/>) whereby users can find out about the status (listed or unlisted) of a component free of charge. The manufacturer name and certificate number (cURus) are required. At Weidmüller, this information can be found in the online catalogue under "nominal data as per UL 1059".

5.2. Procedure for component listing

One example - the following product information is provided: overvoltage category III, 600 V and pollution severity 3.

Component requirements

All components must have approval in accordance with UL 1059. This guarantees the general technical data and is registered with UL. As mentioned above, the general technical data can be viewed in the UL file.

From a design perspective, the wire entry for plug-in connectors and PCB terminal blocks must be designed to prevent splicing of individual strands during the wiring process.

Details on material are also saved in the UL Yellow Card. This represents a classification of the insulation group of the insulation material based on the CTI value (Comparative Tracking Index). The CTI value is standardised for voltages of up to 600 V.

Example of a device specification



Component approval according to UL 1059:

(Ensure general technical data)
File no.: E60693

Wire entry - Protection against splicing strands according to:

UL 61800-5-1,
section 4.3.6.4DV.1.1.1
UL 61800-5-1,
section 4.3.6.5DV.1

Specification of insulating material:

UL yellow card:

Index 0 = CTI ≥ 600

UL 61800-5-1,
section 4.3.6.5.2

Rated values according to UL 1059

Institute (UR)



Certificate No. (UR) E60693

Rated voltage	(User group B)	300 V
Rated voltage	(User group C)	150 V
Rated voltage	(User group D)	600 V
Rated current	(User group B)	65 A
Rated current	(User group C)	65 A



UL Certification

Component - Plastics (guide info)

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str

Comparative Tracking Index (CTI):	0	Inclined Plane Tracking (IPT):	60 min at 1kV
Dielectric Strength (kV/mm):	-	Volume Resistivity (10 ¹² ohm-cm):	-
High-Voltage Arc Tracking Rate (HVTR):	0	High Voltage,	
Dimensional Stability (%):	-	Low Current Arc resis (0495):	6

4.3.6.5.2 Materials

Insulating materials are classified into four groups corresponding to their comparative tracking index (CTI) when tested according to 6.2 of IEC 60112:

- Insulating material group I	CTI ≥ 600;
- Insulating material group II	600 ≥ CTI ≥ 400;
- Insulating material group IIIa	400 ≥ CTI ≥ 175;
- Insulating material group IIIb	175 ≥ CTI ≥ 100.

Evidence of clearance distances

The clearance distance required is based on the UL classification of pollution severity (see Table 6 below), the overvoltage category (Table 7) and the impulse voltage (Table 9).

If the requirement is for pollution severity 3 and overvoltage category III for 600 V then the impulse voltage is therefore 6000 V.

In accordance with Table 9, the impulse voltage of 6000 V and the pollution severity of 3 result in a minimum clearance distance of 5.5 mm.

Example of a device specification



UL61800-5-1 – Table 6
Pollution degree 3

UL61800-5-1 – Table 7
Overvoltage categorie III for 600 Volt

UL61800-5-1 – Table 9
Clearance distance, Impulse voltage

Minimum clearance distance = 5,5 mm

Table 6 – Definitions of pollution degrees

Pollution degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs, Occasionally, however a temporary conductivity caused by condensation is to be expected, when the PDS is out of operation.
3	Conductive pollution or non-conductive pollution occurs, which becomes conductive due to condensation, which is to be expected.
4	The pollution generates persistent conductivity caused, for example by conductive dust or rain or snow.

Table 7 – Insulation voltage for low voltage circuits

Column 1	2	3	4	5	6
System Voltage (4.3.6.2.1) (V)	Impulse voltage (V)				Temporary Overvoltage (crest value / r.m.s.) ^a (V)
	Overvoltage Categorie				
	I	II	III	IV	
≤ 50	330	500	800	1500	1770 / 1250
100	500	800	1500	2500	1840 / 1300
150	800	1500	2500	4000	1910 / 1350
300	1500	2500	4000	6000	2120 / 1500
600	2500	4000	6000	8000	2550 / 1800
1000	4000	6000	8000	12000	3110 / 2200

NOTE 1 Interpolation is not permitted

NOTE 2 The last row only applies to single-phase systems, or to the phase-to-phase voltage in three phase system.

^a These values are derived using the formula (1200 V + SYSTEM VOLTAGE) from IEC 60664-1.

Table 9 – Clearance distances

Column 1	2	3	4	5	6
Impulse voltage (Table 4, Table 5) (V)	Temporary overvoltage (crest value) for determining insulation between surroundings an circuits or working voltage (recurring peak) for determining functional isolation (V)	Working voltage (recurring peak) for determining insulation between surroundings and circuits (V)	Minimum clearance mm		
			Pollution degree		
			1	2	3
N/A	≤ 110	≤ 71	0,01	0,20 ^a	0,80
N/A	225	141	0,01	0,20	0,80
330	340	212	0,01	0,20	0,80
500	530	330	0,04	0,20	0,80
800	700	440	0,10	0,20	0,80
1500	960	600	0,50	0,50	0,80
2500	1600	1000	1,5		
4000	2600	1600	3,0		
6000	3700	2300	5,5		
8000	4800	3000	8,0		
12000	7400	4600	14		
20000	12000	7600	25		

Evidence of creepage distance

The creepage distance can be derived from Table 10 of UL 61800-5-1.

The required creepage distance can be determined based on both the classified pollution severity and the material group (CTI value). So, for a CTI value > 600 for a pollution severity of 2, the minimum creepage distance is 3.2 and for pollution severity 3, the minimum creepage distance is 8.0 mm.

Attention: since the creepage distance is less than the clearance distance for pollution severity 2, the creepage distance needs to be increased to the clearance distance. So a creepage distance of 5.5 mm applies.

Example of a device specification		Table 10 – Creepage distances (mm)												
		Column 1	2	3	4	5	6	7	8	9	10	11	12	
UL61800-5-1 - Table 10		Working voltage (r.m.S.)	PWBs ^a			Other insulators								
Pollution degree 2			Pollution degree			Pollution degree								
Pollution degree 3		(V)	1	2	1	2				3				
Material group I (CTI 600)			b	c	b	Insulating material group				Insulating material group				
						I	II	IIIa	IIIb	I	II	IIIa	IIIb	
	≤ 2	0,025	0,04	0,056	0,35	0,35	0,35	0,87	0,87	0,87				
	5	0,025	0,04	0,065	0,37	0,37	0,37	0,92	0,92	0,92				
	10	0,025	0,04	0,08	0,40	0,40	0,40	1,0	1,0	1,0				
	25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25				
	32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3				
	40	0,025	0,04	0,16	0,56	0,80	1,1	1,4	1,6	1,8				
	50	0,025	0,04	0,18	0,6	0,85	1,20	1,5	1,7	1,9				
	63	0,04	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0				
	80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1				
	100	0,10	0,16	0,25	0,71	1,0	1,4	1,8	2,0	2,2				
	125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4				
	160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5				
	200	0,40	0,63	0,42	1,0	1,4	2,0	2,5	2,8	3,2				
	250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0				
	320	0,75	1,6	0,75	1,6	2,2	3,2	4,0	4,5	5,0				
	400	1,0	2,0	1,0	2,0	2,8	4,0	5,6	5,6	6,3				
	500	1,3	2,5	1,3	2,5	3,6	5,0	7,1	7,1	8,0				
	630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0				
	800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5				

Minimum creepage distance Pollution degree 2 = 3,2 mm / Pollution degree 3 = 8,0 mm

If creepage distance < Clearance distances then clearance distances = Creepage distance
i.e. a defined creepage distance of 5,5 mm

6. Summary

Global certification of electronic components and devices

Before they are launched on the market, electronic components and devices are checked for safety. The leading global organisations for the certification of product safety are Underwriters Laboratories (UL) and the International Electrotechnical Commission (IEC). In many cases, there are substantial differences between the standards, which makes global product approval more difficult. In general, the requirements for UL are stricter than those for the IEC. So when developing devices for the global market, the aim is therefore to consider the requirements of the UL standards as priority.

In general, UL makes a distinction between field and factory wiring. This differentiation is important for the certification of connection systems. Field wiring covers, for example, connectors and terminals with cables or lines for the connection of field components which can also be operated by non-specialists. These components are approved in accordance with UL 1059. Factory wiring components are fitted into an end device under factory conditions. Factory wiring components include plug-in connectors which are attached or soldered to a PCB and fitted into a device during the device manufacturing process.

When developing the device, device connectivity components are used as external connection components. Device connectivity components are subject to the UL 1059 standard. Depending on the purposes, this standard sets out different requirements. To do this, they are broken down into use groups (A, B, C and D). They differ in terms of the clearance and creepage distances required and the limits of the rated voltages. Standards UL 1059C and UL 1059D apply in industrial environments. In the event of certification in accordance with Use Group D, a maximum of 15 A cannot be exceeded at 51 V to 150 V, with 10 A for 151 to 300 V and 5 A for 301 V to 600 V, in order to guarantee safety despite reduced clearance and creepage distances compared to Use Group C.

Components can also be approved with deviations to UL 1059. This then involves device approval. Deviant to component approval to UL 1059, factory and field wiring with splice protection allows for smaller clearance and creepage distances according to UL 61800-5-1.

An end device can also be approved in accordance with UL 600 V for smaller dimensions of PCB plug-in connectors and terminal blocks where their component approval is not for 600 V in accordance with UL 1059.

Approved components can be found on the UL website by entering the manufacturer file number.

Today, the aim is to produce electrical electronic products which meet the requirements for increasing packing density and complexity, use state-of-the-art technology and also meet the various regulations and requirements. The solutions offered by Weidmüller are globally applicable concepts and largely exceed these requirements by some way.

More information:

► www.weidmueller.com/omnimate

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Co-author of the white paper

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