Safety Standards for Photocouplers

Overview

This document explains frequently used terminology and examples from component and equipment safety standards for photocoupler products.

Content

Photocouplers are devices that provide important functionality in the form of electrical insulation. They consist of a light-emitting element and a light-receiving element packaged together through an optically transparent insulator. Photocouplers are commonly used in switching power sources in office equipment such as printers and household appliances such as LCD televisions, for signal transmission between the primary and secondary sides of the power supply. Photocoupler designs are subject to the requirements of safety standards for electrical shock prevention. Standards vary from country to country but all are based on the relevant international standards. The most commonly quoted standards are VDE and DIN in Germany and the UL standard in the United States. This document provides a general overview of safety standards.

1. Structure of standards

International standards in fields such as electrical, electronics and communications are set out by the IEC (International Electrotechnical Commission). Regional standards are modified versions of IEC standards and specifications that take account of local variations such as voltage. Safety standards at the national level are based on the IEC standards and/or regional standards, as shown in Figure 1.1, and are administered by local certification authorities. The application process for certification involves testing in accordance with the relevant standard.

Global IEC standards: global standards drawn up and agreed upon by IEC (International Electrotechnical Commission) member nations

Regional standards: applicable to a general region; based on IEC standards, tailored to regional conditions (e.g. EN (European Norm) in Europe)

National standards: applicable to particular nations or territories; based on IEC and regional standards, tailored to local conditions (e.g. UL in the United States, DIN in Germany)

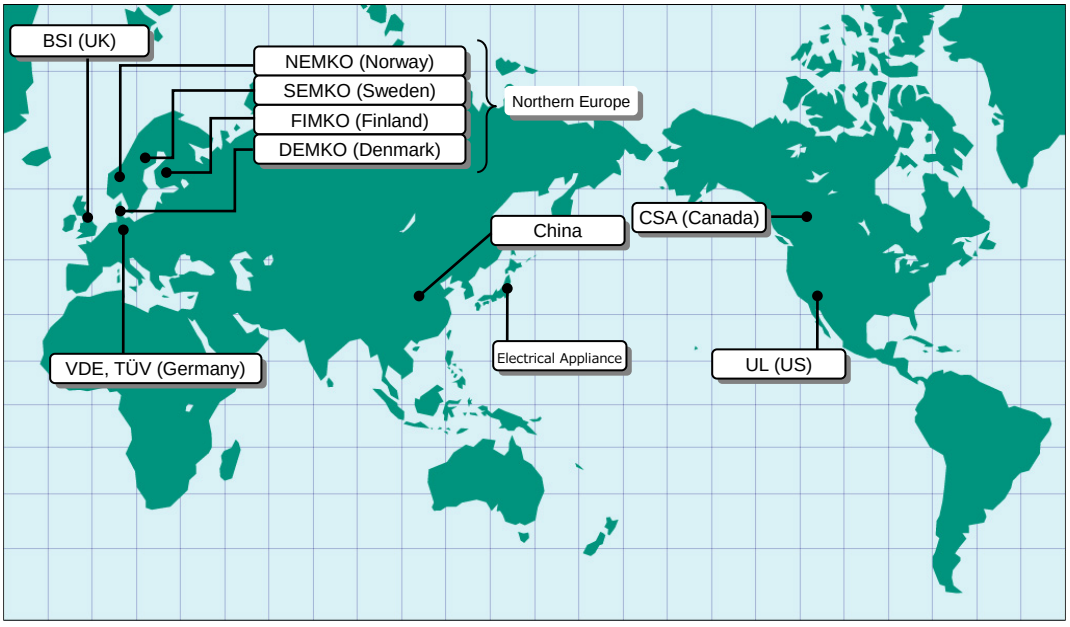


Figure 1.1 Major certification authorities and associated standards

A brief overview of the major certification authorities in the world is provided below.

UL (Underwriters Laboratories Inc.) compiles safety standards and provides related testing and certification services on everything from production materials through to finished products. The UL logo is displayed on products that comply with UL product safety certification requirements. UL certification is required on virtually all imported electric products and products with electrical components in the United States. The UL standard for photocoupler devices, UL 1577, defines insulation performance in terms of the probability of dielectric breakdown under high-voltage load.

CSA (Canadian Standard Association) compiles safety standards for electrical equipment and devices within Canada. Under provincial laws, electrical equipment connected to commercial power must be compliant with CSA standards. A Multi Recognition Agreement (MRA) between Canada and the United States allows mutual recognition of standards in both countries. Thus, CSA approved products made for Canadian markets are accepted by UL for distribution in the United States, bearing the cUL logo. Many Toshiba photocoupler devices are cUL certified.

VDE (Verband Der Elektrotechnik Elektronik Informationstechnik e.V, or Association of German Electrical Engineers) is a private-sector agency in Germany that provides compliance testing and certification services in accordance with its own VDE standards as well as government standards such as DIN. The DIN standard for photocoupler devices, DIN EN 60747-5-5 (formerly DIN VDE 0884), uses the partial discharge test to evaluate photocoupler insulation performance. VDE certified Toshiba photocouplers are compliant with EN 60747-5-5, and many also have additional certification options such as EN 60065, EN60950-1 or EN 62368-1.

SEMKO (Svenska Elektriska Materialkontroll Anstalten or Sweden Electric Equipment Testing and Appraisal Institution) is the agency in charge of standards and certification services for electrical products in Sweden. Toshiba photocoupler products with EN 60065 and EN 60950-1 certification are SEMKO compliant.

CQC (China Quality Certification Center) is the Chinese government agency responsible for testing and approval of compliance with Chinese standards, primarily under the CCC (China Compulsory Certifcation) scheme for imported products. Toshiba photocouplers such as GB4943.1 (IEC 60950-1 MOD*) and GB8898 (IEC 60065 MOD*) are CCC certified.

* MOD denotes a modified version of the IEC standard. This is permitted in cases where the local standard is structured in the same way as the international standard to allow direct comparison so that revisions to technical content can be readily identified.

2. Component and equipment standards

Safety standards for design and manufacture are broadly divided into component standards and equipment standards. Table 2.1 lists the major component and equipment standards applicable to photocouplers.

Equipment standards consider the overall safety of a piece of equipment or device in its entirety. Typical examples are IEC 60950-1 for IT equipment and devices (including office equipment) and IEC 60065 for audio and video equipment. Country-specific standards (for example, DIN EN 60950-1 in Germany) are generally aligned with the relevant IEC and/or EN standard. IEC 60950-1 and IEC 60065 stipulate the level of insulation or physical separation between components that are isolated from one another; where photocouplers are used for insulation, these must be certified via testing.

Table 2.1 Major component and equipment standards applicable to photocouplers

Safety standards		IEC	EN	Country-specific standards
Equipment standards	IT equipment	IEC 60950-1	EN 60950-1	DIN EN 60950-1, BS EN 60950-1, GB4943.1, etc.
	Audio and video equipment	IEC 60065	EN 60065	DIN EN 60065, BS EN 60065, GB8898, etc.
	IT equipment (IEC60950/IEC60065 combined)	IEC 62368-1	EN 62368-1	-
	Household electrical appliances	IEC 60335-1	EN 60335-1	-
	Inverters	IEC 61800-5	EN 61800-5	-
	Solar power systems	IEC 62109-1	EN 62109-1	-
	Industrial controllers	IEC 61010-1	EN 61010-1	-
	Low-voltage systems	IEC 60664-1	EN 60664-1	-
Component standards	Photocouplers	-	-	UL1577* CSA component acceptance notice No.5A (CA5A)*
		IEC 60747-5-5	EN 60747-5-5	DIN EN 60747-5-5

* UL1577 and CA5A have different insulation testing standards to IEC60747-5-5.

IEC 60950-1 : Information technology equipment - Safety - Part 1: General requirements
IEC 60065 : Audio, video and similar electronic apparatus - Safety requirements
IEC 62368-1 : Audio/video, information and communication technology equipment - Part 1: Safety requirements
IEC 60335-1 : Household and similar electrical appliances - Safety - Part 1: General requirements
IEC 61800-5-1 : Adjustable speed electrical power drive systems - Part 5-1: Safety requirements - Electrical, thermal and energy

IEC 62109-1 : Safety of power converters for use in photovoltaic power systems - Part 1: General requirements

IEC 61010-1 : Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements

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

IEC 60747-5-5 : Semiconductor devices - Discrete devices - Part 5-5: Optoelectronic devices – Photocouplers

Component standards apply to individual components such as photocouplers. Commonly used photocoupler standards include UL 1577 and IEC 60747-5-5. These two standards differ quite significantly with respect to definitions of insulation performance testing between input and output terminals and also compliance requirements. While component standards are normally independent of equipment standards, in some cases there is a degree of overlap and exemptions may apply. For example, the equipment standard IEC 60950-1 normally requires 0.4 mm of insulation thickness in the coupler for reinforced insulation, but this requirement is waived if the photocoupler components are compliant with the component standard IEC 60747-5-5. Section 3 below discusses the requirements in more detail.

As we will see in Section 3.2, component standards such as IEC 60747-5-5 use the partial discharge test. Industrial equipment standards such as IEC 61800-5, IEC 62109-1 and IEC 61010-1 are likewise based on partial discharge testing, which means that photocouplers used in industrial equipment should be compliant with partial discharge test requirements.

Compliance with safety standards is evaluated by national testing and accreditation bodies, which are also responsible for issuing certifications. Table 2.2 lists the main safety standards used for accreditation of photocoupler components. The safety standards vary by product depending on how the component is used. For product selection purposes, the applicable standards are listed on the Toshiba Electronic Device & Storage Corporation website and on the relevant product data sheets.

Table 2.2 Main safety standards for photocouplers

Accreditation agency	Safety standards	Description
UL	UL 1577 CA5A (cUL)	Based on insulating resin properties such as dielectric strength and flame resistance
VDE	DIN EN 60747-5-5 EN 62368-1	Based on partial discharge test
CQC	GB4943.1 GB8898	Based on insulation distance and insulation resistance/dielectric strength test
SEMKO	EN 60950-1 EN 60065 EN 62368-1	

3. Safety standards

This section provides a general overview of UL 1577 and EN 60747-5-5, the main component standards applicable to photocouplers, as well as the equipment standards IEC 62368-1 and IEC 60335-1, which are typically used on products containing photocouplers.

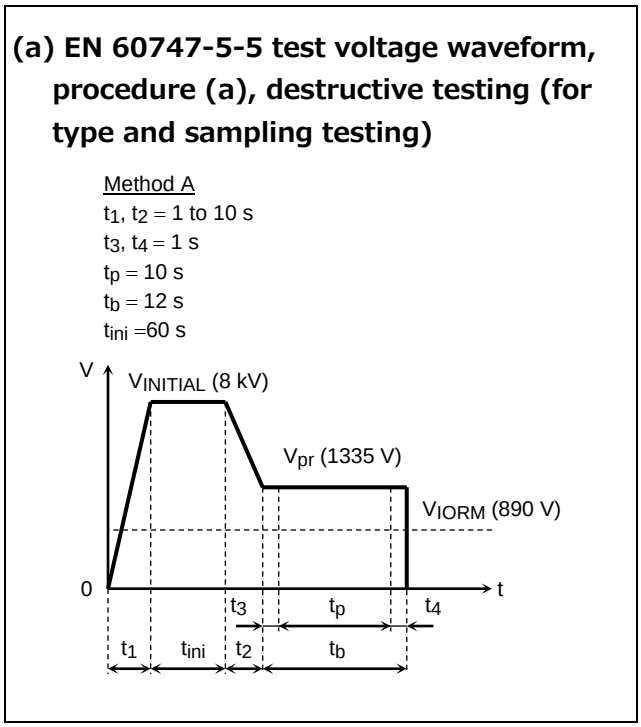
3.1 UL 1577

UL 1577 uses the dielectric strength test method to assess dielectric breakdown characteristics under high-voltage load. Generally this involves applying an AC sinusoidal voltage at 50 Hz or 60 Hz for one minute and monitoring insulation performance between the input and output terminals. Note that there is no prescribed safety action for the voltage normally applied between the input and output terminals. Toshiba photocouplers are tested for isolation voltage BVs in accordance with UL 1577.

3.2 EN 60747-5-5/IEC 60747-5-5

EN 60747-5-5 uses the partial discharge test method to measure insulation performance under high-voltage load. Electric charge from partial corona discharge should be no greater than 5 pC. For example, in a 100% test on photocoupler components using the voltages shown in Figure 3.1(b), electric charge should be below 5 pC. Thus, the partial discharge test must be used on EN 60747-5-5 compliant products. For Toshiba photocouplers, this test has been incorporated in addition to the standard load testing regimen.

(a) EN 60747-5-5 test voltage waveform, procedure (a), destructive testing (for type and sampling testing)



(b) EN 60747-5-5 test voltage waveform, procedure (b), non-destructive testing (for 100% testing)

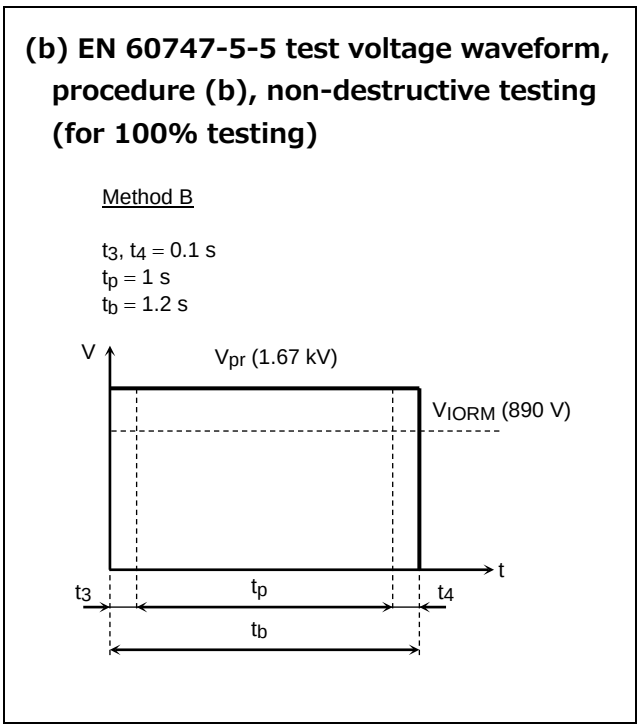


Figure 3.1 EN 60747-5-5 test voltage waveform (TLP701H)

Since EN 60747-5-5 certification requires a partial discharge test in addition to the standard load test, Toshiba has adopted the following position on EN 60747-5-5 certification:

(1) Products that comply with EN 60747-5-5 testing requirements are given consistent naming conventions for D4 and V4 options.
(2) Product names are consistent across all products with D4/V4 options, as shown in Table 3.1.
(3) D4 denotes packages with guaranteed creepage/clearance distance of at least 6.4 mm (such as DIP and SDIP) while V4 denotes surface-mounted packages with creepage/clearance distance of up to 5 mm (such as SO4, SO6 and MFSOP6).

Table 3.1 Naming conventions for D4 and V4 options

Example 1: DIP8 package
Standard TLP352 (TP1,F) → TLP352 (D4-TP1,F)
D4: EN 60747-5-5 option
TP1: taping specs
F : [[G]]/ RoHS compatible
Note: Use standard model name (as per previously) for multiple safety standard application.
Example: TLP352(D4-TP1,F) → TLP352

Example 2: SO6 package
Standard TLP2368 (TPL,E → TLP2368(V4-TPL,E
V4 : EN60747-5-5 option
TPL: taping specs
E : [[G]]/ RoHS compatible
Note: Use standard model name (as per previously) for multiple safety standard application.
Example: TLP2368(V4-TPL,E → TLP2368

3.3 IEC 62368-1

The IEC 62368-1 safety standard is designed to minimize the potential for electric shock and injury from digital equipment and devices during normal usage or maintenance procedures. Photocouplers are commonly used to provide insulation for safety purposes. Insulating components in electrical equipment are defined by physical parameters such as creepage/clearance distance. Requirements may vary depending on factors such as the operating environment and the nature of the insulating material. This is because the protection level of the equipment depends on the way it is used, as set out in IEC 60664-1. This is discussed in Section 4 onwards, along with details of the corresponding Toshiba photocoupler products.

3.4 IEC 60335-1

IEC 60335-1 is an equipment safety standard primarily intended for household electrical appliances. Table 3.2 lists insulation test voltages. The test voltage is a sinusoidal voltage at 50 Hz or 60 Hz applied for a period of one minute. Toshiba produces a wide range of photocouplers to suit the test voltages listed in IEC 60335-1.

Table 3.2 Insulation test voltage in IEC 60335-1

Rated voltage	Basic insulation	Supplementary insulation	Reinforced insulation
Safety extra-low voltage (SELV) <25Vac/60Vdc	500 Vac	–	–
≤130V	1000 Vac	1500 Vac	2500 Vac
＞130V	1000 Vac	2750 Vac	3750 Vac

4. Commonly used parameters and terminology in safety standards

The safety of an electrical device depends on factors such as the operating environment and voltage class. When selecting a photocoupler it is important to know the class of the electrical equipment and the parameter requirements. Safety standards are arranged in terms of parameters. This section describes the most important parameters with respect to compatibility between photocouplers and equipment standards, along with the associated terminology. Equipment standards frequently refer to or quote from IEC 60664-1, so IEC 60664-1 definitions will be used here.

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

4.1 Overvoltage category

Overvoltage is the phenomenon of a voltage in excess of the normal operating voltage reaching the electrical equipment from the AC main power source. The overvoltage level is governed by the voltage of the power source and the equipment status. There are four overvoltage categories for electrical equipment that denote the level of protection provided to installed equipment.

Overvoltage category I: Secondary circuit of equipment connected to hard-wired power outlet or equivalent

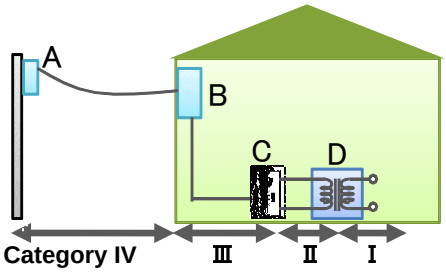
Overvoltage category II: Primary circuit of equipment connected to hard-wired power outlet or equivalent (such as common and household appliances)

Overvoltage category III: Equipment connected to building distribution board either directly or through a power outlet or equivalent (typically industrial equipment)

Overvoltage category IV : Equipment connected outside the distribution board, for instance to wiring between the pole transformer and the switchboard (such as power meters)

A higher overvoltage category indicates a greater risk of exposure to overvoltage. Overvoltage category IV applies to power meters and other equipment used in the place to contact with high-voltage power from transmission lines. Overvoltage category III denotes a lower risk of overvoltage, typically due to the presence of safety circuits on a building distribution board or

equivalent, and is intended for installed equipment such as air conditioners. Household appliances powered from a standard wall outlet, such as televisions and refrigerators, are normally classifed as standard overvoltage category II. Household appliances are generally not designed to withstand category III levels of overvoltage and therefore must not be connect to direct lines from the distribution board.



A: Pole-mounted transformer
B: Distribution board
C: Power outlet
D: Insulation

Figure 4.1 Overvoltage categories

Table 4.1 Rated impulse voltage

Mains voltage Vrms	Rated impulse voltage (V)			
	Category I	Category II	Category III	Category IV
50	330	500	800	1500
100	500	800	1500	2500
150	800	1500	2500	4000
300	1500	2500	4000	6000
600	2500	4000	6000	8000
1000	4000	6000	8000	12000

4.2 Pollution degree

The pollution level of the operating environment is similarly classified into four categories. Pollution creates a harsher opeating environment, necessitating higher insulation performance in terms of parameters such as creepage/clearance distance.

Pollution degree 1: Pollutants are either non-existent or present only in dry, non-conductive form;for example, potted and fully sealed devices that prevent ingress of dust and humidity.

Pollution degree 2: Pollutants are entirely non-conductive but could potentially be rendered conductive by condensation;for example, at the typical office or home environment.

Pollution degree 3: Either conductive pollutants are present, or condensation could cause dry, non-conductive pollutants to become conductive; for example, at a manufacturing facility.

Pollution degree 4: Conductive matter is present on an ongoing basis (such as dust particles, rain or snow); for example, in an outdoor environment.

4.3 CTI (Comparative Tracking Index)

Tracking refers to dielectric breakdown caused by repeated micro discharges forming a carbonized conductive path on the surface of the insulating material. IEC 60112 defines CTI as the maximum possible voltage before droplets of ammonium chloride solution on the surface of the insulating material cause tracking, under the given test conditions. IEC 60664-1 groups molded materials according to CTI value. Most Toshiba photocouplers use Group IIIa insulating materials.

Material Group I : $600 \leq CTI$
Material Group II : $400 \leq CTI < 600$
Material Group III a : $175 \leq CTI < 400$
Material Group III b : $100 \leq CTI < 175$

IEC 60664-1 : Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
IEC 60112 : Method for the determination of the proof and the comparative tracking indices of solid insulating materials

4.4 Types of insulation

The preceding three sections have described classification of environmental conditions affecting insulation performance. In IEC 60950-1 and some other standards, the insulation structure is divided into five classes as follows.

・Functional insulation: Minimum level of insulation required to ensure intended operation. Won't prevent electric shock but should reduce the likelihood of sparking.

・Basic insulation: Base level of protection from electric shock.

・Supplementary insulation: Additional independent insulation designed to mitigate the risk of

electric shock in the event of damage to the basic insulation.

・Double insulation: Combination of basic and supplementary insulation.

・Reinforced insulation: Single insluation layer deemed equivalent to double insulation in terms of protection from electric shock.

4.5 Insulation protection class

IEC 60950-1 and other standards use the following classifications for electric shock protection for electrical devices.

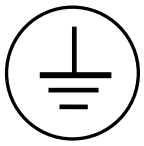
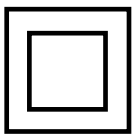
Class I: Provides basic insulation against electric shock as well as electrical earthing of all potentially conductive parts via earth conductor to provide a higher level of protection in the event of damage to the basic insulation.

Class II: Augments basic insulation against electric shock with a separate layer of either double insulation or supplementary insulation.

Class III: Uses a SELV power supply to ensure that voltage cannot cause electric shock.

Class I electrical equipment must be connected to protective earth. For permanently connected equipment, the protective earth terminal must be labeled as shown in Table 4.2. Class II equipment should be provided with supplementary insulation to prevent dangerous voltage in the event of damge to the basic insulation. Most but not all Class II equipment is labeled as such. For instance, some household appliances that are rated at AC 150 V or below and use the standard twin-prong power plug may be classified as Class 0 in Japan, and so are not labeled as Class II. Meanwhile, AC adaptors for laptop computers typically accept a wide range of voltages and are therefore Class II. Class III electrical equipment fitted with a SELV (Separated Extra Low Voltage) power supply is essentially incapable of causing an electric shock so the safety requirements do not apply.

Table 4.2 4.5 Insulation protection class marks

Class I protection earth	Class II
	

5. Structural parameters for photocouplers

The required physical separation for insulated parts varies depending on the operating environment and type of insulation, as we have seen. Table 5.1 and Figure 5.1 show the relevant structural parameters for photocouplers.

Table 5.1 Structural parameters for photocouplers

Parameter	Description
Isolation Voltage	Insulation performance between input and output terminals expressed as voltage
Creepage Distance	Shortest distance along the surface of insulating material between the two conductors (input and output)
Clearance Distance	Shortest distance in air clearance between the two conductors (input and output)
Insulation Thickness	Minimum thickness of insulating material between the two conductors (input and output)

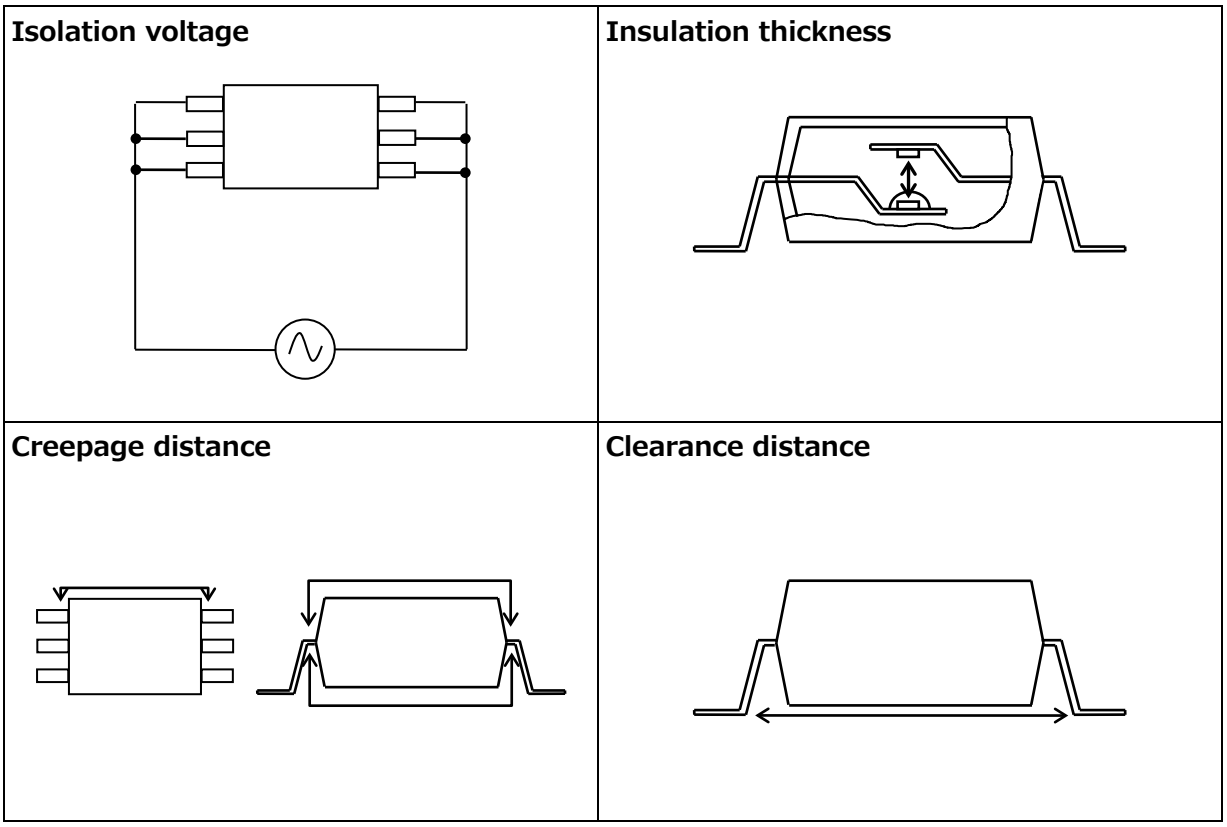


Figure 5.1 Structural parameters for photocouplers

5.1 Isolation voltage

Insulation should be able to withstand AC 50Hz/60Hz sinusoidal wave or DC voltage equivalent to peak value without deterioration in performance. The test voltage is governed by the type of insulation (typically basic or reinforced) and the operating voltage.

5.2 Clearance distance

Clearance distance and creepage distance are governed by a range of factors including installation category and pollution level mentioned earlier. The leading equipment standards for IT systems and industrial equipment stipulate minimum clearance distances corresponding to the overvoltage categories described in Section 4.1, based on definitions taken from IEC 60664-1. Table 5.2 shows clearances for IT systems from IEC 62368-1. The clearance distance is governed by factors affecting insulation performance; a greater distance is required in harsh operating environments. At high-altitude multiplier also comes into effect at altitudes of 2,000 m or more. In GB 4943.1-2011, the clearance distance high-altitude multipier is 1.48 for equipment used at altitudes in the range 2,000 – 4,999 m.

Table 5.2 Minimum clearance distance based on IEC 62368-1 definitions

(mm)

Overvoltage category	AC mains voltage Vrms	Basic insulation	Reinforced insulation
II (IT equipment)	**150**	0.5	1.0
	300	1.5	3.0
	400	3.0	5.5
III (industrial equipment)	**600 (includes 400 and 690)**	5.5	8.0

Pollution degree 2

5.3 Creepage distance:

For photocouplers, creepage distance is measured along outside the package, and is therefore governed to some extent by the CTI of the package material (or material group). Creepage distance should always be equal to or greater than clearance distance. Toshiba photocouplers are made from Group IIIa materials. Table 5.3 lists the minimum creepage distances for Group IIIa materials, as per the definitions in IEC 62368-1. Normally the clearance distance required for reinforced insulation is double the distance for basic insulation.

Table 5.3 Minimum creepage distance using IEC 62368-1 definitions

(mm)

Maximum working voltage Vrms	Basic insulation	Reinforced insulation
160	1.6	3.2
200	2.0	4.0
250	2.5	5.0
320	3.2	6.4
400	4.0	8.0
630	6.3	12.6
800	8.0	16.0

Note: Assumes Group IIIa materials and pollution degree 2; linear interpolation may be used for voltages that lie between the figures given above.

5.4 Insulation thickness:

The IEC 62368-1 equipment standard specifies a minimum insulation thickness of 0.4 mm for supplementary and reinforced insulation but no minimum for functional and basic insulation. Minimum insulation thickness requirements do not apply to products that are compliant with IEC 60747-5-5. Some other equipment standards give 0.4 mm as the minimum thickness. The vast majority of Toshiba products guarantee minimum 0.4 mm thickness, equivalent to reinforced insulation.

5.5 Creepage/clearance distance for typical photocouplers

The examples below are for Toshiba 5 Mbps class high-speed IC photocouplers. Compact package products include the MFSOP6 (TLP105) and the SO6 (TLP2355). Both of those have the same pin configuration and recommended pad dimensions for mounting; the SO6 has a guaranteed minimum creepage/clearance distance of 5 mm, 1 mm more than the MFSOP6. We offers a range of optimized SO6 packages that are intended for higher voltage classes than MFSOP6. For higher voltage classes again, there are the SO6L (TLP2745) and SO6L&LF4 lead forming (TLP2745(LF4)) with guaranteed creepage/clearance distance of 8 mm. Since all products deliver equivalent performance characteristics, the choice comes down to required product safety.

Table 5.4 Package type and creepage/clearance distance

Package	Product code	Creepage distance	Clearance distance	Insulation thickness
MFSOP6 	TLP105	4.0 mm	4.0 mm	-
SO6 	TLP2355	5.0 mm	5.0 mm	0.4 mm
SO6L 	TLP2745	8.0 mm	8.0 mm	0.4 mm
SO6L(LF4) 	TLP2745（LF4）	8.0 mm	8.0 mm	0.4 mm

Table 5.5 lists creepage distance, clearance distance and insulation thickness requirements in the IEC 62368-1 equipment standard, along with the recommended scope for the 5 Mbps class high-speed IC photocoupler product described in Table 5.4. The MFSOP6 (TLP105) is suitable at levels up to basic insulation, since it does not stipulate a minimum insulation thickness. The SO6 (TLP2355), meanwhile, has a guaranteed insulation thickness of 0.4 mm and is therefore compatible with reinforced insulation and systems operating at voltages of up to 250 Vrms. SO6 products allow greater flexibility with regards to potential system design changes in the future. In the case of reinforced insulation, SO6L TLP2745 can be used at system operating voltages up to 400 Vrms.

Table 5.5 Creepage distance, clearance distance and insulation thickness for IEC 62368-1 equipment standard and applicable scope for high-speed IC photocoupler product

Overvoltage category II, pollution degree 2, material group IIIa, reinforced insulation

Unit:[mm]

Maximum operating voltage Vrms	Creepage distance	Clearance distance	Insulation thickness	Recommended product
150	3.0	1.0	0.4	TLP2355
200	4.0	3.0	0.4	TLP2355
250	5.0	3.0	0.4	TLP2355
300	6.0	3.0	0.4	TLP2745
400	8.0	5.5	0.4	TLP2745(LF4)

6. Conclusion

This document provides a general overview of safety standards. Safety standards stipulate performance requirements for photocouplers, which can vary depending on the nature of the equipment operating environment and the operating voltage class. Note that the information provided in this document does not cover all installation and all situations, and that exceptions may apply. When selecting a photocoupler product, be sure to check the latest edition of the relevant safety standard for the equipment in which it will be used.

Revision history

Version	Date	Page reference	Details
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