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INTERNATIONAL STANDARD

Semiconductor devices –
Part 5-5: Optoelectronic devices – Photocouplers

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SEMICONDUCTOR DEVICES –

**Part 5-5: Optoelectronic devices –
Photocouplers**

FOREWORD

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International Standard IEC 60747-5-5 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition published in 2007 and Amendment 1:2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) optional data sheet basic insulation rating in accordance with IEC 60664-1:2007, 6.1.3.5;
b) editorial corrections on the use of V_{IORM};
c) editorial corrections on Figure 2: Time intervals for method b);
d) addition of an alternative surge pulse V_{IOSM} test method.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
47E/706/FDIS	47E/714/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts in the IEC 60747 series, published under the general title *Semiconductor devices*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SEMICONDUCTOR DEVICES –

Part 5-5: Optoelectronic devices – Photocouplers

1 Scope

This part of IEC 60747 specifies the terminology, essential ratings, characteristics, safety tests, as well as the measuring methods for photocouplers.

NOTE The term "optocoupler" can also be used instead of "photocoupler".

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-17, *Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing*

IEC 60068-2-20, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60216-1, *Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60672-2, *Ceramic and glass insulating materials – Part 2: Methods of test*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 62368-1:2018, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1
photocoupler
optoelectronic device designed for the transfer of electrical signals by utilizing optical radiation to provide coupling with electrical isolation between the input and the output

Note 1 to entry: Different types of photocouplers include ambient-rated or case-rated photocouplers, for signal-isolation applications.

3.1.1
DC input photocoupler
photocoupler consisting at the input of a photoemitter to which DC current is applied

3.1.2
AC input photocoupler
photocoupler consisting at the input of antiparallel photoemitters to which AC current is applied

3.1.3
phototransistor output photocoupler
photocoupler whose photosensitive element is a phototransistor

Note 1 to entry: Phototransistor is a transistor in which the current produced by the photoelectric effect in the neighbourhood of the emitter-base junction acts as base current, which is amplified.

3.1.4
photothyristor photocoupler
photocoupler whose photosensitive element is a photothyristor

Note 1 to entry: Photothyristor is a thyristor that is designed to be triggered by optical radiation.

Note 2 to entry: Gate terminal may or may not be provided.

3.1.5
phototriac output photocoupler
photocoupler whose photosensitive element is a phototriac and photocoupler whose photosensitive element is a phototriac and output is triac

Note 1 to entry: A phototriac is a triac that is designed to be triggered by optical radiation.

3.1.6
IC photocoupler
photocoupler whose photosensitive element is a photodiode/phototransistor and an integrated circuit

3.1.7
FET photocoupler
photocoupler with one or more field-effect transistors (FETs) in the output stage

Note 1 to entry: A FET is activated by photoemitter by direct optical radiation from a photoemitter.

3.1.8
photodiode photocoupler
photocoupler whose photosensitive element is a photodiode or photodiode array

3.1.9
IC input photocoupler
photocoupler whose input element consists of an integrated circuit and a photoemitter

3.1.10
solid state opto-relay
photocoupler whose output switches digitally without requiring a supply voltage

Note 1 to entry: The term "solid state opto-relay" includes photorelay, photothyristor photocoupler, phototriac photocoupler and FET/IGBT photocoupler.

3.1.11
current transfer ratio
$H_{\mathrm{f(ctr)}}$
ratio of the DC output current to the DC input current, the output voltage being held constant

Note 1 to entry: The abbreviated term CTR (DC) is sometimes used instead of a symbol.

3.1.12
small-signal short-circuit forward current transfer ratio
$h_{\mathrm{f(ctr)}}$
ratio of the AC output current to the AC input current, the output being short-circuited to AC

Note 1 to entry: The abbreviated term CTR (AC) is sometimes used instead of a symbol.

3.2
cut-off frequency
f_{co}
frequency at which the modulus of the small-signal current transfer ratio has decreased to $1/\sqrt{2}$ of its low-frequency value

3.3
input-to-output capacitance
C_{IO}
total capacitance between all input terminals or pins connected together and all output terminals or pins connected together

3.4
isolation resistance
R_{IO}
resistance between all input terminals or pins connected together and all output terminals or pins connected together

3.4.1
repetitive peak off-state voltage for phototriac output and/or solid state opto-relay with triac output
V_{DRM}
maximum applicable repetitive peak reverse voltage between anode and cathode in off-state under specified gate conditions

3.4.2
peak off-state current
I_{DRM}
forward leakage current between the off-state output terminals under specified conditions

3.4.3
peak on-state voltage
V_{TM}
peak forward voltage between on-state output terminals under specified conditions

3.4.4
DC off-state current
I_{BD}
forward leakage current between off-state output terminals under specified conditions

3.4.5
DC on-state voltage
V_{T}
DC forward voltage between on-state output terminals under specified conditions, when the specified forward current is applied between on-state output terminals

3.4.6
holding current
I_{H}
minimum on-state current in output to maintain the on-state under specified conditions

3.4.7
critical rate of rise of off-state voltage
dV/dt
rate of rise of off-state voltage just before the transition from off-state to on-state under the specified operating conditions

3.4.8
trigger input current
I_{FT}
minimum input forward current to switch from off-state to on-state in output under specified conditions

3.5
common mode transient immunity
CMTI
maximum tolerable rate of rise (or fall) of a common mode voltage (V_{CM}), the specification of which should include the amplitude of the common mode pulse (V_{CM}), which is applied across the two grounds of the photocoupler and should not exceed the maximum rated transient isolation voltage specification of the photocoupler as defined by the V_{IOTM}

3.6
photocoupler providing protection against electric shock
photocoupler which has been subjected to operating conditions (safety ratings) that exceed the specified ratings (limiting values) for normal operation

3.6.1
safety rating
<of a photocoupler> electrical, thermal, and mechanical operating conditions that exceed the specified ratings for reinforced isolation (limiting values) for normal operation, and to which the specified safety requirements refer

3.6.2
electrical safety requirement
<of a photocoupler> electrical requirements for reinforced or double insulation that have to be met and maintained after the photocoupler has been subjected to specified safety ratings, to ensure protection against electrical shock

Note 1 to entry: The photocoupler may become permanently inoperative when safety ratings are applied.

Note 2 to entry: For the definition of double and reinforced insulation, see 3.17.4 and 3.17.5 of IEC 60664-1:2007.

3.6.3
partial discharge
p_d
localized electrical discharge which occurs in the insulation between input and output terminals of the photocoupler

Note 1 to entry: For the technical details of partial discharge, see 3.1 of IEC 60270:2000.

3.6.4
apparent charge
q
electrical charge caused by a partial discharge in the photocoupler

3.6.5
threshold apparent charge
q_{TH}
specified value of apparent charge that is as small as technically feasible and to which measured values of the partial-discharge inception voltage or extinction voltage, respectively, refer

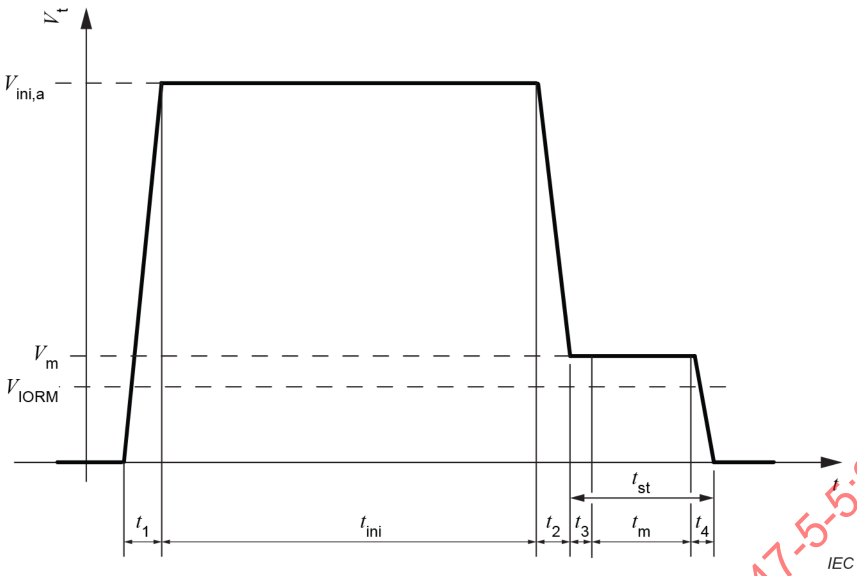
Note 1 to entry: A threshold apparent charge of 5 pC was found to be a practicable criterion for a photocoupler. Otherwise it should be defined on each individual device design. Smaller values are desirable but are not viable at this time.

Note 2 to entry: In actual tests, this criterion applies to the apparent charge pulse with the maximum value.

Note 3 to entry: The term "specified discharge magnitude" (see 3.18.2 of IEC 60664-1:2007) is synonymous with "threshold apparent charge".

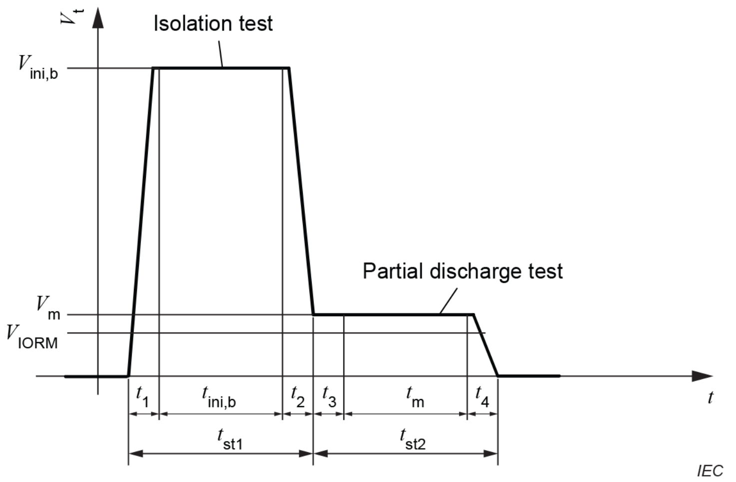
3.6.6
partial discharge test voltage
V_m
isolation voltage applied during the partial discharge test period

Note 1 to entry: Figure 1 and Figure 2 illustrate the related terms and letter symbols for methods a and b respectively.

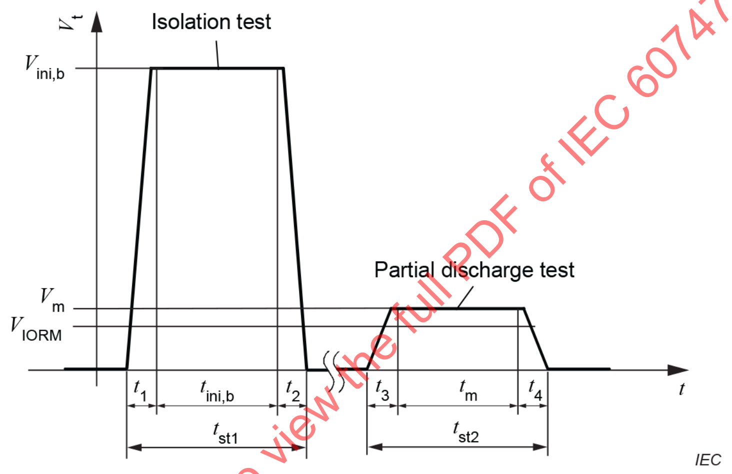


t_{ini}	initial time (method a) only)
t_{st}	(partial-discharge) stress time
t_m	(partial-discharge) measuring time
t_1, t_2, t_3, t_4	settling times

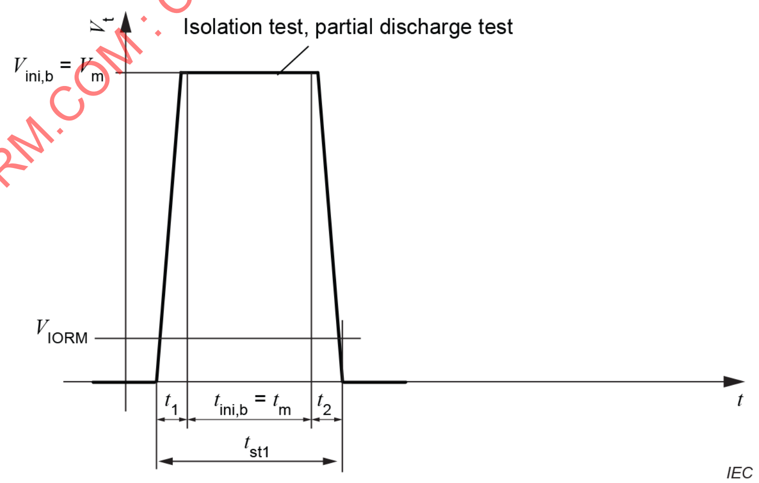
Figure 1 – Time intervals for method a)



Method b1)



Method b2)



Method b3)

$t_{ini,b}$	isolation test time (method b) only)	t_{st1}	isolation test stress time (method b) only)
t_{st2}	(partial-discharge) stress time	t_m	(partial-discharge) measuring time
t_1, t_2, t_3, t_4	settling times		

Figure 2 – Time intervals for method b)

Note 2 to entry: Specified values of this voltage may be expressed as a multiple of the specified value of the maximum working isolation voltage or maximum repetitive peak isolation voltage: $V_m = F \times V_{IOWM}$ if $V_{IOWM} \geq V_{IORM}$. ($V_m = F \times V_{IOWM}$ or $V_m = F \times V_{IORM}$, whichever is higher. Refer to 3.6.7 c) for multiplying factor.

Note 3 to entry: Test voltage, where the apparent charge has to be equal or less than the specified value.

3.6.7
initial test voltage

V_{ini}

test voltage applied during the initial test time t_{ini}

Note 1 to entry:

a) Initial voltage method a; $V_{ini,a}$, see Table F.1 of IEC 60664-1:2007 for minimum voltages; interpolation is also possible). The value of the voltage applied at the beginning of the measurement, for a specified time t_{ini}, which is intended to simulate the occurrence of a transient overvoltage.

b) Initial test voltage method b; $V_{ini,b}$, the isolation test voltage applied between the short-circuited input and the short-circuited output terminals at routine test (method b). A withstand voltage equal to the manufacturer's rating with a maximum of V_{IOTM}.

c) Multiplying factor: F in accordance with IEC 60664-1:2007, 6.1.3.5.1,

   at routine test stage: F = 1,875;

   at sample test stage and after the life tests, subgroup 1: F = 1,6;

   after endurance tests, subgroups 2 and 3: F = 1,2

Note 2 to entry: The initial test voltage is higher than or equal to the test voltage in the second part of the test period in which partial discharge characteristics are measured, see 3.6.6.

Note 3 to entry: For method a), the specified value for the initial test voltage is equal to the specified value of the maximum transient isolation voltage V_{IOTM}.

Note 4 to entry: For method b), the specified value for the initial test voltage (isolation voltage) is equal to or lower than the specified value of the maximum transient isolation voltage V_{IOTM}.

Note 5 to entry: The equivalent RMS value of the AC test voltage may also be used.

3.6.8
partial-discharge inception voltage

V_i

lowest peak value of the AC test voltage at which the apparent charge is greater than the specified threshold apparent charge, if the test voltage is increased from a lower value where no partial discharge occurs

Note 1 to entry: The equivalent RMS value of the AC test voltage may also be used.

3.6.9
partial-discharge extinction voltage

V_e

lowest peak value of the AC test voltage at which the apparent charge is smaller than the specified threshold apparent charge, if the test voltage is reduced from a higher value where such discharge occurs

Note 1 to entry: The equivalent RMS value of the AC test voltage may also be used.

3.6.10
maximum working isolation voltage

V_{IOWM}

RMS value of withstand voltage assigned by the manufacturer of the photocoupler, characterizing the specified (long term or the working voltage) withstand capability of its reinforced isolation

Note 1 to entry: The RMS voltage includes equivalent DC voltage.

3.6.11
maximum surge isolation voltage
V_{IOSM}
highest instantaneous value of an isolation voltage pulse of specified wave shape with short time duration, pulses of both polarities

Note 1 to entry: See Figure 3 for details on the test voltage.

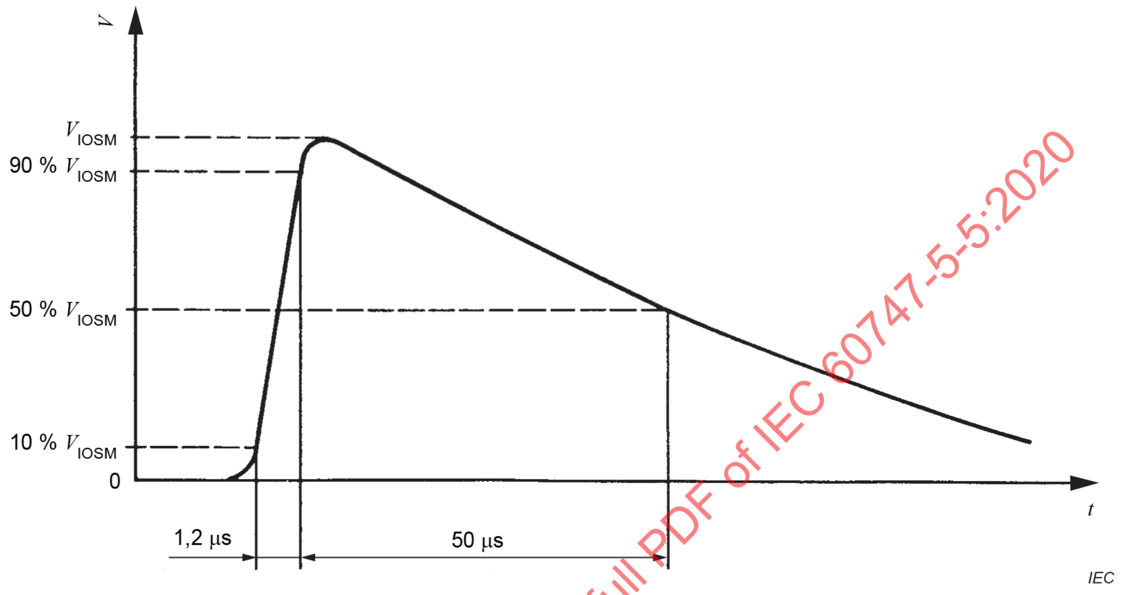


Figure 3 – Test voltage

3.6.12
DC isolation voltage
V_{IO}
value of the constant isolation voltage

3.6.13
repetitive peak isolation voltage
V_{IORM}
highest instantaneous value of the isolation voltage including all repetitive transient voltages, but excluding all non-repetitive transient voltages

Note 1 to entry: It is implied that this is a reinforced rating.

Note 2 to entry: A repetitive transient voltage is usually a function of the circuit. A non-repetitive transient voltage is usually due to an external cause and it is assumed that its effect has completely disappeared before the next non-repetitive voltage transient arrives.

3.6.14
maximum transient isolation voltage
V_{IOTM}
value of impulse withstand voltage assigned by the manufacturer of the photocoupler characterizing the specified withstand capability of its isolation against transient overvoltage

3.6.15
maximum withstanding isolation voltage
V_{ISO}
maximum withstanding isolation AC (RMS) voltage for 1 min

Note 1 to entry: The RMS voltage includes equivalent DC voltage. maximum transient isolation voltage.

3.7 Symbols for limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

$T_{stg\ min}$	minimum storage temperature
$T_{stg\ max}$	maximum storage temperature
T_{amb}	minimum or maximum ambient operating temperature
T_{ref}	minimum or maximum reference-point operating temperature
T_{sld}	maximum soldering temperature
V_R	maximum continuous reverse input voltage
V_{CBO}	maximum collector-base voltage
I_C	maximum continuous collector current
I_F	maximum continuous forward input current
I_{FM}	maximum peak forward input current
P_{max}	maximum power dissipation
P_{tot}	maximum total power dissipation of the package

4 Electrical characteristics

4.1 Phototransistor output photocoupler

See Table 1 for the electrical characteristics of the phototransistor output photocoupler.

Table 1 – Phototransistor electrical characteristics

	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
4.1.1	Input diode forward voltage	I_F specified		V_F		Max.
4.1.2	Input diode reverse current	V_R specified		I_R		Max.
4.1.3	Collector-emitter dark current or, where appropriate*, collector-base dark current	V_{CE} specified, I_F = 0, I_B = 0 (base open-circuit) V_{CB} specified, I_F = 0, I_E = 0		I_{CEO} I_{CBO}		Max. Max.
4.1.4	Collector-emitter dark current or, where appropriate*, collector-base dark current	V_{CE} specified, I_F = 0, I_B = 0, T_{amb} or T_{ref} specified V_{CB} specified, I_F = 0, I_E = 0 T_{amb} or T_{ref} specified		I_{CEO} I_{CBO}		Max. Max.
4.1.5	Collector-emitter saturation voltage or, where appropriate*, collector-base voltage	I_F and I_C specified, I_B = 0 I_F and I_C specified, I_B = 0		$V_{CE(sat)}$ V_{CB}		Max. Max.
4.1.6	Current transfer ratio	I_F or I_C and V_{CE} specified, I_B = 0		h_F or CTR (DC)	Min.	Max.
4.1.7	Where appropriate, differential current transfer ratio	I_F or I_C and V_{CE} specified, I_B = 0, frequency specified		h_f or CTR (AC)	Min.	Max.

	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
4.1.8	Isolation resistance between input and output	V_{IO} specified	1	R_{IO}	Min.	
4.1.9	Where appropriate, input-to-output capacitance	f = 1 MHz, I_F = 0, I_C = 0	1	C_{IO}		Max.
4.1.10	Where appropriate, switching times: turn-on time and turn-off time or: rise time and fall time	Specified V_{CC}, I_F and R_L, and nominal I_C, test circuit specified Specified V_{CC}, I_F and R_L, and nominal I_C, test circuit specified		t_{on} t_{off} t_r t_f		Max. Max. Max. Max.
4.1.11	Where appropriate, cut-off frequency	I_F or I_C and V_{CE} specified, I_B = 0	2	F_{co}	Min.	

* For operation in the diode mode.

All input terminals should be connected together and all output terminals should be connected together.

NOTE The cut-off frequency is the lowest frequency at which the magnitude of the AC current transfer ratio is 0,707 times its value at very low frequency.

4.2 Phototriac output photocoupler or solid state opto-relay

See Table 2 for the electrical characteristics of the phototriac output photocoupler or solid state opto-relay.

Table 2 – Phototriac electrical characteristics

	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
4.2.1	Peak off-state current	Peak off-state voltage (V_{DRM}) and T_{amb} specified		I_{DRM}		Max.
4.2.2	Peak on-state voltage	Peak on-state current (I_{TM}), input forward current (I_F) and T_{amb} specified		V_{TM}		Max.
4.2.3	DC off-state current	DC off-state voltage (V_{BD}) and T_{amb} specified		I_{BD}		Max.
4.2.4	DC on-state voltage	DC on-state current (I_T), I_B = 0, T_{amb} specified		V_T		Max.
4.2.5	Holding current	T_{amb} specified		I_H		Max.
4.2.6	Critical rate of rise of off-state voltage	Off-state voltage (V_D) and T_{amb} specified		dV/dt	Min.	Max.
4.2.7	Trigger input current	Supply voltage (V_D), load resistance, output terminal voltage and T_{amb} specified		I_{FT}	Min.	Max.
4.2.8	Isolation resistance between input and output	V_{IO} specified	See [a]	R_{IO}	Min.	

[a] All input terminals should be connected together and all output terminals should be connected together.

5 Photocouplers providing protection against electric shock

5.1 General

All requirements contained in this Clause 5 are valid for photocouplers whatever the configuration of the input and/or the output (phototransistor, IC output, phototriac, etc.).

5.2 Type

Ambient-rated or case-rated photocouplers designed to provide protection against electric shock when bridging double or reinforced insulation.

5.3 Ratings

5.3.1 Datasheet ratings

Ratings have to be mentioned in a special section in the manufacturer's datasheet.

5.3.2 Safety ratings

a) Maximum ambient safety temperature T_s

b) Maximum input current or maximum input power dissipation I_{SI} or P_{SI}

c) Maximum output current or maximum output power dissipation I_{SO} or P_{SO}

5.3.3 Functional ratings

Package related values: temperatures, total power dissipation.

Input and output related values: voltages, currents, power dissipation.

5.3.4 Rated isolation voltages

a) Maximum working isolation voltage V_{IOWM}

b) Maximum repetitive peak isolation voltage V_{IORM}

c) Maximum transient isolation voltage V_{IOTM}

d) Maximum withstanding isolation voltage V_{ISO}

5.4 Electrical safety requirements

In addition to the characteristics listed in this Clause 5, characteristics 1 to 7 in Table 3 (characteristic 8 of Table 3 is optional), are required to be on the manufacturer's datasheet. Basic insulation rating is determined by 100 % routine test at V_m = (V_{IORM} × 1,875), no additional test is required for basic insulation rating.

Table 3 – Datasheet characteristics

	Characteristics	Conditions	Notes	Symbol	Require-ments
1	Apparent charge (method a)	See 6.5		q_{pd}	Max.
2	Apparent charge (method b)			q_{pd}	Max.
3	Isolation resistance	100 °C ≤ T_{amb} ≤ T_{amb} max. V_{IO} = 500 V		R_{IO}	Min.
4	Isolation resistance (under fault conditions)	T_{amb} = T_S (see 6.3) V_{IO} = 500 V		R_{IO}	Min.
5	External clearance, External creepage distance	In accordance with IEC 60664-1:2007, Tables F.2 and F.4 or equivalent for minimum requirements (inhomogeneous field). Refer to related equipment standards for further requirements.		Symbols under consideration	Min. Min.
6	Comparative tracking index	See IEC 60112		....CTI	Min.
7	Maximum withstanding isolation voltage	AC voltage with commercial frequency for 1 min. Routine test for 1 s or 2 s is at 100 % or maximum 120 % of 1 min rating.		V_{ISO}	Max.
8	Maximum repetitive peak voltage for basic insulation	See IEC 60664-1. Maximum repetitive peak voltage for basic insulation rating = 1,25 × V_{IORM}.	See [a]	Symbols under consideration	Max.

[a] IEC 60664-1:2007, 6.1.3.5.1, based on pass criteria at V_m test voltage during t_1 measurement period.

The implied reinforced insulation rating (V_{IORM}) = V_m/1,875.

Basic insulation rating = V_m/1,5, therefore it follows that basic insulation rating = V_{IORM} × (1,875/1,5).

The basic insulation rating requirements are defined by the end product standard.

5.5 Electrical, environmental and/or endurance test information (supplementary information)

5.5.1 Test and test sequence

Refer to Table 4 and Table 5.

5.5.2 Routine test

At the routine test stage (method b), an isolation test according to 6.4 shall be performed followed by a partial discharge test according to 6.5. Both tests may be performed either on the same test equipment without delay (method b1) or on different test equipment with delay (method b2). The isolation test can be omitted if the partial discharge test is performed at $V_{ini,b}$ (method b3).

Any isolation tests either by the equipment or photocoupler manufacturer can be performed with voltages greater than or equal to test voltages defined in equipment standards (e.g. 4 kV RMS), but have to be equal to or lower than $V_{pd(ini),b}$.

5.5.3 Sample test

A sample test shall be performed once per quarter. See 2) in Table 4. A minimum sample of 20 devices shall be picked from a random production lot for each package type. The sample selection shall preclude pre-selection procedures.

Package types shall be significantly different in terms of package outline dimensions. The lead form option is not construed as a significant difference, for example, through hole or surface mounting device (SMD).

A production lot is defined here as the number of devices which have been produced using the same production line and production conditions. Examples of different package types are: DIP-4,-6,-8,…SOP-4,-6,-8,…, etc. Thus, if a manufacturer has five different package types then 20 samples each would be pulled for this sample test for a total of (5 × 20 = 100 photocouplers) per quarter. Multiple channels do not constitute a package type difference.

The purpose of this random testing per quarter is to monitor the quality of the manufacturing with respect to selected criteria.

The minimum sampling size of the total is $n = 80$. The failures shall be $c = 0$, i.e. there shall be no failures.

5.5.4 Type test

5.5.4.1 Type test requirements

A type test shall be performed with the different package types in one or more of the following items:

- Package materials relevant for insulation: mold materials, silicone gels, foils, etc.;
- Lead frame: if the new lead frame affects the external creepage distance or external clearance or thermal resistance of the package, thereby affecting I_{si} or P_{si} or I_{so} or P_{so};
- Package construction, for example change from single-mold coplanar to a double-mold coplanar package.

Any changes of one or more of the items in the dashed list above are considered major changes, which require a new type test.

The number of channels is not a consideration in determining a unique package platform.

The difference of a chip size is not considered for the type test as long as the safety limiting values are not affected.

Type tests shall include at least the following subgroups (5.5.4.3.1 to 5.5.4.7, inclusive), with the following conditions:

- zero failure shall be achieved;
- if one failure occurs out of the 130 devices, further quantities of devices shall be subjected to the subgroup (in which the failure occurred), with no more failures permitted.

NOTE Safety limiting values (I_{si}, P_{si}, I_{so}, P_{so}, T_s).

For components to provide safe electrical isolation, the requirements for satisfactory isolation have the first priority.

The safety limiting values are the maximum input current (I_{si}), or maximum input power (P_{si}), or maximum output current (I_{so}), or maximum output power (P_{so}), or the maximum ambient safety temperature (T_s) that are defined by the manufacturer for a photocoupler device that can be allowed in the event of a fault or a failure without causing the insulation of the device to breakdown.

The safety limiting values determine the maximum range of input or output power dissipations allowed over which, although the function of the coupling elements may be destroyed, the isolation specification of the photocoupler device remains intact. The maximum ambient safety temperature (T_s) is the highest enclosure temperature permitted in the event of a fault.

The requirement for isolation remains even when the operation of the photocoupler is no longer in existence due to the external electrical thermal stress, when for example:

1) the emitter diode becomes damaged;
2) the detector is damaged;
3) operation of the photocoupler is impeded by an external heat source (e.g. resistor).

The safety limiting values are governed by the materials and circuit design parameters adopted by the manufacturer, and the user should ensure that the safety limiting values are not exceeded, to make certain that the isolation resistance or insulation of the photocoupler remains intact. The user will ensure the safety limiting values are not exceeded through adequate safety arrangements in the circuit design and application conditions of the photocoupler, for example:

a) current limitation of the input/output circuit;
b) voltage limitation of the input/output circuit;
c) thermal management of the circuit, which ensures that the absolute maximum junction temperature or absolute maximum operating temperature as specified in the manufacturer's data sheet is not exceeded;
d) the surrounding circuit shall be ignition-resistant;

in the event of a fault or failure, the external current or voltage limiting safety mechanisms or methods shall ensure that the safety limiting values are not exceeded.

5.5.4.2 Preconditioning

Visual inspection	According to manufacturer's specification
Resistance to soldering heat	260 °C ± 5 °C, 5 s ± 1 s specified in IEC 60068-2-20, Test Tb, Method 1)

For photocouplers in SMD versions, the conditions according to IEC 60068-2-58 are applied with temperature T_{sld}.

Apparent charge	Method b1 $V_m = F \times V_{IORM}$ (V_{IOWM}), (see 3.6.7 c)) $V_{ini,b}$ (according to manufacturer's specification) $\leq V_{ini,a}$ $q_{pd} \leq 5$ pC
Parametric test	According to manufacturer's specification
Isolation resistance	$R_{IO} \geq 10^{11}$ Ω at V_{IO} = 500 V, t = 1 min, T_{amb}max.

5.5.4.3 Subgroup 1:20 samples

5.5.4.3.1 Tests

Preconditioning	See 5.5.4.2
Rapid change of temperature	In accordance with IEC 60068-2-14 T_{stg} (maximum and minimum temperature T_{stgmin}, T_{stgmax}), 10 cycles, dwell time 3 h
Vibration	In accordance with IEC 60068-2-6 Axes: 3 Frequency area: between 10 Hz and 500 Hz Transition frequency: 58 Hz Amplitude: 0,75 mm, 98 m/s^2 dependent on stress level Cycles: 10 cycles Criteria: no damage
Shock	In accordance with IEC 60068-2-27 Axes: 3 Wave form: Half sine wave Acceleration: 980 m/s^2 Shock duration: 6 ms Numbers: 3 shocks/axes Criteria: no damage
Sealing (not for plastic)	In accordance with IEC 60068-2-17 Pressure: 200 kPa Duration: 6 h Recover time: 0,5 h Maximum pressure: depending on manufacturer's specification
Dry heat	In accordance with IEC 60068-2-2 $V \geq V_{IORM}$ (min. 700 V), $T_{amb} = T_{amb}$max. (min. = 100 °C) Duration = 16 h
Accelerated damp heat	In accordance with IEC 60068-2-30 Method: 1 Temperature: 55 °C Cycles: 1
Storage temperature	In accordance with IEC 60068-2-1 2 h at T_{stgmin}
Damp heat (steady state)	In accordance with IEC 60068-2-78, 85 % RH at 85 °C, duration = 21 days

5.5.4.3.2 Final measurements

Dry samples for at least 1 h to 2 h before doing final measurements.

Apparent charge	Method a) F = 1,6 (see 3.6.7 c)) $q_{pd} \leq 5$ pC
Isolation resistance	$R_{IO} \geq 10^{12}$ Ω at V_{IO} = 500 V, t = 1 min, T_{amb} = 25 °C
Surge test (type test only)	The applied test pulse V_{IOSM} shall be identified by the manufacturer in the datasheet: Recommended pulse shape is 1,2 µs / 50 µs in accordance with IEC 61000-4-5. An alternative pulse shape is generated in accordance with IEC 62368-1:2018, Clause D.2, circuit 3. Number of discharges: 50 (25 pulses of each polarity) Voltage: 10 kV Cycles: maximum 12 discharges per minute
Isolation resistance	$R_{IO} \geq 10^{9}$ Ω at V_{IO} = 500 V, t = 1 min, T_{amb} = 25 °C

5.5.4.4 Subgroup 2: 30 samples

5.5.4.4.1 Tests or examination

Preconditioning	See 5.5.4.2
Input safety test	See Annex A At limiting values under fault conditions: Maximum input current or maximum input power dissipation, $T_{amb} = T_s$, duration: 72 h

5.5.4.4.2 Final measurements

Apparent charge	Method a) F = 1,2 (see 3.6.7 c)); $q_{pd} \leq 5$ pC
Isolation resistance	$R_{IO} \geq 10^{9}$ Ω at V_{IO} = 500 V, t = 1 min, T_{amb} = 25 °C

5.5.4.5 Subgroup 3: 30 samples

5.5.4.5.1 Tests or examination

Preconditioning	See 5.5.4.2
Output safety test	See Annex A At limiting values under fault conditions: At maximum output current or maximum output power dissipation; $T_{amb} = T_s$, duration: 72 h

5.5.4.5.2 Final measurements

See 5.5.4.4.2.

5.5.4.6 Subgroup 4: 40 samples – Examinations

Isolation resistance at:

T_{amb}max. (min. 100 °C),	$R_{IO} \geq 10^{11}$ Ω at V_{IO} = 500 V, t = 1 min
T_S	$R_{IO} \geq 10^{9}$ Ω at V_{IO} = 500 V, t = 1 min

5.5.4.7 Subgroup 5: 10 samples – Examinations

External clearance	In accordance with IEC 60664-1	
External creepage distance	In accordance with IEC 60664-1	
Flammability test	In accordance with IEC 60695-11-5	Time of application of the test flame
(type test only)		t = 10 s
		After burning time ≤ 30 s

5.5.4.8 Testing of insulating materials

5.5.4.8.1 Tracking resistance

The insulating materials employed and their tracking resistance are important factors in determining the rated insulation voltage for photocouplers. For evaluation of insulating materials and determination of the comparative tracking index (CTI), IEC 60112 shall be used.

$$\text{CTI} \geq 175$$

5.5.4.8.2 Limit temperature of insulating materials

The limit temperature of insulating materials is determined in accordance with IEC 60216-1 and IEC 60216-2.

It shall be greater than the maximum storage temperature T_{stgmax} but lower than or equal to the glass transition temperature T_g.

5.5.4.8.3 Ceramic materials

If ceramic materials are employed, IEC 60672-2 shall be complied with.

5.5.4.9 Marking, labels, information in datasheets

5.5.4.9.1 Minimum marking requirements

If it is not possible, for reasons of space, to accommodate the data in accordance with 5.5.4.9.2 on the component, the data may be given on the packing. The component shall, however, incorporate at least a mark, which gives a clear reference to the datasheet.

5.5.4.9.2 Data on the photocoupler

The following data shall be applied in a durable manner to the photocoupler, in the priority shown:

1) type identification which gives a clear reference to the datasheet;
2) manufacturer's mark;
3) terminal markings;
4) date code.

5.5.4.9.3 Information in datasheets

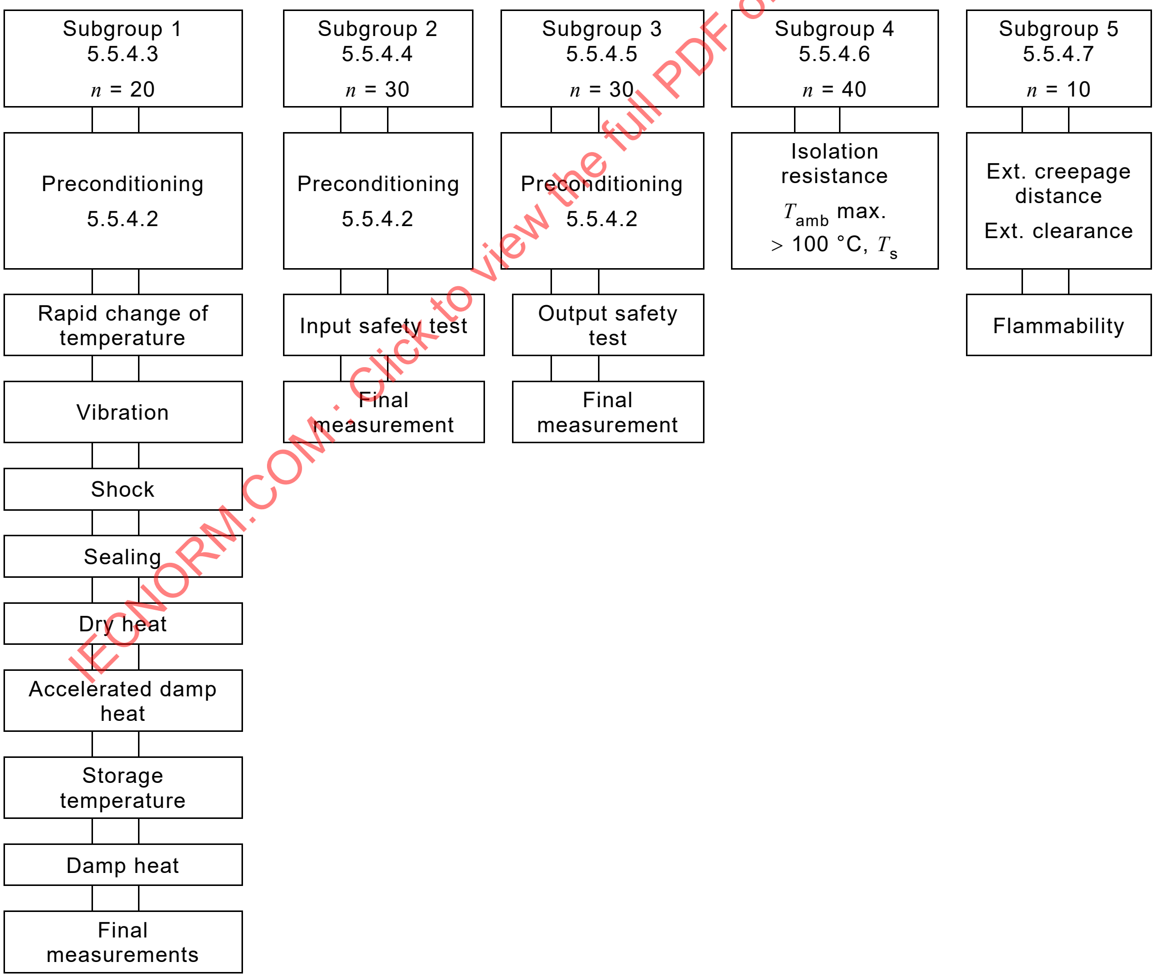
The datasheet shall include the following information:

- ratings, see 5.3;
- electrical safety requirements, see 5.4;
- characteristics;
- properties of the package (sealing);
- terminal arrangement;
- datasheet imprint:

  "This photocoupler is suitable for 'safe electrical insulation' only within the safety ratings. Compliance with the safety ratings shall be ensured by means of suitable protective circuits."

Table 4 – Tests and test sequence for photocoupler providing protection against electrical shock

1)	**Routine test (non-destructive), see 5.5.2**	
	1.1	Apparent charge magnitude at 1,875 × V_{IORM}, method b1), b2) or b3), q_c ≤ 5 pC, $V_{ini,b}$ ≤ $V_{ini,a}$ See 3.6.7 c)
	1.2	Parametric test according to manufacturer's specification
2)	**Sample test (destructive), *n* = 20 per platform, with minimum *n* = 80 in total, *c* = 0, see 5.5.3**	
	2.1	Visual inspection according to manufacturer's specification, see 5.5.4.2
	2.2	Resistance to soldering heat, see 5.5.4.2
	2.3	Apparent charge magnitude at 1,6 × V_{IORM}, method a), q_c ≤ 5 pC, $V_{ini,a}$, see 3.6.7 c)
	2.4	Parametric test according to manufacturer's specification
	2.5	Isolation resistance, see 5.5.4.2
	2.6	External creepage distance and clearance, *n* = 10, *c* = 0, see 5.5.4.7
	2.7	Isolation resistance at high temperatures, *n* = 40, *c* = 0, see 5.5.4.6 a) T_{amb}max.(min. 100 °C) b) T_s
3)	**Type test, destructive, *n* = 130, *c* = 0, see 5.5.4**	



Testing of insulating materials (type test only), see 5.5.4.8

Marking, labels, information in datasheets, see 5.5.4.9

Table 5 – Test conditions

Method a)	Parameter	Method b)
t_{in} = 60 s	Initial time	$t_{ini,b}$ = 1 s
$V_{ini,a}$	Initial voltage	$V_{ini,b} \leq V_{ini,a}$
$V_m = F \times V_{IORM}$ or V_{IOWM}	Apparent charge test voltage	$V_m = 1{,}875 \times V_{IORM}$ or V_{IOWM}
t_m = 10 s	Apparent charge measuring time	t_m = 1 s
t_{st} typically 1,2 s	Specified test time	t_{st1} typically 1,2 s t_{st2} typically 1,2 s
dV/dt during t_1, t_2 = 100 V/s to 1 000 V/s	Rate of rise/fall (V_{ini})	–
t_3, t_4 typ. 1 s	Transient recovery time	–
T_{amb} = 15 °C to 45 °C	Ambient temperature	T_{amb} = 15 °C to 45 °C
150 kHz $\leq f_o \leq$ 5 MHz	Centre frequency	150 kHz $\leq f_o \leq$ 5 MHz
$\Delta f \leq$ 15 kHz	Bandwidth	$\Delta f \leq$ 15 kHz
q_o = 5 pC	Calibration value	q_o = 5 pC
q_{min} = 1 pC	Smallest measurable value	q_{min} = 1 pC
q_{pd} = 5 pC	Apparent charge test limit	q_{pd} = 5 pC
$C_C \geq$ 1 nF	Coupling capacitor	$C_C \geq$ 1 nF
$V_m = F \times V_{IORM}$ or V_{IOWM} (F factor: see 3.6.7 c))		

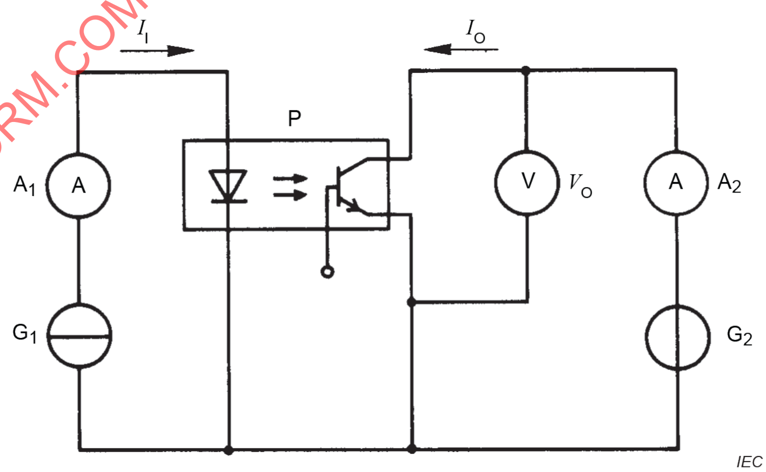
6 Measuring methods for photocouplers

6.1 Current transfer ratio $H_{f(ctr)}$

a) Purpose

To measure the static value of the forward current transfer ratio of photocouplers under specified conditions.

b) Circuit diagram, see Figure 4



P photocoupler being measured

Figure 4 – Measurement circuit

c) Circuit description and requirements

I_I input current = forward current I_F of the photoemitter

I_O output current = reverse current I_R of the photodiode or collector current I_C of the phototransistor

V_O output voltage = reverse voltage V_R of the photodiode or collector-emitter voltage V_{CE} of the phototransistor

A_1, A_2 = ammeters

G_1 = current source

G_2 = voltage source

d) Measurement procedure

The measurement shall be performed under standard atmospheric conditions, unless otherwise specified.

The constant current source G_1 is adjusted to obtain the specified input current through the photoemitter.

The voltage source G_2 is adjusted to the specified value V_R or V_{CE}. The output current I_R or I_C is measured with ammeter A_2.

The current transfer ratio is calculated by the following formulae:

$$H_{F(ctr)} = \frac{I_O}{I_F} \tag{1}$$

hence, for a photocoupler with photodiode output,

$$H_{F(ctr)} = \frac{I_R}{I_F} \tag{2}$$

and, for a photocoupler with transistor output,

$$H_{F(ctr)} = \frac{I_C}{I_F} \tag{3}$$

e) Precautions to be observed

If the photocoupler is sensitive to external radiation, the precautions to be taken in measurement should be stated and observed.

f) Specified conditions

– ambient temperature;

– input or output current, DC or pulse;

– output voltage (V_R or V_{CE});

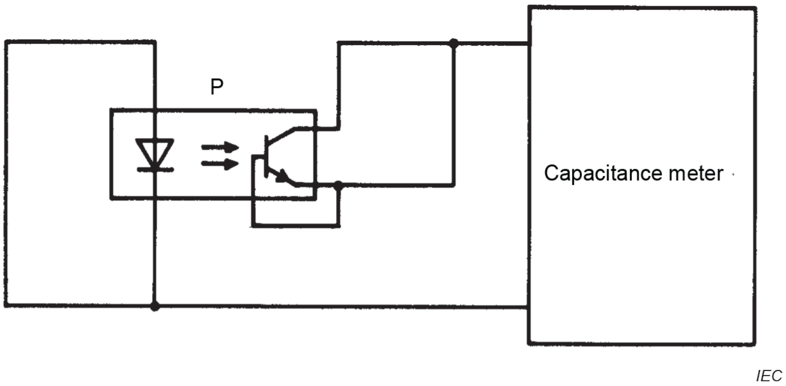
– the atmospheric conditions (when appropriate).

6.2 Input-to-output capacitance C_{IO}

a) Purpose

To measure the capacitance between the input and output terminals of a photocoupler under specified conditions.

b) Circuit diagram, see Figure 5



P Photocoupler being measured

Figure 5 – Measurement circuit for input to output capacitance

c) Measurement procedure

The photoemitter terminals are connected together and the photodetector terminals are connected together. The capacitance between the photoemitter and the photodetector terminals is measured at a frequency of 1 MHz (unless otherwise specified), using a suitable capacitance meter.

d) Precautions to be observed

Allowance should be made for the stray capacitance of the test fixture and the connecting leads.

e) Specified conditions

– ambient temperature;

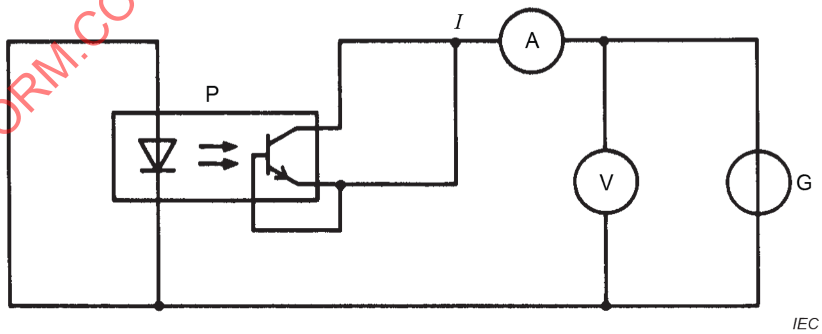
– measurement frequency, if different from 1 MHz.

6.3 Isolation resistance between input and output R_{IO}

a) Purpose

To measure the isolation resistance between the input and output terminals of a photocoupler when subjected to DC voltage, under specified conditions.

b) Circuit diagram, see Figure 6



P photocoupler being measured

G voltage source

Figure 6 – Measurement circuit for isolation resistance

c) Precautions to be observed

Allowance should be made for the leakage current of the test fixture and the leads.

d) Measurement procedure

The photoemitter terminals, as well as the photodetector terminals, are connected together.

The specified measurement voltage between the photoemitter and photodetector terminals is applied for 60 s. The isolation resistance is calculated as V/I.

e) Specified conditions

– ambient temperature;

– measurement voltage;

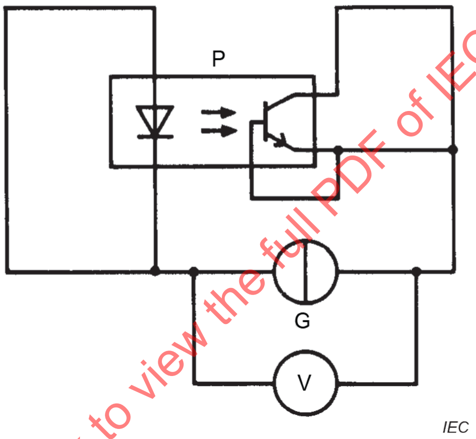
– time after which the measurement is performed, if different from 60 s.

6.4 Isolation test

a) Purpose

To verify the ability of the device to withstand the isolation test voltage (V_{ISO} or V_{IORM}) under specified conditions.

b) Circuit diagram, see Figure 7



P photocoupler under test

G voltage source

Figure 7 – Test circuit for withstanding isolation voltage

c) Test procedure

The test shall be carried out under the standard atmospheric conditions in accordance with 4.3 of IEC 60068-1:2013.

The device is inserted into the test socket. The photoemitter terminals, as well as the photodetector terminals, are connected together.

The DC or AC test voltage is increased from zero to the specified value.

The voltage is maintained for 1 min for type testing, and 1 s or 2 s at 100 % or maximum 120 % of the type testing voltage for routine testing.

d) Requirements

External or internal flash-over shall not occur during the test.

The device shall pass the post-test measurements.

e) Specified conditions

– isolation voltage (V_{ISO});

– test time (if different from 1 min);

– post-test measurements.

6.5 Partial discharges of photocouplers

a) Purpose

To verify the performance of insulation between input and output of a photocoupler by measuring the partial discharge level under specified conditions.

This test is non-destructive.

NOTE 1 For the definition of partial discharge, see 3.1 of IEC 60270:2000.

NOTE 2 Circuit diagram of partial discharge test, see Figure 8.

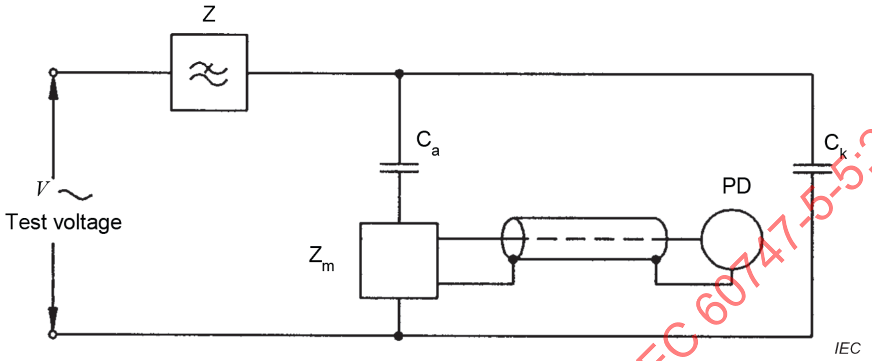


Figure 8 – Partial discharge test circuit

b) Description of the test circuit and requirements

(see also NOTES 3, 4 and 5)

1) Test circuit

The circuit consists mainly of:

C_a photocoupler under test which can be regarded as a capacitance;

C_k coupling capacitor bypassing partial discharge current;

Z_m measuring circuit consisting of the measuring impedance, the connecting lead, the surge limiting device and the measuring instrument;

PD partial discharge measuring instrument;

Z a low-pass filter to reduce interference from the source (see also NOTE 3).

2) Equipment characteristics

The peak value of the test voltage shall be measured. An RMS measuring instrument may be used provided that the distortion of the sine wave of the test voltage is less than 5 %.

The bandwidth of the partial discharge measuring equipment shall be less than 15 kHz.

The centre frequency shall be between 150 kHz and 2 MHz.

The resonance frequency of the test circuit shall be at least three times the centre frequency used (see also NOTE 3).

3) Coupling capacitor

The coupling capacitor shall be of a low-impedance design and the coupling capacitor shall not exhibit any partial discharges at the test voltage.

c) Test procedure

1) Calibration

i) General

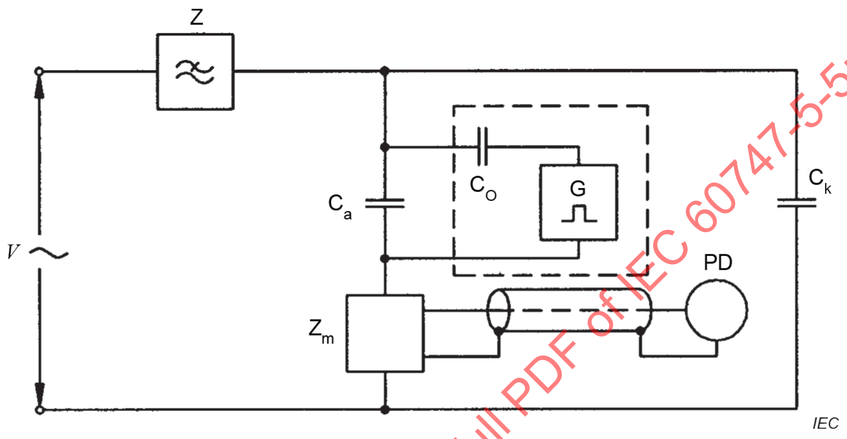
Calibration involves two separate procedures: one is a complete determination of the characteristics of the measuring instrument itself including a detailed calibration and should be performed after major repairs or at least once per year; the other is a routine calibration of the instrument in the complete test circuit and should be performed before every test or, if many identical test objects are being tested, then it may be performed at suitable times to be determined by the user. The latter calibration shall include a verification that the instrument, as used in the test circuit, shall be able to measure a partial discharge level of 1 pC (minimum).

ii) Calibration of partial discharge measuring instrument

The partial discharge measuring instrument is calibrated according to the instructions of the manufacturer of the instrument.

iii) Calibration of the instrument in the complete test arrangement

The calibration of the instrument in the complete test arrangement is made according to Figure 9.



C_o pulse generator capacitance

C_a photocoupler under test which can be regarded as a capacitance

G pulse generator

C_k coupling capacitor bypassing partial discharge current

Z_m measuring circuit consisting of the measuring impedance, the connecting lead, the surge limiting device and the measuring instrument

PD partial discharge measuring instrument

Figure 9 – Complete test arrangement connections for calibration

The calibration shall be repeated every day and for each device with a different design.

The pulse generator is adjusted so that the output pulse represents a charge of 5 pC.

The pulse of the calibration generator shall have a rise time of less than 50 ns. The delay time shall be between 100 µs and 1 000 µs.

The reading of the instrument should be at least half of full scale.

The pulse generator shall be removed before energizing the test circuit.

The test voltage is set to the highest applicable level relevant to the device under test.

The measuring instrument shall enable the reading described in c)2). For this verification of the test circuit noise level, C_a shall be free of partial discharge.

2) Test methods

The partial discharge basic noise level value shall not be subtracted from the partial discharge value of a specimen.

The partial discharge magnitude q_c is the instantaneous maximum read out value during the partial discharge measuring time interval t_m.

See 3.6.7 for time intervals and test voltages for test methods a), b1), b2) and b3).

The apparent partial discharge magnitude q_c of 5 pC was found to be a practicable criterion for photocouplers. Otherwise it should be defined on each individual device design.

i) Method a)

(See Figure 1). A voltage well below the expected inception value is applied to the test object and gradually increased to the specified value V_{ini} at which partial discharge is allowed.

The initial test voltage is maintained for the specified time (t_{ini}).

Thereafter, the test voltage is reduced to the value of the partial discharge test voltage (V_m).

The test voltage (V_m) is maintained for a specified time (t_{st}) during which the partial discharge magnitude is measured in a given time interval (t_m).

$V_{ini} = V_{IOTM}$ $V_m = F \times V_{IORM}$ ($F > 1$)

ii) Method b)

(See Figure 2). The partial discharge test voltage (V_p) is applied. This voltage is maintained for a specified time (t_{st}) during which the partial discharge magnitude is measured in a given time interval (t_m).

$V_m = F \times V_{IORM}$

d) Precautions to be observed

Unless otherwise stated, all applicable test voltages in this document are peak voltages.

e) Specified conditions (see Table 6)

Table 6 – Specified conditions for methods a) and b)

Parameter	Method a)	Method b)
Initial time t_{ini}	x	–
Initial voltage V_{IOTM}	x	–
Partial discharge test voltage V_m; $V_m = F \times V_{IORM}$	x	x
Partial discharge measuring time t_p	x	x
Stress time t_{st}	x	x
Settling time t_1, t_2, t_3, t_4	x	x
Ambient temperature T_{amb}	x	x

NOTE 3 Partial discharges in the test object cause charge transfer in the test circuit giving rise to current pulses through the measuring impedance. This impedance, in combination with the test object and coupling capacitor, determines the duration and shape of the measured voltage pulses. These pulses are further shaped and amplified in order to supply a measuring instrument a value proportional to the apparent charge quantity.

NOTE 4 The measuring impedance usually acts as a four-terminal network with a frequency response chosen to prevent the test supply frequency from reaching the instrument. This can be achieved in the case of a resistive impedance by connecting an inductor in parallel with the resistor, or by connecting a capacitor in series between the measuring resistor and the connecting lead to the instrument. The measuring impedance can consist of a resistor, a resistor in parallel with a capacitor, a tuned circuit or a more complex filter design.

NOTE 5 Instruments for the measurement of apparent charges q: the current pulses due to partial discharges produce a signal at the terminals of the measuring impedance. For short-duration current pulses, the signal produced is a voltage pulse whose peak value is proportional to the apparent charge of the photocoupler under test (see 3.3.1 of IEC 60270:2000).

The individual pulses are typically displayed on an oscilloscope and the magnitude of the apparent charge can be determined by calibration. The pulses can be displayed on a linear time-base which is triggered, for example, by the discharge pulse or by the test voltage.

The oscillogram assists in distinguishing between different types of partial discharges and between the discharges to be measured and extraneous disturbances. The magnitude of the apparent charge which is measured during an actual test is generally understood to be that associated with the largest repeatedly occurring pulse.

6.6 Collector-emitter saturation voltage $V_{CE(sat)}$ of a photocoupler

6.6.1 Collector-emitter saturation voltage (DC method)

a) Purpose

To measure the collector-emitter saturation voltage of a transistor under specified conditions.

b) Circuit diagram, see Figure 10

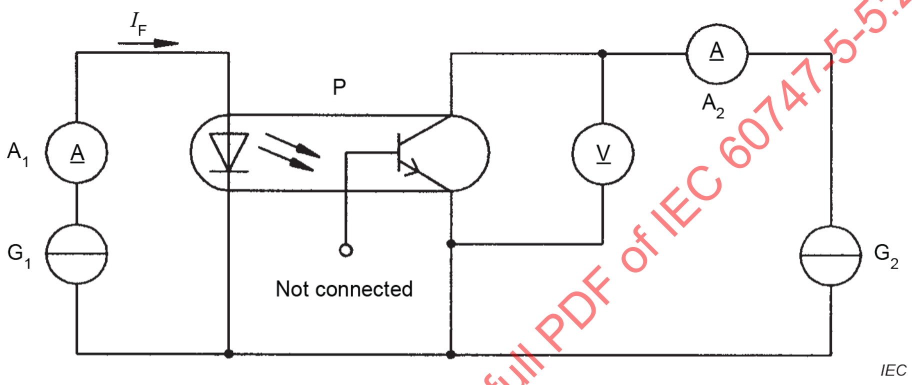


Figure 10 – DC measurement circuit

c) Precautions to be observed

Because of the risk that the maximum power dissipation P_{max} could be exceeded, it is important to follow the order of the measurement procedure.

It may be necessary to modify the measurement circuit, for example by connecting a voltage limiting circuit across the generator G_2.

d) Measurement procedure

The temperature is set to the specified value.

The forward current is adjusted to the specified value read with ammeter A_1.

The collector current is adjusted to the specified value read with ammeter A_2.

The collector-emitter saturation voltage is measured with voltmeter V.

e) Specified conditions

– ambient, case or reference-point temperature (t_{amb}, t_{case}, t_{ref});

– input forward current I_F;

– collector current I_C.

6.6.2 Collector-emitter saturation voltage (pulse method)

a) Purpose

To measure the collector-emitter saturation voltage of a transistor under pulse conditions.

b) Circuit diagram, see Figure 11

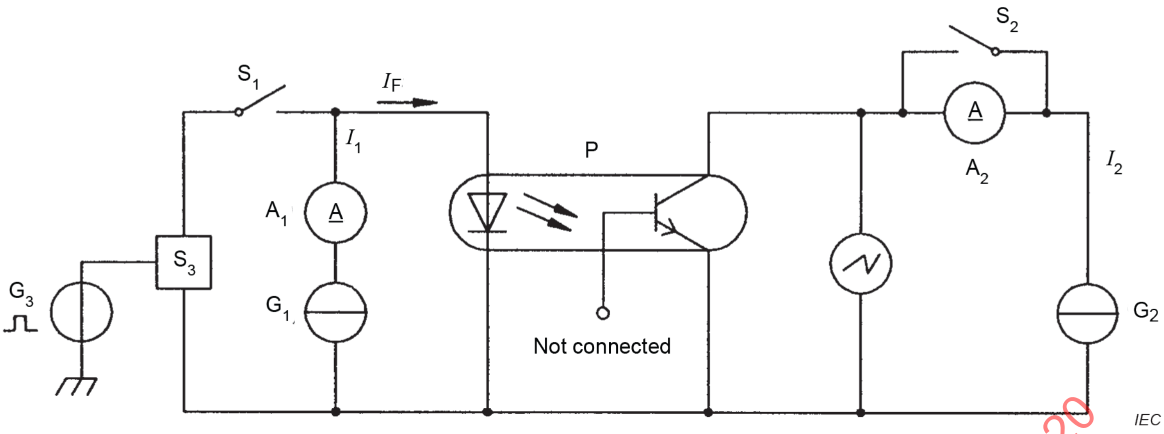


Figure 11 – Pulse measurement circuit

c) Circuit description and requirements

The electronic switch S_3 is normally closed, and opened only when pulses are applied to it by pulse generator G_3.

The value of the internal resistance of the constant-current generator G_2 should be smaller than the value of $V_{CE(sat)}/I_C$.

d) Precautions to be observed

The time of the DC generators to respond to changes in load should be less than the "on" period of the phototransistor being measured.

The specified width and duty cycle of the pulse generator should be so small that no significant heat dissipation occurs in the phototransistor being measured.

The maximum voltage supplied by DC generator G_2 should not exceed the collector-emitter breakdown voltage of the phototransistor.

e) Measurement procedure

The temperature is set to the specified value.

With the switch S_1 open, the current generator G_1 is adjusted until the reading of ammeter A_1 is equal to the specified value I_F.

With the switch S_2 open, the current generator G_2 is adjusted until the reading of ammeter A_2 is equal to the specified value I_C.

With the phototransistor being measured, switches S_1 and S_2 closed, and switch S_3 operated by G_3, the value of the steady voltage of the flat part of the waveform in the "on" period as observed on the oscilloscope is $V_{CE(sat)}$.

f) Specified conditions

- ambient, or case reference-point temperature (t_{amb}, t_{case}, t_{ref});
- input forward current I_F;
- collector current I_C;
- pulse width and duty cycle of pulses (t_p, δ), preferably: t_p = 300 µs, $\delta \leq 2$ %.

6.7 Switching times t_{on}, t_{off} of a photocoupler

a) Purpose

To measure the turn-on and the turn-off times of a photocoupler under specified conditions.

b) Circuit diagram, see Figure 12

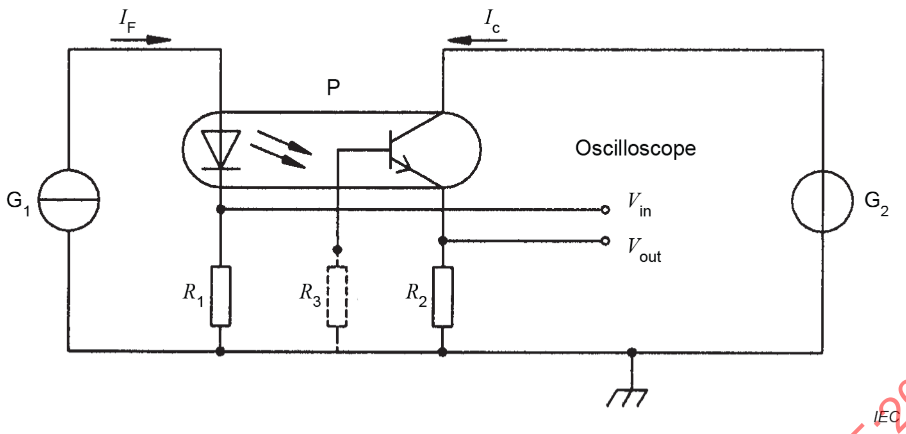


Figure 12 – Switching time measurement circuit

c) Circuit description and requirements

G_1 pulse generator

G_2 supply voltage source (V_{CC})

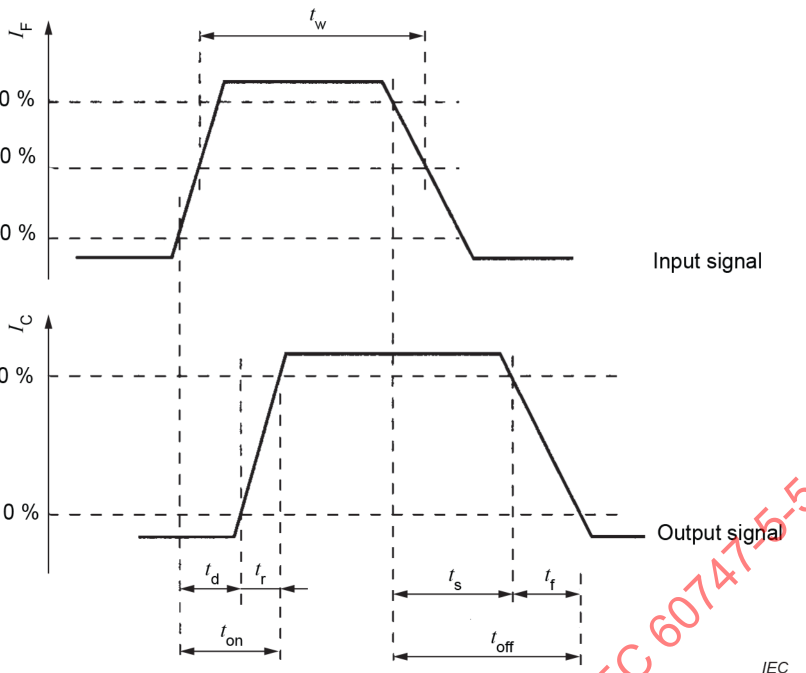
d) Precautions to be observed

Under consideration.

e) Measurement procedure

The supply voltage V_{CC} is applied to the output circuit of the device under test. Pulses delivered by generator G_1 are applied to the input of the device; the amplitude of the pulses is increased until the specified input current I_F or output current I_C value is reached.

The switching times are determined by observing the oscilloscope traces (see Figure 13).



t_d	turn-on delay time	t_s	turn-off delay time
t_r	rise time	t_f	fall time
t_{on}	$t_d + t_r$ = turn-on time	t_{off}	$t_s + t_f$ = turn-off time

Figure 13 – Switching times

f) Specified conditions

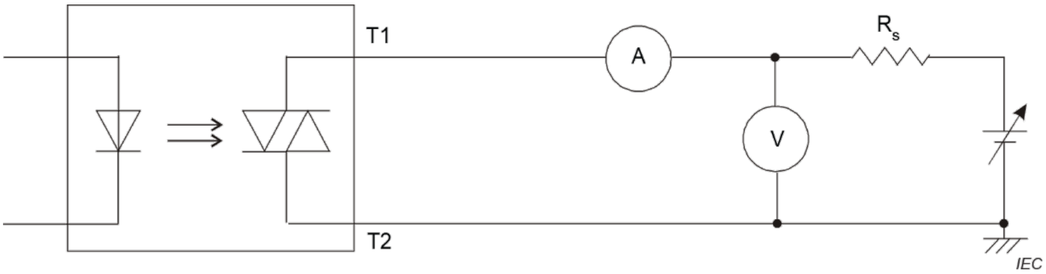
- ambient temperature;
- input or output current (where appropriate);
- output circuit supply voltage;
- pulse width t_w and duty cycle δ (where appropriate);
- R_1 value = 50 Ω, unless otherwise stated;
- R_2 value = 100 Ω, unless otherwise stated;
- R_3 value if used.

6.8 Peak off-state current I_{DRM}

a) Purpose

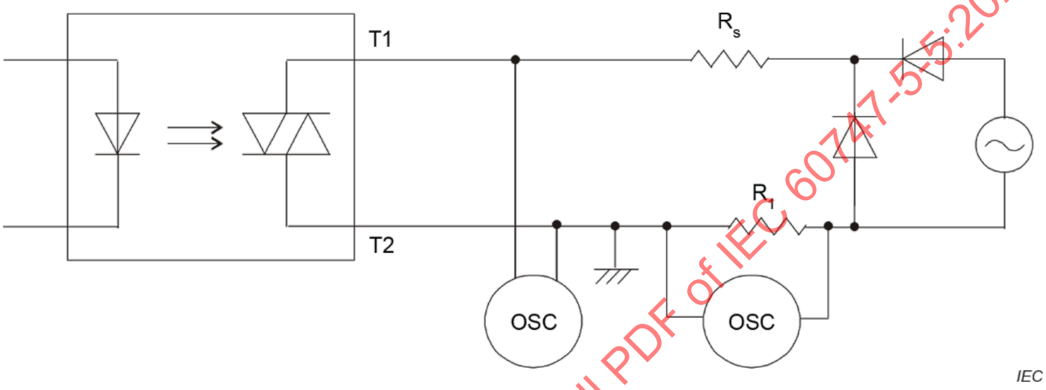
To measure the forward leakage current between the output terminals in off-state under specified conditions.

b) Circuit diagram, see Figure 14



R_s current limiting resistor

a) DC method



R_s current limiting resistor

R_1 current detecting resistor

b) AC method

Figure 14 – Measurement circuit for peak off-state current

c) Measurement procedure, see Figure 15

1) DC method

The peak off-state current (I_{DRM}) is measured with the specified forward off-state voltage which is applied between output terminals in off-state.

The peak off-state current (I_{DRM}) is measured again with inverted polarity of output terminals (T1, T2) by applying the reverse voltage/current between terminals.

2) AC method

The peak off-state current (I_{DRM}) is measured at the specified peak off-state voltage with the half-wave-rectified AC voltage with commercial AC line frequency, which is applied between output terminals in off-state.

The peak off-state current (I_{DRM}) is measured again with inverted polarity of output terminals (T1, T2) by applying the reverse voltage/current between terminals.

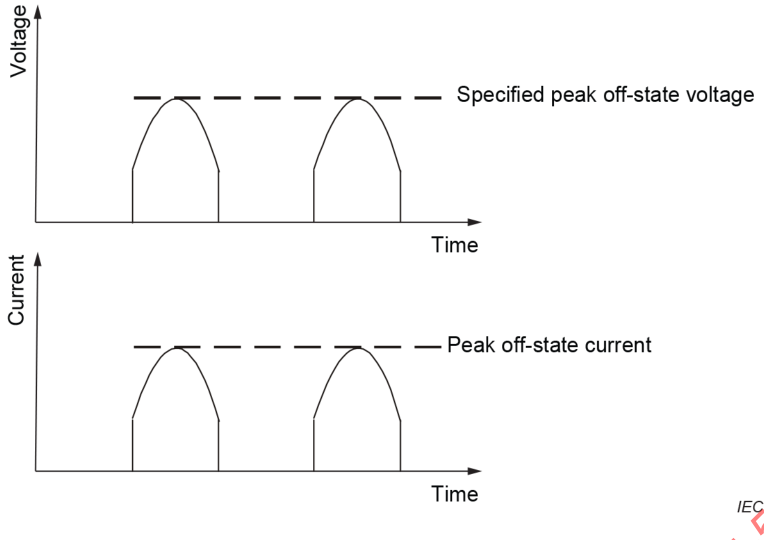


Figure 15 – Waveforms of the peak off-state voltage and current

d) Requirements

1) The measurement method of peak off-state current uses two forced-voltage polarities (T1→T2 and T2→T1).

2) In the case of the DC method, the slew rate of the applied DC voltage between output terminals (T1, T2) should not exceed the critical rate of rise of off-state voltage (dV/dt).

In the case of the AC method, the rate of change (dV/dt) of the applied sine-wavevoltage between output terminals (T1, T2) should not exceed the critical rate of rise of off-state voltage (dV/dt).

e) Specified conditions

1) peak off-state voltage (V_{DRM});

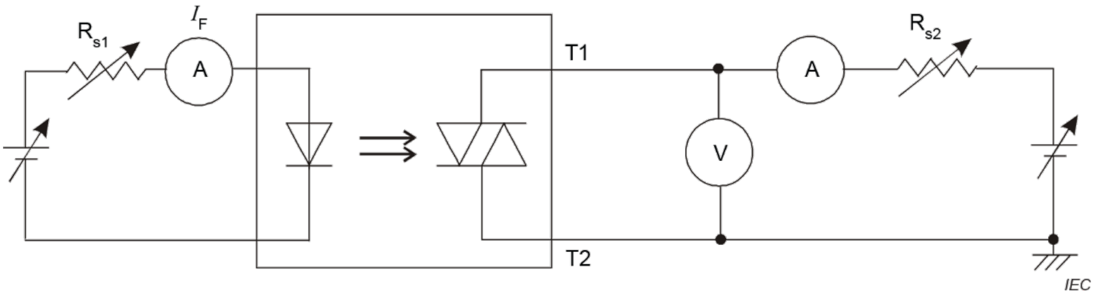
2) ambient temperature (T_{amb}).

6.9 Peak on-state voltage V_{TM}

a) Purpose

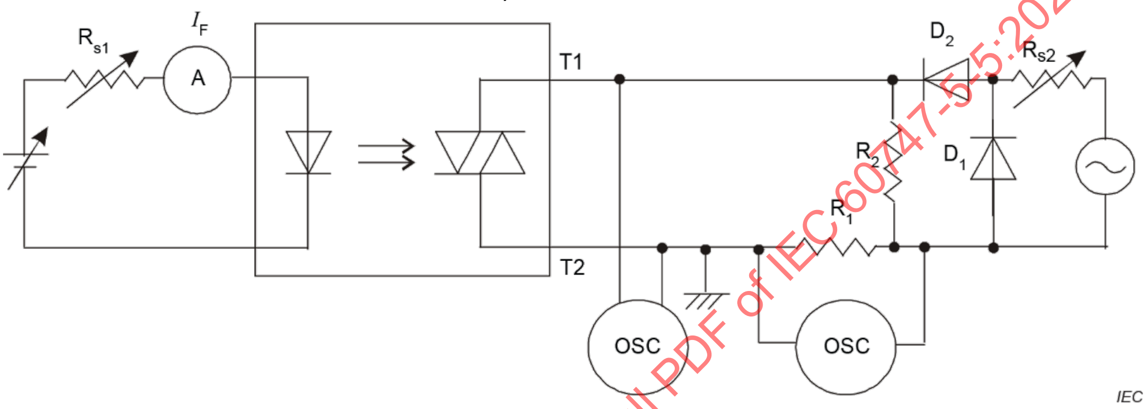
To measure the peak on-state voltage between output terminals in on-state under specified conditions, when the specified on-state current is applied between output terminals in on-state.

b) Circuit diagram, see Figure 16



R_{s1}, R_{s2} current limiting resistors

a) DC method



R_{s1}, R_{s2} current limiting resistors

R_1 current detecting resistor

R_2 resistor to prevent the phototriac from being off-voltage. R_2 should be selected approximately to adjust the voltage between the terminals, which is caused by the leakage current through D_1, to nearly 0 V

D_1 diode for decreasing DC current part in power line

b) AC method

Figure 16 – Measurement circuit for peak on-state voltage

c) Measurement procedure, see Figure 17

1) DC method

The specified input forward current (I_F) is applied to turn on output. Following that, the specified on-state current is applied between output terminals.

The voltage between output terminals (peak on-state voltage (V_{TM})) is measured. The voltage between output terminals is measured again with inverted polarity of output terminals (T1, T2) by applying the reverse voltage/current between terminals.

A constant current source may be used instead of a constant voltage source on the input side.

2) AC method

The specified input forward current (I_F) is applied to turn on output. Following that, the half-wave-rectified AC voltage with commercial AC line frequency is applied between output terminals. The voltage between output terminals (peak on-state voltage (V_{TM})) is measured at the specified peak on-state current.

The voltage between output terminals is measured again with inverted polarity of output terminals (T1, T2) by applying the reverse voltage/current between terminals.

A constant current source may be used instead of a constant voltage source on the input side.

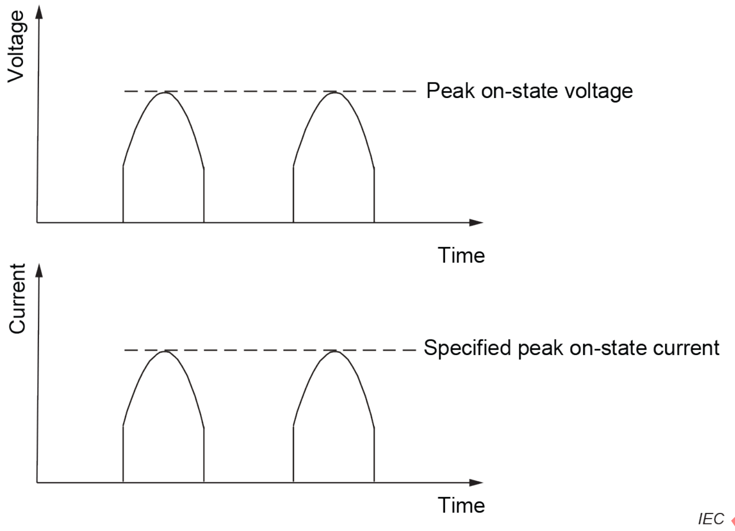


Figure 17 – Waveforms of the peak on-state voltage and current

d) Requirements

The measurement method of peak on-state voltage uses two forced-voltage polarities (T1→T2 and T2→T1).

e) Specified conditions

1) peak on-state current I_{TM};

2) input forward current I_F;

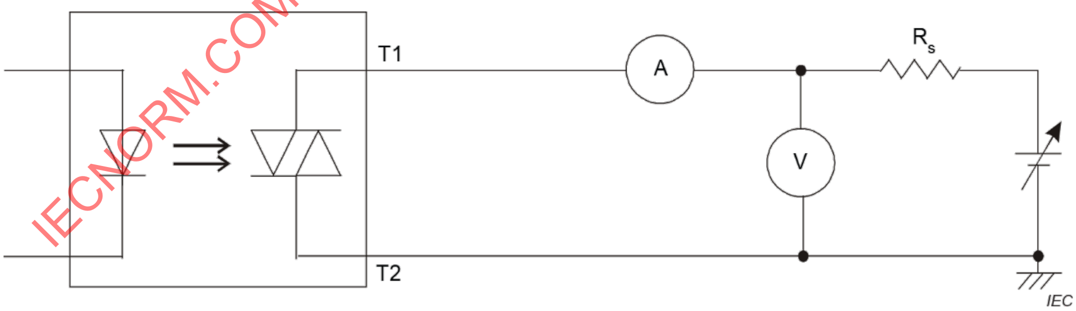
3) ambient temperature T_{amb}.

6.10 DC off-state current I_{BD}

a) Purpose

To measure the leakage current between the output terminals in off-state under specified conditions.

b) Circuit diagram, see Figure 18



R_s current limiting resistor

Figure 18 – Measurement circuit for DC off-state current

c) Measurement procedure

The specified DC off-state voltage is applied between output terminals in off-state. The leakage current is measured again with inverted polarity of output terminals (T1, T2) by applying the reverse voltage/current between terminals.

d) Requirements

1) The measurement method of DC off-state current uses two forced-voltage polarities (T1→T2 and T2→T1).

2) The slew rate of the applied DC voltage between output terminals (T1, T2) should not exceed the critical rate of rise of off-state voltage (dV/dt).

e) Specified conditions

1) DC off-state voltage V_{BD};

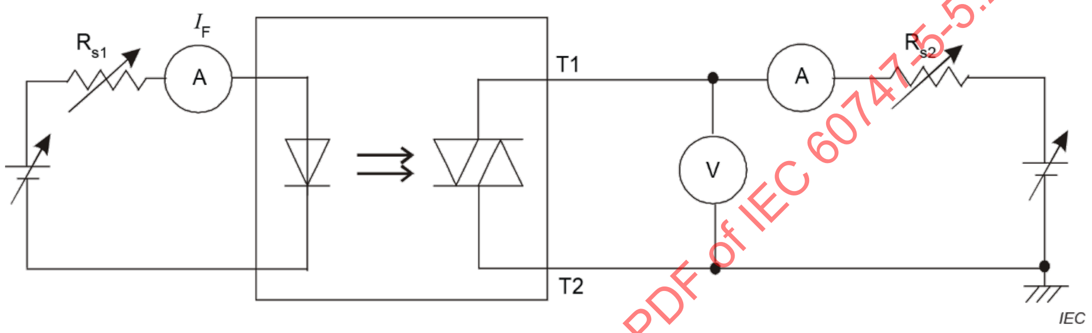
2) ambient temperature T_{amb}.

6.11 DC on-state voltage V_T

a) Purpose

To measure the DC voltage between output terminals in on-state under specified conditions, when the specified forward current is applied between output terminals in on-state.

b) Circuit diagram, see Figure 19



R_{s1}, R_{s2} current limiting resistors

Figure 19 – Measurement circuit for DC on-state voltage

c) Measurement procedure

The specified input forward current (I_F) is applied to turn on output. Following that, the specified DC on-state current is applied between output terminals.

The voltage between output terminals (DC on-state voltage (V_T)) is measured. The voltage between output terminals is measured again with inverted polarity of output terminals (T1, T2) by applying the reverse voltage/current between terminals.

A constant current source may be used instead of a constant voltage source on the input side.

d) Requirements

The measurement method of DC on-state voltage uses two forced-voltage polarities (T1→T2 and T2→T1).

e) Specified conditions

1) DC on-state current I_T;

2) input forward current I_F;

3) ambient temperature T_{amb}.

6.12 Holding current I_H

a) Purpose

To measure the minimum output on-state current to maintain the on-state under specified conditions.