IEC 60747-5-6

Edition 2.0 2021-07
REDLINE VERSION

INTERNATIONAL STANDARD

Semiconductor devices –
Part 5-6: Optoelectronic devices – Light emitting diodes

IEC 60747-5-6:2021-07 RLV(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 60747-5-6

Edition 2.0 2021-07
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Semiconductor devices –
Part 5-6: Optoelectronic devices – Light emitting diodes

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.080.99 ISBN 978-2-8322-1000-9

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 5-6: Optoelectronic devices – Light emitting diodes

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60747-5-6:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 60747-5-6 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) ultraviolet-emitting diodes (UV LED) and their related technical contents were added;
b) power efficiency (η_{PE}) as part of electrical and optical characteristics were added;
c) new measuring methods related to thermal resistance were added;
d) hydrogen sulphide corrosion test was added to quality evaluation;
e) some standards were added to the bibliography.

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

FDIS	Report on voting
47E/745/FDIS	47E/752/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

SEMICONDUCTOR DEVICES –

Part 5-6: Optoelectronic devices – Light emitting diodes

1 Scope

This part of IEC 60747 specifies the terminology, the essential ratings and characteristics, the measuring methods and the quality evaluations of light emitting diodes (LEDs) for general industrial applications such as signals, controllers, sensors, etc.

LEDs for lighting applications are out of the scope of this part of IEC 60747.

LEDs are classified as follows:

a) LED package;
b) LED flat illuminator;
c) LED numeric display and alpha-numeric display;
d) LED dot-matrix display;
e) ~~I LED (~~infrared-emitting diode (IR LED);
f) ultraviolet-emitting diode (UV LED).

LEDs with a heat spreader or having a terminal geometry that performs the function of a heat spreader are within the scope of this part of IEC 60747.

An integration of LEDs and controlgears, integrated LED modules, semi-integrated LED modules, integrated LED lamps or semi-integrated LED lamps, are out of the scope of this part of IEC 60747.

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 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

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

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

IEC 60747-5-13, *Semiconductor devices – Part 5-13: Optoelectronic devices – Hydrogen sulphide corrosion test for LED packages*

IEC 60749-6, *Semiconductor devices – Mechanical and climatic test methods – Part 6: Storage at high temperature*

IEC 60749-10, *Semiconductor devices – Mechanical and climatic test methods – Part 10: Mechanical shock*

IEC 60749-12, *Semiconductor devices – Mechanical and climatic test methods – Part 12: Vibration, variable frequency*

IEC 60749-14, *Semiconductor devices – Mechanical and climatic test methods – Part 14: Robustness of terminations (lead integrity)*

IEC 60749-15, *Semiconductor devices – Mechanical and climatic test methods – Part 15: Resistance to soldering temperature for through-hole mounted devices*

IEC 60749-20, *Semiconductor devices – Mechanical and climatic test methods – Part 20: Resistance of plastic encapsulated SMDs to the combined effect of moisture and soldering heat*

IEC 60749-21, *Semiconductor devices – Mechanical and climatic test methods – Part 21: Solderability*

IEC 60749-24, *Semiconductor devices – Mechanical and climatic test methods – Part 24: Accelerated moisture resistance – Unbiased HAST*

IEC 60749-25, *Semiconductor devices – Mechanical and climatic test methods – Part 25: Temperature cycling*

IEC 60749-36, *Semiconductor devices – Mechanical and climatic test methods – Part 36: Acceleration, steady state*

ISO 2859-1, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

3 Terms, definitions and abbreviations

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:

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

3.1 General terms and definitions

3.1.1
integrating sphere
hollow sphere ~~whose internal surface is a diffuse reflector, as non-selective as possible~~, the interior of which is formed from, or coated with, a diffusely-reflecting material that is as spectrally neutral and as spatially uniform as possible

Note 1 to entry: Owing to the internal reflections within the sphere, the illuminance on any part of the inside surface of the sphere for which the direct flux is hidden is theoretically proportional to the luminous flux entering the sphere or produced inside the sphere. The illuminance of the internal sphere wall can be measured via a small window.

Note 2 to entry: The window of an integrating sphere is often used in radiometric measurement systems to provide a source with good spatial uniformity and with an angular distribution of radiance or luminance that is close to Lambert's cosine law.

[SOURCE: ~~IEC 60050-845:1987, 845-05-24, modified – The term "Ulbricht sphere" and the note have been removed.~~ IEC 60050-845:2020, 845-25-028]

3.1.2
diffuse reflector
reflector composed of a surface with diffuse reflection

3.1.3
diffuse reflection
~~diffusion~~ scattering by reflection in which, on the macroscopic scale, there is no regular reflection

[SOURCE: ~~IEC 60050-845:1987, 845-04-47~~ IEC 60050-845:2020, 845-24-054]

3.1.4
diffuse transmission
~~diffusion~~ scattering by transmission in which, on the macroscopic scale, there is no regular transmission

[SOURCE: ~~IEC 60050-845:1987, 845-04-48~~ IEC 60050-845:2020, 845-24-055]

3.1.5
diffuse reflectance
~~R_d~~ ρ_d
~~ratio~~ quotient of the diffusely reflected part of the (whole) reflected flux~~, to~~ and the incident flux

Note 1 to entry: ~~$R = R_r + R_d$~~ Reflectance, ρ, is the sum of regular reflectance, ρ_r, and diffuse reflectance, ρ_d: $\rho = \rho_r + \rho_d$

Note 2 to entry: ~~The results of the measurements of R_r and R_d depend on the instruments and the measuring techniques used.~~ The diffuse reflectance has unit one.

[SOURCE: ~~IEC 60050-845:1987, 845-04-62~~ IEC 60050-845:2020, 845-24-068]

3.1.6
diffuse transmittance
~~T_d~~ τ_d
~~ratio~~ quotient of the diffusely transmitted part of the (whole) transmitted flux~~, to~~ and the incident flux

Note 1 to entry: ~~$T = T_r + T_d$~~ Transmittance, τ, is the sum of regular transmittance, τ_r, and diffuse transmittance, τ_d: $\tau = \tau_r + \tau_d$.

Note 2 to entry: ~~The results of the measurements of T_r and T_d depend on the instruments and the measuring techniques used.~~ The diffuse transmittance has unit one.

[SOURCE: ~~IEC 60050-845:1987, 845-04-63~~ IEC 60050-845:2020, 845-24-069]

3.1.7
lambertian surface
ideal surface for which the radiation coming from that surface is distributed angularly according to Lambert's cosine law

Note 1 to entry: For a lambertian surface, $M = \pi L$, where M is the radiant exitance or luminous exitance, and L the radiance or luminance.

[SOURCE: ~~IEC 60050-845:1987, 845-04-57~~ IEC 60050-845:2020, 845-24-063]

3.1.8
spectral reflectance
$R(\lambda)$
~~ratio between the spectral radiant flux of wavelength λ that is reflected by an object and the spectral radiant flux of wavelength λ that is absorbed by the object~~

ratio of reflected radiant flux to incident radiant flux for a wavelength λ

Note 1 to entry: Spectral reflectance is also known as the "spectral reflection factor".

3.1.9
spectral transmittance
$T(\lambda)$
~~ratio between the spectral radiant flux of wavelength λ that is transmitted by an object and the spectral radiant flux of wavelength λ that is absorbed by the object~~

ratio of transmitted radiant flux to incident radiant flux for a wavelength λ

Note 1 to entry: Spectral transmittance is also known as the "spectral transmittance factor".

3.1.10
spectral distribution
proportion of the quantum of radiation per unit wavelength included in the micro wavelength interval centre on wavelength λ, which is expressed as a function of wavelength λ

Note 1 to entry: Spectral distribution is also known as the "spectrum distribution".

3.1.11
spectral sensitivity
$S(\lambda)$
light sensitivity as a function of wavelength

Note 1 to entry: The response output of the optical receiver for the radiant ~~power~~ flux (or luminous flux) input of wavelength λ is expressed as a function of wavelength λ.

3.1.12
distribution temperature
T_D
temperature of the Planckian radiator whose relative spectral distribution $S(\lambda)$ is the same or nearly the same as that of the radiation considered in the spectral range of interest for which the following integral is minimized by adjustment of a and T:

$$\int_{\lambda_1}^{\lambda_2} \left[1 - \frac{S_t(\lambda)}{a\, S_b(\lambda, T)} \right]^2 d\lambda$$

where λ is the wavelength, $S_t(\lambda)$ is the relative spectral distribution of the radiation being considered, $S_b(\lambda, T)$ is the relative spectral distribution of the Planckian radiator at temperature T, and a is a scaling factor

Note 1 to entry: The scaling factor a is chosen to make the quotient $\frac{S_t(\lambda)}{S_b(\lambda, T)}$ equal to unity at a convenient wavelength which, in photometry and colorimetry is typically 560 nm.

$$S_b(\lambda, T) = \frac{P(\lambda, T)}{P(560\,\text{nm}, T)} \quad \text{with} \quad P(\lambda, T) = \lambda^{-5} \left(e^{\frac{c_2}{\lambda T}} - 1 \right)^{-1}$$ where c_2 is the second radiation constant.

Note 2 to entry: Distribution temperature is a meaningful characteristic for radiators having a relative spectral distribution similar to that of a Planckian radiator, but only if calculated for an expanded wavelength range and for radiation whose spectral distribution of radiant flux is a continuous function of wavelength in that range.

Note 3 to entry: In photometry and colorimetry the wavelength range set by λ_1 and λ_2 is the visible spectral range, and in these cases the range from at least λ_1 = 400 nm to λ_2 = 750 nm is recommended.

Note 4 to entry: In practice, the integral is replaced by a summation. For incandescent lamps, equally spaced wavelength intervals of 10 nm will usually suffice. All values in the summation are treated with equal weight.

Note 5 to entry: The distribution temperature is expressed in kelvin (K).

Note 6 to entry: For further information, see CIE 114-1994, CIE Collection in Photometry and Radiometry – 114/4 Distribution Temperature and Ratio Temperature.

[SOURCE: ~~IEC 60050-845:1987, 845-04~~ IEC 60050-845:2020, 845-24-017]

3.1.13
infrared-emitting diode
IR LED
light emitting diode that emits infrared radiation

3.1.14
infrared radiation
optical radiation for which the wavelengths are longer than those for visible radiation

Note 1 to entry: For infrared radiation, the range between 780 nm and 1 mm is commonly subdivided into:

IR-A: 780 nm to 1400 nm, or 0,78 µm to 1,4 µm;

IR-B: 1,4 µm to 3 µm;

IR-C: 3 µm to 1 mm.

Note 2 to entry: A precise border between "visible radiation" and "infrared radiation" cannot be defined because visual sensation at wavelengths greater than 780 nm can be experienced.

Note 3 to entry: In some applications the infrared spectrum has also been divided into "near," "middle," and "far" infrared; however, the borders necessarily vary with the application.

[SOURCE: IEC 60050-845:2020, 845-21-004, modified – The second preferred term (IR radiation) and the admitted term (IRR) have been removed.]

3.1.15
ultraviolet-emitting diode
UV LED
light emitting diode that emits ultraviolet radiation

3.1.16
ultraviolet radiation
optical radiation for which the wavelengths are shorter than those for visible radiation

Note 1 to entry: The range between 100 nm and 400 nm is commonly subdivided into:

UV-A: 315 nm to 400 nm;

UV-B: 280 nm to 315 nm;

UV-C: 100 nm to 280 nm.

Note 2 to entry: A precise border between ultraviolet radiation and visible radiation cannot be defined, because visual sensation at wavelengths shorter than 400 nm is noted for very bright sources.

Note 3 to entry: In some applications the ultraviolet spectrum has also been divided into "far," "vacuum," and "near" ultraviolet; however, the borders necessarily vary with the application (e.g. in meteorology, optical design, photochemistry, and thermal physics).

[SOURCE: IEC 60050-845:2020, 845-21-008, modified – The second preferred term (UV radiation) and the admitted term (UVR) have been removed.]

3.2 Terms and definitions relating to the measurement of the quantity of radiation

3.2.1
radiant energy
Q_e

~~time integral of the radiant flux Φ_e over a given duration Δt~~

energy emitted, transferred or received in the form of electromagnetic waves

Note 1 to entry: Radiant energy can be expressed by the time integral of radiant flux, Φ_e, over a given duration, Δt:

$$Q_e = \int_{\Delta t} \Phi_e \, dt$$

Note 2 to entry: Radiant energy is expressed as a function of wavelength, λ, as a function of frequency, ν, or as a function of wavenumber, σ.

Note 3 to entry: The corresponding photometric quantity is "luminous energy". The corresponding quantity for photons is "photon energy".

Note 4 to entry: The radiant energy is expressed in joule (J = W·s).

[SOURCE: ~~IEC 60050-845:1987, 845-01-27~~ IEC 60050-845:2020, 845-21-041]

3.2.2
radiant flux
Φ_e

~~power emitted, transmitted or received in the form of radiation~~

change in radiant energy with time

$$\Phi_e = \frac{dQ_e}{dt}$$

where Q_e is the radiant energy emitted, transferred or received, and t is time

Note 1 to entry: The corresponding photometric quantity is "luminous flux". The corresponding quantity for photons is "photon flux".

Note 2 to entry: The term "radiant flux" is the preferred term for most radiometric applications, with the notable exception of laser radiometry where the term "radiant power" is more commonly used.

Note 3 to entry: The radiant flux is expressed in watt (W).

[SOURCE: ~~IEC 60050-845:1987, 845-01-24, modified – The formula has been added.~~ IEC 60050-845:2020, 845-21-038, modified – The symbols P_e, Φ and P have been removed and the second preferred term "radiant power" has been removed.]

3.2.3
radiant intensity
I_e

~~quotient of the radiant flux $d\Phi_e$ leaving the source and propagated in the element of solid angle $d\Omega$ containing the given direction, by the element of solid angle~~

density of radiant flux with respect to solid angle in a specified direction

$$I_e = \frac{d\Phi_e}{d\Omega}$$

where Φ_e is the radiant flux emitted in a specified direction, and Ω is the solid angle containing that direction

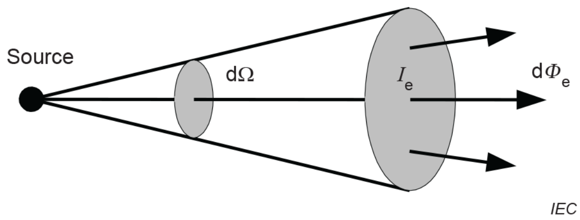


Figure 1 – Radiant intensity

~~Note 1 to entry: For a radiation source that is not regarded as a point radiation source, the limit value determined by the value (which is calculated by dividing the radiant power that is absorbed by a small area by the solid angle formed by the small area toward an arbitrary point on the radiation source) when the distance between the radiation source and the small area becomes longer, is used to calculate the radiant intensity.~~

~~Note 2 to entry: The unit used is: W/sr.~~

Note 1 to entry: The definition holds strictly only for a point source.

Note 2 to entry: The distribution of the radiant intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the radiant flux, Φ_e, within a certain solid angle, Ω, of a source:

$$\Phi_e = \iint_{\Omega} I_e(\vartheta,\varphi)\sin\vartheta\, d\varphi\, d\vartheta.$$

Note 3 to entry: The corresponding photometric quantity is "luminous intensity". The corresponding quantity for photons is "photon intensity".

Note 4 to entry: The radiant intensity is expressed in watt per steradian (W·sr^{-1}).

[SOURCE: ~~IEC 60050-845:1987, 845-01-30~~ IEC 60050-845:2020, 845-21-044, modified – The symbol I has been removed and Figure 1 has been added.]

3.2.4
radiance
L_e

~~quantity defined by the formula $L_e = \frac{d\Phi_e}{dA \cdot \cos\theta \cdot d\Omega}$,~~

~~where~~

~~$d\Phi_e$ is the radiant flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction;~~

~~dA is the area of a section of that beam containing the given point;~~

~~θ is the angle between the normal to that section and the direction of the beam~~

density of radiant intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface

$$L_e = \frac{dI_e}{dA}\frac{1}{\cos\theta},$$

where I_e is radiant intensity, A is area, and θ is the angle between the normal to the surface at the specified point and the specified direction

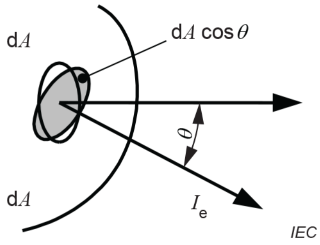


Figure 2 – Radiance

Note 1 to entry: The unit used is: W/(sr·m²). The radiance is expressed in watt per square metre per steradian ($W \cdot m^{-2} \cdot sr^{-1}$).

[SOURCE: IEC 60050-845:1987, 845-01-34, modified – omitting the part about Notes IEC 60050-845:2020, 845-21-049, modified – The symbol L has been removed, the angle symbol α has been replaced by θ, the notes have been removed, a new note has been added and Figure 2 has been added.]

3.2.5
radiant exitance
M_e
quotient of the radiant flux $d\Phi_e$ leaving an element of the surface containing the point, by the area dA of that element

$$M_e = \frac{d\Phi_e}{dA} = \int_{2\pi sr} L_e \cdot \cos\theta \cdot d\Omega$$ (dA: small area)

Note 1 to entry: An equivalent definition could be given as follows: Integral, taken over the hemisphere visible from the given point, of the expression $L_e \cdot \cos\theta \, d\Omega$, where L_e is the radiance at the given point in the various directions of the emitted elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.

Note 2 to entry: The unit used is: W/m².

density of exiting radiant flux with respect to area at a point on a real or imaginary surface

$$M_e = \frac{d\Phi_e}{dA}$$

where Φ_e is radiant flux and A is the area from which the radiant flux leaves

Note 1 to entry: For Planckian radiation, $M_e = \sigma T^4$ where σ is the Stefan-Boltzmann constant and T is thermodynamic temperature.

Note 2 to entry: The corresponding photometric quantity is "luminous exitance". The corresponding photon quantity is "photon exitance".

Note 3 to entry: The radiant exitance is expressed in watt per square metre ($W \cdot m^{-2}$).

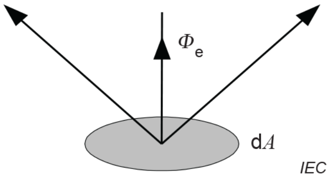


Figure 3 – Radiant exitance

[SOURCE: ~~IEC 60050-845:1987, 845-01-47~~ IEC 60050-845:2020, 845-21-080, modified – The symbol M has been removed and Figure 3 has been added.]

3.2.6
power efficiency
η_{PE}
ratio of the radiant flux (coupled to free space), Φ_e, to the electrical power consumed by the LED, $V_F I_F$, where V_F is the forward voltage and I_F is the forward current of the LED

$$\eta_{PE} = \frac{\Phi_e}{V_F I_F}$$

Note 1 to entry: Power efficiency is also known as the "wall-plug efficiency". Power efficiency is identical to the "radiant efficiency" when the power dissipated by any auxiliary equipment is excluded from the electrical power.

[SOURCE: IEC 60747-5-8:2019, 3.2.1, modified – The term "radiant power" has been replaced with "radiant flux".]

3.2.7
irradiance
E_e
~~quotient of the radiant flux dΦ_e incident on an element of the surface containing the point, by the area dA of that element~~

density of incident radiant flux with respect to area at a point on a real or imaginary surface

$$E_e = \frac{d\Phi_e}{dA}$$

where Φ_e is radiant flux and A is the area on which the radiant flux is incident

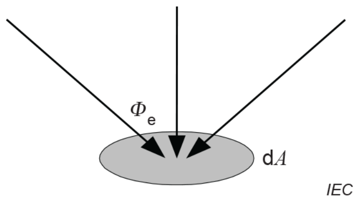


Figure 4 – Irradiance

~~Note 1 to entry: An equivalent definition could be given as follows:Integral, taken over the hemisphere visible from the given point, of the expression $L_e \cdot \cos\theta \cdot d\Omega$, where L_e is the radiance at the given point in the various directions of the incident elementary beams solid angle dΩ, and θ is the angle between any of these beams and the normal to the surface at the given point.~~

~~Note 2 to entry: The unit used is: W/m^2.~~

Note 1 to entry: The corresponding photometric quantity is "illuminance". The corresponding quantity for photons is "photon irradiance".

Note 2 to entry: The irradiance is expressed in watt per square metre ($W \cdot m^{-2}$).

[SOURCE: ~~IEC 60050-845:1987, 845-01-37~~ IEC 60050-845:2020, 845-21-053, modified – The symbol E has been removed and Figure 4 has been added.]

3.3 Terms and definitions relating to the measurement of the photometric quantity

3.3.1
photometric standard lamp
lamp used for photometry that provides excellent stability and reproducibility and can indicate the photometric quantity

Note 1 to entry: There are two types of these lamps: luminous intensity standard lamps to which the luminous intensity value is added and luminous flux standard lamps to which the total flux value is added.

3.3.2
spectral luminous efficiency
$V(\lambda)$
relative spectral efficiency, which is defined as the standard value of spectral luminous efficiency for human eyes and whose maximum value is set to 1

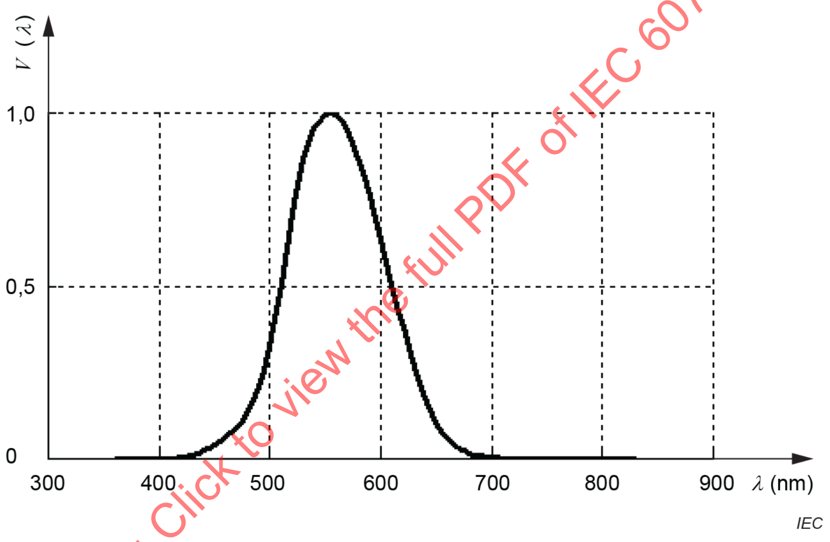


Figure 5 – Spectral luminous efficiency

Note 1 to entry: The spectral luminous efficiency for photopic vision was agreed at the CIE (International Commission on Illumination) in 1924 and adopted by the CIPM (*Comité International des Poids et Mesures* – International Committee for Weights and Measures in English) in 1933. The values for spectral luminous efficiency were originally given for the wavelength range 380 nm to 780 nm at 10 nm intervals. In 1972, new values were adopted by the CIPM for the wavelength range 360 nm to 830 nm at 1 nm intervals.

Note 2 to entry: Figure 5 and Table A.1 in Annex A show the graph and the numerical scheme for the spectral luminous efficiency, respectively.

3.3.3
maximum spectral luminous efficiency
K_m
maximum value that is expressed as the spectral concentration of the luminous flux in wavelength λ divided by the spectral concentration of the corresponding radiant ~~power~~ flux

Note 1 to entry: 683 lm/W (λ = 555 nm) is the value adopted by the CIPM.

3.3.4
luminous flux
Φ_v

~~quantity derived from radiant flux Φ_e by evaluating the radiation according to its action upon the CIE standard photometric observer~~

~~Note 1 to entry: This definition was adopted by the CIE in 1948. The relation between luminous flux and radiant power is expressed by the following formula.~~

~~For photopic vision~~ $\Phi_v = K_m \int_0^\infty \frac{d\Phi_e(\lambda)}{d\lambda} \cdot V(\lambda) d\lambda$

~~where~~

$\frac{d\Phi_e(\lambda)}{d\lambda}$ ~~is the spectral distribution of the radiant flux and $V(\lambda)$ is the spectral luminous efficiency.~~

~~Note 2 to entry: The unit used is: lm.~~

change in luminous energy with time

$$\Phi_V = \frac{dQ_V}{dt}$$

where Q_V is the luminous energy emitted, transferred or received, and t is time

Note 1 to entry: Luminous flux is a quantity derived from the radiant flux, Φ_e, by evaluating the radiation according to its action upon the CIE standard photometric observer. Luminous flux can be derived from the spectral radiant flux distribution by

$$\Phi_V = K_m \int_0^\infty \Phi_{e,\lambda}(\lambda) V(\lambda) d\lambda$$

where K_m is maximum luminous efficacy, $\Phi_{e,\lambda}(\lambda)$ is spectral radiant flux, $V(\lambda)$ is spectral luminous efficiency and λ is wavelength.

Note 2 to entry: The distribution of the luminous intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the luminous flux, Φ_v, within a certain solid angle, Ω, of a source:

$$\Phi_v = \iint_{\Omega} I_v(\vartheta, \varphi) \sin\vartheta \, d\varphi \, d\vartheta.$$

Note 3 to entry: The corresponding radiometric quantity is "radiant flux". The corresponding quantity for photons is "photon flux".

Note 4 to entry: The luminous flux is expressed in lumen (lm).

[SOURCE: ~~IEC 60050-845:1987, 845-01-25, modified – The note has been removed and part of the definition has been moved to notes to entry.~~ IEC 60050-845:2020, 845-21-039, modified – The symbol Φ has been removed.]

~~**3.3.5**~~
~~**quantity of light**~~
~~Q_v~~

~~time integral of the luminous flux Φ_v over a given duration Δt~~

~~$Q_V = \int_{\Delta t} \Phi_V dt$~~

~~Note 1 to entry: The unit used is: lm·s (other unit: lm·h).~~

[SOURCE: IEC 60050-845:1987, 845-01-28]

3.3.5
luminous energy

Q_v

energy of electromagnetic waves weighted by the spectral luminous efficiency multiplied by maximum luminous efficacy of a specified photometric condition

Note 1 to entry: Luminous energy for photopic vision is expressed by

$$\Phi_v = K_m \int_0^\infty \Phi_{e,\lambda}(\lambda) V(\lambda) \mathrm{d}\lambda$$

where $Q_{e,\lambda}(\lambda)$ is the spectral radiant energy at wavelength λ, $V(\lambda)$ is spectral luminous efficiency, and K_m is maximum luminous efficacy.

Note 2 to entry: The term "quantity of light" is no longer used.

Note 3 to entry: Luminous energy can be emitted, transferred or received.

Note 4 to entry: Luminous energy can be expressed by the time integral of the luminous flux, Φ_v, over a given duration, Δt:

$$Q_v = \int_{\Delta t} \Phi_v \mathrm{d}t$$

Note 5 to entry: The corresponding radiometric quantity is "radiant energy". The corresponding quantity for photons is "photon energy".

Note 6 to entry: The luminous energy is expressed in lumen second (lm·s) or lumen hour (lm·h).

[SOURCE: IEC 60050-845:2020, 845-21-037, modified – The symbol Q has been removed.]

3.3.6
luminous intensity

I_v

quotient of the luminous flux $\mathrm{d}\Phi_v$ leaving the source and propagated in the element of solid angle $\mathrm{d}\Omega$ containing the given direction, by the element of solid angle

$$I_v = \frac{\mathrm{d}\Phi_v}{\mathrm{d}\Omega} \quad (\mathrm{d}\Omega\text{: solid angle})$$

Note 1 to entry: The spatial definition of luminous intensity is shown in Figure 1; however, symbols I_e and Φ_e should be changed to I_v and Φ_v, respectively.

Note 2 to entry: For a light source that is not regarded as a point light source, the limit value determined by the value (which is calculated by dividing the luminous flux that is absorbed by a small area by the solid angle formed by the small area toward an arbitrary point on the light source) when the distance between the light source and the small area becomes longer, is used to calculate the luminous intensity.

Note 3 to entry: A luminous intensity of 1 cd is defined as 1/(60 × 10^4) of the perpendicular oriented luminous intensity on a 1 m^2 flat surface of a black-body whose temperature is equivalent to the freezing point of platinum under a pressure of 101,325 N/m^2.

density of luminous flux with respect to solid angle in a specified direction

$$I_v = \frac{\mathrm{d}\Phi_v}{\mathrm{d}\Omega}$$

where Φ_v is the luminous flux emitted in a specified direction, and Ω is the solid angle containing that direction

Note 1 to entry: For practical realization of the quantity, the source is approximated by a point source.

Note 2 to entry: The distribution of the luminous intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the luminous flux, Φ_v, within a certain solid angle, Ω, of a source:

$$\Phi_v = \iint_{\Omega} I_v(\vartheta,\varphi)\sin\vartheta\,d\varphi\,d\vartheta.$$

Note 3 to entry: Luminous intensity can be derived from the spectral radiant intensity distribution by

$$I_v = K_m \int_0^{\infty} I_{e,\lambda}(\lambda)V(\lambda)d\lambda$$

where K_m is maximum luminous efficacy, $I_{e,\lambda}(\lambda)$ is the spectral radiant intensity at wavelength λ, and $V(\lambda)$ is spectral luminous efficiency.

Note 4 to entry: The corresponding radiometric quantity is "radiant intensity". The corresponding quantity for photons is "photon intensity".

Note 5 to entry: The luminous intensity is expressed in candela (cd = lm·sr^{-1}).

[SOURCE: ~~IEC 60050-845:1987, 845-01-31, modified – Two notes to entry have been added.~~ IEC 60050-845:2020, 845-21-045, modified – The symbol I has been removed.]

3.3.7
luminance
L_v
~~quantity defined by the formula~~

$$L_v = \frac{d\Phi_v}{dA\cdot\cos\theta\cdot d\Omega},$$

~~where~~

~~$d\Phi_v$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction;~~

~~dA is the area of a section of that beam containing the given point;~~

~~θ is the angle between the normal to that section and the direction of the beam~~

density of luminous intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface

$$L_v = \frac{dI_v}{dA}\,\frac{1}{\cos\theta},$$

where I_v is luminous intensity, A is area and θ is the angle between the normal to the surface at the specified point and the specified direction

Note 1 to entry: The spatial definition of luminance is shown in Figure 2; however, symbol I_e should be changed to I_v.

Note 2 to entry: ~~The unit used is: cd/m^2~~ The luminance is expressed in candela per square metre (cd·m^{-2} = lm·m^{-2}·sr^{-1}).

[SOURCE: ~~IEC 60050-845:1987, 845-01-35, modified – The note has been removed and a new Note has been added.~~ IEC 60050-845:2020, 845-21-050, modified – The symbol L has been removed, the angle symbol α has been replaced by θ, the notes have been removed except Note 8, that has become Note 2 and a new Note 1 has been added.]

3.3.8
luminous exitance
M_v
quotient of the luminous flux dΦ_v leaving an element of the surface containing the point, by the area dA of that element

$$M_v = \frac{d\Phi_v}{dA} = \int_{2\pi sr} L_v \cdot \cos\theta \cdot d\Omega$$ (dA: small area)

Note 1 to entry: An equivalent definition could be given as follows: integral, taken over the hemisphere visible from the given point, of the expression $L_v \cdot \cos\theta \cdot d\Omega$, where L_v is the luminance at the given point in the various directions of the emitted elementary beams of solid angle dΩ, and θ is the angle between any of these beams and the normal to the surface at the given point.

Note 2 to entry: The spatial definition of luminous exitance is shown in Figure 3; however, symbol Φ_e should be changed to Φ_v.

density of exiting luminous flux with respect to area at a point on a real or imaginary surface

$$M_v = \frac{d\Phi_v}{dA}$$

where Φ_v is luminous flux and A is the area from which the luminous flux leaves

Note 1 to entry: Luminous exitance can be derived from the spectral radiant exitance distribution by

$$M_v = K_m \int_0^\infty M_{e,\lambda}(\lambda) V(\lambda) d\lambda$$

where K_m is maximum luminous efficacy, $M_{e,\lambda}(\lambda)$ is the spectral radiant exitance at wavelength λ and $V(\lambda)$ is spectral luminous efficiency.

Integral limits can be confined depending on the spectral responsivity of the detectors used as a sensor.

Note 2 to entry: The corresponding radiometric quantity is "radiant exitance". The corresponding quantity for photons is "photon exitance".

Note 3 to entry: The luminous exitance is expressed in lumen per square metre (lm·m^{-2}).

[SOURCE: IEC 60050-845:1987, 845-01-48, modified – Note 2 to entry has been added. IEC 60050-845:2020, 845-21-081, modified – The symbol M has been removed.]

3.3.9
illuminance
E_v
quotient of the luminous flux dΦ_v incident on an element of the surface containing the point, by the area dA of that element

$$E_v = \frac{d\Phi_v}{dA} = \int_{2\pi sr} L_v \cdot \cos\theta \cdot d\Omega$$ (dA: small area)

Note 1 to entry: An equivalent definition could be given as follows: integral, taken over the hemisphere visible from the given point, of the expression $L_v \cdot \cos\theta \cdot d\Omega$ where L_v is the luminance at the given point in the various directions of the incident elementary beams of solid angle dΩ, and θ is the angle between any of these beams and the normal to the surface at the given point.

density of incident luminous flux with respect to area at a point on a real or imaginary surface

$$E_v = \frac{d\Phi_v}{dA}$$

where Φ_v is luminous flux and A is the area on which the luminous flux is incident

Note 1 to entry: Illuminance can be derived from the spectral irradiance distribution by

$$E_v = K_m \int_0^\infty E_{e,\lambda}(\lambda) V(\lambda) d\lambda$$

where K_m is maximum luminous efficacy, $E_{e,\lambda}(\lambda)$ is the spectral irradiance at wavelength λ and $V(\lambda)$ is spectral luminous efficiency.

Note 2 to entry: The corresponding radiometric quantity is "irradiance". The corresponding quantity for photons is "photon irradiance".

Note 3 to entry: The illuminance is expressed in lux (lx = lm·m^{-2}).

Note 4 to entry: The spatial definition of illuminance is shown in Figure 4; however, symbol Φ_e should be changed to Φ_v.

[SOURCE: ~~IEC 60050-845:1987, 845-01-38, modified – Note 2 to entry has been added.~~ IEC 60050-845:2020, 845-21-060, modified – The symbol E has been removed and Note 4 has been added.]

3.4 Terms and definitions relating to the measurement of the thermal quantity

3.4.1
thermal resistance

quotient of the difference between the virtual temperature of the device and the temperature of a stated external reference point, by the steady-state power dissipation in the device

[SOURCE: IEC 60050-521:2002, 521-05-13]

3.4.2
electrical thermal resistance

$R_{th(j\text{-}X)el}$

quotient of the difference in the thermodynamic temperature between the junction temperature T_j and the reference point temperature T_X, by the electrical power dissipation P

$$R_{th(j\text{-}X)el} = \frac{T_j - T_X}{P}$$

Note 1 to entry: The electrical thermal resistance is expressed in kelvin per watt (K·W^{-1}).

3.4.3
real thermal resistance

$R_{th(j\text{-}X)real}$

quotient of the difference in the thermodynamic temperature between the junction temperature T_j and the reference point temperature T_X, by the heating power dissipation (the heating power dissipation is the electrical power dissipation minus the radiant flux)

$$R_{th(j\text{-}X)real} = \frac{T_j - T_X}{P - \Phi_e}$$

Note 1 to entry: The real thermal resistance is expressed in kelvin per watt (K·W^{-1}).

3.5 Abbreviations

PCB printed circuit board

AC alternating current

DC direct current

4 Absolute maximum ratings

Absolute maximum ratings are shown in Table 1. They are specified at the ambient temperature or the reference point temperature T_X = (25 ± 3) °C, unless otherwise stated.

These ratings are applicable to ~~the five types of LED as described in Clause 1~~ the six types as follows:

a) LED package;

b) LED flat illuminator;

c) LED numeric display and alpha-numeric display;

d) LED dot-matrix display;

e) ~~I-LED(infrared-emitting diode)~~ IR LED;

f) UV LED.

Table 1 – Absolute maximum ratings

Item	Symbol	Conditions	Ratings	Unit	To be applicable for LEDs of type					
					a)	b)	c)	d)	e)	f)
Allowed forward current [a]	I_F	–		mA	○	○	○	○	○	○
Total allowed forward current [b]	I_F	–		mA	○	○	○	○	○	○
Forward current lapse rate [b]	ΔI_F	–		mA/°C	○	○	○	○	○	○
Allowed forward pulse current [a, e]	I_{FPM}	Pw = Duty =		A	○	○	○	○	○	○
Total allowed forward pulse current [b, e]	I_{FPM}	Pw = Duty =		A	○	○	○	○	○	○
Allowed forward pulse current lapse rate [b, e]	ΔI_{FPM}	Pw = Duty =		A	○	○	○	○	○	○
Reverse voltage	V_R			V	○	○		○	○	○
Electrostatic discharge [b, f]	ESD	HBM		V	○	○			○	○
Allowed power dissipation [b]	P_D	T_j = or T_X =		mW	○	○	○	○	○	○
Operating temperature [c]	T_j or T_X	–	~	°C	○	○	○	○	○	○
Storage temperature [d]	T_{stg}	–	~	°C	○	○	○	○	○	○
Soldering temperature	T_{sol}	–		°C	○	○	○		○	○

[a] These values are specified for each segment.

[b] These items are specified when necessary.

[c] The operating temperature is specified based on junction temperature T_j or reference point temperature T_X at X.

Reference point X shall be selected according to the purpose.

Reference point temperatures are described as T_c for case, T_S for soldering point and T_a for atmosphere.

[d] The storage temperature is specified for ambient temperature.

[e] Pw = pulse width.

[f] HBM/ESD = human body model / electrostatic discharge test (IEC 60749-26).

5 Electrical and optical characteristics

Electrical and optical characteristics are shown in Table 2. They are specified at the ambient temperature or the reference point temperature T_X = (25 ± 3) °C, unless otherwise stated.

These electrical and optical characteristics are applicable to ~~the five types of LED as described in Clause 1~~ the six types as follows:

a) LED package;

b) LED flat illuminator;

c) LED numeric display and alpha-numeric display;

d) LED dot-matrix display;

e) ~~I LED(infrared-emitting diode)~~ IR LED;

f) UV LED.

Table 2 – Electrical and optical characteristics

Item	Symbol	Measuring method	Conditions	Characteristics			Unit	To be applicable for [a]					
				min.	typ.	max.		a)	b)	c)	d)	e)	f)
Forward voltage	V_F	see 6.2	I_F = .. mA	–			V	○	○	○	○	○	○
Reverse current	I_R	see 6.5	V_R = .. V	–	–		µA	○	○	○	○	○	○
Luminous flux [b]	Φ_v	see 6.10	I_F = .. mA				lm	○	○	○	○		
Radiant flux [c]	Φ_e	see 6.11	I_F = .. mA				mW					○	○
Luminous intensity [b, d]	I_v	see 6.12	I_F = .. mA				mcd	○	○	○			
Radiant intensity ~~[b]~~[c]	I_e	see 6.13	I_F = .. mA				mW/sr					○	○
Luminance ~~[c]~~[d]	L_v	see 6.14	I_F = .. mA				cd/cm²		○	○	○		
Peak emission wavelength [e]	λ_p	see 6.15	I_F = .. mA				nm	○	○	~~○~~	○	○	○
Spectrum width of half value	$\Delta\lambda$	see 6.15	I_F = .. mA	–		–	nm	○	○	○	○	○	○
Dominant emission wavelength [e]	λ_d	see 6.16	I_F = .. mA				nm	○	○	○	○		
Chromaticity ~~[d]~~ [f]	x,y	see 6.16	I_F = .. mA				–	○	○	○	○		
Cut-off frequency ~~[d,e]~~ [f, g]	f_c	see 6.9	I_F = .. mA $I_p(f_0)$ = ..mA f_0 = .. MHz	–			MHz					○	○

Item	Symbol	Measuring method	Conditions	Characteristics			Unit	To be applicable for [a]					
				min.	typ.	max.		a)	b)	c)	d)	e)	f)
Thermal resistance ~~d,~~ f, h, i	$R_{th(j-X)el}$	see 6.7	P_D = .. mW	–		–	K/W	○				○	○
	$R_{th(j-X)real}$ [j]	see 6.7	P_D = .. mW	–		–	K/W	○				○	○
Power efficiency [f, j]	η_{PE}	IEC 60747-5-8	I_F = .. mA	–		–	–	○				○	○
Full width half maximum of an intensity [k]	$2\theta_{1/2}$	see 6.17	I_F = .. mA		–		°	○				○	○

a These values are specified for each segment.

~~b Either radiant intensity or luminous flux is specified.~~

~~c Either luminance or luminous intensity is specified.~~

b Either luminous intensity or luminous flux or both of them is specified.

c Either radiant intensity or radiant flux or both of them is specified.

d Either luminance or luminous intensity or both of them is specified.

e Either peak emission wavelength or dominant emission wavelength or both of them is specified.

~~d~~f These items are specified when necessary.

~~e~~g Either cut-off frequency or response time (rise time, fall time) is specified.

~~f~~h Reference point X is selected according to the purpose.
Thermal resistances are described using reference points $R_{th(j-c)}$ for case, $R_{th(j-s)}$ for solder point and $R_{th(j-a)}$ for ambient.

i The following measurement condition should be described:

- measuring method (heating method or cooling method);
- the configuration, size and material of the PCB that the test LED is mounted on;
- the thickness and area of the pattern (copper) that is on the PCB;
- the size, material and fin of the attached heat sink (if appropriate).

j It should be specified for LEDs with power consumption ≥0,5 W and power efficiency ≥10 %.

~~g~~k The radiation pattern of LEDs is shown with a figure.

6 Measuring method

6.1 Basic requirements

6.1.1 Measuring conditions

The measuring conditions are the following:

a) Temperature

~~If not specified,~~ Measurements shall be made at an ambient (T_a) or reference point temperature (T_X) of (25 ± 3) °C in a condition of ~~free air~~ natural convection unless otherwise specified.

b) Humidity

~~When humidity condition is not specified,~~ Relative humidity shall be between ~~45~~ 25 % and ~~85~~ 75 % unless otherwise specified.

c) Atmospheric condition

Atmospheric condition shall be between 86 kPa and 106 kPa unless otherwise specified.

d) Precaution

In some cases, measurements change because of heat generation in the test LED over time. In that case, it is necessary to decide on the measurement time, otherwise the measurement shall be performed after reaching thermal equilibrium.

Thermal equilibrium may be considered to have been achieved if doubling the time between the application of power and the measurement causes no change in the indicated result within the precision of the measurement instruments.

6.1.2 Measuring instruments and equipment

6.1.2.1 General

The measuring instruments and equipment are specified in 6.1.2.2 to 6.1.2.7.

6.1.2.2 Power supplies

DC power-supply ripple shall be less than 3 %. In addition, the impedance value of the power supply shall not affect the measurement.

6.1.2.3 Instruments for electric characteristics and measuring instruments

When the accuracy is not specified, the instrument shall be as specified in IEC 60051 (all parts). A digital instrument and the measuring instrument shall have an accuracy either equalling or surpassing IEC 60051 (all parts), and the impedance shall be such that the influence on the measurement system can be ignored. ~~However, this is not the case in the following situations:~~

~~a) when no serious influence affects a measurement result;~~

~~b) when no serious influence affects a judgment of result.~~

NOTE Instead of the semiconductor electric characteristic measurement with the set of power supply and current source, the source monitor unit (SMU) that combines voltage/current source and digital measurement functions, or SMU system, has become the industry-wide standard. The measurement with SMU is suitable for high-accuracy measurements, such as in 6.5.

6.1.2.4 Standard light source

A light source for the photometry with high stability, high reproducibility and with an appropriate photometric value shall be used.

6.1.2.5 Measuring instruments for photometry

One of the following instruments shall be used:

a) A ~~monochrometer~~monochromator-type instrument (a wavelength scanning type monochromatic light spectrophotometer):

A spectrophotometer that measures a spectrum by turning a diffraction grating, and taking light of a specific wavelength through a slit sequentially and selectively.

b) A ~~polycrometer~~polychromator-type instrument (many wavelength spectrophotometer):

A spectrophotometer which measures a spectrum with a detector at the same time using a one-dimensional photodiode array from the diffraction light out of a fixed diffraction grating.

c) A filter-type instrument ($V(\lambda)$ spectrophotometer):

A photometer which has characteristics that are similar to spectral luminous efficiency, without using a spectrum optical system. This photometer comprises a photoelectric tube, a photomultiplier or a photoelectromotive force device whose sensitivity distribution on the light receiving side is flat and stable with a filter for visual sensitivity revision. In using this filter-type photometer, the measuring light shall be monochromatic, and the wavelength range of objective light should be within the wavelength range of the measuring instrument.

NOTE The filter-type photometer is not suitable for the photometry of the following products:

– product which has a light mixing method using excited light emission from the LED die and the fluorescent substance applied onto the LED die (phosphor based LEDs), or
– product of a many-wavelength light emission method equipped with different LEDs of a plurality of emission spectra.

6.1.2.6 Measuring instruments for radiometry

The measuring instruments for radiometry are the following:

a) A ~~monochrometer~~ monochromator type instrument (a wavelength scanning type monochromatic light radiometer):

   A spectroradiometer that measures a spectrum turning a diffraction grating, and taking light of a specific wavelength through a slit sequentially and selectively.

b) A ~~polycrometer~~ polychromator type instrument (many wavelength radiometer):

   A spectroradiometer which measures a spectrum with a detector at the same time using a one-dimensional photodiode array from the diffraction light out of a fixed diffraction grating.

c) Optical power meter:

   A radiometer consisting of a phototube, a photomultiplier or a photoelectromotive-force device. It provides a flat and stable response sensitivity characteristic in a wavelength range of measurement light, and is calibrated so as not to keep a weighting of the response sensitivity for the wavelength, without using a spectrum optical system. In using this radiometer, the measuring light shall be monochromatic, and the wavelength range of objective light should be within the wavelength range of the measuring instrument.

6.1.2.7 Devices used for the emission spectrum characteristic measurement

Devices with necessary wavelength bandwidth and resolution for the measurement of the LED under test shall be used.

6.1.3 Essential requirements

6.1.3.1 General

The essential requirements are given in 6.1.3.2 to 6.1.3.4.

6.1.3.2 Point with zero electric potential

The point with zero electric potential to apply the potential on each electrode of the LED under test shall be the cathode terminal.

6.1.3.3 Power supply

The power supply shall be the following:

a) Applied voltage

   The applied voltage to a certain electrode is the potential difference between the electrode and the point with zero electric potential.

b) Supply voltage

   The supply voltage is the voltage supplied to a circuit including the LED under test.

c) Polarity

   The polarity of all electric potential is specified by the polarity for the point with zero electric potential.

6.1.3.4 Shading

During the measurement, suitable shading shall be given so that the light from the outside or other emission does not affect the measurements.

6.1.4 General precautions

The general precautions are as follows:

a) Absolute maximum rating

Even a second, external stress shall not exceed this value to guarantee normal operation of the LED under test.

b) Transient behaviour

Even in a transient state, the voltage and current shall not exceed the value of the absolute maximum rating.

c) Consideration for the heating

In the event that the LED measurement needs to avoid a measurement error produced by heat generation in the LED under test during a measurement period, the measurement shall be performed in a pulse condition.

When absolutely necessary, indicate "Pulse measurement", and specify the pulse state.

d) Consideration for ultraviolet radiation

Provisions for the prevention and control of the risk of ultraviolet radiation.

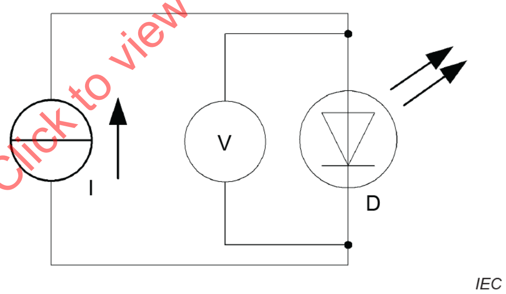
6.2 Forward voltage (V_F) measurement

6.2.1 Purpose

To measure the forward voltage of the LED when a specified forward current is applied.

6.2.2 Circuit diagram

The circuit diagram is shown in Figure 6.



Key

I constant current source

V voltmeter

D light emitting diode being measured

Figure 6 – Circuit diagram for V_F measurement

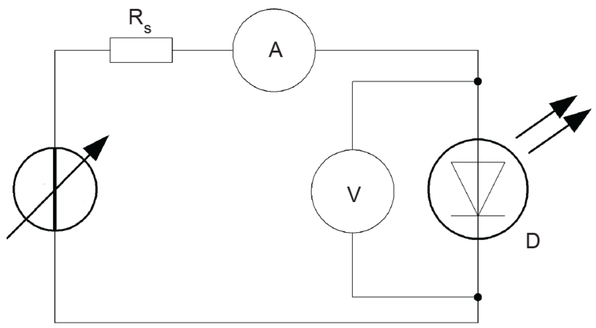
6.2.3 Requirements

A constant current source shall in principle be used for the measuring circuit.

If the forward current ~~needs to be~~ is set to the rated value using a constant voltage source and a current-limiting resistor, ~~design~~ the circuit diagram as shown in Figure 7 shall be applied.

In such a case, to avoid changes in the forward voltage resulting from accumulated heat in the test LED and corresponding changes in the set current, set the impedance for the drive side higher.

$$R_S \cdot I_F >> V_F$$



Key

A ammeter

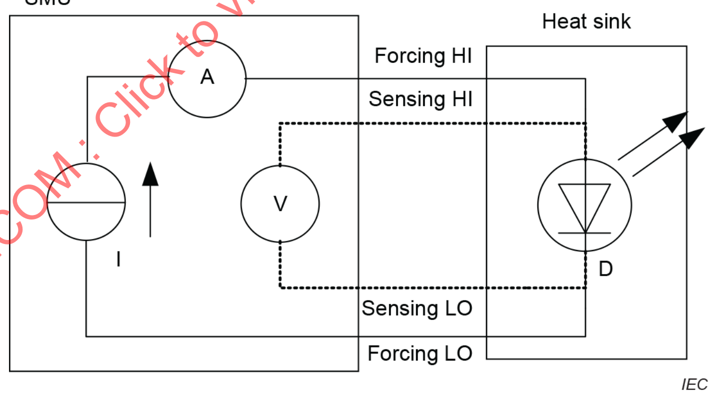
V voltmeter

R_s current limiting resistor

D light emitting diode being measured

Figure 7 – Circuit diagram for V_F measurement with a constant voltage source and a current-limiting resistor

In the case of high driving power LED (high power LED, high-flux LED), the driving current rating is usually specified in a condition using a heat sink instead of free air condition. For the measurement, the LED shall be mounted on an appropriate heat sink, and be measured using Kelvin contact in order to reduce measurement errors resulting from contact resistance and wiring impedance. An example of measurement using SMU is shown in Figure 8.



Key

SMU source measurement unit

I constant current source

A ammeter

V voltmeter

D light emitting diode being measured (high driving current LED)

Figure 8 – Circuit diagram for V_F measurement using an SMU

6.2.4 Measurement procedure

Forward voltage (V_F) is measured when the specified forward current (I_F) is applied to the test LED.

6.2.5 Precautions to be observed

See 6.1.

6.2.6 Specified conditions

The specified conditions are as follows:

– forward current and the driving conditions;
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.3 Reverse voltage (V_R) measurement

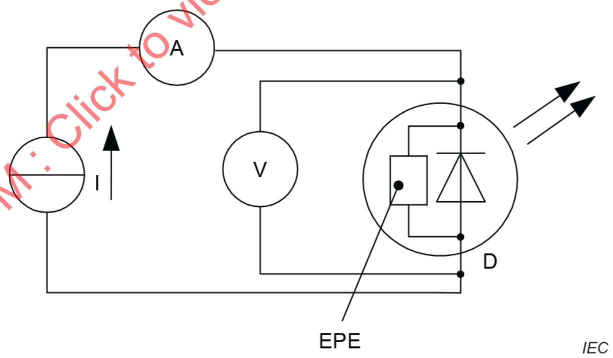
6.3.1 Purpose

To measure the reverse voltage of the LED when a specified reverse current is applied.

This measurement is performed for the reverse characteristics test in the case of LED mounting a parallel-connected Zener diode for electrostatic discharge protection. In measuring voltage at a rated current, thoughtless measurement of the reverse voltage for a general LED without any protection circuit should not be performed to avoid a stress voltage at breakdown voltage or above the absolute maximum rating of reverse voltage.

6.3.2 Circuit diagram

The circuit diagram is shown in Figure 9.



Key

~~I_R~~ I	constant current source
V	voltmeter
A	ammeter
D	light emitting diode being measured
EPE	electrostatic protection element

Figure 9 – Circuit diagram for V_R measurement

6.3.3 Measurement procedure

Reverse voltage (V_R) is measured when the specified reverse current (I_R) is applied to the test LED.

6.3.4 Precautions to be observed

See 6.1.

6.3.5 Specified conditions

The specified conditions are as follows:

– reverse current (I_R);
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.4 Differential resistance (r_f) measurement

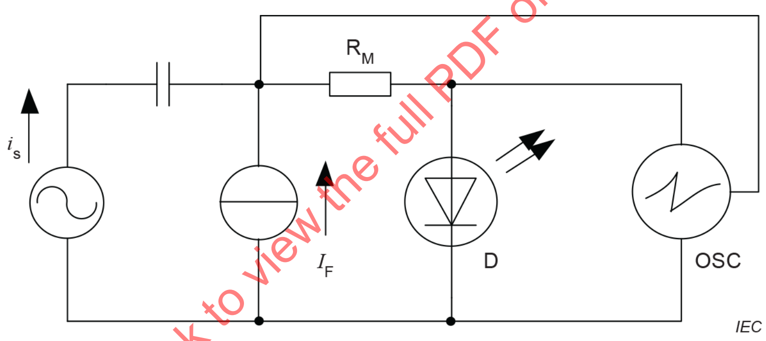
6.4.1 Purpose

To measure the differential resistance of the LED in specified measuring conditions.

NOTE Generally the series resistance of a LED is greater than that of a general rectifier diode. This measurement is performed to determine required driving voltage and to design the driving circuit for a power LED or a high flux LED driven by high current.

6.4.2 Circuit diagram

The circuit diagram is shown in Figure 10.



Key

R$_M$ current detect resistor

i_s superimposed AC

I_F forward DC

OSC oscilloscope

D light emitting diode being measured

Figure 10 – Circuit diagram for r_f measurement

6.4.3 Requirements

In principle, the differential resistance shall be measured in such a manner that the AC is superimposed on the specified DC.

NOTE If the region in which the forward characteristic curve of the LED can be substantially regarded as a straight line near the specified current, the measurement can also be performed by calculating the resistance value based on the gradient of the current and voltage values between two points near the region.

6.4.4 Measurement procedure

The specified forward DC and AC to be superimposed are applied to the test LED.

After measurement of forward current and forward voltage waveforms of the LED with a calibrated oscilloscope, the differential resistance is calculated using their amplitude by the following formula:

$$r_f = \frac{\Delta V_F}{\Delta I_F}$$

where

ΔV_F is the amplitude of forward voltage waveform;

ΔI_F is the amplitude of forward current waveform.

6.4.5 Precautions to be observed

The precautions to be observed are as follows:

a) The frequency of AC to be superimposed should be around 10 kHz so that it will not affect the measurement.
b) The forward current including AC should be as high as possible within the rated value.
c) For details other than those provided in a) and b) above, see 6.1.

6.4.6 Specified conditions

The specified conditions are as follows:

– the value of forward current and the amplitude of AC to be superimposed, or the amplitude modulation factor $\left(M = \left(\max\left|(i_s)\right|\right) / I_F\right)$;
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

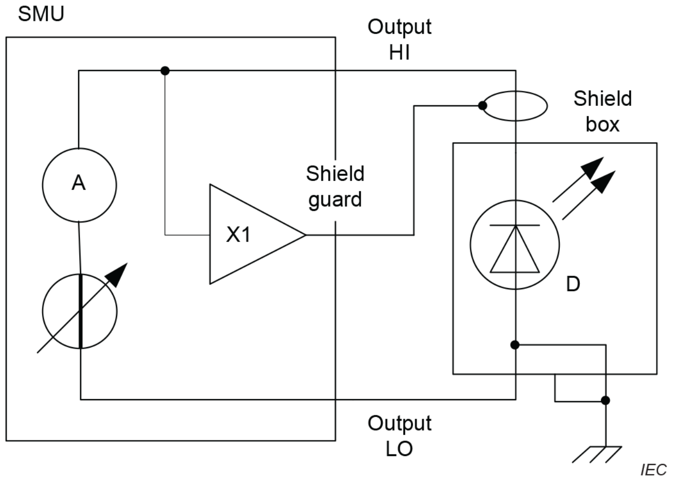
6.5 Reverse current (I_R) measurement

6.5.1 Purpose

To measure the reverse current of the LED at a specified reverse voltage.

6.5.2 Circuit diagram

Figure 11 is an example using the SMU.



Key

SMU source measurement unit

A ammeter

X1 buffer amplifier

D light emitting diode being measured

Figure 11 – Circuit diagram for I_R measurement

6.5.3 Provisions

Since the reverse current is extremely small within the rated applied voltage, the measurement becomes the "minute current measurement". It is desirable to have a shield to eliminate foreign noise, prevent leaks at cables and the connecting terminals, and prevent any electrostatic discharge. If the SMU has a current limiter function, it is desirable to set the current limiter to prevent the test LED from being destroyed.

6.5.4 Measurement procedure

The reverse current (I_R) is measured when specified reverse voltage (V_R) is applied to the test LED.

6.5.5 Precautions to be observed

See 6.1.

6.5.6 Specified conditions

The specified conditions are as follows:

– reverse voltage (V_R);

– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.6 Measurement of capacitance between terminals (C_t)

6.6.1 General

Two measuring methods are specified:

– measurement using LCR meter;

– measurement using AC bridge.

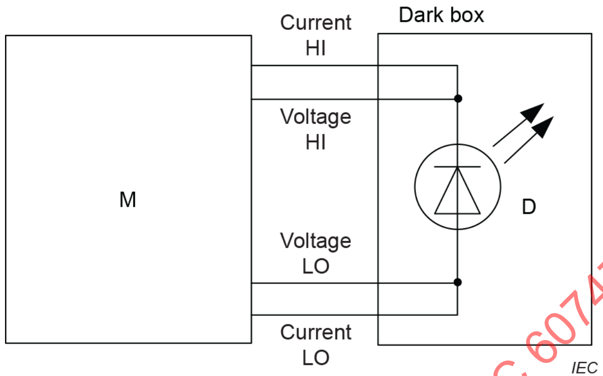
6.6.2 Measurement using LCR meter

6.6.2.1 Purpose

To measure the capacitance between terminals of the LED when the specified reverse voltage is applied (including zero bias voltage).

6.6.2.2 Circuit diagram

The circuit diagram is shown in Figure 12.



Key

D light emitting diode being measured

M LCR meter (or impedance analyzer) using a self-balancing bridge system

Figure 12 – Circuit diagram for C_t measurement

6.6.2.3 Requirements

The self-balancing bridge system represents a system in which the impedance is calculated using the phase information of the signal source and comparison of the voltage of the AC signal source with the value of the voltage that is converted from the current flowing along the test sample.

6.6.2.4 Measurement procedure

The capacitance between the terminals (C_t) is measured when the specific DC bias voltage is applied to the test LED.

6.6.2.5 Precautions to be observed

See 6.1.

6.6.2.6 Specified conditions

The specified conditions are as follows:

– DC bias voltage;
– frequency to be measured (f) – usually 1 MHz is used;
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

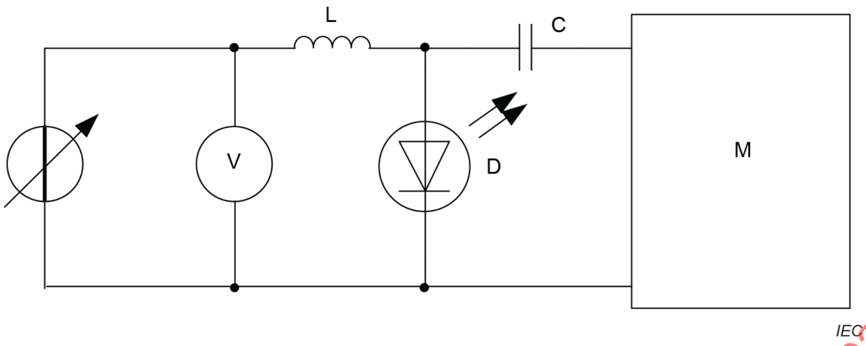
6.6.3 Measurement using AC bridge

6.6.3.1 Purpose

To measure the capacitance between the terminals of the LED when the specified reverse voltage is applied other than for a zero-bias voltage.

6.6.3.2 Circuit diagram

The circuit diagram is shown in Figure 13.



Key

D light emitting diode being measured

M AC bridge

L inductor

C capacitor

Figure 13 – Circuit diagram for C_t measurement

6.6.3.3 Requirements

The bias circuit for the test LED shall satisfy the following condition in order to maintain the accuracy of the measurement and the measuring signal voltage shall be a signal that is sufficiently smaller than the bias voltage.

$$C \gg C_X \gg \frac{1}{(2\pi f)^2 L}$$

where

C_X is the capacitance of the test LED;

f is the measuring frequency.

6.6.3.4 Measurement procedure

The capacitance between terminals (C_t) is measured when the specific DC bias voltage is applied to the test LED.

6.6.3.5 Precautions to be observed

See 6.1.

6.6.3.6 Specified conditions

The specified conditions are as follows:

– DC bias voltage;
– measuring frequency (f) – usually 1 MHz is used;
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.7 Measurement of junction temperature (T_j) and thermal resistance ($R_{th(j-X)el}$, $R_{th(j-X)real}$)

6.7.1 Purpose

To measure the junction temperature and the thermal resistance under ~~established~~ specified conditions.

6.7.2 Measurement principle

~~While specified total power dissipation (P) is applied to the LED keeping the specified condition of heat radiation and ambient temperature, the junction temperature (T_j) and the reference point temperature (T_X) at reference point X are measured. Thermal resistance $R_{th(j-X)}$ is calculated from the following formula.~~

$$R_{th(j-X)} = \frac{T_j - T_X}{P}$$

~~The reference point shall be chosen according to the purpose and the reference point temperature (T_X) will equal, for example, that of the ambient temperature (T_a), the case temperature (T_c) or the soldering position temperature (T_S).~~

~~T_j is estimated by using the temperature dependence of the forward voltage (V_F) as a temperature sensitive parameter. The temperature dependence of forward voltage is obtained by the measurement of forward voltage (V_F) at different points of ambient temperature. The rise of junction temperature is estimated by the change in forward voltage (V_F) induced by total power dissipation (P).~~

~~The thermal resistance is classified into "saturated thermal resistance" and "transient thermal resistance" as follows depending on time duration (t_p) of total power dissipation (P).~~

~~a) Saturated thermal resistance~~

~~The thermal resistance under the condition in which the total power dissipation (P) is continuously applied until the thermal equilibrium is reached.~~

~~b) Transient thermal resistance~~

~~The thermal resistance when power dissipation is applied for a short period of time. The value of thermal resistance depends on time duration (t_p) of power.~~

While specified electrical power dissipation (P) is applied to the device being measured, the electrical thermal resistance $R_{th(j-X)el}$ is calculated by using the junction temperature (T_j) and the reference point temperature (T_X) as follows.

$$R_{th(j-X)el} = \frac{T_j - T_X}{P}$$

Change in the forward voltage (V_F) induced by electrical power dissipation (P) causes the rise of T_j. T_j is derived from the temperature dependence of the forward voltage (V_F) as a temperature sensitive parameter. The temperature dependence of the forward voltage is obtained by measuring the forward voltage (V_F) at different ambient temperatures.

The real thermal resistance $R_{th(j-X)real}$ is calculated by using the heating power dissipation that is the subtraction of the radiant flux from the electrical power dissipation. It can be derived from the optical energy conversion efficiency (power efficiency η_{PE}) as follows.

$$R_{\text{th(j-X)real}} = \frac{T_{\text{j}} - T_{\text{X}}}{P(1 - \eta_{\text{PE}})}$$

However, it should be noted that power efficiency η_{PE} is a temperature dependent parameter.

To calculate the actual junction temperature more accurately, η_{PE} shall be determined under actual usage conditions by considering its temperature dependence.

η_{PE} shall be derived separately according to the temperature at the reference point X and the driving current.

Figure 14 shows an example of the temperature dependence of η_{PE}.

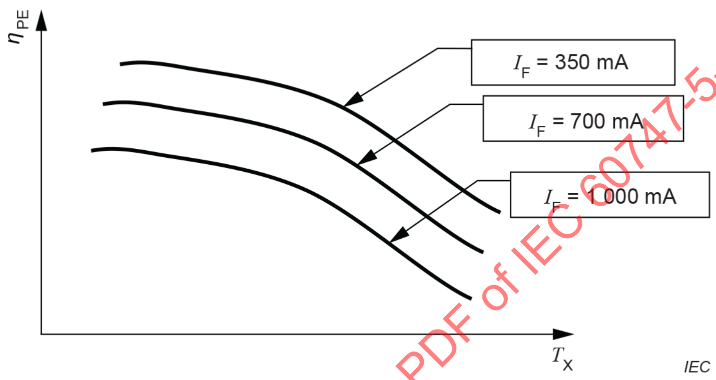


Figure 14 – An example of the temperature dependence of η_{PE}

Reference point X shall be on the heat flow path of the substrate mounted LED, and the temperature shall be measured when the LED is lit.

For example, for a 2-terminal LED device, the reference point X should be a terminal side with higher heat flow, namely the soldering point of the terminal on which the LED die is mounted.

However, when it is difficult to locate the reference point X in such an area, the reference point shall be set at the location where the heat flow rate is as large as possible.

The measured thermal resistance of a LED with appropriate heat sink shows a dependence on the heating time duration (t_p) as shown in Figure 15.

Figure 15 shows an example that two saturation regions are observed.

The first saturated region indicates the state in which the case (or the soldering point) has almost warmed up, while the last saturated region indicates the process until the whole test sample has reached the steady state.

That is, the two saturation regions above correspond to the junction-to-case thermal resistance Rth(j-c) or the junction-to-soldering point thermal resistance Rth(j-s) and the junction-to-ambient thermal resistance Rth(j-a), respectively.

Figure 16 shows the cumulative thermal capacitance versus cumulative thermal resistance characteristics (generally referred to as the "structural function") determined by mathematically converting the data given in Figure 15.

In the structural function, Figure 16, the part with large inclination such as the one between B and C corresponds to one of the structural layers of the tested LED package which have low thermal resistance and high thermal capacitance values. On the other hand, the part with low inclination in the structural function such as the one between A and B corresponds to one of the structural layers of the tested LED package which have high thermal resistance and low thermal capacitance values.

This means that the point where the inclination changes in the structural function reveals the difference in the structure. By using this property, the thermal resistance and the thermal capacitance can be estimated separately for each structural layer of the LED package.

Therefore, it is recommended to use the cumulative thermal capacitance versus cumulative thermal resistance characteristics (structural function) for the thermal design of a pulse-driven systems.

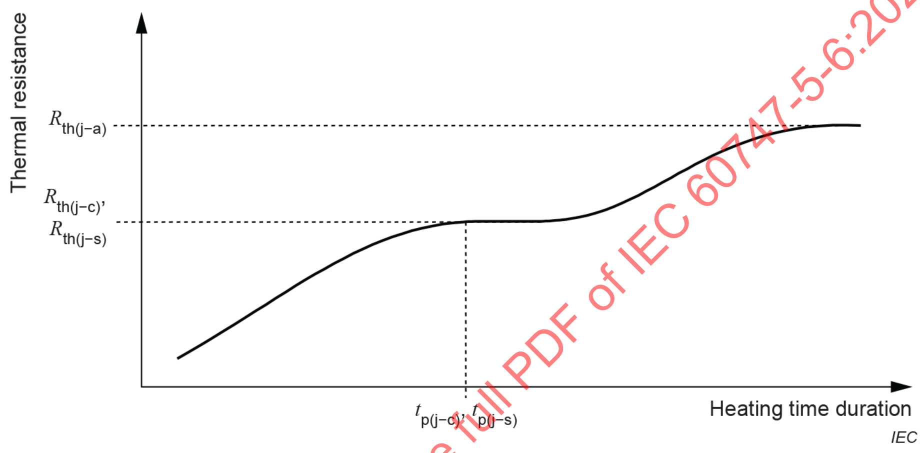


Figure 15 – Heating time duration dependence of the measured thermal resistance

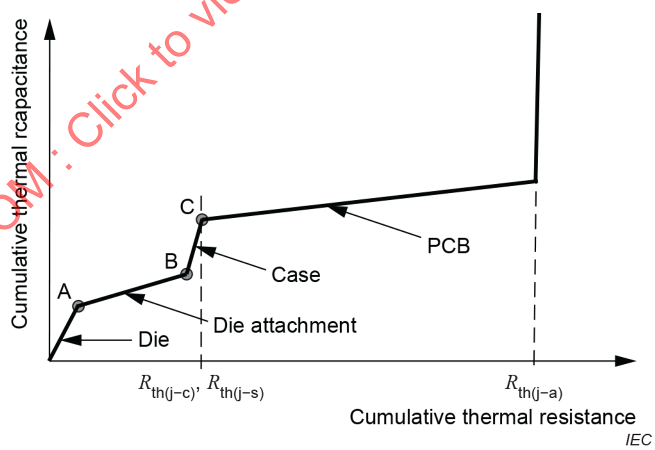


Figure 16 – Cumulative thermal capacitance versus cumulative thermal resistance characteristics (structural function)

6.7.3 Measurement procedure

6.7.3.1 Preparation

The test LED shall be mounted on PCB and/or thermally managed. Measuring atmosphere around the test LED shall be natural convection.

If the LED is to be enclosed in a box to prevent effect from external heat and wind, the box size and material shall be selected appropriately according to the degree of heat. If the measurement is not performed in a dark environment, influence of the photoelectric effect on the measurement accuracy shall be checked in advance.

6.7.3.2 Measurement of temperature coefficient of forward voltage (V_F)

~~The relationship between the forward voltage (V_F) and junction temperature (T_j) is obtained as the temperature coefficient by the following procedure.~~

~~At first, the LED is held in a variable temperature oven and left until it is considered to be at equilibrium as T_j becomes equal to the oven temperature. Then the forward voltage (V_F) is measured at a small measuring current (I_M) so that the temperature rise by the measurement is negligible.~~

~~Subsequently, several points of the forward voltage are measured sequentially corresponding to the varied oven temperature as a temperature dependent characteristic of the forward voltage.~~

Temperature coefficient of the forward voltage (V_F) shall be measured by using the following procedure.

The LED being measured is held in a variable temperature oven. Then wait until reaching at thermal equilibrium as T_j becomes equal to the oven temperature. Then measure the forward voltage (V_F) at a small forward current (I_M). The forward current shall be small enough so that the junction temperature rise is negligible. Generally, approximately 1 mA per die should be applied for the measurement.

Subsequently, repeat the above procedure sequentially at different oven temperatures to get the temperature dependent characteristic of the forward voltage. Derive the temperature coefficient of the forward voltage from the measurement result.

NOTE In the case of LED with resistor, even though the measured temperature coefficient includes the temperature dependence of the resistor, the measured value is still considered to be the temperature coefficient of the LED.

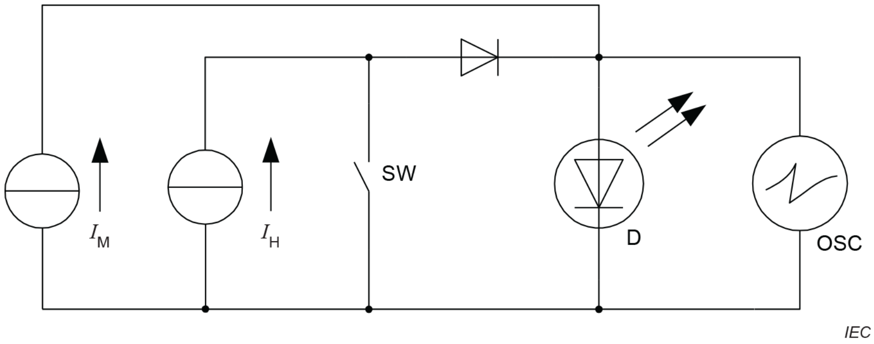
6.7.3.3 Measurement of change in forward voltage (V_F) induced by power dissipation (P)

~~The change in forward voltage (V_F) induced by the power dissipation (P) given on the LED is measured by the circuit shown in Figure 14 as an example.~~

There are two methods for the measurement of the change in the forward voltage (V_F) induced by the power dissipation (P) given on the LED. One is heating method (dynamic mode) and the other is cooling method (static mode). Both methods can be applicable for calculating the thermal resistance of the LED, but it shall be stated in the specification table that which method is used for the derivation of the thermal resistance.

Both methods use the measuring circuit shown in Figure 17. However, the two methods differ from each other in terms of how the electrical power dissipation (P) is applied and when the forward voltage (V_F) is measured after heating.

In these methods of measurement, the transient thermal resistance can be measured more quickly using the static mode, and the junction temperature may be slightly lower using the dynamic mode.



Key

I_M	measuring current
I_H	heating current
SW	switch
D	light emitting diode being measured
OSC	oscilloscope

Figure 17 – Circuit diagram for measurement of change in V_F

a) Heating method (dynamic mode)

Turn the SW on.

Apply a small measuring current (I_M) only to the LED where the junction temperature rise is negligible, and measure the forward voltage before heating (V_{F1}).

Turn the SW off for applying the heating current (I_H) superimposed on I_M at the same time.

The heating current is applied for power dissipation during a specified "heating time duration (t_p)".

Then, turn the SW on. In this situation, only the small measuring current (I_M) is applied to the LED.

Measure the forward voltage again (V_{F2}) just after the SW on.

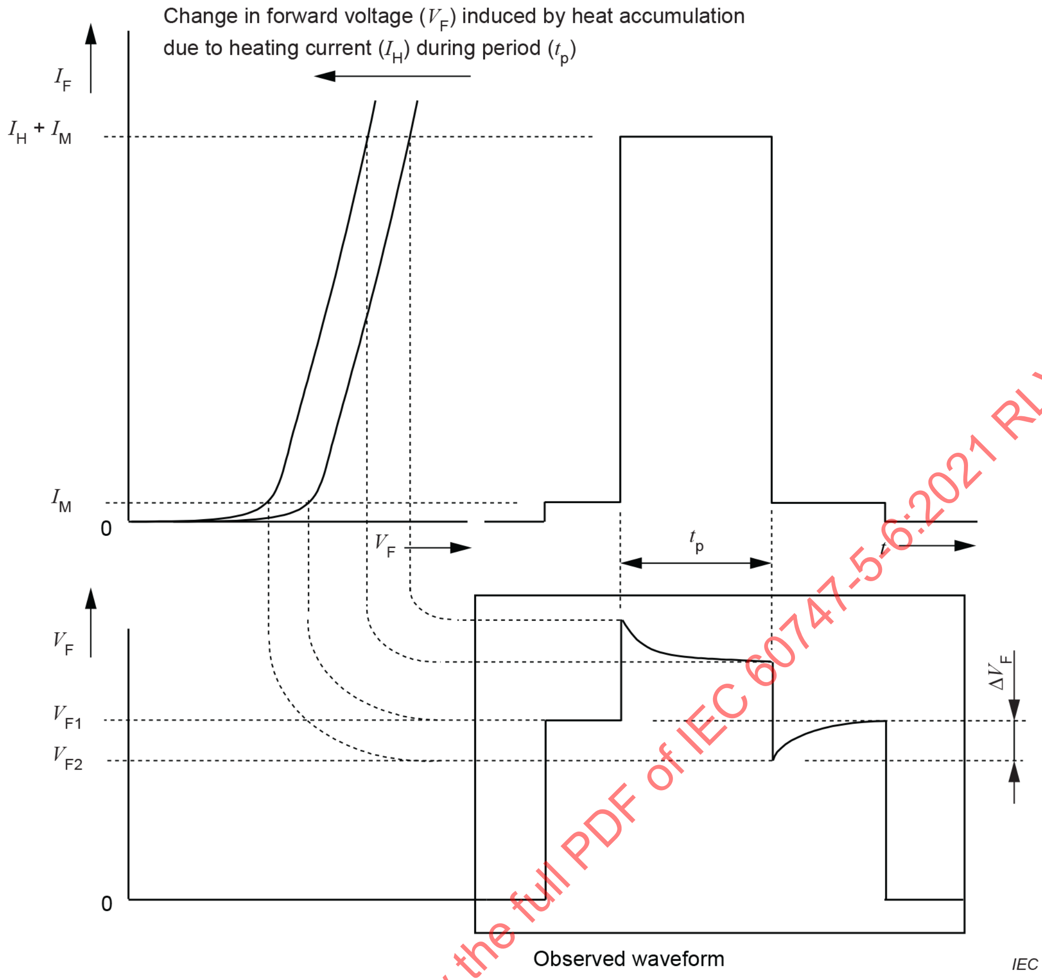


Figure 18 – Change in V_F during the measurement

The measured forward voltage V_{F2} just after the end of power dissipation is lower than the forward voltage V_{F1} before heating due to heat accumulation produced by power dissipation. However, V_{F2} will return to value V_{F1} afterwards.

The forward voltage change observed by a oscilloscope are shown in Figure 18.

The measurement timing of V_{F2} just after the end of heating shall be short enough in comparison with the thermal time constant of the test LED. However, since a transient ringing noise is superimposed onto the observed waveform due to the cut-off of the heating current (I_H), V_{F2} sampling is done after a certain delay time to avoid the influence of the ringing noise. The junction temperature T_j that is determined by using the dynamic mode is corresponds to specific delay time has passed, not immediately after the heating is off. Accordingly, junction temperature T_j may be slightly lower for some types of LED.

b) Cooling method (static mode)

Turn the SW off.

Heating current and a small measuring current are applied to the LED for a sufficiently long time until the system reaches the equilibrium state.

After heating current is off, namely just after turning the SW is on, measure the time variation in V_F.

In this situation, only the small measuring current (I_M) is applied to the LED.

Figure 19 shows an example of the measured time variation in V_F.

Since the forward voltage V_F that is observed immediately after the heating current (I_H) is off inevitably contains the transient vibration waveform, an accurate V_F value cannot be determined from the observed waveform.

An accurate V_F can be calculated by extrapolating the cooling behaviour which is linear to the square root of time as shown in Figure 20.

The junction temperature T_j is determined from the derived values by performing a conversion in accordance with 6.7.3.2. Details on this approach are provided in the JEDEC standards (JESD51-14).

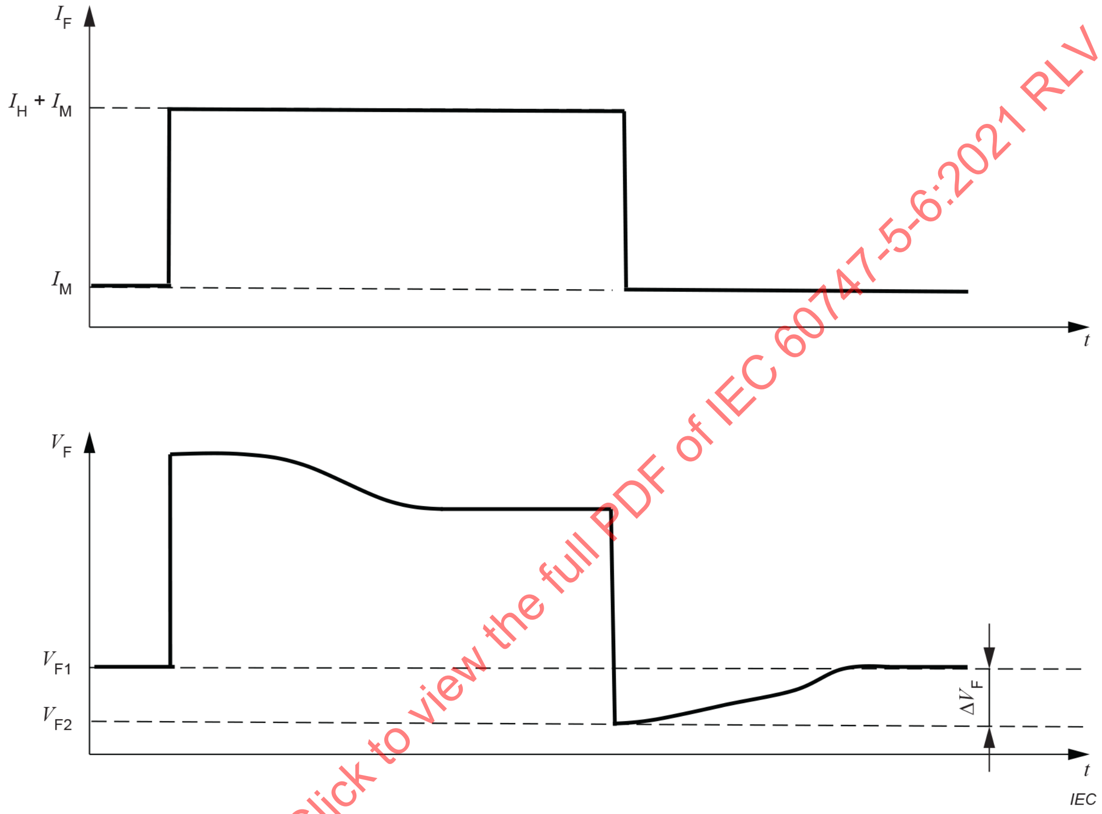


Figure 19 – Example of the time variation in V_F

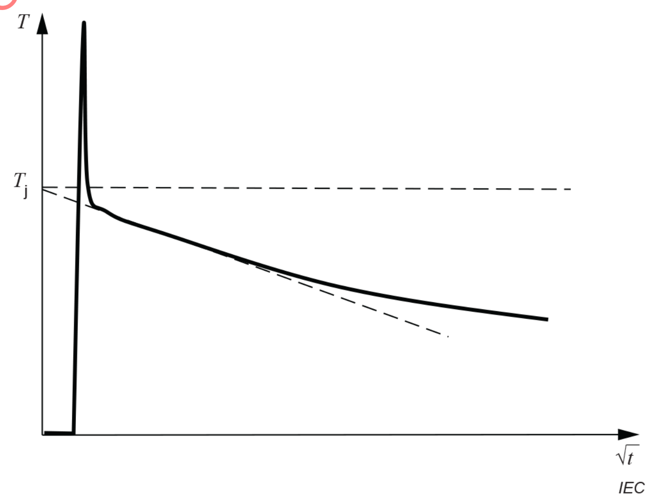


Figure 20 – Transient vibration waveform immediately after the heating is off

6.7.3.3 Thermal resistance measurement

6.7.3.3.1 Transient thermal resistance measurement

The switch is closed beforehand.

Only a small measuring current (I_M) is applied to the LED where the junction temperature rise is negligible, and the forward voltage (V_{F1}) before heating is measured with a calibrated DC oscilloscope.

When the switch is open, a heating current (I_H) is superimposed at the same time.

The heating current is applied for power dissipation during a specified "power dissipating time (t_p)".

The switch is then closed.

Forward voltage (V_{F2}) just after the time of the return to only the "measurement current (I_M)" is measured again with the calibrated DC oscilloscope.

6.7.3.3.2 Saturated thermal resistance measurement

Close the switch beforehand.

Only a small measuring current (I_M) is applied to the LED where the junction temperature rise is negligible, and the forward voltage (V_{F1}) before heating is measured with the calibrated DC oscilloscope.

When the switch is open, the heating current (I_H) is superimposed at the same time.

The heating current is applied for power dissipation for a long time until the system reaches the equilibrium state.

Forward voltage (V_{F2}) just after the time of the return to only the "measurement current (I_M)" is measured again with the calibrated DC oscilloscope.

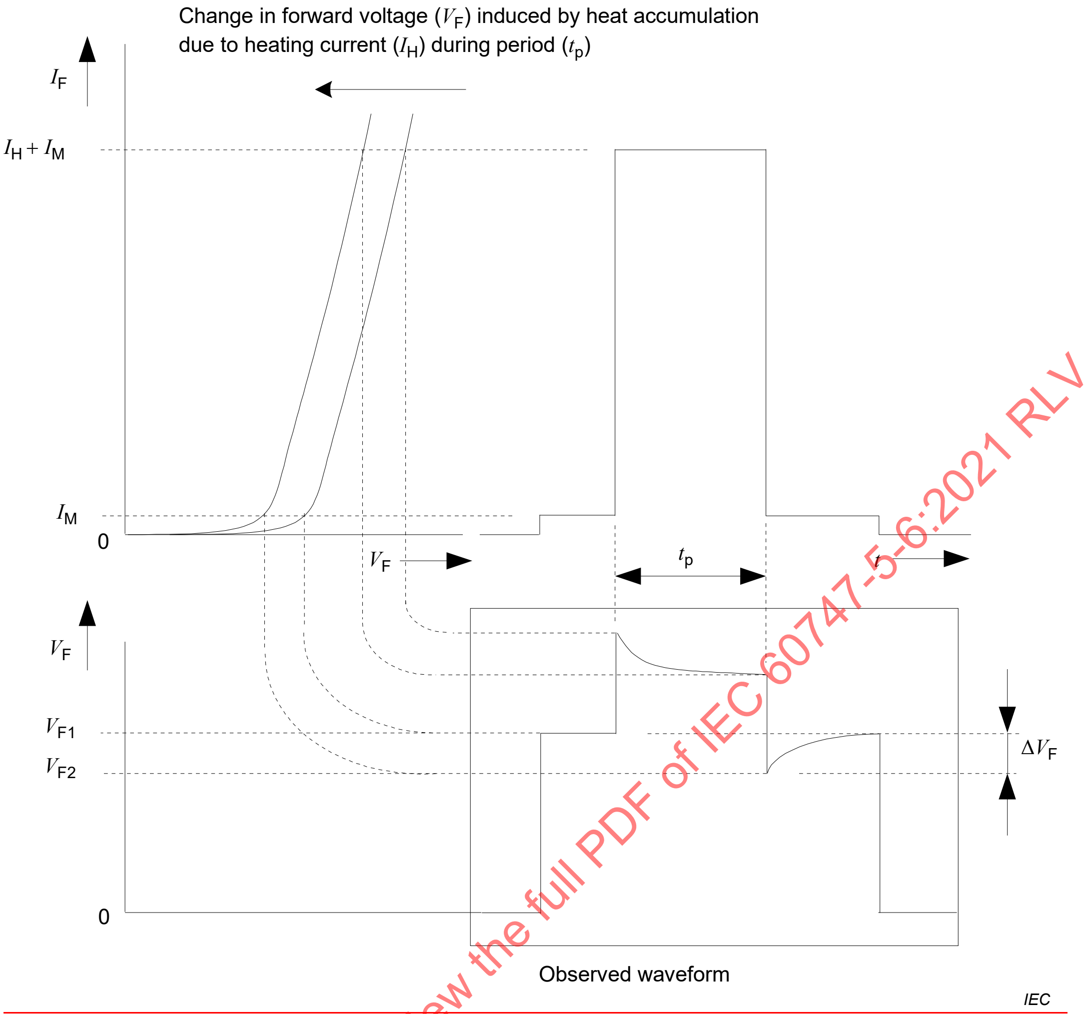


Figure 15 – Waveform of change in V_F

The measured forward voltage V_{F2} just after the end of power dissipation is lower than the forward voltage V_{F1} before heating due to heat accumulation that is produced by power dissipation. However, V_{F2} will return to value V_{F1} before the heating with cooling of junction temperature afterwards.

The forward voltage change and waveform observed by the DC oscilloscope are shown in Figure 15.

The measurement timing of V_{F2} just after the end of heating needs to be short enough in comparison with the thermal time constant of the test LED. However, since a transient ringing noise is superimposed onto the observed waveform due to the cut-off of the heating current (I_H), V_{F2} sampling is done after a certain delay time to avoid the influence of the ringing noise.

6.7.3.4 Measurement of the temperature at the reference point T_X

The temperature should be measured using a proper thermocouple.

For a measurement conducted using a thermocouple, its type (material) and wire size shall be carefully selected in order to prevent the measurement point from being cooled down by the thermocouple.

6.7.3.5 Calculation of thermal resistance

The thermal resistance from the junction to a certain reference point X, $R_{th(j-X)}$, is calculated using the following formula:

$$R_{th(j-X)} = \frac{T_j - T_X}{P} \approx \frac{\Delta V_F / b}{I_H \cdot V_F} \quad (I_M \ll I_H)$$

where

T_j is the junction temperature;

T_X is the reference point temperature;

P is the total power dissipation;

b is the temperature coefficient of the forward voltage;

$\Delta V_F = |V_{F1} - V_{F2}|$.

Transient thermal resistance $R_{th(j-X)}$ of an LED which has an appropriate heat sink varies with the heating time (t_p) as shown in Figure 16.

Two saturated regions are observed in this example.

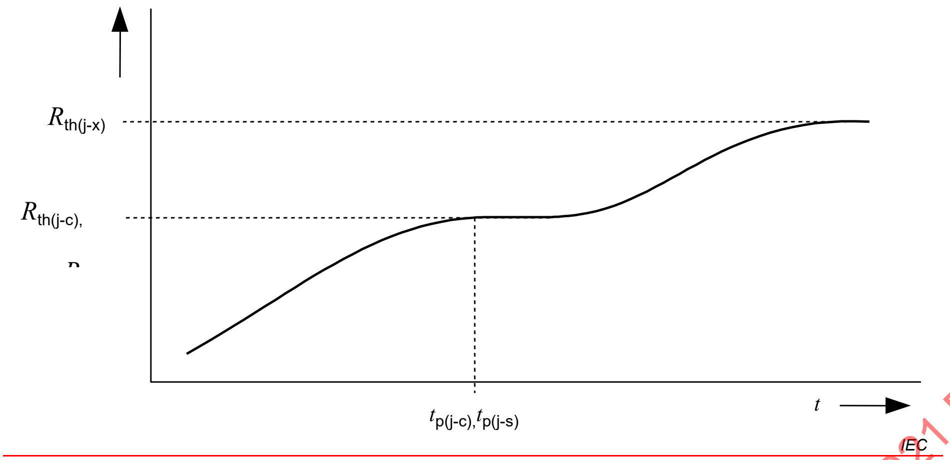
The first saturated region indicates the state in which the LED die has almost warmed up, while the last region indicates the process until the case (of the soldering point) has reached the steady state.

The two saturated regions reflect the junction-to-case thermal resistance $R_{th(j-c)}$ (or the junction-to-soldering point thermal resistance $R_{th(j-s)}$) and the junction-to-ambient thermal resistance $R_{th(j-a)}$, respectively.

Because the thermal resistance from the reference point is determined by t_p, the value of t_p shall be chosen in accordance with the purpose.

The thermal resistance of LEDs that the rated driving current establishes assuming use of the heat sink should be clearly specified by $R_{th(j-c)}$ or $R_{th(j-s)}$.

For measurement of the LED which has an appropriate heat sink, transient thermal resistance $R_{th(j-c)}$ (or $R_{th(j-s)}$) is measured by choosing $t_{p(j-c)}$ (or $t_{p(j-s)}$) as the value of t_p which is considered to be a thermal time constant until the case (or the soldering point) as shown in Figure 16.



~~**Figure 16 – Transient change in thermal resistance (double-logarithmic plots)**~~

The thermal resistance from the junction to a certain reference point X, $R_{th(j\text{-}X)}$, shall be calculated using the following formula. The power efficiency η_{PE} should be measured at the same time when the thermal resistance is measured.

$$R_{th(j\text{-}X)el} \equiv \frac{T_j - T_X}{P} \approx \frac{\Delta V_F / b}{I_H \cdot V_F} (I_M \langle\langle I_H)$$

$$R_{th(j\text{-}X)real} \equiv \frac{T_j - T_X}{P(1-\eta_{PE})} \approx \frac{\Delta V_F / b}{I_H V_F (1-\eta_{PE})} (I_M \langle\langle I_H)$$

where

T_j junction temperature

T_X temperature at reference point X

P electrical power dissipation

ΔV_F $V_{F1} - V_{F2}$

b temperature coefficient for forward voltage

η_{PE} power efficiency

NOTE There are other ways to calculate the thermal resistance from the junction to the reference point.

This is a method in which the separate point in the structural function of a LED, which has different heat flow paths after the reference point, is regarded as the thermal resistance from the junction to the reference point.

In the JEDEC standards (JESD51-14), this approach is recommended as a method for calculating the thermal resistance from the junction of a semiconductor device to the rear surface of its package.

Since the precondition for this approach is that the heat flow paths before the separate point are identical, so this path is one-dimensional.

JESD51-14 explains that with a heat sink is attached to make the heat flow path one-dimensional, the heat flow path beyond the rear surface of the package can be changed by applying grease selectively.

According to JESD51-14, this separate point for the Structural function corresponds to the thermal resistance from the junction to the rear surface of the package.

This idea can be applied to a LED as follows. For example, taking a soldering point on the LED as a reference point, the LED is mounted on two types of PCB that have differently designed soldering pads, which allows the separate point to be determined. The two types of PCB can be one with a different pad size or one with a different copper thickness.

Since the thermal resistance calculated using this approach is the thermal resistance from the junction to the temperature of isothermal surface near the reference point, it may differ from the thermal resistance corresponding to the reference point.

However, this approach is an effective way of calculating with a LED for which a reference point cannot be set on its heat flow path or the accuracy of a temperature measurement taken at its reference point is insufficient.

This calculated value is also suitable for the thermal design of the heat flow on the downstream (the PCB and heat sink) of a LED if the design is conducted by a simulation

6.7.4 Precautions to be observed

The precautions to be observed are as follows:

a) The heating current ~~(I_H) shall be set as high as possible so as to ensure~~ should be the same value as the forward current actually used. However, if sufficient detection sensitivity ~~of~~ (i.e., forward voltage difference ΔV_F before and after heating) cannot be achieved by applying this current value, the heating current (I_H) should be set as high as possible within the absolute maximum ratings by controlling the heating time not to exceed the $T_j$max. If it is difficult to detect enough temperature rise to derive the thermal resistance by applying this condition, the method should be abandoned.

b) For details other than those provided in a) above, see 6.1.

6.7.5 Specified conditions

a) Forward current I_F;

b) Ambient temperature T_a, case temperature T_c, or reference-point temperature T_X;

c) In the case where T_a is used for the reference point temperature:

- The configuration, size and material of the PCB that the test LED is mounted on.
- The thickness and area of the pattern (copper) that is on the PCB.
- The size, material and fin of the attached heat sink (if appropriate).

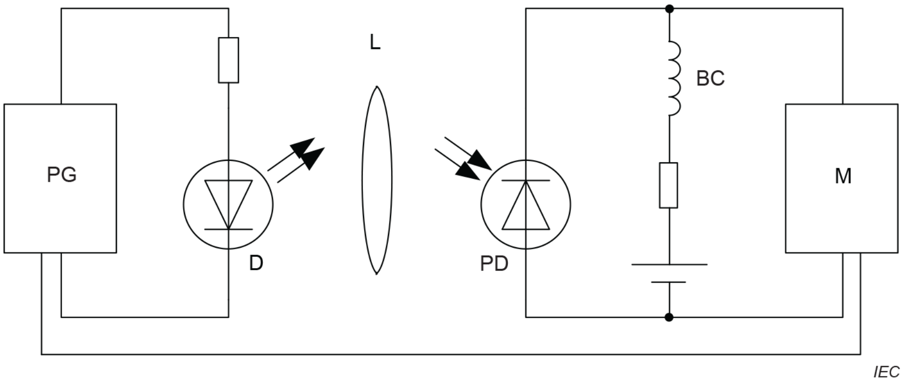
6.8 Response time measurement

6.8.1 Purpose

To measure the response time of the LED under the specified conditions.

6.8.2 Circuit diagram

The circuit diagram is shown in Figure 21.



Key

PG	pulse generator
D	light emitting diode being measured
L	collective lens
PD	photo detector
BC	bias circuit
M	optical pulse measurement system

Figure 21 – Circuit diagram for response time measurement

6.8.3 Provisions

To detect the photocurrent signals at the photo detector, a transimpedance amplifier that ensures sufficient response characteristics shall generally be used; however, this may also be performed by measuring the voltage using a resistor whose resistance is low enough to ensure ~~responsiveness~~ responsivity and linearity.

The rise and fall times of the pulse generator and the optical pulse measurement system should be sufficiently lower than the response time of the test LED. The ~~responsiveness~~ responsivity of a photo detector may worsen when outside of a specific wavelength region depending on the crystalline material and device structure. The combination of wavelength regions and device structures should be properly selected.

The collective lens may be omitted if it is not needed depending on the optical characteristics of the test LED.

6.8.4 Measurement procedure

The measurement procedure is as follows:

a) Apply the specified forward current pulse to the test LED.

b) The light emitted from the LED is received by the photo detector and converted into an electrical signal.

c) Measure this electrical signal with an oscilloscope or other suitable measurement instrument that has been synchronized with the pulse generator. Next, measure the rise time (t_r) and fall time (t_f) (and, if necessary, the turn-on delay time ($t_{d(on)}$) and turn-off delay time ($t_{d(off)}$) based on the relationship between the input and output waveforms shown in Figure 22 in accordance with the following definitions.

   1) Rise time (t_r)

      The time required for the amplitude of the output waveform to increase from 10 % to 90 %.

   2) Turn-on delay time ($t_{d(on)}$)

The time that elapses from when the amplitude of the input waveform reaches 10 % until that of the output waveform reaches 10 %.

3) Fall time (t_f)

The time required for the amplitude of the output waveform to decrease from 90 % to 10 %.

4) Turn-off delay time ($t_{d(off)}$)

The time that elapses from when the amplitude of the input waveform drops to 90 % until that of the output waveform drops to 90 %.

6.8.5 Precautions to be observed

The precautions to be observed are as follows:

a) The rise, fall, and delay times of the forward current pulse generator and the optical pulse measurement system shall be sufficiently lower than those of the test LED.

b) The linearity of the optical pulse measurement system shall be corrected to within the measurement range of the measured value before use.

c) For details other than those provided in a) and b) above, see 6.1.

6.8.6 Specified conditions

The specified conditions are as follows:

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);

– input pulse signal (pulse current, pulse width, duty ratio).

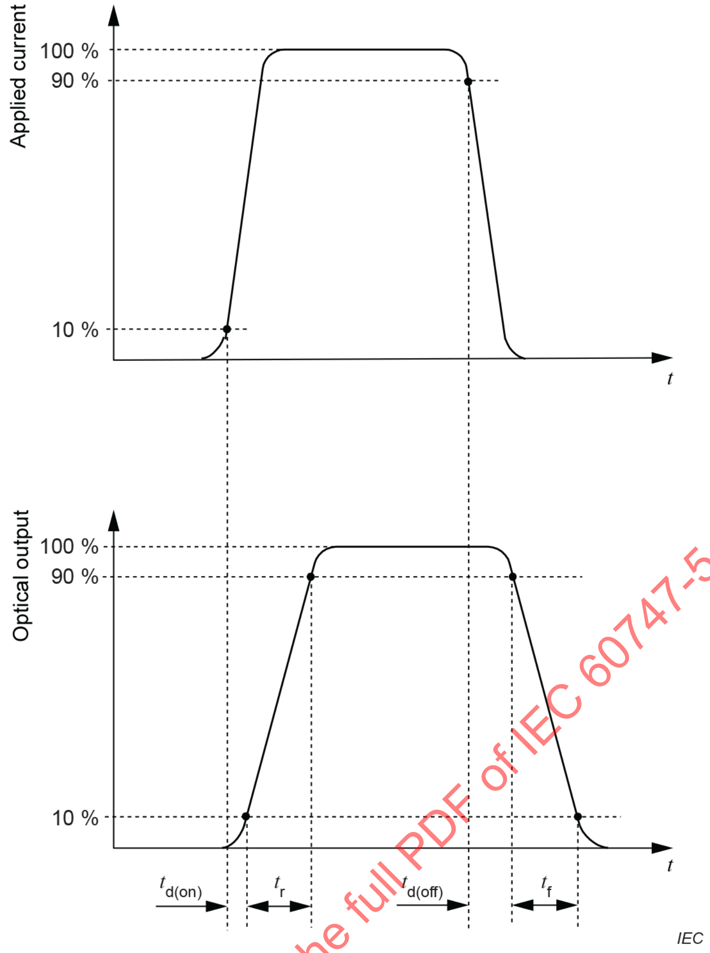


Figure 22 – Waveform of response time measurement

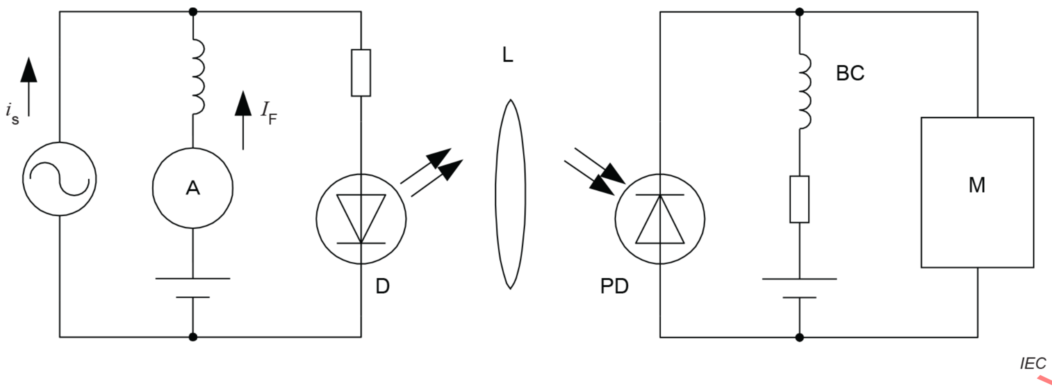
6.9 Frequency response and cut-off frequency (f_c) measurement

6.9.1 Purpose

To measure the frequency response and cut-off frequency of the LED under the specified conditions.

6.9.2 Circuit diagram

The measuring circuit should be designed as shown in Figure 23 in principle.



Key

i_s	small signal AC
I_F	forward DC
D	light emitting diode being measured
L	collective lens
PD	photo detector
BC	bias circuit
M	optical pulse measurement system

Figure 23 – Circuit diagram for f_c measurement

6.9.3 Provisions

To detect the photocurrent signals of the photo detector, a transimpedance amplifier that ensures sufficient response characteristics shall generally be used; however, this may also be performed by measuring the voltage using a resistor whose resistance is low enough to ensure ~~responsiveness~~ responsivity and linearity.

The ~~responsiveness~~ responsivity of a photo detector may worsen when outside of a specific wavelength region depending on the crystalline material and device structure. The combination of wavelength regions and device structures should be properly selected.

The frequency variation of the AC signal source output shall be sufficiently low, either equalling or surpassing IEC 60051 (all parts).

The collective lens may be omitted if it is not needed depending on the optical characteristics of the test LED.

6.9.4 Measurement procedure

The measurement procedure is as follows:

a) Apply the specified forward current to the test LED and superimpose the small signal AC of frequency f.

b) The light emitted from the LED is received by the photo detector and converted into an electrical signal.

c) Measure the AC, $i_p(f)$, that corresponds to the modulated light with a measuring instrument such as a spectrum analyzer.

d) Obtain $i_p(f)/i_p(f_0)$ for the alternating current $i_p(f_0)$ that corresponds to a sufficiently low reference frequency f_0 ($f_0 \leqq f_c/100$) as the frequency response.

e) The cut-off frequency (f_c) is the frequency at which the frequency response decreases by 3 dB with respect to the reference frequency.

$$-3\,\text{dB} = 10\log\left[i_p(f_c)/i_p(f_0)\right]$$

6.9.5 Precautions to be observed

The precautions to be observed are as follows:

a) Use the frequency characteristics of the small-signal AC source and the optical signal measurement system with a range that is sufficiently wider than that of the frequency characteristics of the LED.

b) The linearity of the optical signal measurement system should be corrected to within the measurement range of the measured value before use.

c) When photoelectric conversion is performed on the optical output from the LED by a photo detector, because the frequency at which the electric output from the photo detector decreases by 3 dB and that at which the optical output of the light source decreases by 3 dB and are different, be careful not to perform the conversion incorrectly.

d) For details other than those provided in a), b), and c) above, see 6.1.

6.9.6 Specified conditions

The specified conditions are as follows:

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);

– bias forward current (I_F) of the LED;

– amplitude $\left(\max\left|(i_s)\right|\right)$ or modulation factor $\left(M = \left(\max\left|(i_s)\right|\right)/I_F\right)$ of the AC signal.

6.10 Luminous flux (Φ_v) measurement

6.10.1 Purpose

The purpose of this measurement is to measure the total or partial luminous flux of the LED under established conditions.

6.10.2 Measurement principle

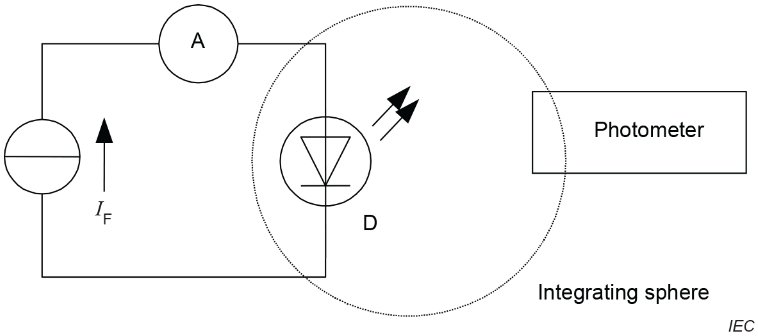
Alternately illuminate a luminous-flux standard LED whose total flux (Φ_{vS}) is known and the test LED at the centre of the integrating sphere and read the output value from each photometer. With I_{vS} as the optical output of the photometer when the luminous-flux standard LED is illuminated under established conditions and I_{vT} as the optical output of the photometer when the test LED is illuminated, the total flux Φ_{vT}(1 m) of the test LED will be as follows.

$$\Phi_{vT} = \Phi_{vS} \cdot \frac{I_{vT}}{I_{vS}}$$

If the values of Φ_{vT} and Φ_{vS} differ greatly, it may be particularly appropriate to have a filter whose attenuation is known between the photometer and the photometer window.

6.10.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 24 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 24 – Circuit diagram for Φ_V measurement

~~It is preferable that~~ A monochromator-method or polychromator-method photometer should be used.

The sensor window inside the integrating sphere should be designed to be sufficiently small for the area of the internal surface. However, if it is difficult to design such an integrating sphere because of the spherical diameter of the integrating sphere as well as the shape and type of the photometer, a photometer with bundled fibres whose attenuation and wavelength sensitivity have been sufficiently corrected can be used for the measurement.

If it is obvious that no radiation is being emitted in the reverse direction, the test LED may be installed at the incident window to perform a 2π space measurement.

6.10.4 Measurement procedure

The measurement procedure is as follows:

a) Perform the measurement by alternately placing the test LED and the luminous-flux standard LED in the centre of the integrating sphere. Start the photometry when the luminous flux reaches a stable state during the preliminary lighting time (sufficient time for changes in the luminous flux resulting from the temperature rise of the test LED when it is turned on to become stable).

b) Read each measured output value for the test LED and the luminous-flux standard LED shown on the photometer.

6.10.5 Precautions to be observed

The precautions to be observed are as follows:

a) Make sure that you use a luminous-flux standard LED that has the same configuration as and an emission spectrum distribution equivalent to the test LED to which the values have been added by the standard light source as a luminous-flux standard LED.

   If the configuration and emission spectrum distribution of the luminous-flux standard LED are not equivalent to those of the test LED, use the following formula to correct them as needed – particularly if the photometer is a filter-type (e.g. $V(\lambda)$ photometer):

$$\Phi_{VT} = \alpha \cdot k \cdot \Phi_{VS} \cdot \frac{I_{VT}}{I_{VS}}$$

where

α is the self-absorption correction factor;

k is the colour correction factor.

NOTE 1 Details on how to obtain the self-absorption correction factor can be found in Annex B.

NOTE 2 Details on how to obtain the colour correction factor can be found in Annex C.

b) The light receiving luminous flux and the optical output of the photometer shall be in direct proportion to each other. If they are not in direct proportion to each other, they ~~need to~~ shall be corrected.

c) The diameter of the integrating sphere shall be sufficiently larger than the test device in principle. The size of the light shielding plate should be the minimum required to completely block the light source viewed from the photometer window. The plate should be fixed on the line connecting the centre of the integrating sphere and the photometer window at a point that is a third to half the radius from the centre. All parts of the inner surface of the integrating sphere shall be diffusing surfaces that provide as uniform a reflectivity as possible (lambertian surface).

   Errors may be included in the result of the photometry depending on how close the relative spectral sensitivity curve (in which the spectral reflection factor of the integrating sphere paint, the spectral transmittance of the diffuse transmission plate at the photometer window, and the relative spectrum of the photometer are combined to form a photometry system) is to the standard luminous efficiency curve. Therefore, these errors ~~need to~~ shall be evaluated and corrected.

d) For details other than those provided in a), b), and c) above, see 6.1.

6.10.6 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.11 Radiant ~~power~~ flux (Φ_e) measurement

6.11.1 Purpose

The purpose of this measurement is to measure the total radiant ~~power~~ flux of the LED under established conditions.

6.11.2 Measurement principle

Alternately illuminate a radiant-~~power~~flux standard LED whose total radiant ~~power~~ flux (Φ_{eS}) is known and the test LED at the centre of the integrating sphere and read the output value from each radiometer.

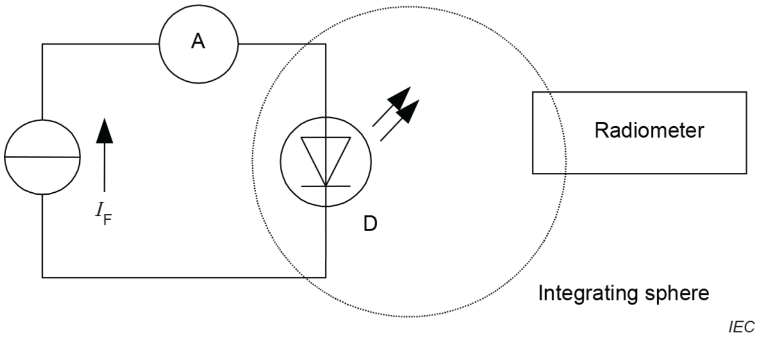
With I_{eS} as the optical output of the radiometer when the radiant-~~power~~flux standard LED is illuminated under established conditions and I_{eT} as the output of the radiometer when the test LED is illuminated, the radiant ~~power~~ flux Φ_{eT} of the test LED will be as follows.

$$\Phi_{eT} = \Phi_{eS} \cdot \frac{I_{eT}}{I_{eS}}$$

If the values of Φ_{eT} and Φ_{eS} differ greatly, it may be particularly appropriate to have a filter whose attenuation is known between the radiometer and the photometer window.

6.11.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 25 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 25 – Circuit diagram for Φ_e measurement

The sensor window inside the integrating sphere should be designed to be sufficiently small for the area of the internal surface. However, if it is difficult to design such an integrating sphere because of the spherical diameter of the integrating sphere as well as the shape and type of the light receiving portion of the radiometer, a radiometer with bundled fibres whose attenuation and wavelength sensitivity have been sufficiently corrected can be used for the measurement.

If it is obvious that no radiation is being emitted in the reverse direction, the test LED can be installed at the incident window to perform a 2π space measurement.

6.11.4 Measurement procedure

The measurement procedure is as follows:

a) Perform the measurement by alternately placing the test LED and the radiant-~~power~~flux standard LED in the centre of the integrating sphere.

   Start the photometry when the radiant ~~power~~ flux has reached a stable state during the preliminary lighting time (sufficient time for changes in the radiant ~~power~~ flux resulting from the temperature rise of the test LED when it is turned on to become stable).

b) Read each measured output value for the test LED and the radiant-~~power~~flux standard LED shown on the radiometer.

6.11.5 Precautions to be observed

The precautions to be observed are as follows:

a) Make sure that you use a radiant-~~power~~flux standard LED that has the same configuration as and an emission spectrum distribution equivalent to a sufficiently calibrated test LED and a radiometer.

   If the configuration and emission spectrum distribution of the radiant-~~power~~flux standard LED are not equivalent to those of the test LED, use the following formula to correct them as needed.

$$\Phi_{VT} = \alpha \cdot k \cdot \Phi_{VS} \cdot \frac{I_{VT}}{I_{VS}}$$

where

α is the self-absorption correction factor;

k is the colour correction factor.

NOTE 1 Details on how to obtain the self-absorption correction factor can be found in Annex B.

NOTE 2 Details on how to obtain the colour correction factor can be found in Annex C.

When using an optical power meter with a wavelength sensitivity compensation function for the radiometer, correction with the colour correction factor can be omitted if a correction with the corresponding wavelength is performed for each measurement.

b) The diameter of the integrating sphere shall be sufficiently larger than the test LED in principle. The size of the light shielding plate should be the minimum required to completely block the light source viewed from the photometer window. The plate should be fixed on the line connecting the centre of the integrating sphere and the photometer window at a point that is a third to half the radius from the centre. All parts of the inner surface of the integrating sphere shall be diffusing surfaces that provide as uniform a reflectivity as possible (lambertian surface).

c) For details other than those provided in a) and b) above, see 6.1.

6.11.6 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.12 Luminous intensity (I_V) measurement

6.12.1 Purpose

The purpose of this measurement is to measure the luminous intensity of the LED under established conditions.

6.12.2 Measurement principle

The luminous intensity measurement shall conform to the measurement of the CIE-averaged LED intensity. This measurement is performed by turning on a luminous-intensity standard LED whose averaged LED intensity (I_v) is known and the test LED and comparing them alternately under two defined visual (solid angle) conditions.

With I_{vS} as the luminous intensity of the luminous-intensity standard LED, i_{vS} as the read value of the photometer output, and i_{vT} as the read value of the photometer output when the test LED is illuminated, the luminous intensity of the test LED (I_v) will be as follows.

$$I_v = \frac{i_{vT}}{i_{vS}} \cdot I_{vS}$$

The measurement distance should be between the tip of the LED and the reference surface of the light receiving portion of the photometer as shown in Figure 26.

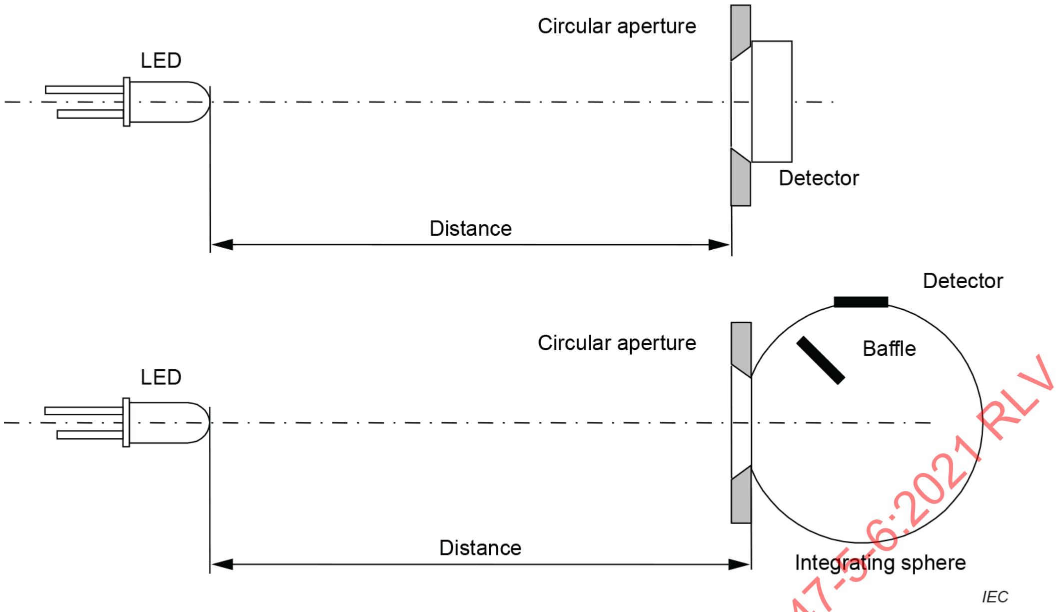


Figure 26 – Schematic diagram for I_V measurement

If the reference surface of the photometer for the measurement distance is not set, take the front surface of the light receiving portion as the reference surface.

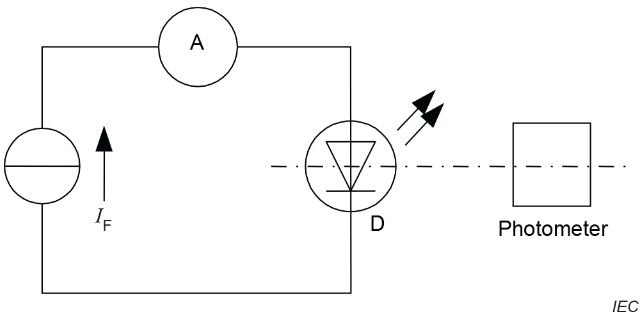
Table 3 shows the view angle conditions for CIE-averaged LED intensity.

Table 3 – CIE averaged LED intensity measurements

	Circular aperture mm²	Distance mm	View angle sr
Condition A	100	316	0,001
Condition B		100	0,01

6.12.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 27 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 27 – Circuit diagram for I_V measurement

6.12.4 Measurement procedure

The measurement procedure is as follows:

a) Set the luminous-intensity standard LED or the test LED in accordance with its external structure. Set the photometer and the test LED at a position where the vertical central axis of the acceptance surface of the photometer is, in principle, coincident with the structural central axis or the optical central axis of the test LED.
b) Set the photometric distance between the LED and the acceptance surface of the photometer to one of the values shown in Table 3 in accordance with the relevant condition.
c) Apply the specified forward current (I_F) to the luminous-intensity standard LED and the test LED alternately to obtain the luminous intensity by reading the photometer.

If the emission spectrum distribution of the luminous-intensity standard LED is not equivalent to that of the test LED, perform corrections with the colour correction factor as needed – particularly if the photometer is a filter-type (e.g. $V(\lambda)$ photometer).

NOTE Details on how to obtain the colour correction factor can be found in Annex B.

6.12.5 Precautions to be observed

The precautions to be observed are the following.

a) In actual measurements, the structural central axis based on the external structure of the test LED is not necessarily coincident with the optical central axis. It is advisable to clarify to which axis the obtained measured value belongs.
b) For details other than those provided in a) above, see 6.1.

6.12.6 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F) and current-carrying time;
– distance (visual) condition;
– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.13 Radiant intensity (I_e) measurement

6.13.1 Purpose

The purpose of this measurement is to measure the radiant intensity of the LED under established conditions.

6.13.2 Measurement principle

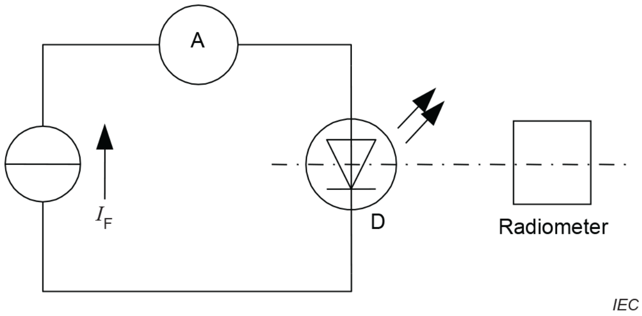
The radiant intensity measurement shall conform to the visual (solid angle) conditions and the conditions for the positional relation between the light receiving portion and the LED, as specified for the measurement of CIE-averaged LED intensity in 6.12. This measurement is performed by alternately turning on a radiant-intensity standard LED whose radiant intensity (I_e) is known and the test LED and comparing them.

With I_{eS} as the radiant intensity of the radiant-intensity standard LED, i_{eS} as the read value of the radiometer output, and i_{eT} as the read value of the radiometer output when the test LED is illuminated, the radiant intensity of the test LED (I_e) will be as follows.

$$I_e = \frac{i_{eT}}{i_{eS}} \cdot I_{eS}$$

6.13.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 28 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 28 – Circuit diagram for I_e measurement

6.13.4 Measurement procedure

The measurement procedure is as follows:

a) Set the radiant-intensity standard LED or the test LED in accordance with its external structure. Set the radiometer and the test LED at a position where the vertical central axis of the acceptance surface of the optical receiver is, in principle, coincident with the structural central axis or the optical central axis of the test LED.

b) Set the photometric distance between the LED and the acceptance surface of the radiometer to one of the values shown in Table 3 in accordance with the relevant condition.

c) Apply the specified forward current to the radiant-intensity standard LED and the test LED alternately to obtain the radiant intensity by reading the radiometer output. When using an optical power meter with a wavelength sensitivity compensation function for the radiometer, make sure that you calibrate it with the corresponding wavelength for each measurement.

In actual measurements, the structural central axis based on the external structure of the test LED is not necessarily coincident with the optical central axis. It is advisable to clarify to which axis the obtained measured value belongs.

For details other than those provided in a), b) and c) above, see 6.1.

6.13.5 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F) and current-carrying time;

– distance (visual) condition;

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.14 Luminance (L_v) measurement

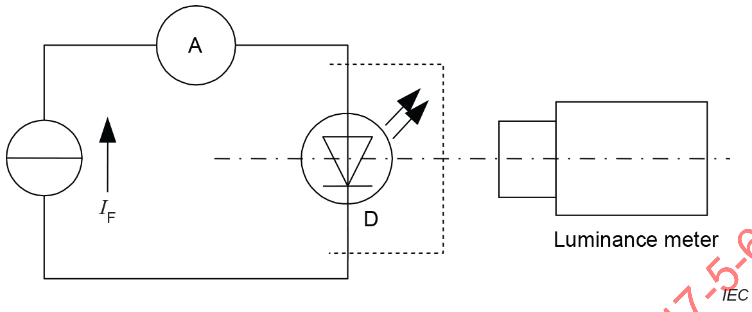
6.14.1 Purpose

The purpose of this measurement is to measure the luminance under established conditions using either a LED flat illuminator that has a light emitting part with a large area in particular and a flat emitting pattern or a LED dot-matrix display.

6.14.2 Measuring circuit

The measuring circuit should be designed as shown in Figure 29 in principle.

Commonly used LED flat illuminators usually have multiple LED dies. Figure 29 shows an example of a LED flat illuminator with a single LED die. The actual driving circuitry should be configured in accordance with the number of LED dies to be used and the LED connection topology.



Key

I_F forward DC

D light emitting diode being measured

Figure 29 – Circuit diagram for L_v measurement

6.14.3 Measurement procedure

The measurement procedure is as follows:

a) Set the test LED in accordance with its external structure. Set the luminance meter and the test LED at a position where the vertical central axis of the acceptance surface of the luminance meter is coincident with the normal in the emitting face of the test LED.

b) Set the distance between the emitting face of the test LED and the acceptance surface of the luminance meter so that the solid angle, which is determined by the size of the diameter of the measurement spot on the specified emitting face, will be appropriate.

c) Apply the specified forward current (I_F) to the test LED to obtain the luminance (L_v) by reading the luminance meter.

Care should be taken when measuring luminance to ensure that the brightness in the view of the luminance meter is uniform and that the field of view is completely filled with the emission of light. If the luminance of the emitting face is not uniform, take the average value as the luminance.

It is advisable to clarify on which part of the emitting face the luminance was measured.

The luminance meter shall be calibrated on a regular basis. For details on calibration, refer to Annex D.

For details other than those provided in a), b), and c) above, see 6.1.

6.14.4 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– photometric distance and solid angle;

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);
– position on the emitting face;
– measured surface.

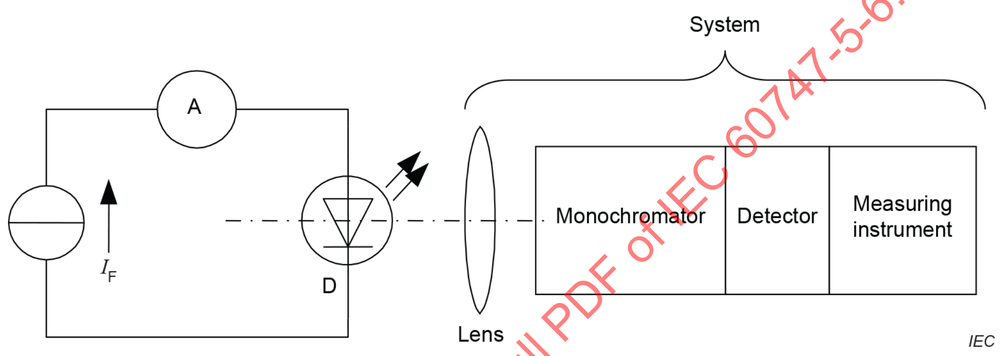
6.15 Emission spectrum distribution, peak emission wavelength (λ_p), and spectral half bandwidth ($\Delta\lambda$) measurement

6.15.1 Purpose

The purpose of this measurement is to measure the emission spectrum distribution, peak emission wavelength, and spectral half bandwidth of the LED under established conditions.

6.15.2 Measuring circuit

The measuring circuit should be designed as shown in Figure 30 in principle.



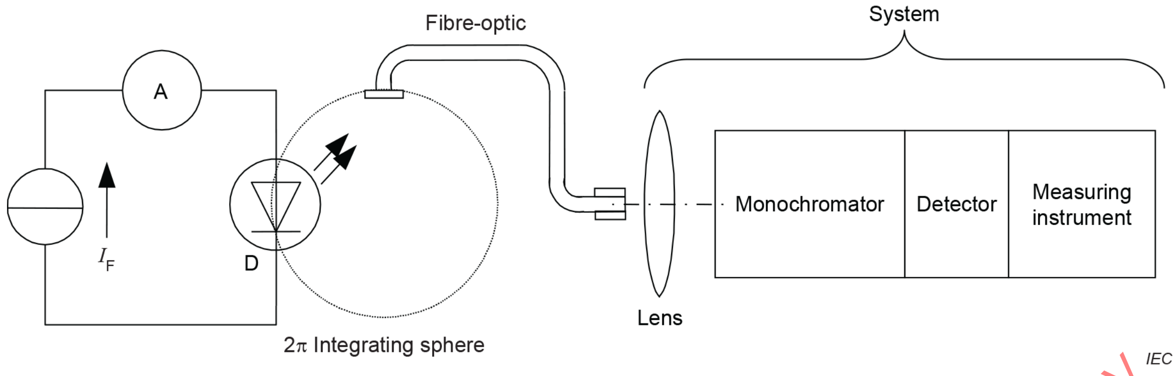
Key

I_F forward DC

D light emitting diode being measured

Figure 30 – Circuit diagram for λ_p measurement

The emission spectrum of LEDs may differ greatly in distribution due to their position in the emitting face and directivity angle. Therefore, the measurement can, depending on the intended use, be performed by using a light receiving system in 2π space through an integrating sphere as shown in Figure 31. Particularly for measurements with a LED in which multiple LED dies are contained within a single package or with a dual-wavelength emission type LED using an excited luminescence layer in the LED die, use the system shown in Figure 31 unless otherwise specified.



Key

I_F forward DC

D light emitting diode being measured

Figure 31 – Circuit diagram for λ_p measurement

6.15.3 Measurement procedure

The measurement procedure is the following:

a) Apply the specified forward current to the test LED and focus the radiation from the test LED with a lens or mirror to direct it into the spectroscope.

b) Scan the wavelength of the spectroscope across the emission wavelength region of the test LED to read the values indicated in the optical receiver and then create an emission spectrum distribution (see Figure 32).

c) Obtain the wavelength corresponding to the maximum value of the emission spectrum (peak emission wavelength (λ_p)) from the emission spectrum distribution (see Figure 32).

d) Obtain the wavelength interval that corresponds to half the value of the maximum value of the emission spectrum between wavelengths (spectral half bandwidth ($\Delta\lambda$)) from the emission spectrum distribution (see Figure 32).

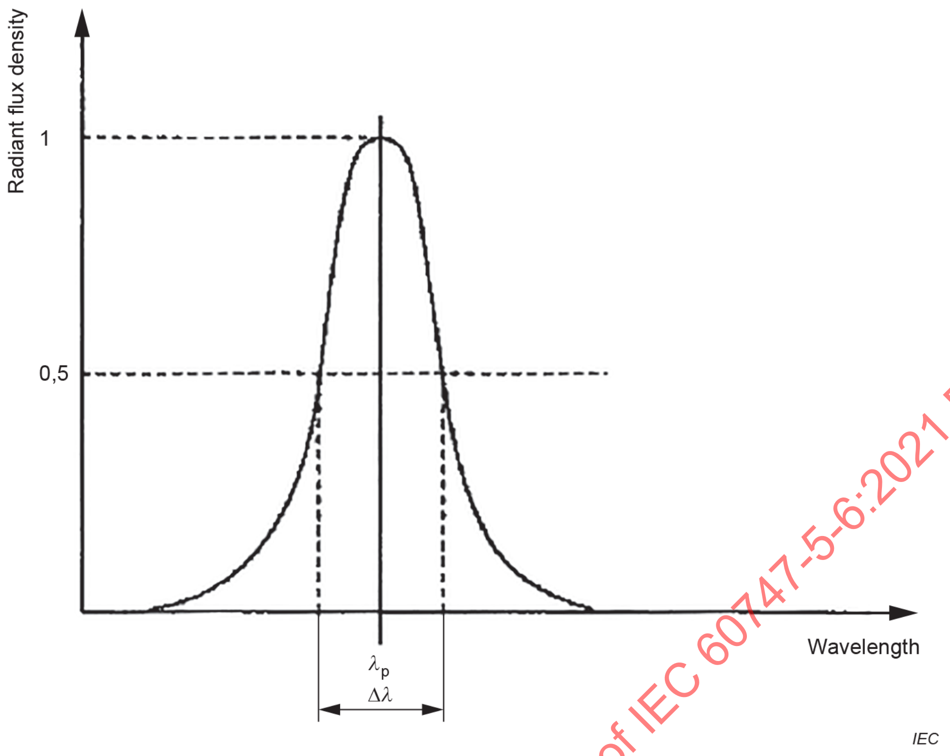


Figure 32 – Schematic diagram of $\Delta\lambda$ measurement

~~It is preferable that the wavelength resolution of the spectroscope is sufficiently smaller than the spectral half bandwidth and it is advisable to set the slit width to support a wavelength interval of 3 nm or less.~~

The slit width of the monochromator should be set at the appropriate value to assure the resolution necessary to measure the spectral half bandwidth of 3 nm or less.

The relative spectral characteristics of the measurement system shall be calibrated throughout the measured emission wavelength by using a standard light source with a known spectral distribution.

For details other than those provided in a) to d) above, see 6.1.

6.15.4 Measurement conditions to be defined

The measurement conditions to be defined are the following:

- forward current (I_F);
- ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.16 Chromaticity measurement

6.16.1 Purpose

The purpose of this measurement is to measure the chromaticity of the visible LED under established conditions.

6.16.2 Measurement principle

6.16.2.1 General

Spectrocolorimetry, based on the CIE 1931 colour system (XYZ standard colour system), is adopted as the measuring method for chromaticity.

6.16.2.2 XYZ colour system

Taking $S_t(\lambda)$ as the emission spectrum distribution of the LED, the tristimulus values X, Y, and Z used in the XYZ system can be obtained as follows.

$$\left.\begin{aligned} X &= k \sum S_t(\lambda)\cdot x(\lambda)\cdot \Delta\lambda \\ Y &= k \sum S_t(\lambda)\cdot y(\lambda)\cdot \Delta\lambda \\ Z &= k \sum S_t(\lambda)\cdot z(\lambda)\cdot \Delta\lambda \end{aligned}\right\}$$

where

$x(\lambda)$, $y(\lambda)$, $z(\lambda)$ are the values of colour-matching function in the XYZ colour system.

$\Delta\lambda$ is the wavelength interval used to calculate the tristimulus values.

k is the constant.

Using the tristimulus values (X, Y, and Z), calculate the chromaticity coordinates x and y using the following formula:

$$x = \frac{X}{X+Y+Z},\quad y = \frac{Y}{X+Y+Z}$$

In principle, use the values for x and y to express the chromaticity of a LED.

In the xy chromaticity diagram using x and y (Figure 33), the spectrum stimulus wavelength, which corresponds to the point S where the spectrum locus and the extension points connecting the white point W and the chromaticity point P cross, is defined as the dominant wavelength (λ_D). In addition, the angle formed by the perpendicular from the white point W to the x-axis and the line segment WS is defined as the colour angle (θ_D).

Dominant wavelength (λ_D) and colour angle (θ_D) may be used to express the chromaticity of a LED.

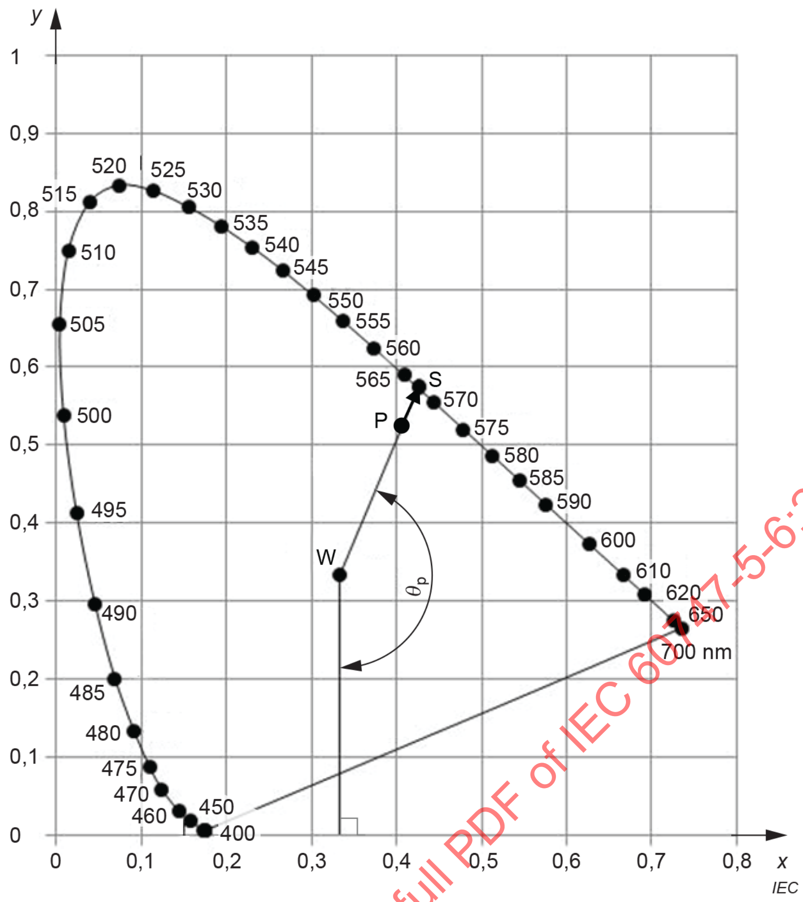


Figure 33 – Chromaticity

The colour-matching function of the XYZ colour system was agreed on by CIE in 1931. Values were given for each 10 nm in the range of wavelengths between 380 nm and 780 nm in the standard luminous efficiency at that time. In 2004, a new standard luminous efficiency where values are given at an interval of 1 nm in the range of wavelengths between 380 nm and 830 nm was agreed upon by CIE. Table E.1 of Annex E shows the colour-matching function of the XYZ colour system.

There are two types of colour-matching function, one of which is shown in Table E.1, applied when the angle of sight toward the emitting face is 4° or smaller, and the other of which consists of $x_{10}(\lambda)$, $y_{10}(\lambda)$, and $z_{10}(\lambda)$ when the angle of sight toward the emitting face is greater than 4°. For measuring LEDs, considering their size and spectral half bandwidth, we generally make use of Table E.1.

As mentioned above, the wavelength interval shall be 1 nm in principle.

The x-y coordinates of the white point are commonly defined as (0,333, 0,333) in the LED field. However, other definitions may be used depending on the purpose.

For LEDs whose peak wavelength (λ_p) falls between 700 nm and 555 nm (between red and pure green), the chromaticity point P of the emission colour is present on the spectrum locus within the margin of error, and P and S give close agreement with each other.

The relationship between the dominant wavelength (λ_D) and the chromaticity coordinate of the spectrum stimulus is shown in Table F.1 of Annex F.

The colour angle (θ_D) can be calculated using the following formula:

$$\theta_D = \arctan\left(\frac{y_P - 0{,}333}{x_P - 0{,}333}\right) + 90° \text{ where } x_P > 0{,}333$$

$$\theta_D = \arctan\left(\frac{y_P - 0{,}333}{x_P - 0{,}333}\right) + 270° \text{ where } x_P < 0{,}333$$

θ_D = 0° or 180° where x_P = 0,333

x_P, y_P are the x-y coordinates of the point P.

6.16.3 Measuring circuit

For information on measuring circuits for emission spectrum distributions, refer to 6.15.2.

6.16.4 Measurement procedure

The measurement procedure is the following:

a) Measure the emission spectrum distribution of the test LED as per a) and b) of 6.15.3.

b) Read the measured value for each wavelength defined in the colour-matching function (Table E.1 of Annex E) from the measured emission spectrum distribution to take the values as the values for each wavelength of $S_t(\lambda)$; refer to 6.16.2.2.

c) Calculate the chromaticity coordinates of x and y; refer to 6.16.2.2.

d) Obtain the dominant wavelength λ_D and the colour angle θ_D from x and y as needed.

~~It is preferable that the wavelength resolution of the spectroscope is sufficiently smaller than the spectral half bandwidth and it is advisable to set the slit width to support a wavelength interval of 3 nm or less.~~

The slit width of the monochromator should be set at the appropriate value to assure the resolution necessary to measure the spectral half bandwidth of 3 nm or less.

The relative spectral characteristics of the measurement system shall be calibrated throughout the measured emission wavelength by using a standard light source with a known spectral distribution.

When expressing the chromaticity using a dominant wavelength λ_D or a colour angle θ_D with reference to a white point that is at other coordinates than x = 0,333 and y = 0,333, make sure to clarify the definition of the white point.

For other notes, refer to 6.1.

6.16.5 Measuring conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

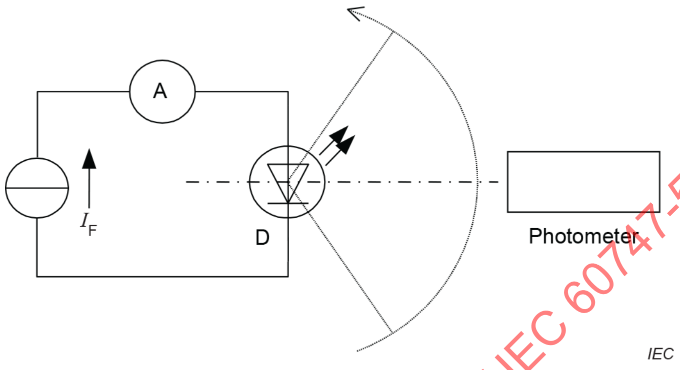
6.17 Directional characteristics and full width half maximum of an intensity measurement

6.17.1 Purpose

The purpose of this measurement is to measure the directional characteristics of the LED under established conditions.

6.17.2 Measuring circuit

The measuring circuit should be designed as shown in Figure 34 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 34 – Circuit diagram for chromaticity measurement

6.17.3 Measurement procedure

The measurement procedure is the following:

a) Set the test LED in accordance with its external structure. Set the optical receiver and the test LED at a position where the vertical central axis of the acceptance surface of the optical receiver is, in principle, coincident with the structural central axis or the optical central axis of the test LED.

b) Set the photometric distance (distance between the reference surface of the LED and the acceptance surface of the optical receiver) so that the solid angle, which is determined by the size of the emitting face and the acceptance surface, is appropriate.

c) Apply the specified forward current (I_F) to the test LED.

d) By rotating the optical receiver around the axis which is located on the emitting face of the test LED and which passes through the centre of the emitting face, steady this LED and then obtain its directional characteristics by reading the angle of rotation and the output measurement part of the optical receiver. (When rotating the LED, steady the optical receiver.)

e) The graphical descriptions of the directional characteristics in principle are shown in Figure 35 and Figure 36.

Take the interior angle that is 50 % of the intensity of the central axis in Figure 35 or Figure 36 as the full width half~~-value angle~~ maximum of an intensity ($2\theta_{1/2}$).

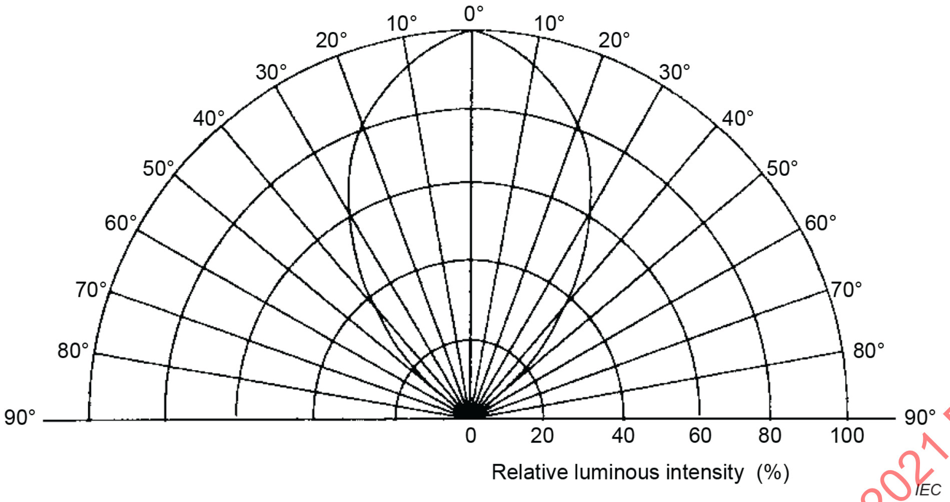


Figure 35 – Directional characteristics (example 1)

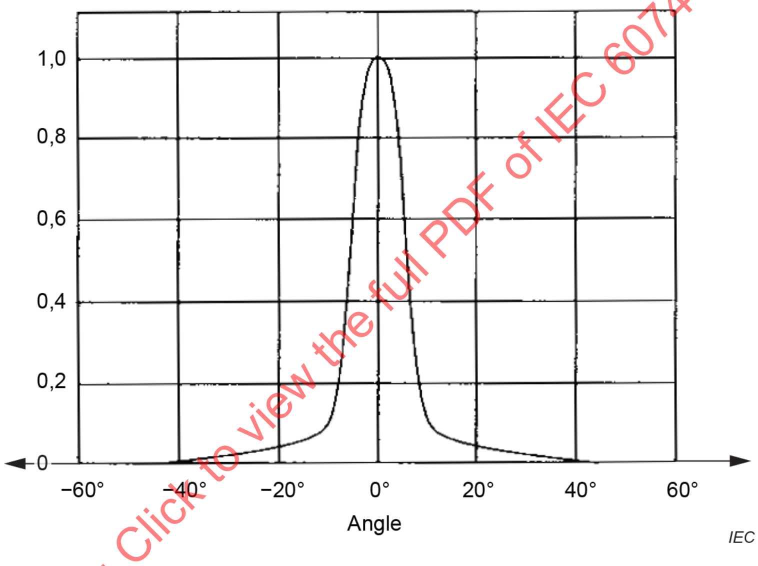


Figure 36 – Directional characteristics (example 2)

When setting the photometric distance, it is advisable to make the solid angle as small as possible, less than 0,004 sr.

In actual measurements, the structural central axis based on the external structure of the test LED is not necessarily coincident with the optical central axis. It is advisable to clarify which axis the obtained directional characteristics belong to.

For other notes, refer to 6.1.

6.17.4 Measuring conditions to be defined

The measurement conditions to be defined are the following:

- forward current (I_F);
- photometric distance and solid angle;
- ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

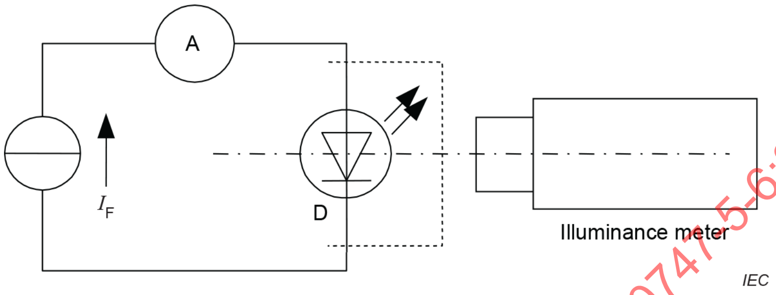
6.18 Illuminance (E_V) measurement

6.18.1 Purpose

The purpose of this measurement is to measure the illuminance of the surface that is irradiated by the LED under established conditions.

6.18.2 Measuring circuit

The measuring circuit should in principle be designed as shown in Figure 37.



Key

I_F forward DC

D light emitting diode being measured

Figure 37 – Circuit diagram for E_v measurement

6.18.3 Measurement procedure

The measurement procedure is the following:

a) Orient the acceptance surface of the calibrated ~~illuminometer~~ illuminance meter to the specified surface that is being irradiated by the test LED.
b) Apply the specified forward current (I_F) to the test LED to obtain the illuminance (E_v) by reading the ~~illuminometer~~ illuminance meter.

The ~~illuminometer~~ illuminance meter shall be calibrated on a regular basis. For information on calibration, refer to Annex G.

For other notes, refer to 6.1.

6.18.4 Measuring conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);
– specified irradiation distance, irradiation direction, light receiving angle, light receiving area;
– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

7 Items to be indicated on the package

The following items shall be indicated on the package:

– model;
– quantity;
– symbols indicating the year and month of manufacture, and identification of lots;

– manufacturer name or its abbreviation.

8 Quality evaluation

8.1 General

Quality evaluation tests, lot quality inspection tests, and periodic quality inspection shall be conducted under the procedure as shown in Table 5, Table 6, and Table 7, respectively.

8.2 Classification of quality evaluations

8.2.1 General

LED quality evaluations fall into three classes based on a combination of quality levels, application tests, inspection items, the number of specimens, and other factors.

8.2.2 Classification I

This classification includes products that not only ~~need to~~ shall obtain the quality certifications for Classification I as defined in Table 5 and pass the lot quality inspections for Group A as defined in Table 6, but also to satisfy all the inspection requirements for the annual quality verification testing for Group B as stipulated in Table 6 and Group C as stipulated in Table 7. Furthermore, products that are required to have the soldering test in Table 5 ~~need to~~ shall satisfy each inspection requirement for the lot quality inspections for soldering every three months.

Products that have obtained the quality certifications for Classifications II and III can also be applied to this class if necessary.

8.2.3 Classification II

This classification includes products that ~~need to~~ shall obtain the quality certifications for Classification II as defined in Table 5 and satisfy all the inspection requirements for the lot quality inspections of each lot for Groups A and B as defined in Table 6 and the periodical quality inspection for Group C in Table 7. Products that have obtained the quality certifications for Classification III stipulated in Table 5 can also be applied to this class if necessary.

8.2.4 Classification III

This classification includes products which all ~~need to~~ shall undergo the screening test and obtain the quality certifications for Classification III as defined in Table 5, and ~~need to~~ shall satisfy all the inspection requirements for the lot quality inspections for Groups A and B in Table 6 and the periodical quality inspection for Group C in Table 7, which are done after the products have obtained the quality certifications.

8.2.5 Precautions to be observed

Items for the screening test and their conditions are shown in Table 4 for reference. However, if some or all of the items for the screening test are tested in the manufacturing processes, those items need not be tested again in the screening test. In addition, items can be added or deleted and their conditions can be eased or strengthened based on the results of consultations between the seller and the purchaser.

Table 4 – Items for the screening test and their conditions(reference)

Items	Conditions
Temperature cycle	T_{stg}max, T_{stg}min, 5 cycles
Continuous current	$I_F$max, $t \geq 24$ h

Table 5 – Quality evaluation tests *(1 of 2)*

Group	Subgroup	Inspection items	Measurement and test methods	Failure criterion	Classification III: Number of specimens	III: Limit number of NG specimens	II: Number of specimens	II: Limit number of NG specimens	I: Number of specimens	I: Limit number of NG specimens	a) LED package	b) LED flat illuminator	c) LED numeric display and alpha-numeric display	d) LED dot-matrix display	e) ~~I LED~~ IR LED	f) UV LED
1 [b]	1-1	Outside	Visual inspection	Lens defect or other outward defect and lighting colour	[a] 38	1	38	1	38	1	○	○	○	○	○	○
	1-2	Forward voltage V_F	see 6.2	U.S.L. [a]							○	○	○	○	○	○
		Reverse current I_R	see 6.5	U.S.L. [a]							○	○	○	○	○	○
		radiation power Φ_e	see 6.11	U.S.L. [a]												○
		Luminous intensity I_v [c]	see 6.12	L.S.L. [a]							○		○			
		Radiant intensity I_e [d]	see 6.13	L.S.L. [a]											○	○
		Luminance L_v [e]	see 6.14	L.S.L. [a]								○	○	○		
		Other	see Clause 6	Relevant specifications							○	○	○	○	○	○
2 ~~[b]~~	2-1	Size	Outline	Outline	18	1	18	1	18	1	○	○	○	○	○	○
3	3-1	Resistance to soldering heat	IEC 60749-15 IEC 60749-20	V_F > 1,1 × U.S.L. I_R > 2 × U.S.L. I_v,I_e,L_v < 0,5 × L.S.L Other relevant specifications	18	1	13	1	8	1	○	○	○		○	○
		Temperature cycling	IEC 60749-25 low temperature T_{stg}min high temperature T_{stg}max								○	○	○	○	○	○
		Damp heat, cyclic [h]	IEC 60068-2-30				—	—	—	—						
4	4-1	Vibration ~~[h]~~	IEC 60749-12	Same as Group 3	18	1	13	1	8	1	○	○	○	○	○	○
		Mechanical shock ~~[h]~~	IEC 60749-10								○	○	○	○	○	○
		Acceleration, steady state ~~[h]~~	IEC 60749-36				—	—	—	—	○	○	○	○	○	○
5	5-1	Solderability [f]	IEC 60749-21	IEC 60749-21	18	1	13	1	8	1	○	○	○		○	○
6	6-1	Terminal strength [f]	IEC 60749-14	IEC 60749-14	13	1	13	1	8	1	○	○	○		○	○

Table 5 *(2 of 2)*

Group	Subgroup	Inspection item	Measurement and test methods	Failure criterion	Classification III		Classification II		Classification I		Types of LED					
					Number of specimens	Limit number of NG specimens	Number of specimens	Limit number of NG specimens	Number of specimens	Limit number of NG specimens	a) LED package	b) LED flat illuminator	c) LED numeric display and alpha-numeric display	d) LED dot-matrix display	e) ~~I LED~~ IR LED	f) UV LED
7	7-1	High temperature storage	IEC 60749-6 Classification I 500 h Classification II 1 000 h Classification III 3 000 h	Same as Group 3	18	1	8	1	8	1	○	○	○	○	○	○
8	8-1	Continuous current	see 8.9 Classification I 500 h Classification II 1 000 h Classification III 3 000 h	Same as Group 3	18	1	8	1	8	1	○	○	○	○	○	○
9	9-1	Resistance to humidity [g]	IEC 60749-24 Classification I 500 h Classification II 1 000 h Classification III 3 000 h	Same as Group 3	18	1	8	1	8	1	○	○	○	○	○	○
10	10-1	Hydrogen sulphide corrosion test	IEC 60747-5-13 H_2S 2ppm NO_2 4ppm	Relevant specifications	18	1	8	1	8	1	○	○	○	○	○	○
11	11-1	Sealing test [i]	IEC 60068-2-17	Relevant specifications	18	1	8	1	8	1						○

[a] U.S.L. and L.S.L. represent the maximum and minimum of the standard value, respectively.

[b] ~~The specimens for Groups 1 and 2 can also be used for other test items.~~

Specimens used in Group 1 shall be used for Group 3 to 11 tests. The number of specimens is the minimum requirement. They should be increased depending on the test group/groups to be required that is selected from Group 3 to 11, and is specified by relevant specifications.

[c] In this test, judgment of acceptance for specimens can also be done in a comparison measurement using a light source whose values, for example its luminous intensity, have been predetermined and set in 6.12.

[d] Either radiant intensity or radiant ~~power~~ flux is defined.

[e] Either luminance or luminous intensity is defined.

[f] Defective products with electrical and optical characteristics can also be used as specimens for this test.

[g] This test is applied to cases other than hermetically sealed packages.

~~[h] This is applied to cases other than mould seal packages.~~

[h] Apply this test if it is necessary to Classification III.

[i] Apply this test if required.

Table 6 – Lot quality inspection

Group	Subgroup	Inspection item	Measurement and test methods	Failure criterion	Classification III: Number of specimens	Classification III: Limit number of NG specimens	Classification II: Number of specimens	Classification II: Limit number of NG specimens	Classification I: Number of specimens	Classification I: Limit number of NG specimens	Types of LED: a) LED package	b) LED flat illuminator	c) LED numeric display and alpha-numeric display	d) LED dot-matrix display	e) ~~I LED~~ IR LED	f) UV LED
A [a]	A_1	Outside	Visual inspection	Lens defect or other outward defect and lighting colour	Acceptable Quality Level 1,5 % (Level I)						○	○	○	○	○	○
	A_2	Forward voltage V_F [b]	see 6.2	U.S.L.	Acceptable Quality Level 1,0 % (Level II)						○	○	○	○	○	○
		Reverse current I_R [b]	see 6.5	U.S.L.							○	○	○	○	○	○
		radiation power Φ_e [b]	see 6.11	U.S.L.												○
		Luminous intensity I_v [b,c]	see 6.12	L.S.L.							○		○			
		Radiant intensity I_e [b,d]	see 6.13	L.S.L.											○	○
		Luminance L_v [b,e]	see 6.14	L.S.L.								○	○	○		
		Other	see Clause 6	Relevant specifications							○	○	○	○	○	○

Group	Subgroup	Inspection item	Measurement and test methods		Failure criterion	Classification III: Number of specimens	III: Limit number of NG specimens	II: Number of specimens	II: Limit number of NG specimens	I: Number of specimens	I: Limit number of NG specimens	Types of LED: a) LED package	b) LED flat illuminator	c) LED numeric display and alpha-numeric display	d) LED dot-matrix display	e) ~~I LED~~ IR LED	f) UV LED
B [k]	B_1 [a]	Size	Outline		Outline	9	1	9	1	9	~~1~~ ○	○	○	○	○	○	○
	B_2	Terminal strength [f]	IEC 60749-14			9	1	6	1	6	1	○	○	○		○	○
	B_3	Solderability [f,h]	IEC 60749-21			9	1	6	1	6	1	○	○	○		○	○
	B_4	Resistance to soldering heat	IEC 60749-15 IEC 60749-20		V_F > 1,1 × U.S.L I_R > 2 × U.S.L I_V, I_e, L_v < 0,5 × L.S.L Other relevant specifications	9	1	6	1	6	~~1~~ ○	○	○	○		○	○
		Temperature cycling	IEC 60749-25 low temperature T_{stg}min high temperature T_{stg}max									○	○	○	○	○	○
		Damp heat, cyclic	IEC 60068-2-30					–	–	–	–	○	○	○	○	○	○
	B_5	Resistance to humidity [g,i]	IEC 60749 -24	500 h	Same as Subgroup B_4	24	1	10	1	10	1	○	○	○	○	○	○
				168 h			0		0		0						
	B_6	Continuous current [i]	see 8.9	500 h	Same as Subgroup B_4	24	1	10	1	10	1	○	○	○	○	○	○
				168 h			0		0		0						
	B_7	High temperature storage [i]	IEC 60749 -6	500 h	Same as Subgroup B_4	24	1	10	1	10	1	○	○	○	○	○	○
				168 h			0		0		0						
	B_8	Hydrogen sulphide corrosion test	IEC 60747-5-13 H_2S 2ppm NO_2 4ppm		Relevant specifications	9	1	6	1	6	1	○	○	○	○	○	○
	B_9	Sealing test [j]	IEC 60068-2-17		Relevant specifications	9	1	6	1	6	1						○

Group	Subgroup	Inspection item	Measurement and test methods	Failure criterion	Classification						Types of LED					
					III		II		I							
					Number of specimens	Limit number of NG specimens	Number of specimens	Limit number of NG specimens	Number of specimens	Limit number of NG specimens	a) LED package	b) LED flat illuminator	c) LED numeric display and alpha-numeric display	d) LED dot-matrix display	e) ~~I LED~~ IR LED	f) UV LED
	$B_{(CRRL)}$ [~~j~~k]	Certificate of test results for Subgroups B_1 to B_7	–	–	–	–	–	–	–	–	○	○	○	○	○	○

[a] ~~The specimens for Group A and Subgroup B_4 can be also used for other test items.~~ Specimens used in Group A shall be used for Subgroup B_4 to B_{10} tests.

[b] U.S.L. and L.S.L. represent the maximum and minimum of the standard value, respectively.

[c] In this test, judgment of acceptance for specimens can also be done in a comparison measurement using a light source whose values, for example its luminous intensity, have been predetermined and set in 6.12.

[d] Either radiant intensity or radiant ~~power~~ flux is defined.

[e] Either luminance or luminous intensity is defined.

[f] Defective products with electrical and optical characteristics can also be used as specimens for this test.

[g] This test is applied to cases other than hermetically sealed packages.

[h] This only needs to be executed as a quality confirmation test every three months for Classification I.

[i] If no defects are found in 168 h of testing, it can be judged that the lot is acceptable and the test can be stopped.

[j] Apply this test if required.

[k] Certificate of test results (CRRL)

[~~k~~l] This only needs to be executed as a quality confirmatory test once a year for Subgroups B_1 through B_7 (except B_3) for Classification I. However, the tests for B_5 through B_7 shall be performed for 500 h.

Table 7 – Periodical quality inspection

Group	Subgroup	Inspection item	Measurement and test methods	Failure criterion	Classification III: Number of specimens	Classification III: Limit number of NG specimens	Classification II: Number of specimens	Classification II: Limit number of NG specimens	Classification I: Number of specimens	Classification I: Limit number of NG specimens	Types of LED: a) LED package	b) LED flat illuminator	c) LED numeric display and alpha-numeric display	d) LED dot-matrix display	e) ~~I-LED~~ IR LED	f) UV LED
C	C_1	Vibration [a,b]	IEC 60749-12	Same as Subgroup B_4	9	1	6	1	6	1	○	○	○	○	○	○
		Mechanical Shock [a,b]	IEC 60749-10								○	○	○	○	○	○
		Acceleration Steady state [a,b]	IEC 60749-36				–	–	–	–	○	○	○	○	○	○
	C_2	Resistance to humidity [a,c]	IEC 60749-24 1 000 h	Same as Subgroup B_4	11	1	5	1	–	–	○	○	○	○	○	○
	C_3	Continuous current [a,c]	see 8.9 1 000 h	Same as Subgroup B_4	11	1	5	1	–	–	○	○	○	○	○	○
	C_4	High temperature storage [a]	IEC 60749-6 1 000 h	Same as Subgroup B_4	11	1	5	1	–	–	○	○	○	○	○	○
	C_5	Hydrogen sulphide corrosion test	IEC 60747-5-13 H_2S 2 ppm NO_2 4 ppm	Relevant specifications	9	1	6	1	6	1	○	○	○	○	○	○
	C_6	Sealing test [d]	IEC 60068-2-17	Relevant specifications	9	1	6	1	6	1						○
	$C_{(CRRL)}$ [~~d~~e]	Certificate of test results for subgroups C_1 to C_4 [a]	–	–	–	–	–	–	–	–	○	○	○	○	○	○

[a] This is applied to cases other than mould seal packages.

[b] These can be executed as annual quality confirmatory tests for Classification I.

[c] This test is applied to cases other than hermetically sealed packages.

[d] Apply this test if required.

[~~d~~e] Certificate of test results (CRRL).

8.3 Quality evaluation test

8.3.1 General

~~The quality evaluation test conforms to Table 5. The test should be performed by working on the test items for each subgroup in Table 5 in order from the top.~~

The quality evaluation test shall conform to Table 5. The samples passed Group 1 test shall be used for Group 3 to 11 tests. Tests from Group 3 to 11 can be performed in parallel. However, inspection items in each subgroup of Table 5 shall be performed in order from the top except for subgroup 1-2.

8.3.2 Specimens

The following provisions apply:

a) Specimens to be used shall be those specimens whose performances and characteristics as defined in the particular standard are representative and which have been manufactured within three months before the test starts.

b) In principle, specimens shall be selected at random from the same lot.

8.4 Lot quality inspection

8.4.1 General

The lot quality inspection ~~conforms~~ shall conform to Table 6. The inspection should be performed by working on the inspection items for each subgroup in order from the top except for Group A in Table 6.

8.4.2 Specimens

The following provisions apply.

a) The sampling specimen AQL in a lot quality inspection shall conform to ISO 2859-1 ~~(sampling *inspection* procedures and tables *by attributes* with severity adjustment: purchase *inspection* where the consumer can select suppliers)~~ (*Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*).

b) Specimens shall be sampled for each inspection lot. The inspection lot can be either a single production lot or a combination of several production lots that are continuously manufactured as shown below.

c) Each production lot shall have identical design, materials, manufacturing processes, manufacturing conditions, and controlled conditions.

d) The time period and method to put together a lot shall be set beforehand. The time period should be a week or less in principle and shall not exceed a month in any event.

8.5 Periodical quality inspection

8.5.1 General

The periodical quality inspection ~~conforms~~ shall conform to Table 7.

8.5.2 Specimens

Specimens are selected from lots that have passed the lot quality inspection. In this case, for family models (models whose basic designs are similar), it is acceptable to test only the representative model of the family instead of testing all of the models.

8.5.3 Inspection period

In principle, the inspection is performed every three months. However, it is acceptable to perform the lot quality inspection for the first lot after restarting the production in the following cases, even if the production of the product is halted for more than three months:

a) when any similar product with the equivalent quality is continuously manufactured;

b) when the production facilities are precisely maintained and controlled.

8.6 Easing of the lot quality inspection standards

If the lot quality inspection of a product has been continuously accepted more than five times, the inspection items of Subgroups B_3 through B_5 shown in Table 6 can be omitted for

Classifications I and II. However, the items of Subgroups B_2 through B_4 shall be inspected in periodical quality inspections.

For Classification III, it is acceptable to perform the quality inspection for Subgroups B_2 through B_4, changing the classification of the quality evaluation with the eased standards (standards for Classification II).

However, if the product fails the quality inspection with the eased standards even once, the product shall be inspected at the original inspection level the next time.

8.7 Periodical evaluation maintenance tests

8.7.1 Test items and specimens

The test items and specimens shall conform to the evaluation test.

In this case, for the test of products belonging to an identical family, it is acceptable to test only the representative specimens of the family.

8.7.2 Test period

In principle, the test is performed once a year. However, this test can be omitted and replaced with the lot quality inspection or the periodical quality inspection, if it can be determined by the accumulated data of the tests that the results of the inspection show equivalent or better results than the quality evaluation test when performing the specified lot quality inspection in 8.4 or the specified periodical quality inspection in 8.5.

8.8 Long-term storage products

Products that have been stored for 24 months or longer after the lot quality inspection shall be given the Group A and Subgroup B_3 (soldering quality) inspection shown in Table 6 before they are delivered. The year and month of the inspection shall be additionally printed on the package or the storage box of the re-inspected products.

8.9 Continuous current test

8.9.1 General

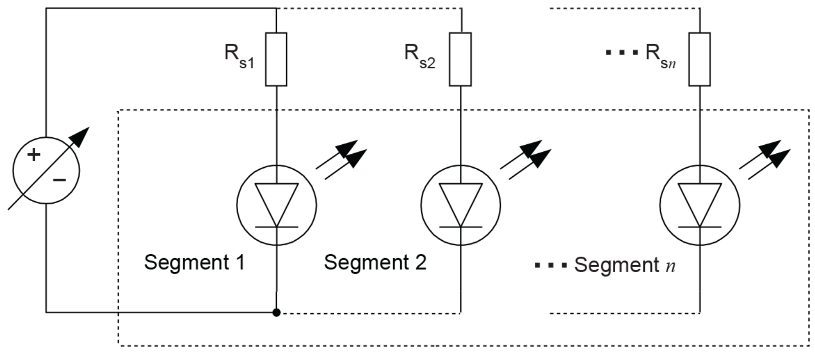
The purpose of this test is to evaluate the resistance characteristics of the test LED when electrical and thermal stresses are applied to it over a prolonged period of time.

8.9.2 Initial measurement

Initial measurements should be performed for the specified items and under the specified conditions for each standard.

8.9.3 Test circuits

The test circuit should be designed as shown in Figure 38.



R_{s1}, R_{s2}, R_{sn} Resistor for current limit

Figure 38 – Circuit diagram for continuous current test

8.9.4 Test conditions

The test conditions are as follows:

a) Conditions when applying current

Unless otherwise specified, apply the allowable forward current (I_F) per segment continuously.

However, for LEDs with any specified allowance loss standard, apply current under the conditions for the allowance loss standard.

b) Allowable tolerance of the impressed current

Keep the set value within 0 % to 10 %.

c) Ambient temperature

Unless otherwise specified, the ambient temperature should be (25 ± 5) °C.

d) Test time

Unless otherwise specified, the test time is 1 000 h.

e) Mounting method for the test LED

It should conform to the relevant specifications as needed.

8.9.5 Post-treatment

Leave the circuit for two hours or longer after the termination of the test.

8.9.6 Final measurement

The final measurement should be performed for the specified items and under the specified conditions for each standard.

Annex A
(normative)

Standard luminous efficiency

Table A.1 show the numerical scheme for the spectral luminous efficiency. This table shall be applied when calculating related parameters. See 3.3 for more details.

Table A.1 – Definitive values of the spectral luminous efficiency function for photopic vision $V(\lambda)$ *(1 of 3)*

λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$
360	0,000 003 9	400	0,000 396 0	440	0,023 000 0	480	0,139 020 0
361	0,000 004 4	401	0,000 433 7	441	0,024 294 6	481	0,144 676 4
362	0,000 004 9	402	0,000 473 0	442	0,025 610 2	482	0,150 469 3
363	0,000 005 5	403	0,000 517 9	443	0,026 958 6	483	0,156 461 9
364	0,000 006 2	404	0,000 572 2	444	0,028 351 3	484	0,162 717 7
365	0,000 007 0	405	0,000 640 0	445	0,029 800 0	485	0,169 300 0
366	0,000 007 8	406	0,000 724 6	446	0,031 310 8	486	0,176 243 1
367	0,000 008 8	407	0,000 825 5	447	0,032 883 7	487	0,183 558 1
368	0,000 009 8	408	0,000 941 2	448	0,034 521 1	488	0,191 273 5
369	0,000 011 0	409	0,001 069 9	449	0,036 225 7	489	0,199 418 0
370	0,000 012 4	410	0,001 210 0	450	0,038 000 0	490	0,208 020 0
371	0,000 013 9	411	0,001 362 1	451	0,039 846 7	491	0,217 119 9
372	0,000 015 6	412	0,001 530 8	452	0,041 768 0	492	0,226 734 5
373	0,000 017 4	413	0,001 720 4	453	0,043 766 0	493	0,236 857 1
374	0,000 019 6	414	0,001 935 3	454	0,045 842 7	494	0,247 481 2
375	0,000 022 0	415	0,002 180 0	455	0,048 000 0	495	0,258 600 0
376	0,000 024 8	416	0,002 454 8	456	0,050 243 7	496	0,270 184 9
377	0,000 028 0	417	0,002 764 0	457	0,052 573 0	497	0,282 293 9
378	0,000 031 5	418	0,003 117 8	458	0,054 980 6	498	0,295 050 5
379	0,000 035 2	419	0,003 526 4	459	0,057 458 7	499	0,308 578 0
380	0,000 039 0	420	0,004 000 0	460	0,060 000 0	500	0,323 000 0
381	0,000 042 8	421	0,004 546 2	461	0,062 602 0	501	0,338 402 1
382	0,000 046 9	422	0,005 159 3	462	0,065 277 5	502	0,354 685 8
383	0,000 051 6	423	0,005 829 3	463	0,068 042 1	503	0,371 698 6
384	0,000 057 2	424	0,006 546 2	464	0,070 911 1	504	0,389 287 5
385	0,000 064 0	425	0,007 300 0	465	0,073 900 0	505	0,407 300 0
386	0,000 072 3	426	0,008 086 5	466	0,077 016 0	506	0,425 629 9
387	0,000 082 2	427	0,008 908 7	467	0,080 266 4	507	0,444 309 6
388	0,000 093 5	428	0,009 767 7	468	0,083 666 8	508	0,463 394 4
389	0,000 106 1	429	0,010 664 4	469	0,087 232 8	509	0,482 939 5
390	0,000 120 0	430	0,011 600 0	470	0,090 980 0	510	0,503 000 0
391	0,000 135 0	431	0,012 573 2	471	0,094 917 6	511	0,523 569 3
392	0,000 151 5	432	0,013 582 7	472	0,099 045 8	512	0,544 512 0
393	0,000 170 2	433	0,014 629 7	473	0,103 367 4	513	0,565 690 0
394	0,000 191 8	434	0,015 715 1	474	0,107 884 6	514	0,586 965 3
395	0,000 217 0	435	0,016 840 0	475	0,112 600 0	515	0,608 200 0
396	0,000 246 9	436	0,018 007 4	476	0,117 532 0	516	0,629 345 6
397	0,000 281 2	437	0,019 214 5	477	0,122 674 4	517	0,650 306 8
398	0,000 318 5	438	0,020 453 9	478	0,127 992 8	518	0,670 875 2
399	0,000 357 3	439	0,021 718 2	479	0,133 452 8	519	0,690 842 4

Table A.1 *(2 of 3)*

λ (nm)	V(λ)	λ (nm)	V(λ)	λ (nm)	V(λ)	λ (nm)	V(λ)
520	0,710 000 0	560	0,995 000 0	600	0,631 000 0	640	0,175 000 0
521	0,728 185 2	561	0,992 600 5	601	0,618 155 5	641	0,167 223 5
522	0,745 463 6	562	0,989 742 6	602	0,605 314 4	642	0,159 646 4
523	0,761 969 4	563	0,986 444 4	603	0,592 475 6	643	0,152 277 6
524	0,777 836 8	564	0,982 724 1	604	0,579 637 9	644	0,145 125 9
525	0,793 200 0	565	0,978 600 0	605	0,566 800 0	645	0,138 200 0
526	0,808 110 4	566	0,974 083 7	606	0,553 961 1	646	0,131 500 3
527	0,822 493 2	567	0,969 171 2	607	0,541 137 2	647	0,125 024 8
528	0,836 306 8	568	0,963 856 8	608	0,528 352 8	648	0,118 779 2
529	0,849 491 6	569	0,958 134 9	609	0,515 632 3	649	0,112 769 1
530	0,862 000 0	570	0,952 000 0	610	0,503 000 0	650	0,107 000 0
531	0,873 810 8	571	0,945 450 4	611	0,490 468 8	651	0,101 476 2
532	0,884 962 4	572	0,938 499 2	612	0,478 030 4	652	0,096 188 6
533	0,895 493 6	573	0,931 162 8	613	0,465 677 6	653	0,091 123 0
534	0,905 443 2	574	0,923 457 6	614	0,453 403 2	654	0,086 264 9
535	0,914 850 1	575	0,915 400 0	615	0,441 200 0	655	0,081 600 0
536	0,923 734 8	576	0,907 006 4	616	0,429 080 0	656	0,077 120 6
537	0,932 092 4	577	0,898 277 2	617	0,417 036 0	657	0,072 825 5
538	0,939 922 6	578	0,889 204 8	618	0,405 032 0	658	0,068 710 1
539	0,947 225 2	579	0,879 781 6	619	0,393 032 0	659	0,064 769 8
540	0,954 000 0	580	0,870 000 0	620	0,381 000 0	660	0,061 000 0
541	0,960 256 1	581	0,859 861 3	621	0,368 918 4	661	0,057 396 2
542	0,966 007 4	582	0,849 392 0	622	0,356 827 2	662	0,053 955 0
543	0,971 260 6	583	0,838 622 0	623	0,344 776 8	663	0,050 673 8
544	0,976 022 5	584	0,827 581 3	624	0,332 817 6	664	0,047 549 7
545	0,980 300 0	585	0,816 300 0	625	0,321 000 0	665	0,044 580 0
546	0,984 092 4	586	0,804 794 7	626	0,309 338 1	666	0,041 758 7
547	0,987 418 2	587	0,793 082 0	627	0,297 850 4	667	0,039 085 0
548	0,990 312 8	588	0,781 192 0	628	0,286 593 6	668	0,036 563 8
549	0,992 811 6	589	0,769 154 7	629	0,275 624 5	669	0,034 200 5
550	0,994 950 1	590	0,757 000 0	630	0,265 000 0	670	0,032 000 0
551	0,996 710 8	591	0,744 754 1	631	0,254 763 2	671	0,029 962 6
552	0,998 098 3	592	0,732 422 4	632	0,244 889 6	672	0,028 076 6
553	0,999 112 0	593	0,720 003 6	633	0,235 334 4	673	0,026 329 4
554	0,999 748 2	594	0,707 496 5	634	0,226 052 8	674	0,024 708 1
555	1,000 000 0	595	0,694 900 0	635	0,217 000 0	675	0,023 200 0
556	0,999 856 7	596	0,682 219 2	636	0,208 161 6	676	0,021 800 8
557	0,999 304 6	597	0,669 471 6	637	0,199 548 8	677	0,020 501 1
558	0,998 325 5	598	0,656 674 4	638	0,191 155 2	678	0,019 281 1
559	0,996 898 7	599	0,643 844 8	639	0,182 974 4	679	0,018 120 7

Table A.1 *(3 of 3)*

λ (nm)	$V(\lambda)$
680	0,017 000 0
681	0,015 903 8
682	0,014 837 2
683	0,013 810 7
684	0,012 834 8
685	0,011 920 0
686	0,011 068 3
687	0,010 273 4
688	0,009 533 3
689	0,008 846 2
690	0,008 210 0
691	0,007 623 8
692	0,007 085 4
693	0,006 591 5
694	0,006 138 5
695	0,005 723 0
696	0,005 343 1
697	0,004 995 8
698	0,004 676 4
699	0,004 380 1
700	0,004 102 0
701	0,003 838 5
702	0,003 589 1
703	0,003 354 2
704	0,003 134 1
705	0,002 929 0
706	0,002 738 1
707	0,002 559 9
708	0,002 393 2
709	0,002 237 3
710	0,002 091 0
711	0,001 953 6
712	0,001 824 6
713	0,001 703 6
714	0,001 590 2
715	0,001 484 0
716	0,001 384 5
717	0,001 291 3
718	0,001 204 1
719	0,001 122 7

λ (nm)	$V(\lambda)$
720	0,001 047 0
721	0,000 976 6
722	0,000 911 1
723	0,000 850 1
724	0,000 793 2
725	0,000 740 0
726	0,000 690 1
727	0,000 643 3
728	0,000 599 5
729	0,000 558 5
730	0,000 520 0
731	0,000 483 9
732	0,000 450 1
733	0,000 418 3
734	0,000 388 7
735	0,000 361 1
736	0,000 335 4
737	0,000 311 4
738	0,000 289 2
739	0,000 268 5
740	0,000 249 2
741	0,000 231 3
742	0,000 214 7
743	0,000 199 3
744	0,000 185 0
745	0,000 171 9
746	0,000 159 8
747	0,000 148 6
748	0,000 138 3
749	0,000 128 8
750	0,000 120 0
751	0,000 111 9
752	0,000 104 3
753	0,000 097 3
754	0,000 090 8
755	0,000 084 8
756	0,000 079 1
757	0,000 073 9
758	0,000 068 9
759	0,000 064 3

λ (nm)	$V(\lambda)$
760	0,000 060 0
761	0,000 056 0
762	0,000 052 2
763	0,000 048 7
764	0,000 045 4
765	0,000 042 4
766	0,000 039 6
767	0,000 036 9
768	0,000 034 4
769	0,000 032 1
770	0,000 030 0
771	0,000 028 0
772	0,000 026 1
773	0,000 024 4
774	0,000 022 7
775	0,000 021 2
776	0,000 019 8
777	0,000 018 5
778	0,000 017 2
779	0,000 016 1
780	0,000 015 0
781	0,000 014 0
782	0,000 013 1
783	0,000 012 2
784	0,000 011 4
785	0,000 010 6
786	0,000 009 9
787	0,000 009 2
788	0,000 008 6
789	0,000 008 0
790	0,000 007 5
791	0,000 007 0
792	0,000 006 5
793	0,000 006 0
794	0,000 005 6
795	0,000 005 3
796	0,000 004 9
797	0,000 004 6
798	0,000 004 3
799	0,000 004 0

λ (nm)	$V(\lambda)$
800	0,000 003 7
801	0,000 003 5
802	0,000 003 2
803	0,000 003 0
804	0,000 002 8
805	0,000 002 6
806	0,000 002 4
807	0,000 002 3
808	0,000 002 1
809	0,000 002 0
810	0,000 001 8
811	0,000 001 7
812	0,000 001 6
813	0,000 001 5
814	0,000 001 4
815	0,000 001 3
816	0,000 001 2
817	0,000 001 1
818	0,000 001 0
819	0,000 001 0
820	0,000 000 9
821	0,000 000 8
822	0,000 000 8
823	0,000 000 7
824	0,000 000 7
825	0,000 000 6
826	0,000 000 6
827	0,000 000 6
828	0,000 000 5
829	0,000 000 5
830	0,000 000 5

Annex B
(normative)

How to obtain the self-absorption correction factor

B.1 Purpose

Because the standard and test LEDs have self-absorption in their package and the sealed part of the resin as well as absorption in their connectors, when measuring the luminous flux and the radiant ~~power~~ flux using an integrating sphere, if the difference in absorption between the standard LED and the test LED cannot be ignored, the absorption error shall be corrected.

The purpose here is to obtain the self-absorption correction factor used for this correction calculation.

B.2 LED light sources for self-absorption measurement

As shown in Figure B.1, the LED light source for self-absorption measurement should have light shielding plates to prevent light-transmittance inside the integrating sphere. These shielding plates shall be placed at positions where direct light from the LED does not enter the light receiving portion or the LED to be measured within the integrating sphere.

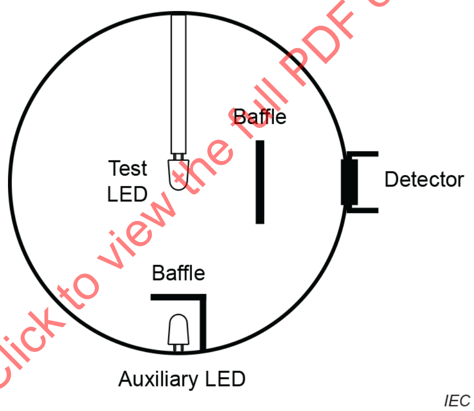


Figure B.1 – Schematic diagram for self-absorption measurement

B.3 Method

Switch on the LED for measuring the self-absorption to obtain the read value (r_{s1}) of the photometer when the LED is turned off while the standard LED is attached, and the read value (r_{t1}) of the photometer when the LED is turned off while the test LED is attached.

The self-absorption correction factor (α) can be calculated using the following formula:

$$\alpha = \frac{r_{s1}}{r_{t1}} \tag{B.1}$$

It is preferable that the standard LED and the test LED have as similar a spectral distribution as possible. However, if the difference in spectral distribution between the two LEDs is large and the photometer or the radiometer is a filter photometer ($V(\lambda)$ photometer) or an optical power meter, which tend to easily show errors from the difference in spectral distribution, prepare a LED for measuring the self-absorption in accordance with the spectral distribution suitable for each of the standard and test LEDs and calculate based on the read value and the following formula:

$$\alpha = \frac{r_{s1} / r_{s2}}{r_{t1} / r_{t2}} \tag{B.2}$$

where

r_{s2} is the read value of the photometer in the case that the standard LED is detached from the integrating sphere and that the LED for measuring the self-absorption is simultaneously turned on (r_{s1} is the light source lighting and the same method as in Formula (B.1));

r_{t2} is the read value of the photometer in case the test LED is detached from the integrating sphere after the LED for measuring the self-absorption of the test LED is turned on [r_{t1} is the light source lighting and the same method as in Formula (B.1)].

Annex C
(normative)

How to obtain the colour correction factor

C.1 Purpose

When measuring the luminous flux or the luminous intensity using a filter photometer ($V(\lambda)$ photometer), the misalignment of the $V(\lambda)$ photometer shall be corrected as needed to prevent a reduction in measured data quality due to misalignment after the $V(\lambda)$ filter correction for the standard spectral luminous efficiency distribution.

In addition, when measuring the radiant ~~power~~ flux or the radiant intensity using an optical power meter, if the relative spectral efficiency of the optical receiver is not sufficiently flat in the emission wavelength of the light source for radiation to be measured, correction shall be performed.

The purpose here is to obtain the colour correction factor used for this correction calculation.

C.2 Method

C.2.1 Luminous flux and luminous intensity measurement

Check beforehand the relative spectral efficiency of the filter photometer ($V(\lambda)$ photometer) used for the measurement and the relative spectral distribution data of the standard LED and the test LED.

The colour correction factor (k) can be calculated using the following formula:

$$k = \frac{\int_0^\infty P_t(\lambda)V(\lambda)\mathrm{d}\lambda \cdot \int_0^\infty P_s(\lambda)S(\lambda)\mathrm{d}\lambda}{\int_0^\infty P_s(\lambda)V(\lambda)\mathrm{d}\lambda \cdot \int_0^\infty P_t(\lambda)S(\lambda)\mathrm{d}\lambda}$$

where

$P_t(\lambda)$ is the relative spectral distribution of the test LED;

$P_s(\lambda)$ is the relative spectral distribution of the standard LED;

$V(\lambda)$ is the standard luminous efficiency;

$S(\lambda)$ is the relative spectral efficiency of the photometer.

If the optical receiver is a sphere photometer, perform the calculation in consideration of the total spectral reflection factor $\rho'(\lambda)$ of the inner wall of the integrating sphere:

$$k = \frac{\int_0^\infty P_t(\lambda)V(\lambda)\mathrm{d}\lambda \cdot \int_0^\infty P_s(\lambda)S(\lambda)\rho'(\lambda)\mathrm{d}\lambda}{\int_0^\infty P_s(\lambda)V(\lambda)\mathrm{d}\lambda \cdot \int_0^\infty P_t(\lambda)S(\lambda)\rho'(\lambda)\mathrm{d}\lambda}$$

$$\rho'(\lambda) = \frac{\rho(\lambda)}{1-\rho(\lambda)}$$

where

$\rho(\lambda)$ is the spectral reflectance (average value of each part) of a part of the inner wall of the integrating sphere.

C.2.2 Radiant ~~power~~ flux and radiant intensity measurement

Check beforehand the relative spectral efficiency of the optical receiver used for the measurement and the relative spectral distribution data of the standard LED and the test LED. The colour correction factor (k) can be calculated using the following formula:

$$k = \frac{\int_{\lambda L}^{\lambda H} P_t(\lambda)\mathrm{d}\lambda \cdot \int_{\lambda L}^{\lambda H} P_s(\lambda)S(\lambda)\mathrm{d}\lambda}{\int_{\lambda L}^{\lambda H} P_s(\lambda)\mathrm{d}\lambda \cdot \int_{\lambda L}^{\lambda H} P_t(\lambda)S(\lambda)\mathrm{d}\lambda}$$

where

$P_t(\lambda)$ is the relative spectral distribution of the test LED;

$P_s(\lambda)$ is the relative spectral distribution of the standard LED;

$S(\lambda)$ is the relative spectral efficiency of the optical receiver;

λH, λL are the upper- and lower-limit wavelengths of the emission wavelength range of the radiation measurement source to be measured.

If the optical receiver is a sphere radiometer, perform the calculation in consideration of the total spectral reflection factor $\rho'(\lambda)$ of the inner wall of the integrating sphere.

$$k = \frac{\int_{\lambda L}^{\lambda H} P_t(\lambda)\mathrm{d}\lambda \cdot \int_{\lambda L}^{\lambda H} P_s(\lambda)S(\lambda)\rho'(\lambda)\mathrm{d}\lambda}{\int_{\lambda L}^{\lambda H} P_s(\lambda)\mathrm{d}\lambda \cdot \int_{\lambda L}^{\lambda H} P_t(\lambda)S(\lambda)\rho'(\lambda)\mathrm{d}\lambda}$$

$$\rho'(\lambda) = \frac{\rho(\lambda)}{1-\rho(\lambda)}$$

where

$\rho(\lambda)$ is the spectral reflectance (average value of each part) of a part of the inner wall of the integrating sphere.

Annex D
(normative)

Calibration of the luminance meter

D.1 Purpose

The purpose here is to calibrate the luminance meter using a standard light source.

D.2 How to perform the calibration

As shown in Figure D.1 a), when the distance between the standard light source for the luminous intensity I_V(cd) and the white diffuse reflector with reflectance ρ is S (m), the luminance L_v of the white diffuse reflector can be obtained using the following formula:

$$L_v = \frac{\rho I_v}{\pi S^2} \text{ (cd/m}^2\text{)}$$

Therefore, by performing the photometric measurement using a luminance meter while taking the white diffuse reflector as the standard luminance surface, the relationship between the luminance meter reading and the correct luminance can be obtained.

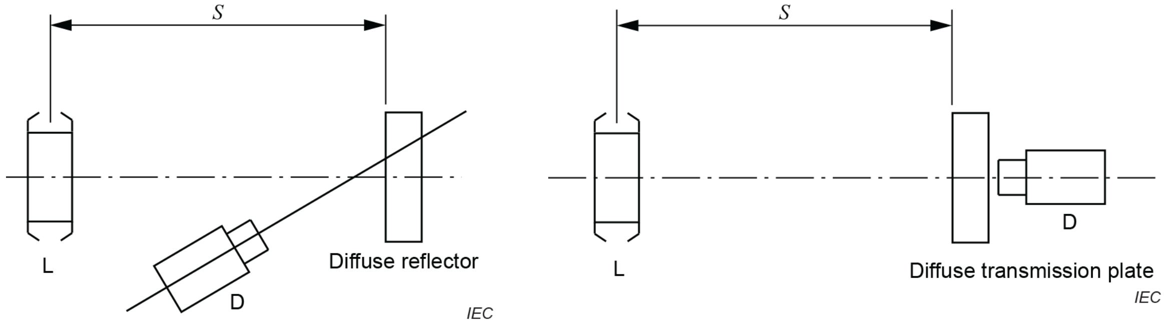
As shown in Figure D.1 b), a method that takes the white diffuse transmission plate as the standard luminance surface is also available. At this time, by taking τ as the transmittance of the white diffuse transmission plate, I_V(cd) as the luminous intensity of the standard light source, and S (m) as the distance between the standard light source and the white diffuse transmission plate, the luminance L_v of the white diffuse transmission plate can be obtained using the following formula:

$$L_v = \frac{\tau I_v}{\pi S^2} \text{ (cd/m}^2\text{)}$$

Care is required in this formula, as the measurement of transmittance τ of the diffuse transmission plate is problematic.

Because the diffuseness obtained from a diffuse reflector tends to be better than that obtained from a diffuse transmission plate, the accuracy of the diffuseness obtained from a diffuse reflector is generally higher. However, use of a diffuse reflector is disadvantageous in that corrections cannot be performed by moving the luminance meter closer. In either case, it is advisable to keep the colour temperature of the standard light source constant.

When calibrating a luminance meter, it is advisable to carefully examine in advance the linearity of the luminance meter to determine the appropriate calibration point.



a) Use of diffuse reflector **b) Use of diffuse transmission plate**

Key

L standard light source

D luminance meter

Figure D.1 – Schematic diagrams for calibration

Annex E
(normative)

Colour-matching function of the *XYZ* colour system

~~See Table E.1.~~ Table E.1 shows the colour-matching function of the *XYZ* colour system. This table shall be applied when calculating related parameters. See 6.16.2.2 for more details.

Table E.1 – Colour-matching function of the XYZ colour system *(1 of 5)*

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
360	0,000 130	0,000 004	0,000 606
361	0,000 146	0,000 004	0,000 681
362	0,000 164	0,000 005	0,000 765
363	0,000 184	0,000 006	0,000 860
364	0,000 207	0,000 006	0,000 967
365	0,000 232	0,000 007	0,001 086
366	0,000 261	0,000 008	0,001 221
367	0,000 293	0,000 009	0,001 373
368	0,000 329	0,000 010	0,001 544
369	0,000 370	0,000 011	0,001 734
370	0,000 415	0,000 012	0,001 946
371	0,000 464	0,000 014	0,002 178
372	0,000 519	0,000 016	0,002 436
373	0,000 582	0,000 017	0,002 732
374	0,000 655	0,000 020	0,003 078
375	0,000 742	0,000 022	0,003 486
376	0,000 845	0,000 025	0,003 975
377	0,000 965	0,000 028	0,004 541
378	0,001 095	0,000 032	0,005 158
379	0,001 231	0,000 035	0,005 803
380	0,001 368	0,000 039	0,006 450
381	0,001 502	0,000 043	0,007 083
382	0,001 642	0,000 047	0,007 745
383	0,001 802	0,000 052	0,008 501
384	0,001 996	0,000 057	0,009 415
385	0,002 236	0,000 064	0,010 550
386	0,002 535	0,000 072	0,011 966
387	0,002 893	0,000 082	0,013 656
388	0,003 301	0,000 094	0,015 588
389	0,003 753	0,000 106	0,017 730
390	0,004 243	0,000 120	0,020 050
391	0,004 762	0,000 135	0,022 511
392	0,005 330	0,000 151	0,025 203
393	0,005 979	0,000 170	0,028 280
394	0,006 741	0,000 192	0,031 897
395	0,007 650	0,000 217	0,036 210
396	0,008 751	0,000 247	0,041 438
397	0,010 029	0,000 281	0,047 504
398	0,011 422	0,000 319	0,054 120
399	0,012 869	0,000 357	0,060 998
400	0,014 310	0,000 396	0,067 850
401	0,015 704	0,000 434	0,074 486
402	0,017 147	0,000 473	0,081 362
403	0,018 781	0,000 518	0,089 154
404	0,020 748	0,000 572	0,098 540
405	0,023 190	0,000 640	0,110 200
406	0,026 207	0,000 725	0,124 613
407	0,029 782	0,000 826	0,141 702
408	0,033 881	0,000 941	0,161 304
409	0,038 468	0,001 070	0,183 257
410	0,043 510	0,001 210	0,207 400
411	0,048 996	0,001 362	0,233 692
412	0,055 023	0,001 531	0,262 611
413	0,061 719	0,001 720	0,294 775
414	0,069 212	0,001 935	0,330 799
415	0,077 630	0,002 180	0,371 300
416	0,086 958	0,002 455	0,416 209
417	0,097 177	0,002 764	0,465 464
418	0,108 406	0,003 118	0,519 695
419	0,120 767	0,003 526	0,579 530
420	0,134 380	0,004 000	0,645 600
421	0,149 358	0,004 546	0,718 484
422	0,165 396	0,005 159	0,796 713
423	0,181 983	0,005 829	0,877 846
424	0,198 611	0,006 546	0,959 439
425	0,214 770	0,007 300	1,039 050
426	0,230 187	0,008 087	1,115 367
427	0,244 880	0,008 909	1,188 497
428	0,258 777	0,009 768	1,258 123
429	0,271 808	0,010 664	1,323 930
430	0,283 900	0,011 600	1,385 600
431	0,294 944	0,012 573	1,442 635
432	0,304 897	0,013 583	1,494 804
433	0,313 787	0,014 630	1,542 190
434	0,321 645	0,015 715	1,584 881
435	0,328 500	0,016 840	1,622 960
436	0,334 351	0,018 007	1,656 405
437	0,339 210	0,019 214	1,685 296
438	0,343 121	0,020 454	1,709 875
439	0,346 130	0,021 718	1,730 382

Table E.1 *(2 of 5)*

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
440	0,348 280	0,023 000	1,747 060
441	0,349 600	0,024 295	1,760 045
442	0,350 147	0,025 610	1,769 623
443	0,350 013	0,026 959	1,776 264
444	0,349 287	0,028 351	1,780 433
445	0,348 060	0,029 800	1,782 600
446	0,346 373	0,031 311	1,782 968
447	0,344 262	0,032 884	1,781 700
448	0,341 809	0,034 521	1,779 198
449	0,339 094	0,036 226	1,775 867
450	0,336 200	0,038 000	1,772 110
451	0,333 198	0,039 847	1,768 259
452	0,330 041	0,041 768	1,764 039
453	0,326 636	0,043 766	1,758 944
454	0,322 887	0,045 843	1,752 466
455	0,318 700	0,048 000	1,744 100
456	0,314 025	0,050 244	1,733 560
457	0,308 884	0,052 573	1,720 858
458	0,303 290	0,054 981	1,705 937
459	0,297 258	0,057 459	1,688 737
460	0,290 800	0,060 000	1,669 200
461	0,283 970	0,062 602	1,647 529
462	0,276 721	0,065 278	1,623 413
463	0,268 918	0,068 042	1,596 022
464	0,260 423	0,070 911	1,564 528
465	0,251 100	0,073 900	1,528 100
466	0,240 848	0,077 016	1,486 111
467	0,229 851	0,080 266	1,439 522
468	0,218 407	0,083 667	1,389 880
469	0,206 812	0,087 233	1,338 736
470	0,195 360	0,090 980	1,287 640
471	0,184 214	0,094 918	1,237 422
472	0,173 327	0,099 046	1,187 824
473	0,162 688	0,103 367	1,138 761
474	0,152 283	0,107 885	1,090 148
475	0,142 100	0,112 600	1,041 900
476	0,132 179	0,117 532	0,994 198
477	0,122 570	0,122 674	0,947 347
478	0,113 275	0,127 993	0,901 453
479	0,104 298	0,133 453	0,856 619
480	0,095 640	0,139 020	0,812 950
481	0,087 300	0,144 676	0,770 517
482	0,079 308	0,150 469	0,729 445
483	0,071 718	0,156 462	0,689 914
484	0,064 581	0,162 718	0,652 105
485	0,057 950	0,169 300	0,616 200
486	0,051 862	0,176 243	0,582 329
487	0,046 282	0,183 558	0,550 416
488	0,041 151	0,191 274	0,520 338
489	0,036 413	0,199 418	0,491 967

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
490	0,032 010	0,208 020	0,465 180
491	0,027 917	0,217 120	0,439 925
492	0,024 144	0,226 735	0,416 184
493	0,020 687	0,236 857	0,393 882
494	0,017 540	0,247 481	0,372 946
495	0,014 700	0,258 600	0,353 300
496	0,012 162	0,270 185	0,334 858
497	0,009 920	0,282 294	0,317 552
498	0,007 967	0,295 051	0,301 338
499	0,006 296	0,308 578	0,286 169
500	0,004 900	0,323 000	0,272 000
501	0,003 777	0,338 402	0,258 817
502	0,002 945	0,354 686	0,246 484
503	0,002 425	0,371 699	0,234 772
504	0,002 236	0,389 288	0,223 453
505	0,002 400	0,407 300	0,212 300
506	0,002 926	0,425 630	0,201 169
507	0,003 837	0,444 310	0,190 120
508	0,005 175	0,463 394	0,179 225
509	0,006 982	0,482 940	0,168 561
510	0,009 300	0,503 000	0,158 200
511	0,012 149	0,523 569	0,148 138
512	0,015 536	0,544 512	0,138 376
513	0,019 478	0,565 690	0,128 994
514	0,023 993	0,586 965	0,120 075
515	0,029 100	0,608 200	0,111 700
516	0,034 815	0,629 346	0,103 905
517	0,041 120	0,650 307	0,096 667
518	0,047 985	0,670 875	0,089 983
519	0,055 379	0,690 842	0,083 845
520	0,063 270	0,710 000	0,078 250
521	0,071 635	0,728 185	0,073 209
522	0,080 462	0,745 464	0,068 678
523	0,089 740	0,761 969	0,064 568
524	0,099 456	0,777 837	0,060 788
525	0,109 600	0,793 200	0,057 250
526	0,120 167	0,808 110	0,053 904
527	0,131 115	0,822 496	0,050 747
528	0,142 368	0,836 307	0,047 753
529	0,153 854	0,849 492	0,044 899
530	0,165 500	0,862 000	0,042 160
531	0,177 257	0,873 811	0,039 507
532	0,189 140	0,884 962	0,036 936
533	0,201 169	0,895 494	0,034 458
534	0,213 366	0,905 443	0,032 089
535	0,225 750	0,914 850	0,029 840
536	0,238 321	0,923 735	0,027 712
537	0,251 067	0,932 092	0,025 694
538	0,263 992	0,939 923	0,023 787
539	0,277 102	0,947 225	0,021 989

Table E.1 *(3 of 5)*

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
540	0,290 400	0,954 000	0,020 300
541	0,303 891	0,960 256	0,018 718
542	0,317 573	0,966 007	0,017 240
543	0,331 438	0,971 261	0,015 864
544	0,345 483	0,976 023	0,014 585
545	0,359 700	0,980 300	0,013 400
546	0,374 084	0,984 092	0,012 307
547	0,388 640	0,987 418	0,011 302
548	0,403 378	0,990 313	0,010 378
549	0,418 312	0,992 812	0,009 529
550	0,433 450	0,994 950	0,008 750
551	0,448 795	0,996 711	0,008 035
552	0,464 336	0,998 098	0,007 382
553	0,480 064	0,999 112	0,006 785
554	0,495 971	0,999 748	0,006 243
555	0,512 050	1,000 000	0,005 750
556	0,528 296	0,999 857	0,005 304
557	0,544 692	0,999 305	0,004 900
558	0,561 209	0,998 326	0,004 534
559	0,577 822	0,996 899	0,004 202
560	0,594 500	0,995 000	0,003 900
561	0,611 221	0,992 601	0,003 623
562	0,627 976	0,989 743	0,003 371
563	0,644 760	0,986 444	0,003 141
564	0,661 570	0,982 724	0,002 935
565	0,678 400	0,978 600	0,002 750
566	0,695 239	0,974 084	0,002 585
567	0,712 059	0,969 171	0,002 439
568	0,728 828	0,963 857	0,002 309
569	0,745 519	0,958 135	0,002 197
570	0,762 100	0,952 000	0,002 100
571	0,778 543	0,945 450	0,002 018
572	0,794 826	0,938 499	0,001 948
573	0,810 926	0,931 163	0,001 890
574	0,826 825	0,923 458	0,001 841
575	0,842 500	0,915 400	0,001 800
576	0,857 933	0,907 006	0,001 766
577	0,873 082	0,898 277	0,001 738
578	0,887 894	0,889 205	0,001 711
579	0,902 318	0,879 782	0,001 683
580	0,916 300	0,870 000	0,001 650
581	0,929 800	0,859 861	0,001 610
582	0,942 798	0,849 392	0,001 564
583	0,955 278	0,838 622	0,001 514
584	0,967 218	0,827 581	0,001 459
585	0,978 600	0,816 300	0,001 400
586	0,989 386	0,804 795	0,001 337
587	0,999 549	0,793 082	0,001 270
588	1,009 089	0,781 192	0,001 205
589	1,018 006	0,769 155	0,001 147

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
590	1,026 300	0,757 000	0,001 100
591	1,033 983	0,744 754	0,001 069
592	1,040 986	0,732 422	0,001 049
593	1,047 188	0,720 004	0,001 036
594	1,052 467	0,707 497	0,001 021
595	1,056 700	0,694 900	0,001 000
596	1,059 794	0,682 219	0,000 969
597	1,061 799	0,669 472	0,000 930
598	1,062 807	0,656 674	0,000 887
599	1,062 910	0,643 845	0,000 843
600	1,062 200	0,631 000	0,000 800
601	1,060 735	0,618 156	0,000 761
602	1,058 444	0,605 314	0,000 724
603	1,055 224	0,592 476	0,000 686
604	1,050 977	0,579 638	0,000 645
605	1,045 600	0,566 800	0,000 600
606	1,039 037	0,553 961	0,000 548
607	1,031 361	0,541 137	0,000 492
608	1,022 666	0,528 353	0,000 435
609	1,013 048	0,515 632	0,000 383
610	1,002 600	0,503 000	0,000 340
611	0,991 368	0,490 469	0,000 307
612	0,979 331	0,478 030	0,000 283
613	0,966 492	0,465 678	0,000 265
614	0,952 848	0,453 403	0,000 252
615	0,938 400	0,441 200	0,000 240
616	0,923 194	0,429 080	0,000 230
617	0,907 244	0,417 036	0,000 221
618	0,890 502	0,405 032	0,000 212
619	0,872 920	0,393 032	0,000 202
620	0,854 450	0,381 000	0,000 190
621	0,835 084	0,368 918	0,000 174
622	0,814 946	0,356 827	0,000 156
623	0,794 186	0,344 777	0,000 136
624	0,772 954	0,332 818	0,000 117
625	0,751 400	0,321 000	0,000 100
626	0,729 584	0,309 338	0,000 086
627	0,707 589	0,297 850	0,000 075
628	0,685 602	0,286 594	0,000 065
629	0,663 810	0,275 625	0,000 057
630	0,642 400	0,265 000	0,000 050
631	0,621 515	0,254 763	0,000 044
632	0,601 114	0,244 890	0,000 040
633	0,581 105	0,235 334	0,000 036
634	0,561 398	0,226 053	0,000 033
635	0,541 900	0,217 000	0,000 030
636	0,522 600	0,208 162	0,000 028
637	0,503 546	0,199 549	0,000 026
638	0,484 744	0,191 155	0,000 024
639	0,466 194	0,182 974	0,000 022

Table E.1 *(4 of 5)*

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
640	0,447 900	0,175 000	0,000 020
641	0,429 861	0,167 224	0,000 018
642	0,412 098	0,159 646	0,000 016
643	0,394 644	0,152 278	0,000 014
644	0,377 533	0,145 126	0,000 012
645	0,360 800	0,138 200	0,000 010
646	0,344 456	0,131 500	0,000 008
647	0,328 517	0,125 025	0,000 005
648	0,313 019	0,118 779	0,000 003
649	0,298 001	0,112 769	0,000 001
650	0,283 500	0,107 000	0,000 000
651	0,269 545	0,101 476	0,000 000
652	0,256 118	0,096 189	0,000 000
653	0,243 190	0,091 123	0,000 000
654	0,230 727	0,086 265	0,000 000
655	0,218 700	0,081 600	0,000 000
656	0,207 097	0,077 121	0,000 000
657	0,195 923	0,072 826	0,000 000
658	0,185 171	0,068 710	0,000 000
659	0,174 832	0,064 770	0,000 000
660	0,164 900	0,061 000	0,000 000
661	0,155 367	0,057 396	0,000 000
662	0,146 230	0,053 955	0,000 000
663	0,137 490	0,050 674	0,000 000
664	0,129 147	0,047 550	0,000 000
665	0,121 200	0,044 580	0,000 000
666	0,113 640	0,041 759	0,000 000
667	0,106 465	0,039 085	0,000 000
668	0,099 690	0,036 564	0,000 000
669	0,093 331	0,034 200	0,000 000
670	0,087 400	0,032 000	0,000 000
671	0,081 901	0,029 963	0,000 000
672	0,076 804	0,028 077	0,000 000
673	0,072 077	0,026 329	0,000 000
674	0,067 687	0,024 708	0,000 000
675	0,063 600	0,023 200	0,000 000
676	0,059 807	0,021 801	0,000 000
677	0,056 282	0,020 501	0,000 000
678	0,052 971	0,019 281	0,000 000
679	0,049 819	0,018 121	0,000 000
680	0,046 770	0,017 000	0,000 000
681	0,043 784	0,015 904	0,000 000
682	0,040 875	0,014 837	0,000 000
683	0,038 073	0,013 811	0,000 000
684	0,035 405	0,012 835	0,000 000
685	0,032 900	0,011 920	0,000 000
686	0,030 564	0,011 068	0,000 000
687	0,028 381	0,010 273	0,000 000
688	0,026 345	0,009 533	0,000 000
689	0,024 453	0,008 846	0,000 000

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
690	0,022 700	0,008 210	0,000 000
691	0,021 084	0,007 624	0,000 000
692	0,019 600	0,007 085	0,000 000
693	0,018 237	0,006 591	0,000 000
694	0,016 987	0,006 138	0,000 000
695	0,015 840	0,005 723	0,000 000
696	0,014 791	0,005 343	0,000 000
697	0,013 831	0,004 996	0,000 000
698	0,012 949	0,004 676	0,000 000
699	0,012 129	0,004 380	0,000 000
700	0,011 359	0,004 102	0,000 000
701	0,010 629	0,003 838	0,000 000
702	0,009 939	0,003 589	0,000 000
703	0,009 288	0,003 354	0,000 000
704	0,008 679	0,003 134	0,000 000
705	0,008 111	0,002 929	0,000 000
706	0,007 582	0,002 738	0,000 000
707	0,007 089	0,002 560	0,000 000
708	0,006 627	0,002 393	0,000 000
709	0,006 195	0,002 237	0,000 000
710	0,005 790	0,002 091	0,000 000
711	0,005 410	0,001 954	0,000 000
712	0,005 053	0,001 825	0,000 000
713	0,004 718	0,001 704	0,000 000
714	0,004 404	0,001 590	0,000 000
715	0,004 109	0,001 484	0,000 000
716	0,003 834	0,001 384	0,000 000
717	0,003 576	0,001 291	0,000 000
718	0,003 334	0,001 204	0,000 000
719	0,003 109	0,001 123	0,000 000
720	0,002 899	0,001 047	0,000 000
721	0,002 704	0,000 977	0,000 000
722	0,002 523	0,000 911	0,000 000
723	0,002 354	0,000 850	0,000 000
724	0,002 197	0,000 793	0,000 000
725	0,002 049	0,000 740	0,000 000
726	0,001 911	0,000 690	0,000 000
727	0,001 781	0,000 643	0,000 000
728	0,001 660	0,000 599	0,000 000
729	0,001 546	0,000 558	0,000 000
730	0,001 440	0,000 520	0,000 000
731	0,001 340	0,000 484	0,000 000
732	0,001 246	0,000 450	0,000 000
733	0,001 158	0,000 418	0,000 000
734	0,001 076	0,000 389	0,000 000
735	0,001 000	0,000 361	0,000 000
736	0,000 929	0,000 335	0,000 000
737	0,000 862	0,000 311	0,000 000
738	0,000 801	0,000 289	0,000 000
739	0,000 743	0,000 268	0,000 000

Table E.1 *(5 of 5)*

λ (nm)	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
740	0,000 690	0,000 249	0,000 000
741	0,000 641	0,000 231	0,000 000
742	0,000 595	0,000 215	0,000 000
743	0,000 552	0,000 199	0,000 000
744	0,000 512	0,000 185	0,000 000
745	0,000 476	0,000 172	0,000 000
746	0,000 442	0,000 160	0,000 000
747	0,000 412	0,000 149	0,000 000
748	0,000 383	0,000 138	0,000 000
749	0,000 357	0,000 129	0,000 000
750	0,000 332	0,000 120	0,000 000
751	0,000 310	0,000 112	0,000 000
752	0,000 289	0,000 104	0,000 000
753	0,000 270	0,000 097	0,000 000
754	0,000 252	0,000 091	0,000 000
755	0,000 235	0,000 085	0,000 000
756	0,000 219	0,000 079	0,000 000
757	0,000 205	0,000 074	0,000 000
758	0,000 191	0,000 069	0,000 000
759	0,000 178	0,000 064	0,000 000
760	0,000 166	0,000 060	0,000 000
761	0,000 155	0,000 056	0,000 000
762	0,000 145	0,000 052	0,000 000
763	0,000 135	0,000 049	0,000 000
764	0,000 126	0,000 045	0,000 000
765	0,000 117	0,000 042	0,000 000
766	0,000 110	0,000 040	0,000 000
767	0,000 102	0,000 037	0,000 000
768	0,000 095	0,000 034	0,000 000
769	0,000 089	0,000 032	0,000 000
770	0,000 083	0,000 030	0,000 000
771	0,000 078	0,000 028	0,000 000
772	0,000 072	0,000 026	0,000 000
773	0,000 068	0,000 024	0,000 000
774	0,000 063	0,000 023	0,000 000
775	0,000 059	0,000 021	0,000 000
776	0,000 055	0,000 020	0,000 000
777	0,000 051	0,000 019	0,000 000
778	0,000 048	0,000 017	0,000 000
779	0,000 045	0,000 016	0,000 000
780	0,000 042	0,000 015	0,000 000
781	0,000 039	0,000 014	0,000 000
782	0,000 036	0,000 013	0,000 000
783	0,000 034	0,000 012	0,000 000
784	0,000 032	0,000 011	0,000 000
785	0,000 029	0,000 011	0,000 000
786	0,000 027	0,000 010	0,000 000
787	0,000 026	0,000 009	0,000 000
788	0,000 024	0,000 009	0,000 000
789	0,000 022	0,000 008	0,000 000
790	0,000 021	0,000 007	0,000 000
791	0,000 019	0,000 007	0,000 000
792	0,000 018	0,000 006	0,000 000
793	0,000 017	0,000 006	0,000 000
794	0,000 016	0,000 006	0,000 000
795	0,000 015	0,000 005	0,000 000
796	0,000 014	0,000 005	0,000 000
797	0,000 013	0,000 005	0,000 000
798	0,000 012	0,000 004	0,000 000
799	0,000 011	0,000 004	0,000 000
800	0,000 010	0,000 004	0,000 000
801	0,000 010	0,000 003	0,000 000
802	0,000 009	0,000 003	0,000 000
803	0,000 008	0,000 003	0,000 000
804	0,000 008	0,000 003	0,000 000
805	0,000 007	0,000 003	0,000 000
806	0,000 007	0,000 002	0,000 000
807	0,000 006	0,000 002	0,000 000
808	0,000 006	0,000 002	0,000 000
809	0,000 005	0,000 002	0,000 000
810	0,000 005	0,000 002	0,000 000
811	0,000 005	0,000 002	0,000 000
812	0,000 004	0,000 002	0,000 000
813	0,000 004	0,000 001	0,000 000
814	0,000 004	0,000 001	0,000 000
815	0,000 004	0,000 001	0,000 000
816	0,000 003	0,000 001	0,000 000
817	0,000 003	0,000 001	0,000 000
818	0,000 003	0,000 001	0,000 000
819	0,000 003	0,000 001	0,000 000
820	0,000 003	0,000 001	0,000 000
821	0,000 002	0,000 001	0,000 000
822	0,000 002	0,000 001	0,000 000
823	0,000 002	0,000 001	0,000 000
824	0,000 002	0,000 001	0,000 000
825	0,000 002	0,000 001	0,000 000
826	0,000 002	0,000 001	0,000 000
827	0,000 002	0,000 001	0,000 000
828	0,000 001	0,000 001	0,000 000
829	0,000 001	0,000 000	0,000 000
830	0,000 001	0,000 000	0,000 000

Annex F
(normative)

Spectral chromaticity coordinates

~~See Table F.1.~~ Table F.1 show the numerical scheme for the relationship between the dominant wavelength (λ_D) and the chromaticity coordinate of the spectrum stimulus. This table shall be applied when calculating related parameters. See 6.16.2.2 for more details.

Table F.1 – Spectral chromaticity coordinates *(1 of 5)*

λ (nm)	Spectral chromaticity coordinates		
	x_λ	y_λ	z_λ
380	0,174 11	0,004 96	0,820 92
381	0,174 08	0,004 98	0,820 93
382	0,174 05	0,004 98	0,820 97
383	0,174 02	0,005 02	0,820 96
384	0,174 05	0,004 97	0,820 98
385	0,174 01	0,004 98	0,821 01
386	0,173 95	0,004 94	0,821 11
387	0,173 95	0,004 93	0,821 12
388	0,173 89	0,004 95	0,821 16
389	0,173 84	0,004 91	0,821 25
390	0,173 80	0,004 92	0,821 28
391	0,173 74	0,004 93	0,821 33
392	0,173 71	0,004 92	0,821 37
393	0,173 66	0,004 94	0,821 40
394	0,173 60	0,004 94	0,821 45
395	0,173 56	0,004 92	0,821 52
396	0,173 51	0,004 90	0,821 60
397	0,173 47	0,004 86	0,821 67
398	0,173 43	0,004 84	0,821 73
399	0,173 38	0,004 81	0,821 81
400	0,173 34	0,004 80	0,821 87
401	0,173 29	0,004 79	0,821 92
402	0,173 23	0,004 78	0,821 99
403	0,173 17	0,004 78	0,822 05
404	0,173 10	0,004 77	0,822 13
405	0,173 02	0,004 78	0,822 20
406	0,172 93	0,004 78	0,822 28
407	0,172 84	0,004 79	0,822 37
408	0,172 75	0,004 80	0,822 45
409	0,172 66	0,004 80	0,822 54
410	0,172 58	0,004 80	0,822 62
411	0,172 49	0,004 79	0,822 71
412	0,172 40	0,004 80	0,822 81
413	0,172 30	0,004 80	0,822 90
414	0,172 19	0,004 81	0,822 99
415	0,172 09	0,004 83	0,823 08
416	0,171 98	0,004 86	0,823 16
417	0,171 87	0,004 89	0,823 24
418	0,171 74	0,004 94	0,823 32
419	0,171 59	0,005 01	0,823 40
420	0,171 41	0,005 10	0,823 49
421	0,171 21	0,005 21	0,823 58
422	0,170 99	0,005 33	0,823 67
423	0,170 77	0,005 47	0,823 76
424	0,170 54	0,005 62	0,823 84
425	0,170 30	0,005 79	0,823 91
426	0,170 05	0,005 97	0,823 98
427	0,169 79	0,006 18	0,824 04
428	0,169 50	0,006 40	0,824 10
429	0,169 20	0,006 64	0,824 16
430	0,168 88	0,006 90	0,824 22
431	0,168 52	0,007 18	0,824 29
432	0,168 15	0,007 49	0,824 36
433	0,167 75	0,007 82	0,824 43
434	0,167 33	0,008 18	0,824 50
435	0,166 90	0,008 56	0,824 55
436	0,166 45	0,008 96	0,824 59
437	0,165 98	0,009 40	0,824 62
438	0,165 48	0,009 86	0,824 65
439	0,164 96	0,010 35	0,824 69
440	0,164 41	0,010 86	0,824 73
441	0,163 83	0,011 39	0,824 79
442	0,163 21	0,011 94	0,824 85
443	0,162 55	0,012 52	0,824 93
444	0,161 85	0,013 14	0,825 01
445	0,161 10	0,013 79	0,825 10
446	0,160 31	0,014 49	0,825 20
447	0,159 47	0,015 23	0,825 30
448	0,158 57	0,016 02	0,825 41
449	0,157 63	0,016 84	0,825 53
450	0,156 64	0,017 70	0,825 65
451	0,155 61	0,018 61	0,825 79
452	0,154 52	0,019 56	0,825 92
453	0,153 40	0,020 55	0,826 05
454	0,152 22	0,021 61	0,826 17
455	0,150 99	0,022 74	0,826 27
456	0,149 69	0,023 95	0,826 36
457	0,148 34	0,025 25	0,826 42
458	0,146 93	0,026 64	0,826 44
459	0,145 47	0,028 12	0,826 41

Table F.1 *(2 of 5)*

λ (nm)	x_λ	y_λ	z_λ
460	0,143 96	0,029 70	0,826 34
461	0,142 41	0,031 39	0,826 20
462	0,140 80	0,033 21	0,825 99
463	0,139 12	0,035 20	0,825 68
464	0,137 36	0,037 40	0,825 23
465	0,135 50	0,039 88	0,824 62
466	0,133 51	0,042 69	0,823 80
467	0,131 37	0,045 88	0,822 75
468	0,129 09	0,049 45	0,821 46
469	0,126 66	0,053 43	0,819 91
470	0,124 12	0,057 80	0,818 08
471	0,121 47	0,062 59	0,815 94
472	0,118 70	0,067 83	0,813 47
473	0,115 81	0,073 58	0,810 61
474	0,112 78	0,079 90	0,807 33
475	0,109 59	0,086 84	0,803 56
476	0,106 26	0,094 49	0,799 25
477	0,102 78	0,102 86	0,794 36
478	0,099 13	0,112 01	0,788 87
479	0,095 30	0,121 95	0,782 75
480	0,091 29	0,132 70	0,776 00
481	0,087 08	0,144 32	0,768 60
482	0,082 68	0,156 87	0,760 45
483	0,078 12	0,170 42	0,751 46
484	0,073 44	0,185 03	0,741 53
485	0,068 71	0,200 72	0,730 57
486	0,063 99	0,217 47	0,718 54
487	0,059 32	0,235 25	0,705 43
488	0,054 67	0,254 10	0,691 24
489	0,050 03	0,274 00	0,675 97
490	0,045 39	0,294 98	0,659 63
491	0,040 76	0,316 98	0,642 26
492	0,036 19	0,339 90	0,623 91
493	0,031 76	0,363 60	0,604 65
494	0,027 49	0,387 92	0,584 59
495	0,023 46	0,412 70	0,563 84
496	0,019 70	0,437 76	0,542 54
497	0,016 27	0,462 95	0,520 78
498	0,013 18	0,488 21	0,498 61
499	0,010 48	0,513 40	0,476 12
500	0,008 17	0,538 42	0,453 41
501	0,006 28	0,563 07	0,430 65
502	0,004 87	0,587 12	0,408 01
503	0,003 98	0,610 45	0,385 57
504	0,003 64	0,633 01	0,363 35
505	0,003 86	0,654 82	0,341 32
506	0,004 65	0,675 90	0,319 46
507	0,006 01	0,696 12	0,297 87
508	0,007 99	0,715 34	0,276 67
509	0,010 60	0,733 41	0,255 98

λ (nm)	x_λ	y_λ	z_λ
510	0,013 87	0,750 19	0,235 94
511	0,017 77	0,765 61	0,216 62
512	0,022 24	0,779 63	0,198 13
513	0,027 27	0,792 10	0,180 62
514	0,032 82	0,802 93	0,164 25
515	0,038 85	0,812 02	0,149 13
516	0,045 33	0,819 39	0,135 28
517	0,052 18	0,825 16	0,122 66
518	0,059 33	0,829 43	0,111 25
519	0,066 72	0,832 27	0,101 01
520	0,074 30	0,833 80	0,091 89
521	0,082 05	0,834 09	0,083 86
522	0,089 94	0,833 29	0,076 77
523	0,097 94	0,831 59	0,070 47
524	0,106 02	0,829 18	0,064 80
525	0,114 16	0,826 21	0,059 63
526	0,122 35	0,822 77	0,054 88
527	0,130 55	0,818 93	0,050 53
528	0,138 70	0,814 77	0,046 52
529	0,146 77	0,810 39	0,042 83
530	0,154 72	0,805 86	0,039 41
531	0,162 54	0,801 24	0,036 23
532	0,170 24	0,796 52	0,033 24
533	0,177 85	0,791 69	0,030 46
534	0,185 39	0,786 73	0,027 88
535	0,192 88	0,781 63	0,025 49
536	0,200 31	0,776 40	0,023 29
537	0,207 69	0,771 05	0,021 25
538	0,215 03	0,765 60	0,019 38
539	0,222 34	0,760 02	0,017 64
540	0,229 62	0,754 33	0,016 05
541	0,236 88	0,748 52	0,014 59
542	0,244 13	0,742 61	0,013 25
543	0,251 36	0,736 61	0,012 03
544	0,258 58	0,730 51	0,010 92
545	0,265 78	0,724 32	0,009 90
546	0,272 96	0,718 06	0,008 98
547	0,280 13	0,711 72	0,008 15
548	0,287 29	0,705 32	0,007 39
549	0,294 45	0,698 84	0,006 71
550	0,301 60	0,692 31	0,006 09
551	0,308 76	0,685 71	0,005 53
552	0,315 91	0,679 06	0,005 02
553	0,323 07	0,672 37	0,004 57
554	0,330 22	0,665 63	0,004 16
555	0,337 36	0,658 85	0,003 79
556	0,344 51	0,652 03	0,003 46
557	0,351 66	0,645 17	0,003 16
558	0,358 81	0,638 29	0,002 90
559	0,365 96	0,631 38	0,002 66

Table F.1 *(3 of 5)*

λ (nm)	x_λ	y_λ	z_λ
560	0,373 10	0,624 45	0,002 45
561	0,380 24	0,617 50	0,002 25
562	0,387 38	0,610 54	0,002 08
563	0,394 51	0,603 57	0,001 92
564	0,401 63	0,596 59	0,001 78
565	0,408 74	0,589 61	0,001 66
566	0,415 84	0,582 62	0,001 55
567	0,422 92	0,575 63	0,001 45
568	0,429 99	0,568 65	0,001 36
569	0,437 04	0,561 68	0,001 29
570	0,444 06	0,554 71	0,001 22
571	0,451 06	0,547 77	0,001 17
572	0,458 04	0,540 84	0,001 12
573	0,464 99	0,533 93	0,001 08
574	0,471 90	0,527 05	0,001 05
575	0,478 77	0,520 20	0,001 02
576	0,485 61	0,513 39	0,001 00
577	0,492 41	0,506 61	0,000 98
578	0,499 15	0,499 89	0,000 96
579	0,505 85	0,493 21	0,000 94
580	0,512 49	0,486 59	0,000 92
581	0,519 07	0,480 03	0,000 90
582	0,525 60	0,473 53	0,000 87
583	0,532 07	0,467 09	0,000 84
584	0,538 46	0,460 73	0,000 81
585	0,544 79	0,454 43	0,000 78
586	0,551 03	0,448 22	0,000 74
587	0,557 19	0,442 10	0,000 71
588	0,563 27	0,436 06	0,000 67
589	0,569 26	0,430 10	0,000 64
590	0,575 15	0,424 23	0,000 62
591	0,580 95	0,418 45	0,000 60
592	0,586 65	0,412 76	0,000 59
593	0,592 22	0,407 19	0,000 59
594	0,597 66	0,401 76	0,000 58
595	0,602 93	0,396 50	0,000 57
596	0,608 03	0,391 41	0,000 56
597	0,612 98	0,386 49	0,000 54
598	0,617 78	0,381 71	0,000 52
599	0,622 46	0,377 05	0,000 49
600	0,627 04	0,372 49	0,000 47
601	0,631 52	0,368 03	0,000 45
602	0,635 90	0,363 67	0,000 43
603	0,640 16	0,359 43	0,000 42
604	0,644 27	0,355 33	0,000 40
605	0,648 23	0,351 39	0,000 37
606	0,652 03	0,347 63	0,000 34
607	0,655 67	0,344 02	0,000 31
608	0,659 17	0,340 55	0,000 28
609	0,662 53	0,337 22	0,000 25
610	0,665 76	0,334 01	0,000 23
611	0,668 87	0,330 92	0,000 21
612	0,671 86	0,327 95	0,000 19
613	0,674 72	0,325 10	0,000 18
614	0,677 46	0,322 36	0,000 18
615	0,680 08	0,319 75	0,000 17
616	0,682 58	0,317 25	0,000 17
617	0,684 97	0,314 86	0,000 17
618	0,687 25	0,312 59	0,000 16
619	0,689 43	0,310 41	0,000 16
620	0,691 50	0,308 34	0,000 15
621	0,693 49	0,306 37	0,000 14
622	0,695 39	0,304 48	0,000 13
623	0,697 21	0,302 68	0,000 12
624	0,698 94	0,300 95	0,000 11
625	0,700 61	0,299 30	0,000 09
626	0,702 19	0,297 72	0,000 08
627	0,703 71	0,296 22	0,000 07
628	0,705 16	0,294 77	0,000 07
629	0,706 56	0,293 38	0,000 06
630	0,707 92	0,292 03	0,000 06
631	0,709 23	0,290 72	0,000 05
632	0,710 50	0,289 45	0,000 05
633	0,711 72	0,288 23	0,000 04
634	0,712 90	0,287 06	0,000 04
635	0,714 03	0,285 93	0,000 04
636	0,715 12	0,284 85	0,000 04
637	0,716 16	0,283 80	0,000 04
638	0,717 16	0,282 81	0,000 04
639	0,718 12	0,281 85	0,000 03
640	0,719 03	0,280 93	0,000 03
641	0,719 91	0,280 06	0,000 03
642	0,720 75	0,279 22	0,000 03
643	0,721 55	0,278 42	0,000 03
644	0,722 31	0,277 66	0,000 02
645	0,723 03	0,276 95	0,000 02
646	0,723 70	0,276 28	0,000 02
647	0,724 33	0,275 66	0,000 01
648	0,724 91	0,275 08	0,000 01
649	0,725 47	0,274 53	0,000 00
650	0,725 99	0,274 01	0,000 00
651	0,726 50	0,273 50	0,000 00
652	0,726 97	0,273 03	0,000 00
653	0,727 43	0,272 57	0,000 00
654	0,727 86	0,272 14	0,000 00
655	0,728 27	0,271 73	0,000 00
656	0,728 66	0,271 34	0,000 00
657	0,729 02	0,270 98	0,000 00
658	0,729 36	0,270 64	0,000 00
659	0,729 68	0,270 32	0,000 00

Table F.1 *(4 of 5)*

λ (nm)	x_λ	y_λ	z_λ
660	0,729 97	0,270 03	0,000 00
661	0,730 24	0,269 76	0,000 00
662	0,730 47	0,269 53	0,000 00
663	0,730 69	0,269 31	0,000 00
664	0,730 90	0,269 10	0,000 00
665	0,731 09	0,268 91	0,000 00
666	0,731 28	0,268 72	0,000 00
667	0,731 47	0,268 53	0,000 00
668	0,731 65	0,268 35	0,000 00
669	0,731 83	0,268 17	0,000 00
670	0,731 99	0,268 01	0,000 00
671	0,732 15	0,267 85	0,000 00
672	0,732 30	0,267 70	0,000 00
673	0,732 45	0,267 55	0,000 00
674	0,732 58	0,267 42	0,000 00
675	0,732 72	0,267 28	0,000 00
676	0,732 86	0,267 14	0,000 00
677	0,733 00	0,267 00	0,000 00
678	0,733 14	0,266 86	0,000 00
679	0,733 28	0,266 72	0,000 00
680	0,733 42	0,266 58	0,000 00
681	0,733 55	0,266 45	0,000 00
682	0,733 68	0,266 32	0,000 00
683	0,733 81	0,266 19	0,000 00
684	0,733 93	0,266 07	0,000 00
685	0,734 05	0,265 95	0,000 00
686	0,734 15	0,265 85	0,000 00
687	0,734 23	0,265 77	0,000 00
688	0,734 29	0,265 71	0,000 00
689	0,734 35	0,265 65	0,000 00
690	0,734 39	0,265 61	0,000 00
691	0,734 43	0,265 57	0,000 00
692	0,734 50	0,265 50	0,000 00
693	0,734 53	0,265 47	0,000 00
694	0,734 57	0,265 43	0,000 00
695	0,734 59	0,265 41	0,000 00
696	0,734 63	0,265 37	0,000 00
697	0,734 64	0,265 36	0,000 00
698	0,734 70	0,265 30	0,000 00
699	0,734 69	0,265 31	0,000 00
700	0,734 69	0,265 31	0,000 00
701	0,734 71	0,265 29	0,000 00
702	0,734 70	0,265 30	0,000 00
703	0,734 69	0,265 31	0,000 00
704	0,734 70	0,265 30	0,000 00
705	0,734 69	0,265 31	0,000 00
706	0,734 69	0,265 31	0,000 00
707	0,734 69	0,265 31	0,000 00
708	0,734 70	0,265 30	0,000 00
709	0,734 70	0,265 30	0,000 00
710	0,734 68	0,265 32	0,000 00
711	0,734 66	0,265 34	0,000 00
712	0,734 66	0,265 34	0,000 00
713	0,734 66	0,265 34	0,000 00
714	0,734 73	0,265 27	0,000 00
715	0,734 67	0,265 33	0,000 00
716	0,734 76	0,265 24	0,000 00
717	0,734 74	0,265 26	0,000 00
718	0,734 68	0,265 32	0,000 00
719	0,734 64	0,265 36	0,000 00
720	0,734 67	0,265 33	0,000 00
721	0,734 58	0,265 42	0,000 00
722	0,734 71	0,265 29	0,000 00
723	0,734 71	0,265 29	0,000 00
724	0,734 78	0,265 22	0,000 00
725	0,734 67	0,265 33	0,000 00
726	0,734 72	0,265 28	0,000 00
727	0,734 74	0,265 26	0,000 00
728	0,734 84	0,265 16	0,000 00
729	0,734 79	0,265 21	0,000 00
730	0,734 69	0,265 31	0,000 00
731	0,734 65	0,265 35	0,000 00
732	0,734 67	0,265 33	0,000 00
733	0,734 77	0,265 23	0,000 00
734	0,734 47	0,265 53	0,000 00
735	0,734 75	0,265 25	0,000 00
736	0,734 97	0,265 03	0,000 00
737	0,734 87	0,265 13	0,000 00
738	0,734 86	0,265 14	0,000 00
739	0,734 92	0,265 08	0,000 00
740	0,734 82	0,265 18	0,000 00
741	0,735 09	0,264 91	0,000 00
742	0,734 57	0,265 43	0,000 00
743	0,735 02	0,264 98	0,000 00
744	0,734 58	0,265 42	0,000 00
745	0,734 57	0,265 43	0,000 00
746	0,734 22	0,265 78	0,000 00
747	0,734 40	0,265 60	0,000 00
748	0,735 12	0,264 88	0,000 00
749	0,734 57	0,265 43	0,000 00
750	0,734 51	0,265 49	0,000 00
751	0,734 60	0,265 40	0,000 00
752	0,735 37	0,264 63	0,000 00
753	0,735 69	0,264 31	0,000 00
754	0,734 69	0,265 31	0,000 00
755	0,734 38	0,265 63	0,000 00
756	0,734 90	0,265 10	0,000 00
757	0,734 77	0,265 23	0,000 00
758	0,734 62	0,265 38	0,000 00
759	0,735 54	0,264 46	0,000 00

Table F.1 *(5 of 5)*

λ (nm)	x_λ	y_λ	z_λ
760	0,734 51	0,265 49	0,000 00
761	0,734 60	0,265 40	0,000 00
762	0,736 04	0,263 96	0,000 00
763	0,733 70	0,266 30	0,000 00
764	0,736 84	0,263 16	0,000 00
765	0,735 85	0,264 15	0,000 00
766	0,733 33	0,266 67	0,000 00
767	0,733 81	0,266 19	0,000 00
768	0,736 43	0,263 57	0,000 00
769	0,735 54	0,264 46	0,000 00
770	0,734 51	0,265 49	0,000 00
771	0,735 85	0,264 15	0,000 00
772	0,734 69	0,265 31	0,000 00
773	0,739 13	0,260 87	0,000 00
774	0,732 56	0,267 44	0,000 00
775	0,737 50	0,262 50	0,000 00
776	0,733 33	0,266 67	0,000 00
777	0,728 57	0,271 43	0,000 00
778	0,738 46	0,261 54	0,000 00
779	0,737 70	0,262 30	0,000 00
780	0,736 84	0,263 16	0,000 00

Annex G
(normative)

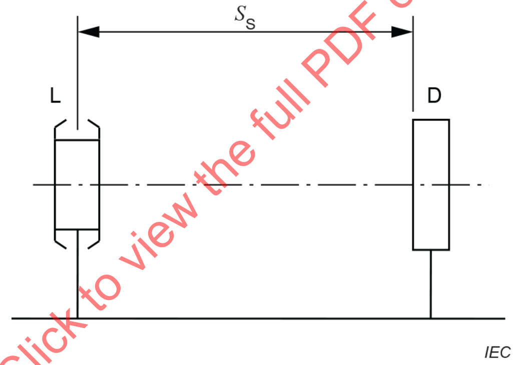
~~Illuminometer~~ Illuminance meter calibration

G.1 Purpose

The purpose here is to calibrate the ~~illuminometer~~ illuminance meter.

G.2 How to perform the calibration

Set a standard light source, the luminous intensity of which has been checked by the regulations of the measurement law and the ~~illuminometer~~ illuminance meter, which has a relative spectral efficiency similar to its standard luminous efficiency and whose ~~illuminometer~~ illuminance meter output proportionality for the incoming luminous flux is excellent, so that the surface of each is perpendicular to a straight line passing through the centre of the emitting face of the standard light source and the acceptance surface of the ~~illuminometer~~ illuminance meter, as shown in Figure G.1. Then measure the distance (photometric distance) between the light centre of the standard light source and the acceptance surface of the ~~illuminometer~~ illuminance meter (ensure that the photometric distance is at least ten times the maximum size of the emitting face or the acceptance surface, whichever is greater).



Key

L standard light source

D illuminance meter

Figure G.1 – Schematic diagram for calibration

When taking I_{vS} as the luminous intensity of the standard light source and S_S as the photometric distance, the illuminance E_{vS} of the acceptance surface of the ~~illuminometer~~ illuminance meter can be calculated using the following formula:

$$E_{vS} = \frac{I_{vS}}{S_S}$$

At this time, the ~~illuminometer~~ illuminance meter can be calibrated using the formula $E_{vS} = \alpha i_{vS}$ (α is the coefficient value), taking I_{vS} as the ~~illuminometer~~ illuminance meter reading.

Bibliography

IEC 60050-521, *International Electrotechnical Vocabulary – Part 521: Semiconductor devices and integrated circuits* (available at: http://www.electropedia.org)

IEC 60050-845:2020, *International Electrotechnical Vocabulary – Part 845: Lighting* (available at: http://www.electropedia.org)

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

IEC 60747-5-8, *Semiconductor devices – Part 5-8: Optoelectronic devices – Light emitting diodes – Test method of optoelectronic efficiencies of light emitting diodes*

IEC 60749 (all parts), *Semiconductor devices – Mechanical and climatic test methods*

IEC 60749-26, *Semiconductor devices – Mechanical and climatic test methods – Part 26: Electrostatic discharge (ESD) sensitivity testing – Human body model (HBM)*

IEC 62504, *General lighting – Light emitting diode (LED) products and related equipment – Terms and definitions*

ISO/CIE 19476:2014, *Characterization of the performance of illuminance meters and luminance meters*

CIE 84:1989, *Measurement of luminous flux*

CIES 010:2004, *Photometry – The CIE system of physical photometry*

CIE 15.3-2004, *Colorimetry*

CIE 127.2-2007, *Measurement of LEDs*

JEDEC JESD51-14 (Nov 2010), *Transient dual interface test method for the measurement of the thermal resistance junction-to-case of semiconductor devices with heat flow through a single path*

____

IEC 60747-5-6

Edition 2.0 2021-07

INTERNATIONAL STANDARD

Semiconductor devices –
Part 5-6: Optoelectronic devices – Light emitting diodes

IEC 60747-5-6:2021-07(en)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

SEMICONDUCTOR DEVICES –

Part 5-6: Optoelectronic devices – Light emitting diodes

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60747-5-6 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) ultraviolet-emitting diodes (UV LED) and their related technical contents were added;
b) power efficiency (η_{PE}) as part of electrical and optical characteristics were added;
c) new measuring methods related to thermal resistance were added;
d) hydrogen sulphide corrosion test was added to quality evaluation;
e) some standards were added to the bibliography.

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

FDIS	Report on voting
47E/745/FDIS	47E/752/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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 5-6: Optoelectronic devices – Light emitting diodes

1 Scope

This part of IEC 60747 specifies the terminology, the essential ratings and characteristics, the measuring methods and the quality evaluations of light emitting diodes (LEDs) for general industrial applications such as signals, controllers, sensors, etc.

LEDs for lighting applications are out of the scope of this part of IEC 60747.

LEDs are classified as follows:

a) LED package;
b) LED flat illuminator;
c) LED numeric display and alpha-numeric display;
d) LED dot-matrix display;
e) infrared-emitting diode (IR LED);
f) ultraviolet-emitting diode (UV LED).

LEDs with a heat spreader or having a terminal geometry that performs the function of a heat spreader are within the scope of this part of IEC 60747.

An integration of LEDs and controlgears, integrated LED modules, semi-integrated LED modules, integrated LED lamps or semi-integrated LED lamps, are out of the scope of this part of IEC 60747.

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 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

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

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

IEC 60747-5-13, *Semiconductor devices – Part 5-13: Optoelectronic devices – Hydrogen sulphide corrosion test for LED packages*

IEC 60749-6, *Semiconductor devices – Mechanical and climatic test methods – Part 6: Storage at high temperature*

IEC 60749-10, *Semiconductor devices – Mechanical and climatic test methods – Part 10: Mechanical shock*

IEC 60749-12, *Semiconductor devices – Mechanical and climatic test methods – Part 12: Vibration, variable frequency*

IEC 60749-14, *Semiconductor devices – Mechanical and climatic test methods – Part 14: Robustness of terminations (lead integrity)*

IEC 60749-15, *Semiconductor devices – Mechanical and climatic test methods – Part 15: Resistance to soldering temperature for through-hole mounted devices*

IEC 60749-20, *Semiconductor devices – Mechanical and climatic test methods – Part 20: Resistance of plastic encapsulated SMDs to the combined effect of moisture and soldering heat*

IEC 60749-21, *Semiconductor devices – Mechanical and climatic test methods – Part 21: Solderability*

IEC 60749-24, *Semiconductor devices – Mechanical and climatic test methods – Part 24: Accelerated moisture resistance – Unbiased HAST*

IEC 60749-25, *Semiconductor devices – Mechanical and climatic test methods – Part 25: Temperature cycling*

IEC 60749-36, *Semiconductor devices – Mechanical and climatic test methods – Part 36: Acceleration, steady state*

ISO 2859-1, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

3 Terms, definitions and abbreviations

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:

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

3.1 General terms and definitions

3.1.1
integrating sphere
hollow sphere, the interior of which is formed from, or coated with, a diffusely-reflecting material that is as spectrally neutral and as spatially uniform as possible

Note 1 to entry: Owing to the internal reflections within the sphere, the illuminance on any part of the inside surface of the sphere for which the direct flux is hidden is theoretically proportional to the luminous flux entering the sphere or produced inside the sphere. The illuminance of the internal sphere wall can be measured via a small window.

Note 2 to entry: The window of an integrating sphere is often used in radiometric measurement systems to provide a source with good spatial uniformity and with an angular distribution of radiance or luminance that is close to Lambert's cosine law.

[SOURCE: IEC 60050-845:2020, 845-25-028]

3.1.2
diffuse reflector
reflector composed of a surface with diffuse reflection

3.1.3
diffuse reflection
scattering by reflection in which, on the macroscopic scale, there is no regular reflection

[SOURCE: IEC 60050-845:2020, 845-24-054]

3.1.4
diffuse transmission
scattering by transmission in which, on the macroscopic scale, there is no regular transmission

[SOURCE: IEC 60050-845:2020, 845-24-055]

3.1.5
diffuse reflectance
ρ_d
quotient of the diffusely reflected part of the (whole) reflected flux and the incident flux

Note 1 to entry: Reflectance, ρ, is the sum of regular reflectance, ρ_r, and diffuse reflectance, ρ_d: $\rho = \rho_\mathrm{r} + \rho_\mathrm{d}$

Note 2 to entry: The diffuse reflectance has unit one.

[SOURCE: IEC 60050-845:2020, 845-24-068]

3.1.6
diffuse transmittance
τ_d
quotient of the diffusely transmitted part of the (whole) transmitted flux and the incident flux

Note 1 to entry: Transmittance, τ, is the sum of regular transmittance, τ_r, and diffuse transmittance, τ_d: $\tau = \tau_\mathrm{r} + \tau_\mathrm{d}$.

Note 2 to entry: The diffuse transmittance has unit one.

[SOURCE: IEC 60050-845:2020, 845-24-069]

3.1.7
lambertian surface
ideal surface for which the radiation coming from that surface is distributed angularly according to Lambert's cosine law

Note 1 to entry: For a lambertian surface, $M = \pi L$, where M is the radiant exitance or luminous exitance, and L the radiance or luminance.

[SOURCE: IEC 60050-845:2020, 845-24-063]

3.1.8
spectral reflectance
$R(\lambda)$
ratio of reflected radiant flux to incident radiant flux for a wavelength λ

Note 1 to entry: Spectral reflectance is also known as the "spectral reflection factor".

3.1.9
spectral transmittance
$T(\lambda)$
ratio of transmitted radiant flux to incident radiant flux for a wavelength λ

Note 1 to entry: Spectral transmittance is also known as the "spectral transmittance factor".

3.1.10
spectral distribution
proportion of the quantum of radiation per unit wavelength included in the micro wavelength interval centre on wavelength λ, which is expressed as a function of wavelength λ

Note 1 to entry: Spectral distribution is also known as the "spectrum distribution".

3.1.11
spectral sensitivity
$S(\lambda)$
light sensitivity as a function of wavelength

Note 1 to entry: The response output of the optical receiver for the radiant flux (or luminous flux) input of wavelength λ is expressed as a function of wavelength λ.

3.1.12
distribution temperature
T_D
temperature of the Planckian radiator whose relative spectral distribution $S(\lambda)$ is the same or nearly the same as that of the radiation considered in the spectral range of interest for which the following integral is minimized by adjustment of a and T:

$$\int_{\lambda_1}^{\lambda_2}\left[1-\frac{S_t(\lambda)}{a\,S_b(\lambda,T)}\right]^2 d\lambda$$

where λ is the wavelength, $S_t(\lambda)$ is the relative spectral distribution of the radiation being considered, $S_b(\lambda, T)$ is the relative spectral distribution of the Planckian radiator at temperature T, and a is a scaling factor

Note 1 to entry: The scaling factor a is chosen to make the quotient $\frac{S_t(\lambda)}{S_b(\lambda,T)}$ equal to unity at a convenient wavelength which, in photometry and colorimetry is typically 560 nm.

$S_b(\lambda,T)=\frac{P(\lambda,T)}{P(560\,\text{nm},T)}$ with $P(\lambda,T)=\lambda^{-5}\left(e^{\frac{c_2}{\lambda T}}-1\right)^{-1}$ where c_2 is the second radiation constant.

Note 2 to entry: Distribution temperature is a meaningful characteristic for radiators having a relative spectral distribution similar to that of a Planckian radiator, but only if calculated for an expanded wavelength range and for radiation whose spectral distribution of radiant flux is a continuous function of wavelength in that range.

Note 3 to entry: In photometry and colorimetry the wavelength range set by λ_1 and λ_2 is the visible spectral range, and in these cases the range from at least λ_1 = 400 nm to λ_2 = 750 nm is recommended.

Note 4 to entry: In practice, the integral is replaced by a summation. For incandescent lamps, equally spaced wavelength intervals of 10 nm will usually suffice. All values in the summation are treated with equal weight.

Note 5 to entry: The distribution temperature is expressed in kelvin (K).

Note 6 to entry: For further information, see CIE 114-1994, CIE Collection in Photometry and Radiometry – 114/4 Distribution Temperature and Ratio Temperature.

[SOURCE: IEC 60050-845:2020, 845-24-017]

3.1.13
infrared-emitting diode
IR LED
light emitting diode that emits infrared radiation

3.1.14
infrared radiation
optical radiation for which the wavelengths are longer than those for visible radiation

Note 1 to entry: For infrared radiation, the range between 780 nm and 1 mm is commonly subdivided into:

IR-A: 780 nm to 1400 nm, or 0,78 µm to 1,4 µm;

IR-B: 1,4 µm to 3 µm;

IR-C: 3 µm to 1 mm.

Note 2 to entry: A precise border between "visible radiation" and "infrared radiation" cannot be defined because visual sensation at wavelengths greater than 780 nm can be experienced.

Note 3 to entry: In some applications the infrared spectrum has also been divided into "near," "middle," and "far" infrared; however, the borders necessarily vary with the application.

[SOURCE: IEC 60050-845:2020, 845-21-004, modified – The second preferred term (IR radiation) and the admitted term (IRR) have been removed.]

3.1.15
ultraviolet-emitting diode
UV LED
light emitting diode that emits ultraviolet radiation

3.1.16
ultraviolet radiation
optical radiation for which the wavelengths are shorter than those for visible radiation

Note 1 to entry: The range between 100 nm and 400 nm is commonly subdivided into:

UV-A: 315 nm to 400 nm;

UV-B: 280 nm to 315 nm;

UV-C: 100 nm to 280 nm.

Note 2 to entry: A precise border between ultraviolet radiation and visible radiation cannot be defined, because visual sensation at wavelengths shorter than 400 nm is noted for very bright sources.

Note 3 to entry: In some applications the ultraviolet spectrum has also been divided into "far," "vacuum," and "near" ultraviolet; however, the borders necessarily vary with the application (e.g. in meteorology, optical design, photochemistry, and thermal physics).

[SOURCE: IEC 60050-845:2020, 845-21-008, modified – The second preferred term (UV radiation) and the admitted term (UVR) have been removed.]

3.2 Terms and definitions relating to the measurement of the quantity of radiation

3.2.1
radiant energy
Q_e
energy emitted, transferred or received in the form of electromagnetic waves

Note 1 to entry: Radiant energy can be expressed by the time integral of radiant flux, Φ_e, over a given duration, Δt:

$$Q_e = \int_{\Delta t} \Phi_e \, dt$$

Note 2 to entry: Radiant energy is expressed as a function of wavelength, λ, as a function of frequency, ν, or as a function of wavenumber, σ.

Note 3 to entry: The corresponding photometric quantity is "luminous energy". The corresponding quantity for photons is "photon energy".

Note 4 to entry: The radiant energy is expressed in joule (J = W·s).

[SOURCE: IEC 60050-845:2020, 845-21-041]

3.2.2
radiant flux
Φ_e

change in radiant energy with time

$$\Phi_e = \frac{dQ_e}{dt}$$

where Q_e is the radiant energy emitted, transferred or received, and t is time

Note 1 to entry: The corresponding photometric quantity is "luminous flux". The corresponding quantity for photons is "photon flux".

Note 2 to entry: The term "radiant flux" is the preferred term for most radiometric applications, with the notable exception of laser radiometry where the term "radiant power" is more commonly used.

Note 3 to entry: The radiant flux is expressed in watt (W).

[SOURCE: IEC 60050-845:2020, 845-21-038, modified – The symbols P_e, Φ and P have been removed and the second preferred term "radiant power" has been removed.]

3.2.3
radiant intensity
I_e

density of radiant flux with respect to solid angle in a specified direction

$$I_e = \frac{d\Phi_e}{d\Omega}$$

where Φ_e is the radiant flux emitted in a specified direction, and Ω is the solid angle containing that direction

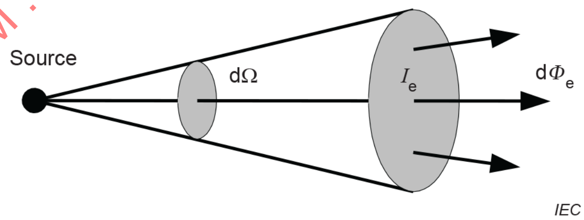


Figure 1 – Radiant intensity

Note 1 to entry: The definition holds strictly only for a point source.

Note 2 to entry: The distribution of the radiant intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the radiant flux, Φ_e, within a certain solid angle, Ω, of a source:

$$\Phi_e = \int\int_{\Omega} I_e(\vartheta,\varphi) \sin\vartheta \, d\varphi \, d\vartheta.$$

Note 3 to entry: The corresponding photometric quantity is "luminous intensity". The corresponding quantity for photons is "photon intensity".

Note 4 to entry: The radiant intensity is expressed in watt per steradian ($W \cdot sr^{-1}$).

[SOURCE: IEC 60050-845:2020, 845-21-044, modified – The symbol I has been removed and Figure 1 has been added.]

3.2.4
radiance
L_e
density of radiant intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface

$$L_e = \frac{dI_e}{dA} \frac{1}{\cos\theta},$$

where I_e is radiant intensity, A is area, and θ is the angle between the normal to the surface at the specified point and the specified direction

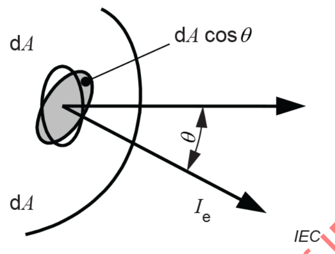


Figure 2 – Radiance

Note 1 to entry: The radiance is expressed in watt per square metre per steradian ($W·m^{-2}·sr^{-1}$).

[SOURCE: IEC 60050-845:2020, 845-21-049, modified – The symbol L has been removed, the angle symbol α has been replaced by θ, the notes have been removed, a new note has been added and Figure 2 has been added.]

3.2.5
radiant exitance
M_e
density of exiting radiant flux with respect to area at a point on a real or imaginary surface

$$M_e = \frac{d\Phi_e}{dA}$$

where Φ_e is radiant flux and A is the area from which the radiant flux leaves

Note 1 to entry: For Planckian radiation, $M_e = \sigma T^4$ where σ is the Stefan-Boltzmann constant and T is thermodynamic temperature.

Note 2 to entry: The corresponding photometric quantity is "luminous exitance". The corresponding photon quantity is "photon exitance".

Note 3 to entry: The radiant exitance is expressed in watt per square metre ($W·m^{-2}$).

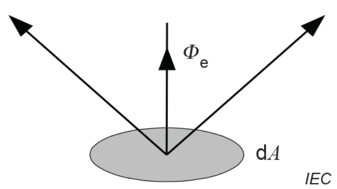


Figure 3 – Radiant exitance

[SOURCE: IEC 60050-845:2020, 845-21-080, modified – The symbol M has been removed and Figure 3 has been added.]

3.2.6
power efficiency
η_{PE}
ratio of the radiant flux (coupled to free space), Φ_e, to the electrical power consumed by the LED, $V_F I_F$, where V_F is the forward voltage and I_F is the forward current of the LED

$$\eta_{PE} = \frac{\Phi_e}{V_F\, I_F}$$

Note 1 to entry: Power efficiency is also known as the "wall-plug efficiency". Power efficiency is identical to the "radiant efficiency" when the power dissipated by any auxiliary equipment is excluded from the electrical power.

[SOURCE: IEC 60747-5-8:2019, 3.2.1, modified – The term "radiant power" has been replaced with "radiant flux".]

3.2.7
irradiance
E_e
density of incident radiant flux with respect to area at a point on a real or imaginary surface

$$E_e = \frac{d\Phi_e}{dA}$$

where Φ_e is radiant flux and A is the area on which the radiant flux is incident

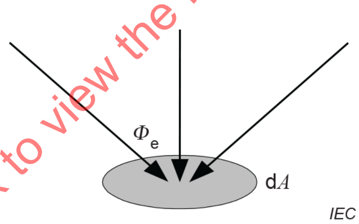


Figure 4 – Irradiance

Note 1 to entry: The corresponding photometric quantity is "illuminance". The corresponding quantity for photons is "photon irradiance".

Note 2 to entry: The irradiance is expressed in watt per square metre ($W \cdot m^{-2}$).

[SOURCE: IEC 60050-845:2020, 845-21-053, modified – The symbol E has been removed and Figure 4 has been added.]

3.3 Terms and definitions relating to the measurement of the photometric quantity

3.3.1
photometric standard lamp
lamp used for photometry that provides excellent stability and reproducibility and can indicate the photometric quantity

Note 1 to entry: There are two types of these lamps: luminous intensity standard lamps to which the luminous intensity value is added and luminous flux standard lamps to which the total flux value is added.

3.3.2
spectral luminous efficiency
$V(\lambda)$
relative spectral efficiency, which is defined as the standard value of spectral luminous efficiency for human eyes and whose maximum value is set to 1

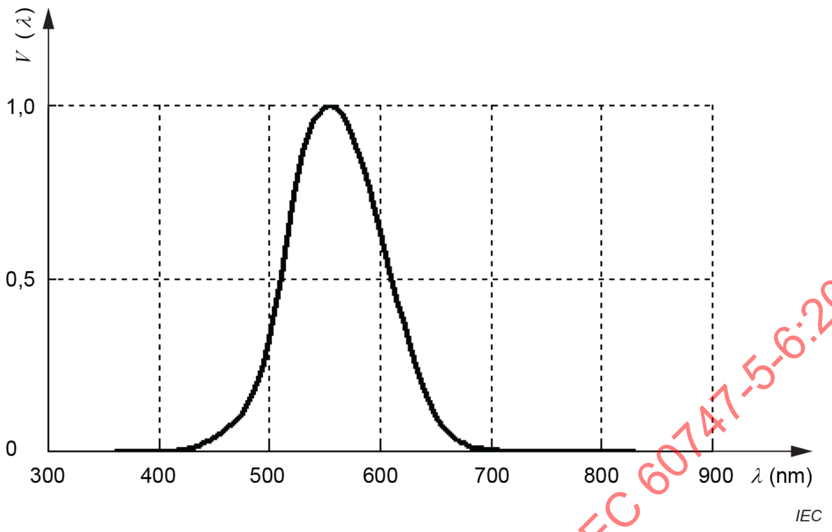


Figure 5 – Spectral luminous efficiency

Note 1 to entry: The spectral luminous efficiency for photopic vision was agreed at the CIE (International Commission on Illumination) in 1924 and adopted by the CIPM (*Comité International des Poids et Mesures* – International Committee for Weights and Measures in English) in 1933. The values for spectral luminous efficiency were originally given for the wavelength range 380 nm to 780 nm at 10 nm intervals. In 1972, new values were adopted by the CIPM for the wavelength range 360 nm to 830 nm at 1 nm intervals.

Note 2 to entry: Figure 5 and Table A.1 in Annex A show the graph and the numerical scheme for the spectral luminous efficiency, respectively.

3.3.3
maximum spectral luminous efficiency
K_m
maximum value that is expressed as the spectral concentration of the luminous flux in wavelength λ divided by the spectral concentration of the corresponding radiant flux

Note 1 to entry: 683 lm/W (λ = 555 nm) is the value adopted by the CIPM.

3.3.4
luminous flux
Φ_v
change in luminous energy with time

$$\Phi_v = \frac{dQ_v}{dt}$$

where Q_v is the luminous energy emitted, transferred or received, and t is time

Note 1 to entry: Luminous flux is a quantity derived from the radiant flux, Φ_e, by evaluating the radiation according to its action upon the CIE standard photometric observer. Luminous flux can be derived from the spectral radiant flux distribution by

$$\Phi_v = K_m \int_0^\infty \Phi_{e,\lambda}(\lambda) V(\lambda) d\lambda$$

where K_m is maximum luminous efficacy, $\Phi_{e,\lambda}(\lambda)$ is spectral radiant flux, $V(\lambda)$ is spectral luminous efficiency and λ is wavelength.

Note 2 to entry: The distribution of the luminous intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the luminous flux, Φ_v, within a certain solid angle, Ω, of a source:

$$\Phi_v = \iint_{\Omega} I_v(\vartheta,\varphi) \sin\vartheta \, d\varphi \, d\vartheta .$$

Note 3 to entry: The corresponding radiometric quantity is "radiant flux". The corresponding quantity for photons is "photon flux".

Note 4 to entry: The luminous flux is expressed in lumen (lm).

[SOURCE: IEC 60050-845:2020, 845-21-039, modified – The symbol Φ has been removed.]

3.3.5
luminous energy

Q_v

energy of electromagnetic waves weighted by the spectral luminous efficiency multiplied by maximum luminous efficacy of a specified photometric condition

Note 1 to entry: Luminous energy for photopic vision is expressed by

$$\Phi_v = K_m \int_0^\infty \Phi_{e,\lambda}(\lambda) V(\lambda) d\lambda$$

where $Q_{e,\lambda}(\lambda)$ is the spectral radiant energy at wavelength λ, $V(\lambda)$ is spectral luminous efficiency, and K_m is maximum luminous efficacy.

Note 2 to entry: The term "quantity of light" is no longer used.

Note 3 to entry: Luminous energy can be emitted, transferred or received.

Note 4 to entry: Luminous energy can be expressed by the time integral of the luminous flux, Φ_v, over a given duration, Δt:

$$Q_v = \int_{\Delta t} \Phi_v dt$$

Note 5 to entry: The corresponding radiometric quantity is "radiant energy". The corresponding quantity for photons is "photon energy".

Note 6 to entry: The luminous energy is expressed in lumen second (lm·s) or lumen hour (lm·h).

[SOURCE: IEC 60050-845:2020, 845-21-037, modified – The symbol Q has been removed.]

3.3.6
luminous intensity

I_v

density of luminous flux with respect to solid angle in a specified direction

$$I_v = \frac{d\Phi_v}{d\Omega}$$

where Φ_v is the luminous flux emitted in a specified direction, and Ω is the solid angle containing that direction

Note 1 to entry: For practical realization of the quantity, the source is approximated by a point source.

Note 2 to entry: The distribution of the luminous intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the luminous flux, Φ_v, within a certain solid angle, Ω, of a source:

$$\Phi_{\mathrm{v}} = \iint_{\Omega} I_{\mathrm{v}}(\vartheta,\varphi)\sin\vartheta\,\mathrm{d}\varphi\,\mathrm{d}\vartheta .$$

Note 3 to entry: Luminous intensity can be derived from the spectral radiant intensity distribution by

$$I_{\mathrm{v}} = K_{\mathrm{m}} \int_{0}^{\infty} I_{\mathrm{e},\lambda}(\lambda) V(\lambda)\,\mathrm{d}\lambda$$

where K_{m} is maximum luminous efficacy, $I_{\mathrm{e},\lambda}(\lambda)$ is the spectral radiant intensity at wavelength λ, and $V(\lambda)$ is spectral luminous efficiency.

Note 4 to entry: The corresponding radiometric quantity is "radiant intensity". The corresponding quantity for photons is "photon intensity".

Note 5 to entry: The luminous intensity is expressed in candela (cd = lm·sr^{-1}).

[SOURCE: IEC 60050-845:2020, 845-21-045, modified – The symbol I has been removed.]

3.3.7
luminance
L_{v}
density of luminous intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface

$$L_{\mathrm{v}} = \frac{\mathrm{d}I_{\mathrm{v}}}{\mathrm{d}A}\frac{1}{\cos\theta},$$

where I_{v} is luminous intensity, A is area and θ is the angle between the normal to the surface at the specified point and the specified direction

Note 1 to entry: The spatial definition of luminance is shown in Figure 2; however, symbol I_{e} should be changed to I_{v}.

Note 2 to entry: The luminance is expressed in candela per square metre (cd·m^{-2} = lm·m^{-2}·sr^{-1}).

[SOURCE: IEC 60050-845:2020, 845-21-050, modified – The symbol L has been removed, the angle symbol α has been replaced by θ, the notes have been removed except Note 8, that has become Note 2 and a new Note 1 has been added.]

3.3.8
luminous exitance
M_{v}
density of exiting luminous flux with respect to area at a point on a real or imaginary surface

$$M_{\mathrm{v}} = \frac{\mathrm{d}\Phi_{\mathrm{v}}}{\mathrm{d}A}$$

where Φ_{v} is luminous flux and A is the area from which the luminous flux leaves

Note 1 to entry: Luminous exitance can be derived from the spectral radiant exitance distribution by

$$M_{\mathrm{v}} = K_{\mathrm{m}} \int_{0}^{\infty} M_{\mathrm{e},\lambda}(\lambda) V(\lambda)\,\mathrm{d}\lambda$$

where K_{m} is maximum luminous efficacy, $M_{\mathrm{e},\lambda}(\lambda)$ is the spectral radiant exitance at wavelength λ and $V(\lambda)$ is spectral luminous efficiency.

Integral limits can be confined depending on the spectral responsivity of the detectors used as a sensor.

Note 2 to entry: The corresponding radiometric quantity is "radiant exitance". The corresponding quantity for photons is "photon exitance".

Note 3 to entry: The luminous exitance is expressed in lumen per square metre ($lm \cdot m^{-2}$).

[SOURCE: IEC 60050-845:2020, 845-21-081, modified – The symbol M has been removed.]

3.3.9
illuminance
$\boldsymbol{E_v}$
density of incident luminous flux with respect to area at a point on a real or imaginary surface

$$E_v = \frac{d\Phi_v}{dA}$$

where Φ_v is luminous flux and A is the area on which the luminous flux is incident

Note 1 to entry: Illuminance can be derived from the spectral irradiance distribution by

$$E_v = K_m \int_0^{\infty} E_{e,\lambda}(\lambda) V(\lambda) d\lambda$$

where K_m is maximum luminous efficacy, $E_{e,\lambda}(\lambda)$ is the spectral irradiance at wavelength λ and $V(\lambda)$ is spectral luminous efficiency.

Note 2 to entry: The corresponding radiometric quantity is "irradiance". The corresponding quantity for photons is "photon irradiance".

Note 3 to entry: The illuminance is expressed in lux ($lx = lm \cdot m^{-2}$).

Note 4 to entry: The spatial definition of illuminance is shown in Figure 4; however, symbol Φ_e should be changed to Φ_v.

[SOURCE: IEC 60050-845:2020, 845-21-060, modified – The symbol E has been removed and Note 4 has been added.]

3.4 Terms and definitions relating to the measurement of the thermal quantity

3.4.1
thermal resistance
quotient of the difference between the virtual temperature of the device and the temperature of a stated external reference point, by the steady-state power dissipation in the device

[SOURCE: IEC 60050-521:2002, 521-05-13]

3.4.2
electrical thermal resistance
$R_{th(j\text{-}X)el}$
quotient of the difference in the thermodynamic temperature between the junction temperature T_j and the reference point temperature T_X, by the electrical power dissipation P

$$R_{th(j\text{-}X)el} = \frac{T_j - T_X}{P}$$

Note 1 to entry: The electrical thermal resistance is expressed in kelvin per watt ($K \cdot W^{-1}$).

3.4.3
real thermal resistance
$R_{th(j\text{-}X)real}$
quotient of the difference in the thermodynamic temperature between the junction temperature T_j and the reference point temperature T_X, by the heating power dissipation (the heating power dissipation is the electrical power dissipation minus the radiant flux)

$$R_{\text{th(j-X)real}} = \frac{T_j - T_X}{P - \Phi_e}$$

Note 1 to entry: The real thermal resistance is expressed in kelvin per watt ($K \cdot W^{-1}$).

3.5 Abbreviations

PCB printed circuit board

AC alternating current

DC direct current

4 Absolute maximum ratings

Absolute maximum ratings are shown in Table 1. They are specified at the ambient temperature or the reference point temperature T_X = (25 ± 3) °C, unless otherwise stated.

These ratings are applicable to the six types as follows:

a) LED package;

b) LED flat illuminator;

c) LED numeric display and alpha-numeric display;

d) LED dot-matrix display;

e) IR LED;

f) UV LED.

Table 1 – Absolute maximum ratings

Item	Symbol	Conditions	Ratings	Unit	To be applicable for LEDs of type					
					a)	b)	c)	d)	e)	f)
Allowed forward current [a]	I_F	–		mA	○	○	○	○	○	○
Total allowed forward current [b]	I_F	–		mA	○	○	○	○	○	○
Forward current lapse rate [b]	ΔI_F	–		mA/°C	○	○	○	○	○	○
Allowed forward pulse current [a, e]	I_{FPM}	Pw = Duty =		A	○	○	○	○	○	○
Total allowed forward pulse current [b, e]	I_{FPM}	Pw = Duty =		A	○	○	○	○	○	○
Allowed forward pulse current lapse rate [b, e]	ΔI_{FPM}	Pw = Duty =		A	○	○	○	○	○	○
Reverse voltage	V_R			V	○	○		○	○	○
Electrostatic discharge [b, f]	ESD	HBM		V	○	○			○	○
Allowed power dissipation [b]	P_D	T_j = or T_X =		mW	○	○	○	○	○	○
Operating temperature [c]	T_j or T_X	–	~	°C	○	○	○	○	○	○
Storage temperature [d]	T_{stg}	–	~	°C	○	○	○	○	○	○
Soldering temperature	T_{sol}	–		°C	○	○	○		○	○

[a] These values are specified for each segment.

[b] These items are specified when necessary.

[c] The operating temperature is specified based on junction temperature T_j or reference point temperature T_X at X.

Reference point X shall be selected according to the purpose.

Reference point temperatures are described as T_c for case, T_S for soldering point and T_a for atmosphere.

[d] The storage temperature is specified for ambient temperature.

[e] Pw = pulse width.

[f] HBM/ESD = human body model / electrostatic discharge test (IEC 60749-26).

5 Electrical and optical characteristics

Electrical and optical characteristics are shown in Table 2. They are specified at the ambient temperature or the reference point temperature T_X = (25 ± 3) °C, unless otherwise stated.

These electrical and optical characteristics are applicable to the six types as follows:

a) LED package;

b) LED flat illuminator;

c) LED numeric display and alpha-numeric display;

d) LED dot-matrix display;

e) IR LED;

f) UV LED.

Table 2 – Electrical and optical characteristics

Item	Symbol	Measuring method	Conditions	Characteristics			Unit	To be applicable for [a]					
				min.	typ.	max.		a)	b)	c)	d)	e)	f)
Forward voltage	V_F	see 6.2	I_F = .. mA	–			V	○	○	○	○	○	○
Reverse current	I_R	see 6.5	V_R = .. V	–	–		µA	○	○	○	○	○	○
Luminous flux [b]	Φ_v	see 6.10	I_F = .. mA				lm	○	○	○	○		
Radiant flux [c]	Φ_e	see 6.11	I_F = .. mA				mW					○	○
Luminous intensity [b, d]	I_v	see 6.12	I_F = .. mA				mcd	○	○	○			
Radiant intensity [c]	I_e	see 6.13	I_F = .. mA				mW/sr					○	○
Luminance [d]	L_v	see 6.14	I_F = .. mA				cd/cm^2		○	○	○		
Peak emission wavelength [e]	λ_p	see 6.15	I_F = .. mA				nm	○	○		○	○	○
Spectrum width of half value	$\Delta\lambda$	see 6.15	I_F = .. mA	–		–	nm	○	○	○	○	○	○
Dominant emission wavelength [e]	λ_d	see 6.16	I_F = .. mA				nm	○	○	○	○		
Chromaticity [f]	x,y	see 6.16	I_F = .. mA				—	○	○	○	○		
Cut-off frequency [f, g]	f_c	see 6.9	I_F = .. mA $I_p(f_0)$ = ..mA f_0 = .. MHz	–			MHz					○	○

Item	Symbol	Measuring method	Conditions	Characteristics			Unit	To be applicable for [a]					
				min.	typ.	max.		a)	b)	c)	d)	e)	f)
Thermal resistance [f, h, i]	$R_{th(j-X)el}$	see 6.7	P_D = .. mW	–		–	K/W	○				○	○
	$R_{th(j-X)real}$ [j]	see 6.7	P_D = .. mW	–		–	K/W	○				○	○
Power efficiency [f, j]	η_{PE}	IEC 60747-5-8	I_F = .. mA	–		–	—	○				○	○
Full width half maximum of an intensity [k]	$2\theta_{1/2}$	see 6.17	I_F = .. mA		–		°	○				○	○

[a] These values are specified for each segment.

[b] Either luminous intensity or luminous flux or both of them is specified.

[c] Either radiant intensity or radiant flux or both of them is specified.

[d] Either luminance or luminous intensity or both of them is specified.

[e] Either peak emission wavelength or dominant emission wavelength or both of them is specified.

[f] These items are specified when necessary.

[g] Either cut-off frequency or response time (rise time, fall time) is specified.

[h] Reference point X is selected according to the purpose.
Thermal resistances are described using reference points $R_{th(j-c)}$ for case, $R_{th(j-s)}$ for solder point and $R_{th(j-a)}$ for ambient.

[i] The following measurement condition should be described:
- measuring method (heating method or cooling method);
- the configuration, size and material of the PCB that the test LED is mounted on;
- the thickness and area of the pattern (copper) that is on the PCB;
- the size, material and fin of the attached heat sink (if appropriate).

[j] It should be specified for LEDs with power consumption ≥0,5 W and power efficiency ≥10 %.

[k] The radiation pattern of LEDs is shown with a figure.

6 Measuring method

6.1 Basic requirements

6.1.1 Measuring conditions

The measuring conditions are the following:

a) Temperature

Measurements shall be made at an ambient (T_a) or reference point temperature (T_X) of (25 ± 3) °C in a condition of natural convection unless otherwise specified.

b) Humidity

Relative humidity shall be between 25 % and 75 % unless otherwise specified.

c) Atmospheric condition

Atmospheric condition shall be between 86 kPa and 106 kPa unless otherwise specified.

d) Precaution

In some cases, measurements change because of heat generation in the test LED over time. In that case, it is necessary to decide on the measurement time, otherwise the measurement shall be performed after reaching thermal equilibrium.

Thermal equilibrium may be considered to have been achieved if doubling the time between the application of power and the measurement causes no change in the indicated result within the precision of the measurement instruments.

6.1.2 Measuring instruments and equipment

6.1.2.1 General

The measuring instruments and equipment are specified in 6.1.2.2 to 6.1.2.7.

6.1.2.2 Power supplies

DC power-supply ripple shall be less than 3 %. In addition, the impedance value of the power supply shall not affect the measurement.

6.1.2.3 Instruments for electric characteristics and measuring instruments

When the accuracy is not specified, the instrument shall be as specified in IEC 60051 (all parts). A digital instrument and the measuring instrument shall have an accuracy either equalling or surpassing IEC 60051 (all parts), and the impedance shall be such that the influence on the measurement system can be ignored.

NOTE Instead of the semiconductor electric characteristic measurement with the set of power supply and current source, the source monitor unit (SMU) that combines voltage/current source and digital measurement functions, or SMU system, has become the industry-wide standard. The measurement with SMU is suitable for high-accuracy measurements, such as in 6.5.

6.1.2.4 Standard light source

A light source for the photometry with high stability, high reproducibility and with an appropriate photometric value shall be used.

6.1.2.5 Measuring instruments for photometry

One of the following instruments shall be used:

a) A monochromator-type instrument (a wavelength scanning type monochromatic light spectrophotometer):

   A spectrophotometer that measures a spectrum by turning a diffraction grating, and taking light of a specific wavelength through a slit sequentially and selectively.

b) A polychromator-type instrument (many wavelength spectrophotometer):

   A spectrophotometer which measures a spectrum with a detector at the same time using a one-dimensional photodiode array from the diffraction light out of a fixed diffraction grating.

c) A filter-type instrument ($V(\lambda)$ spectrophotometer):

   A photometer which has characteristics that are similar to spectral luminous efficiency, without using a spectrum optical system. This photometer comprises a photoelectric tube, a photomultiplier or a photoelectromotive force device whose sensitivity distribution on the light receiving side is flat and stable with a filter for visual sensitivity revision. In using this filter-type photometer, the measuring light shall be monochromatic, and the wavelength range of objective light should be within the wavelength range of the measuring instrument.

   NOTE The filter-type photometer is not suitable for the photometry of the following products:

   – product which has a light mixing method using excited light emission from the LED die and the fluorescent substance applied onto the LED die (phosphor based LEDs), or

   – product of a many-wavelength light emission method equipped with different LEDs of a plurality of emission spectra.

6.1.2.6 Measuring instruments for radiometry

The measuring instruments for radiometry are the following:

a) A monochromator type instrument (a wavelength scanning type monochromatic light radiometer):

   A spectroradiometer that measures a spectrum turning a diffraction grating, and taking light of a specific wavelength through a slit sequentially and selectively.

b) A polychromator type instrument (many wavelength radiometer):

   A spectroradiometer which measures a spectrum with a detector at the same time using a one-dimensional photodiode array from the diffraction light out of a fixed diffraction grating.

c) Optical power meter:

   A radiometer consisting of a phototube, a photomultiplier or a photoelectromotive-force device. It provides a flat and stable response sensitivity characteristic in a wavelength range of measurement light, and is calibrated so as not to keep a weighting of the response sensitivity for the wavelength, without using a spectrum optical system. In using this radiometer, the measuring light shall be monochromatic, and the wavelength range of objective light should be within the wavelength range of the measuring instrument.

6.1.2.7 Devices used for the emission spectrum characteristic measurement

Devices with necessary wavelength bandwidth and resolution for the measurement of the LED under test shall be used.

6.1.3 Essential requirements

6.1.3.1 General

The essential requirements are given in 6.1.3.2 to 6.1.3.4.

6.1.3.2 Point with zero electric potential

The point with zero electric potential to apply the potential on each electrode of the LED under test shall be the cathode terminal.

6.1.3.3 Power supply

The power supply shall be the following:

a) Applied voltage

   The applied voltage to a certain electrode is the potential difference between the electrode and the point with zero electric potential.

b) Supply voltage

   The supply voltage is the voltage supplied to a circuit including the LED under test.

c) Polarity

   The polarity of all electric potential is specified by the polarity for the point with zero electric potential.

6.1.3.4 Shading

During the measurement, suitable shading shall be given so that the light from the outside or other emission does not affect the measurements.

6.1.4 General precautions

The general precautions are as follows:

a) Absolute maximum rating

Even a second, external stress shall not exceed this value to guarantee normal operation of the LED under test.

b) Transient behaviour

Even in a transient state, the voltage and current shall not exceed the value of the absolute maximum rating.

c) Consideration for the heating

In the event that the LED measurement needs to avoid a measurement error produced by heat generation in the LED under test during a measurement period, the measurement shall be performed in a pulse condition.

When absolutely necessary, indicate "Pulse measurement", and specify the pulse state.

d) Consideration for ultraviolet radiation

Provisions for the prevention and control of the risk of ultraviolet radiation.

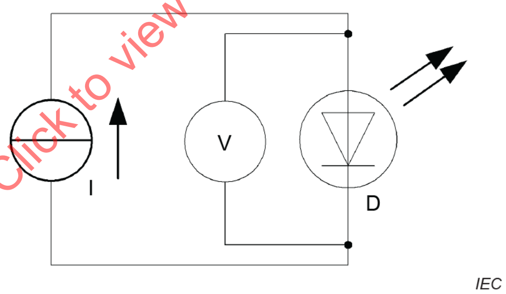
6.2 Forward voltage (V_F) measurement

6.2.1 Purpose

To measure the forward voltage of the LED when a specified forward current is applied.

6.2.2 Circuit diagram

The circuit diagram is shown in Figure 6.



Key

I constant current source

V voltmeter

D light emitting diode being measured

Figure 6 – Circuit diagram for V_F measurement

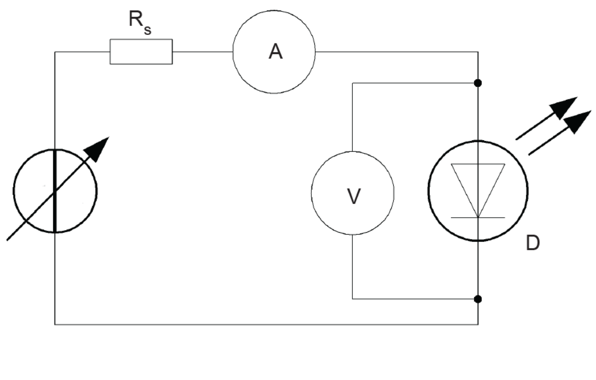
6.2.3 Requirements

A constant current source shall in principle be used for the measuring circuit.

If the forward current is set to the rated value using a constant voltage source and a current-limiting resistor, the circuit diagram as shown in Figure 7 shall be applied.

In such a case, to avoid changes in the forward voltage resulting from accumulated heat in the test LED and corresponding changes in the set current, set the impedance for the drive side higher.

$$R_S \cdot I_F >> V_F$$



Key

A ammeter

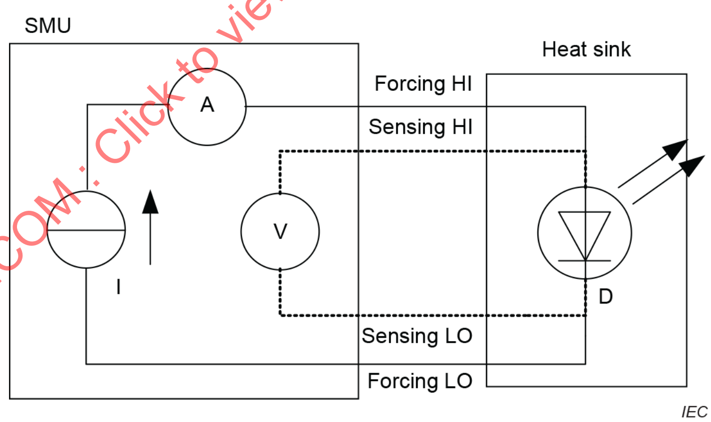
V voltmeter

R_s current limiting resistor

D light emitting diode being measured

Figure 7 – Circuit diagram for V_F measurement with a constant voltage source and a current-limiting resistor

In the case of high driving power LED (high power LED, high-flux LED), the driving current rating is usually specified in a condition using a heat sink instead of free air condition. For the measurement, the LED shall be mounted on an appropriate heat sink, and be measured using Kelvin contact in order to reduce measurement errors resulting from contact resistance and wiring impedance. An example of measurement using SMU is shown in Figure 8.



Key

SMU source measurement unit

I constant current source

A ammeter

V voltmeter

D light emitting diode being measured (high driving current LED)

Figure 8 – Circuit diagram for V_F measurement using an SMU

6.2.4 Measurement procedure

Forward voltage (V_F) is measured when the specified forward current (I_F) is applied to the test LED.

6.2.5 Precautions to be observed

See 6.1.

6.2.6 Specified conditions

The specified conditions are as follows:

– forward current and the driving conditions;
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.3 Reverse voltage (V_R) measurement

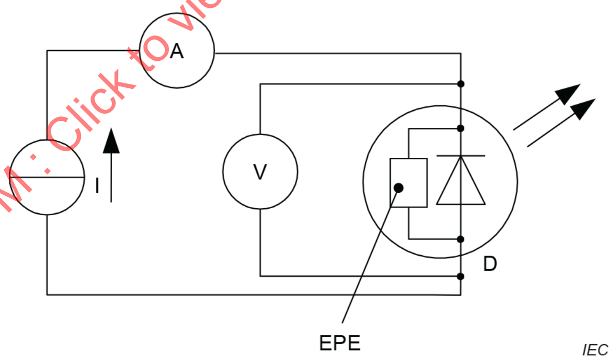
6.3.1 Purpose

To measure the reverse voltage of the LED when a specified reverse current is applied.

This measurement is performed for the reverse characteristics test in the case of LED mounting a parallel-connected Zener diode for electrostatic discharge protection. In measuring voltage at a rated current, thoughtless measurement of the reverse voltage for a general LED without any protection circuit should not be performed to avoid a stress voltage at breakdown voltage or above the absolute maximum rating of reverse voltage.

6.3.2 Circuit diagram

The circuit diagram is shown in Figure 9.



Key

I constant current source
V voltmeter
A ammeter
D light emitting diode being measured
EPE electrostatic protection element

Figure 9 – Circuit diagram for V_R measurement

6.3.3 Measurement procedure

Reverse voltage (V_R) is measured when the specified reverse current (I_R) is applied to the test LED.

6.3.4 Precautions to be observed

See 6.1.

6.3.5 Specified conditions

The specified conditions are as follows:

– reverse current (I_R);
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.4 Differential resistance (r_f) measurement

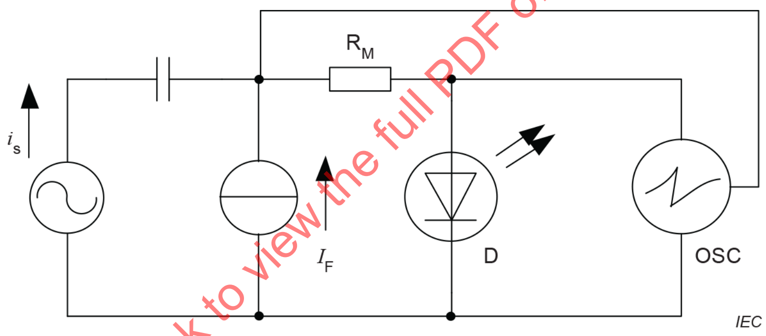
6.4.1 Purpose

To measure the differential resistance of the LED in specified measuring conditions.

NOTE Generally the series resistance of a LED is greater than that of a general rectifier diode. This measurement is performed to determine required driving voltage and to design the driving circuit for a power LED or a high flux LED driven by high current.

6.4.2 Circuit diagram

The circuit diagram is shown in Figure 10.



Key

R_M current detect resistor
i_s superimposed AC
I_F forward DC
OSC oscilloscope
D light emitting diode being measured

Figure 10 – Circuit diagram for r_f measurement

6.4.3 Requirements

In principle, the differential resistance shall be measured in such a manner that the AC is superimposed on the specified DC.

NOTE If the region in which the forward characteristic curve of the LED can be substantially regarded as a straight line near the specified current, the measurement can also be performed by calculating the resistance value based on the gradient of the current and voltage values between two points near the region.

6.4.4 Measurement procedure

The specified forward DC and AC to be superimposed are applied to the test LED.

After measurement of forward current and forward voltage waveforms of the LED with a calibrated oscilloscope, the differential resistance is calculated using their amplitude by the following formula:

$$r_{\mathrm{f}} = \frac{\Delta V_{\mathrm{F}}}{\Delta I_{\mathrm{F}}}$$

where

ΔV_{F} is the amplitude of forward voltage waveform;

ΔI_{F} is the amplitude of forward current waveform.

6.4.5 Precautions to be observed

The precautions to be observed are as follows:

a) The frequency of AC to be superimposed should be around 10 kHz so that it will not affect the measurement.
b) The forward current including AC should be as high as possible within the rated value.
c) For details other than those provided in a) and b) above, see 6.1.

6.4.6 Specified conditions

The specified conditions are as follows:

– the value of forward current and the amplitude of AC to be superimposed, or the amplitude modulation factor $\left(M = \left(\max\left|(i_{\mathrm{s}})\right|\right) / I_{\mathrm{F}}\right)$;
– ambient temperature (T_{a}), case temperature (T_{c}) or reference point temperature (T_{X}).

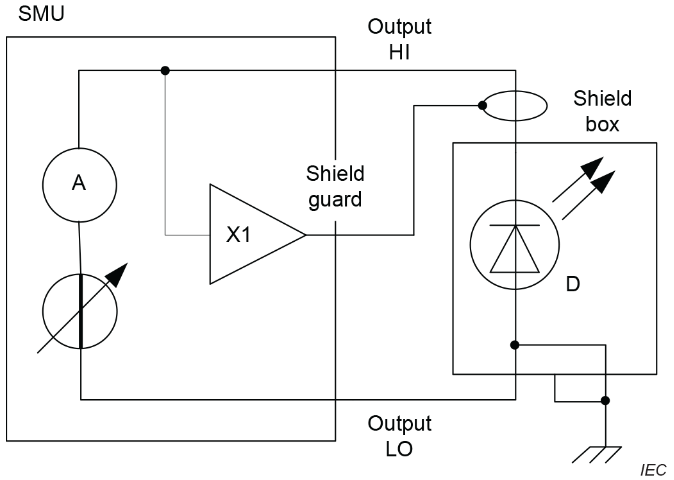
6.5 Reverse current (I_{R}) measurement

6.5.1 Purpose

To measure the reverse current of the LED at a specified reverse voltage.

6.5.2 Circuit diagram

Figure 11 is an example using the SMU.



Key

SMU source measurement unit

A ammeter

X1 buffer amplifier

D light emitting diode being measured

Figure 11 – Circuit diagram for I_R measurement

6.5.3 Provisions

Since the reverse current is extremely small within the rated applied voltage, the measurement becomes the "minute current measurement". It is desirable to have a shield to eliminate foreign noise, prevent leaks at cables and the connecting terminals, and prevent any electrostatic discharge. If the SMU has a current limiter function, it is desirable to set the current limiter to prevent the test LED from being destroyed.

6.5.4 Measurement procedure

The reverse current (I_R) is measured when specified reverse voltage (V_R) is applied to the test LED.

6.5.5 Precautions to be observed

See 6.1.

6.5.6 Specified conditions

The specified conditions are as follows:

– reverse voltage (V_R);

– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.6 Measurement of capacitance between terminals (C_t)

6.6.1 General

Two measuring methods are specified:

– measurement using LCR meter;

– measurement using AC bridge.

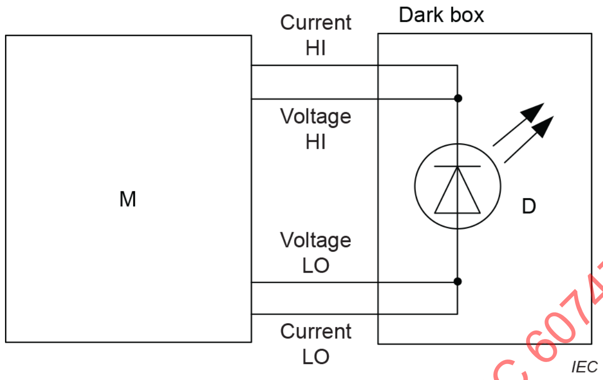
6.6.2 Measurement using LCR meter

6.6.2.1 Purpose

To measure the capacitance between terminals of the LED when the specified reverse voltage is applied (including zero bias voltage).

6.6.2.2 Circuit diagram

The circuit diagram is shown in Figure 12.



Key

D light emitting diode being measured

M LCR meter (or impedance analyzer) using a self-balancing bridge system

Figure 12 – Circuit diagram for C_t measurement

6.6.2.3 Requirements

The self-balancing bridge system represents a system in which the impedance is calculated using the phase information of the signal source and comparison of the voltage of the AC signal source with the value of the voltage that is converted from the current flowing along the test sample.

6.6.2.4 Measurement procedure

The capacitance between the terminals (C_t) is measured when the specific DC bias voltage is applied to the test LED.

6.6.2.5 Precautions to be observed

See 6.1.

6.6.2.6 Specified conditions

The specified conditions are as follows:

– DC bias voltage;
– frequency to be measured (f) – usually 1 MHz is used;
– ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

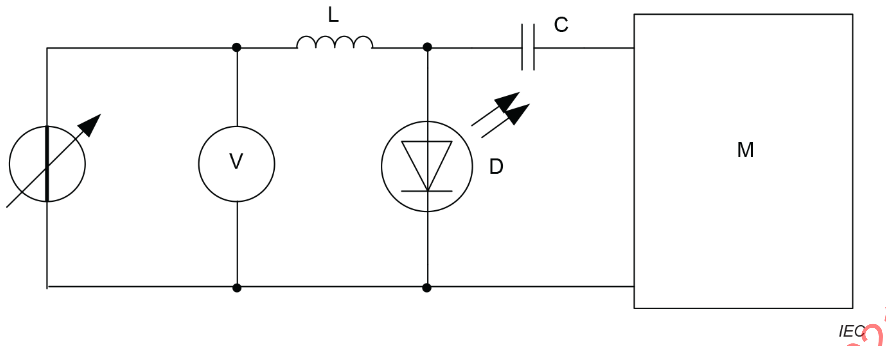
6.6.3 Measurement using AC bridge

6.6.3.1 Purpose

To measure the capacitance between the terminals of the LED when the specified reverse voltage is applied other than for a zero-bias voltage.

6.6.3.2 Circuit diagram

The circuit diagram is shown in Figure 13.



Key

D light emitting diode being measured

M AC bridge

L inductor

C capacitor

Figure 13 – Circuit diagram for C_t measurement

6.6.3.3 Requirements

The bias circuit for the test LED shall satisfy the following condition in order to maintain the accuracy of the measurement and the measuring signal voltage shall be a signal that is sufficiently smaller than the bias voltage.

$$C \gg C_X \gg \frac{1}{(2\pi f)^2 L}$$

where

C_X is the capacitance of the test LED;

f is the measuring frequency.

6.6.3.4 Measurement procedure

The capacitance between terminals (C_t) is measured when the specific DC bias voltage is applied to the test LED.

6.6.3.5 Precautions to be observed

See 6.1.

6.6.3.6 Specified conditions

The specified conditions are as follows:

- DC bias voltage;
- measuring frequency (f) – usually 1 MHz is used;
- ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.7 Measurement of junction temperature (T_j) and thermal resistance ($R_{th(j-X)el}$, $R_{th(j-X)real}$)

6.7.1 Purpose

To measure the junction temperature and the thermal resistance under specified conditions.

6.7.2 Measurement principle

While specified electrical power dissipation (P) is applied to the device being measured, the electrical thermal resistance $R_{th(j-X)el}$ is calculated by using the junction temperature (T_j) and the reference point temperature (T_X) as follows.

$$R_{th(j\text{-}X)el} = \frac{T_j - T_X}{P}$$

Change in the forward voltage (V_F) induced by electrical power dissipation (P) causes the rise of T_j. T_j is derived from the temperature dependence of the forward voltage (V_F) as a temperature sensitive parameter. The temperature dependence of the forward voltage is obtained by measuring the forward voltage (V_F) at different ambient temperatures.

The real thermal resistance $R_{th(j-X)real}$ is calculated by using the heating power dissipation that is the subtraction of the radiant flux from the electrical power dissipation. It can be derived from the optical energy conversion efficiency (power efficiency η_{PE}) as follows.

$$R_{th(j\text{-}X)real} = \frac{T_j - T_X}{P(1 - \eta_{PE})}$$

However, it should be noted that power efficiency η_{PE} is a temperature dependent parameter.

To calculate the actual junction temperature more accurately, η_{PE} shall be determined under actual usage conditions by considering its temperature dependence.

η_{PE} shall be derived separately according to the temperature at the reference point X and the driving current.

Figure 14 shows an example of the temperature dependence of η_{PE}.

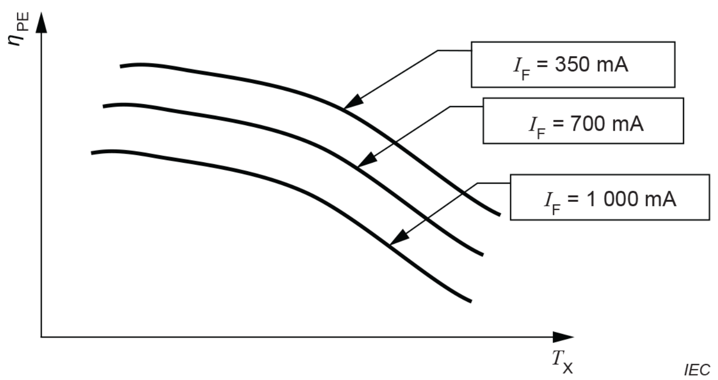


Figure 14 – An example of the temperature dependence of η_{PE}

Reference point X shall be on the heat flow path of the substrate mounted LED, and the temperature shall be measured when the LED is lit.

For example, for a 2-terminal LED device, the reference point X should be a terminal side with higher heat flow, namely the soldering point of the terminal on which the LED die is mounted.

However, when it is difficult to locate the reference point X in such an area, the reference point shall be set at the location where the heat flow rate is as large as possible.

The measured thermal resistance of a LED with appropriate heat sink shows a dependence on the heating time duration (t_p) as shown in Figure 15.

Figure 15 shows an example that two saturation regions are observed.

The first saturated region indicates the state in which the case (or the soldering point) has almost warmed up, while the last saturated region indicates the process until the whole test sample has reached the steady state.

That is, the two saturation regions above correspond to the junction-to-case thermal resistance Rth(j-c) or the junction-to-soldering point thermal resistance Rth(j-s) and the junction-to-ambient thermal resistance Rth(j-a), respectively.

Figure 16 shows the cumulative thermal capacitance versus cumulative thermal resistance characteristics (generally referred to as the "structural function") determined by mathematically converting the data given in Figure 15.

In the structural function, Figure 16, the part with large inclination such as the one between B and C corresponds to one of the structural layers of the tested LED package which have low thermal resistance and high thermal capacitance values. On the other hand, the part with low inclination in the structural function such as the one between A and B corresponds to one of the structural layers of the tested LED package which have high thermal resistance and low thermal capacitance values.

This means that the point where the inclination changes in the structural function reveals the difference in the structure. By using this property, the thermal resistance and the thermal capacitance can be estimated separately for each structural layer of the LED package.

Therefore, it is recommended to use the cumulative thermal capacitance versus cumulative thermal resistance characteristics (structural function) for the thermal design of a pulse-driven systems.

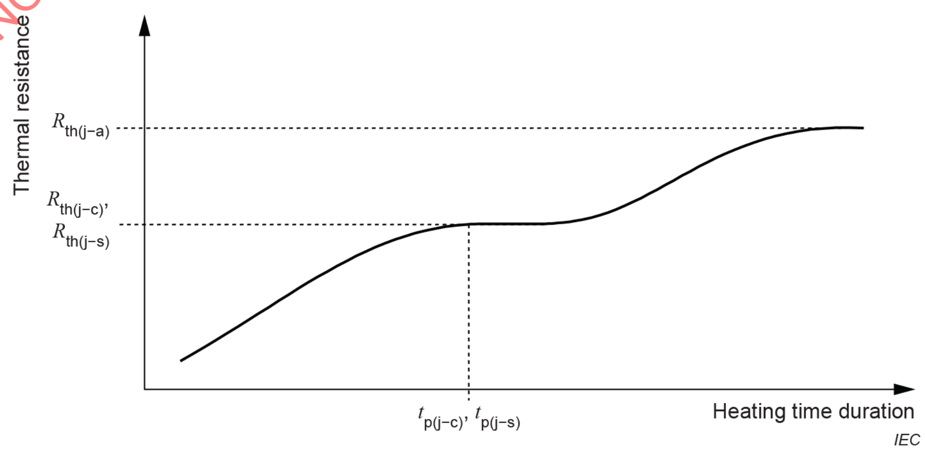


Figure 15 – Heating time duration dependence of the measured thermal resistance

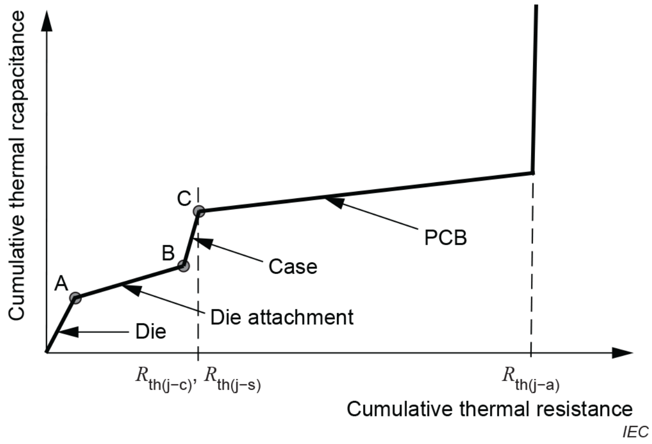


Figure 16 – Cumulative thermal capacitance versus cumulative thermal resistance characteristics (structural function)

6.7.3 Measurement procedure

6.7.3.1 Preparation

The test LED shall be mounted on PCB and/or thermally managed. Measuring atmosphere around the test LED shall be natural convection.

If the LED is to be enclosed in a box to prevent effect from external heat and wind, the box size and material shall be selected appropriately according to the degree of heat. If the measurement is not performed in a dark environment, influence of the photoelectric effect on the measurement accuracy shall be checked in advance.

6.7.3.2 Measurement of temperature coefficient of forward voltage (V_F)

Temperature coefficient of the forward voltage (V_F) shall be measured by using the following procedure.

The LED being measured is held in a variable temperature oven. Then wait until reaching at thermal equilibrium as T_j becomes equal to the oven temperature. Then measure the forward voltage (V_F) at a small forward current (I_M). The forward current shall be small enough so that the junction temperature rise is negligible. Generally, approximately 1 mA per die should be applied for the measurement.

Subsequently, repeat the above procedure sequentially at different oven temperatures to get the temperature dependent characteristic of the forward voltage. Derive the temperature coefficient of the forward voltage from the measurement result.

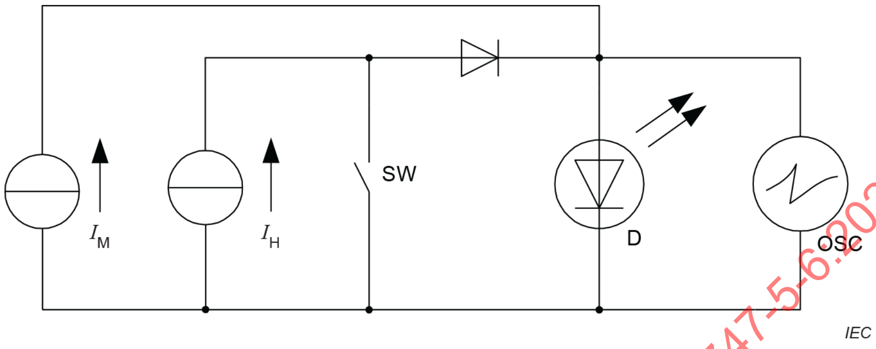
NOTE In the case of LED with resistor, even though the measured temperature coefficient includes the temperature dependence of the resistor, the measured value is still considered to be the temperature coefficient of the LED.

6.7.3.3 Measurement of change in forward voltage (V_F) induced by power dissipation (P)

There are two methods for the measurement of the change in the forward voltage (V_F) induced by the power dissipation (P) given on the LED. One is heating method (dynamic mode) and the other is cooling method (static mode). Both methods can be applicable for calculating the thermal resistance of the LED, but it shall be stated in the specification table that which method is used for the derivation of the thermal resistance.

Both methods use the measuring circuit shown in Figure 17. However, the two methods differ from each other in terms of how the electrical power dissipation (P) is applied and when the forward voltage (V_F) is measured after heating.

In these methods of measurement, the transient thermal resistance can be measured more quickly using the static mode, and the junction temperature may be slightly lower using the dynamic mode.



Key

I_M measuring current

I_H heating current

SW switch

D light emitting diode being measured

OSC oscilloscope

Figure 17 – Circuit diagram for measurement of change in V_F

a) Heating method (dynamic mode)

Turn the SW on.

Apply a small measuring current (I_M) only to the LED where the junction temperature rise is negligible, and measure the forward voltage before heating (V_{F1}).

Turn the SW off for applying the heating current (I_H) superimposed on I_M at the same time.

The heating current is applied for power dissipation during a specified "heating time duration (t_p)".

Then, turn the SW on. In this situation, only the small measuring current (I_M) is applied to the LED.

Measure the forward voltage again (V_{F2}) just after the SW on.

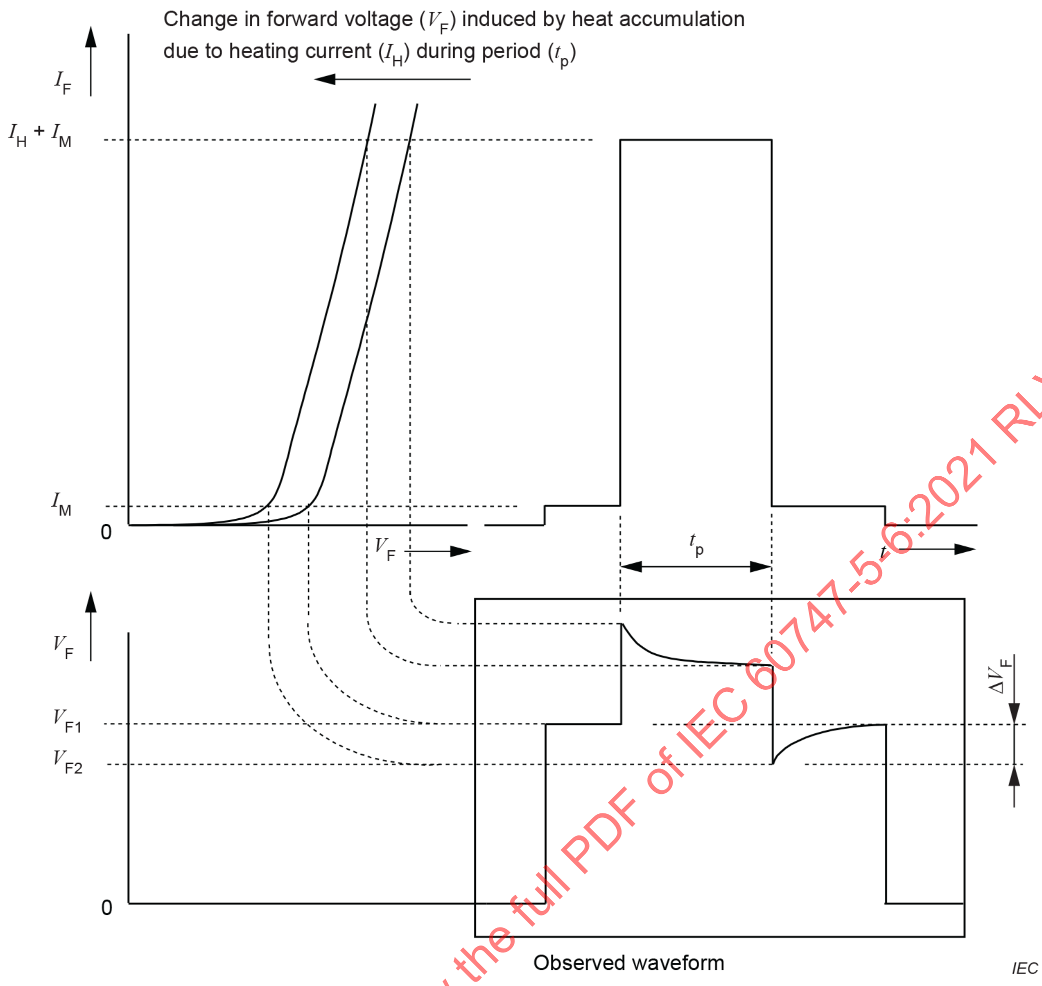


Figure 18 – Change in V_F during the measurement

The measured forward voltage V_{F2} just after the end of power dissipation is lower than the forward voltage V_{F1} before heating due to heat accumulation produced by power dissipation. However, V_{F2} will return to value V_{F1} afterwards.

The forward voltage change observed by a oscilloscope are shown in Figure 18.

The measurement timing of V_{F2} just after the end of heating shall be short enough in comparison with the thermal time constant of the test LED. However, since a transient ringing noise is superimposed onto the observed waveform due to the cut-off of the heating current (I_H), V_{F2} sampling is done after a certain delay time to avoid the influence of the ringing noise. The junction temperature T_j that is determined by using the dynamic mode is corresponds to specific delay time has passed, not immediately after the heating is off. Accordingly, junction temperature T_j may be slightly lower for some types of LED.

b) **Cooling method (static mode)**

Turn the SW off.

Heating current and a small measuring current are applied to the LED for a sufficiently long time until the system reaches the equilibrium state.

After heating current is off, namely just after turning the SW is on, measure the time variation in V_F.

In this situation, only the small measuring current (I_M) is applied to the LED.

Figure 19 shows an example of the measured time variation in V_F.

Since the forward voltage V_F that is observed immediately after the heating current (I_H) is off inevitably contains the transient vibration waveform, an accurate V_F value cannot be determined from the observed waveform.

An accurate V_F can be calculated by extrapolating the cooling behaviour which is linear to the square root of time as shown in Figure 20.

The junction temperature T_j is determined from the derived values by performing a conversion in accordance with 6.7.3.2. Details on this approach are provided in the JEDEC standards (JESD51-14).

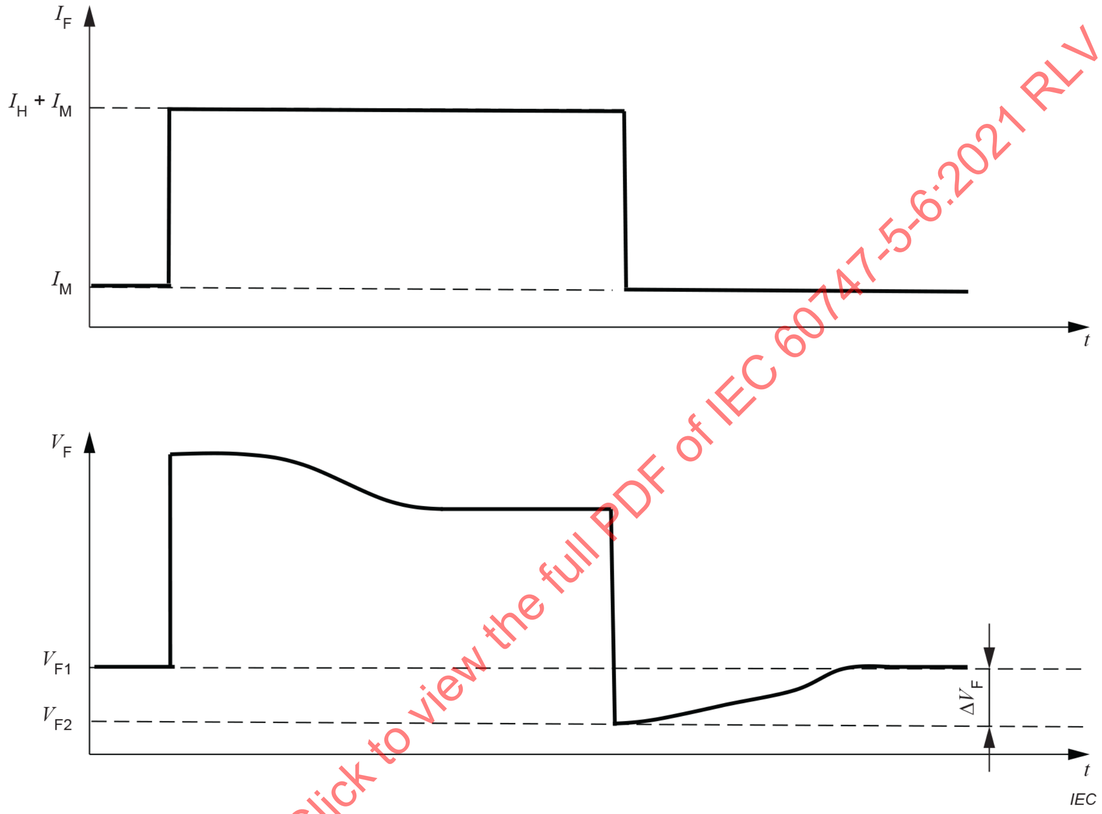


Figure 19 – Example of the time variation in V_F

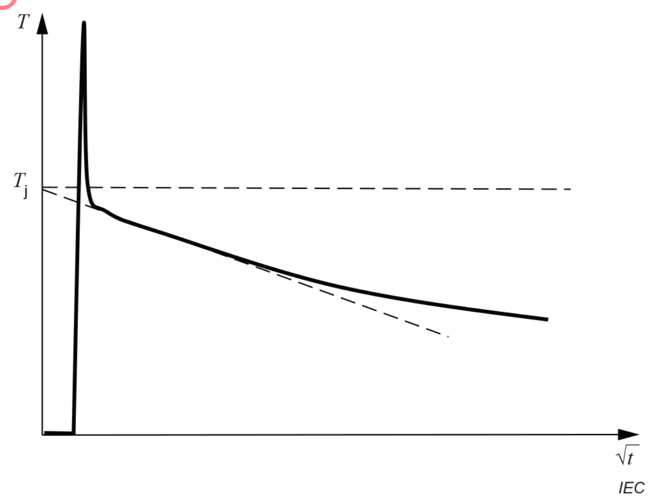


Figure 20 – Transient vibration waveform immediately after the heating is off

6.7.3.4 Measurement of the temperature at the reference point T_X

The temperature should be measured using a proper thermocouple.

For a measurement conducted using a thermocouple, its type (material) and wire size shall be carefully selected in order to prevent the measurement point from being cooled down by the thermocouple.

6.7.3.5 Calculation of thermal resistance

The thermal resistance from the junction to a certain reference point X, $R_{th(j\text{-}X)}$, shall be calculated using the following formula. The power efficiency η_{PE} should be measured at the same time when the thermal resistance is measured.

$$R_{th(j\text{-}X)el} \equiv \frac{T_j - T_X}{P} \approx \frac{\Delta V_F / b}{I_H \cdot V_F} \left(I_M \langle\langle I_H\right)$$

$$R_{th(j\text{-}X)real} \equiv \frac{T_j - T_X}{P\left(1-\eta_{PE}\right)} \approx \frac{\Delta V_F / b}{I_H V_F \left(1-\eta_{PE}\right)} \left(I_M \langle\langle I_H\right)$$

where

T_j junction temperature

T_X temperature at reference point X

P electrical power dissipation

ΔV_F $V_{F1} - V_{F2}$

b temperature coefficient for forward voltage

η_{PE} power efficiency

NOTE There are other ways to calculate the thermal resistance from the junction to the reference point.

This is a method in which the separate point in the structural function of a LED, which has different heat flow paths after the reference point, is regarded as the thermal resistance from the junction to the reference point.

In the JEDEC standards (JESD51-14), this approach is recommended as a method for calculating the thermal resistance from the junction of a semiconductor device to the rear surface of its package.

Since the precondition for this approach is that the heat flow paths before the separate point are identical, so this path is one-dimensional.

JESD51-14 explains that with a heat sink is attached to make the heat flow path one-dimensional, the heat flow path beyond the rear surface of the package can be changed by applying grease selectively.

According to JESD51-14, this separate point for the Structural function corresponds to the thermal resistance from the junction to the rear surface of the package.

This idea can be applied to a LED as follows. For example, taking a soldering point on the LED as a reference point, the LED is mounted on two types of PCB that have differently designed soldering pads, which allows the separate point to be determined. The two types of PCB can be one with a different pad size or one with a different copper thickness.

Since the thermal resistance calculated using this approach is the thermal resistance from the junction to the temperature of isothermal surface near the reference point, it may differ from the thermal resistance corresponding to the reference point.

However, this approach is an effective way of calculating with a LED for which a reference point cannot be set on its heat flow path or the accuracy of a temperature measurement taken at its reference point is insufficient.

This calculated value is also suitable for the thermal design of the heat flow on the downstream (the PCB and heat sink) of a LED if the design is conducted by a simulation

6.7.4 Precautions to be observed

The precautions to be observed are as follows:

a) The heating current I_H should be the same value as the forward current actually used. However, if sufficient detection sensitivity (i.e., forward voltage difference V_F before and after heating) cannot be achieved by applying this current value, the heating current (I_H) should be set as high as possible within the absolute maximum ratings by controlling the heating time not to exceed the $T_j$max. If it is difficult to detect enough temperature rise to derive the thermal resistance by applying this condition, the method should be abandoned.

b) For details other than those provided in a) above, see 6.1.

6.7.5 Specified conditions

a) Forward current I_F;

b) Ambient temperature T_a, case temperature T_c, or reference-point temperature T_X;

c) In the case where T_a is used for the reference point temperature:

- The configuration, size and material of the PCB that the test LED is mounted on.
- The thickness and area of the pattern (copper) that is on the PCB.
- The size, material and fin of the attached heat sink (if appropriate).

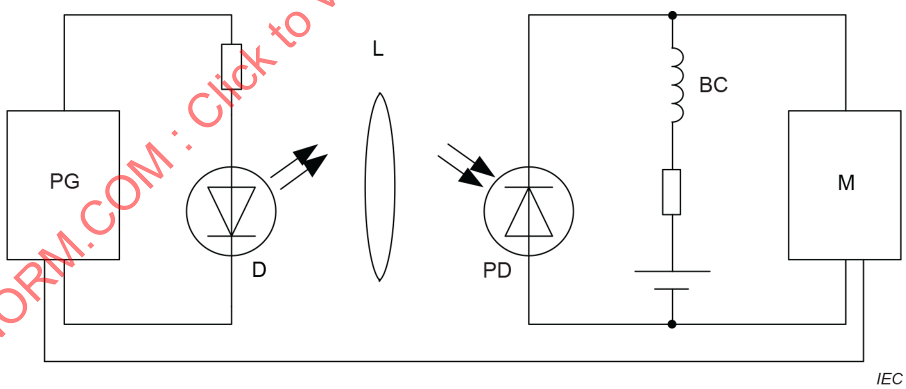
6.8 Response time measurement

6.8.1 Purpose

To measure the response time of the LED under the specified conditions.

6.8.2 Circuit diagram

The circuit diagram is shown in Figure 21.



Key

PG pulse generator

D light emitting diode being measured

L collective lens

PD photo detector

BC bias circuit

M optical pulse measurement system

Figure 21 – Circuit diagram for response time measurement

6.8.3 Provisions

To detect the photocurrent signals at the photo detector, a transimpedance amplifier that ensures sufficient response characteristics shall generally be used; however, this may also be performed by measuring the voltage using a resistor whose resistance is low enough to ensure responsivity and linearity.

The rise and fall times of the pulse generator and the optical pulse measurement system should be sufficiently lower than the response time of the test LED. The responsivity of a photo detector may worsen when outside of a specific wavelength region depending on the crystalline material and device structure. The combination of wavelength regions and device structures should be properly selected.

The collective lens may be omitted if it is not needed depending on the optical characteristics of the test LED.

6.8.4 Measurement procedure

The measurement procedure is as follows:

a) Apply the specified forward current pulse to the test LED.

b) The light emitted from the LED is received by the photo detector and converted into an electrical signal.

c) Measure this electrical signal with an oscilloscope or other suitable measurement instrument that has been synchronized with the pulse generator. Next, measure the rise time (t_r) and fall time (t_f) (and, if necessary, the turn-on delay time ($t_{d(on)}$) and turn-off delay time ($t_{d(off)}$) based on the relationship between the input and output waveforms shown in Figure 22 in accordance with the following definitions.

   1) Rise time (t_r)

      The time required for the amplitude of the output waveform to increase from 10 % to 90 %.

   2) Turn-on delay time ($t_{d(on)}$)

      The time that elapses from when the amplitude of the input waveform reaches 10 % until that of the output waveform reaches 10 %.

   3) Fall time (t_f)

      The time required for the amplitude of the output waveform to decrease from 90 % to 10 %.

   4) Turn-off delay time ($t_{d(off)}$)

      The time that elapses from when the amplitude of the input waveform drops to 90 % until that of the output waveform drops to 90 %.

6.8.5 Precautions to be observed

The precautions to be observed are as follows:

a) The rise, fall, and delay times of the forward current pulse generator and the optical pulse measurement system shall be sufficiently lower than those of the test LED.

b) The linearity of the optical pulse measurement system shall be corrected to within the measurement range of the measured value before use.

c) For details other than those provided in a) and b) above, see 6.1.

6.8.6 Specified conditions

The specified conditions are as follows:

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);

– input pulse signal (pulse current, pulse width, duty ratio).

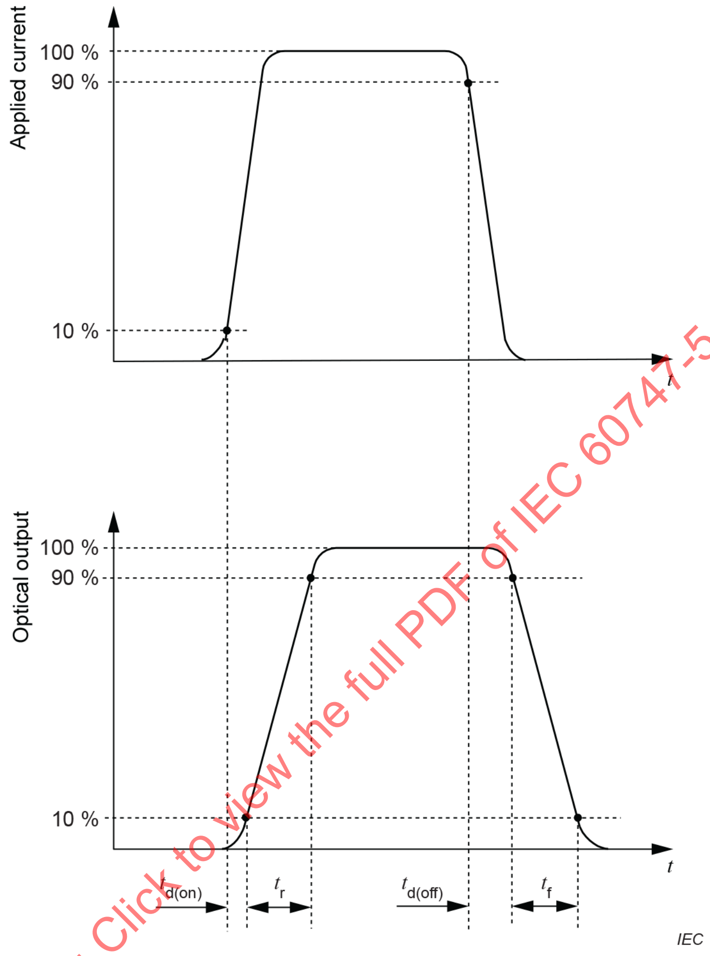


Figure 22 – Waveform of response time measurement

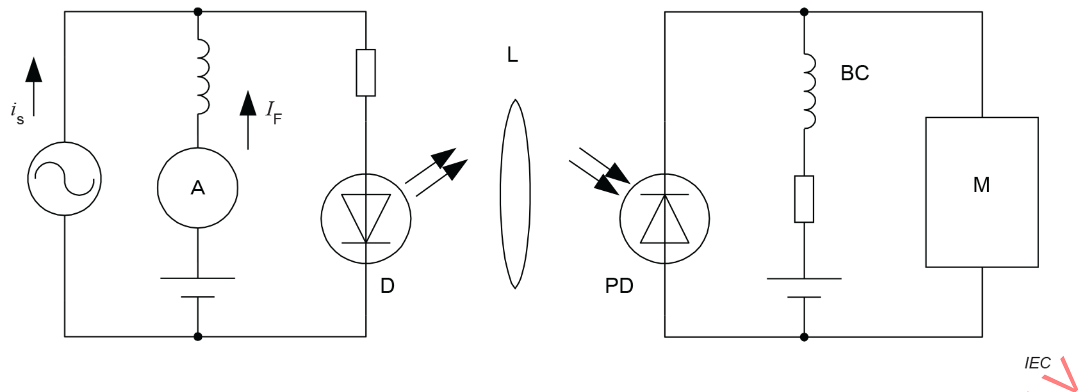
6.9 Frequency response and cut-off frequency (f_c) measurement

6.9.1 Purpose

To measure the frequency response and cut-off frequency of the LED under the specified conditions.

6.9.2 Circuit diagram

The measuring circuit should be designed as shown in Figure 23 in principle.



Key

i_s	small signal AC
I_F	forward DC
D	light emitting diode being measured
L	collective lens
PD	photo detector
BC	bias circuit
M	optical pulse measurement system

Figure 23 – Circuit diagram for f_c measurement

6.9.3 Provisions

To detect the photocurrent signals of the photo detector, a transimpedance amplifier that ensures sufficient response characteristics shall generally be used; however, this may also be performed by measuring the voltage using a resistor whose resistance is low enough to ensure responsivity and linearity.

The responsivity of a photo detector may worsen when outside of a specific wavelength region depending on the crystalline material and device structure. The combination of wavelength regions and device structures should be properly selected.

The frequency variation of the AC signal source output shall be sufficiently low, either equalling or surpassing IEC 60051 (all parts).

The collective lens may be omitted if it is not needed depending on the optical characteristics of the test LED.

6.9.4 Measurement procedure

The measurement procedure is as follows:

a) Apply the specified forward current to the test LED and superimpose the small signal AC of frequency f.

b) The light emitted from the LED is received by the photo detector and converted into an electrical signal.

c) Measure the AC, $i_p(f)$, that corresponds to the modulated light with a measuring instrument such as a spectrum analyzer.

d) Obtain $i_p(f)/i_p(f_0)$ for the alternating current $i_p(f_0)$ that corresponds to a sufficiently low reference frequency f_0 ($f_0 \leqq f_c/100$) as the frequency response.

e) The cut-off frequency (f_c) is the frequency at which the frequency response decreases by 3 dB with respect to the reference frequency.

$$-3\,\text{dB} = 10\log\left[i_p(f_c)/i_p(f_0)\right]$$

6.9.5 Precautions to be observed

The precautions to be observed are as follows:

a) Use the frequency characteristics of the small-signal AC source and the optical signal measurement system with a range that is sufficiently wider than that of the frequency characteristics of the LED.

b) The linearity of the optical signal measurement system should be corrected to within the measurement range of the measured value before use.

c) When photoelectric conversion is performed on the optical output from the LED by a photo detector, because the frequency at which the electric output from the photo detector decreases by 3 dB and that at which the optical output of the light source decreases by 3 dB and are different, be careful not to perform the conversion incorrectly.

d) For details other than those provided in a), b), and c) above, see 6.1.

6.9.6 Specified conditions

The specified conditions are as follows:

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);

– bias forward current (I_F) of the LED;

– amplitude $\left(\max\left|(i_s)\right|\right)$ or modulation factor $\left(M = \left(\max\left|(i_s)\right|\right)/I_F\right)$ of the AC signal.

6.10 Luminous flux (Φ_v) measurement

6.10.1 Purpose

The purpose of this measurement is to measure the total or partial luminous flux of the LED under established conditions.

6.10.2 Measurement principle

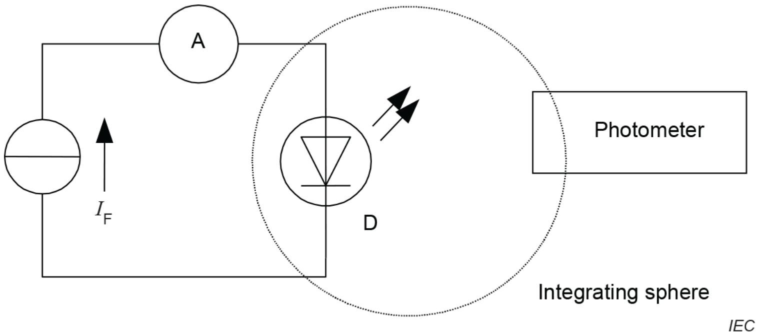
Alternately illuminate a luminous-flux standard LED whose total flux (Φ_{vS}) is known and the test LED at the centre of the integrating sphere and read the output value from each photometer. With I_{vS} as the optical output of the photometer when the luminous-flux standard LED is illuminated under established conditions and I_{vT} as the optical output of the photometer when the test LED is illuminated, the total flux Φ_{vT}(1 m) of the test LED will be as follows.

$$\Phi_{vT} = \Phi_{vS} \cdot \frac{I_{vT}}{I_{vS}}$$

If the values of Φ_{vT} and Φ_{vS} differ greatly, it may be particularly appropriate to have a filter whose attenuation is known between the photometer and the photometer window.

6.10.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 24 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 24 – Circuit diagram for Φ_V measurement

A monochromator-method or polychromator-method photometer should be used.

The sensor window inside the integrating sphere should be designed to be sufficiently small for the area of the internal surface. However, if it is difficult to design such an integrating sphere because of the spherical diameter of the integrating sphere as well as the shape and type of the photometer, a photometer with bundled fibres whose attenuation and wavelength sensitivity have been sufficiently corrected can be used for the measurement.

If it is obvious that no radiation is being emitted in the reverse direction, the test LED may be installed at the incident window to perform a 2π space measurement.

6.10.4 Measurement procedure

The measurement procedure is as follows:

a) Perform the measurement by alternately placing the test LED and the luminous-flux standard LED in the centre of the integrating sphere. Start the photometry when the luminous flux reaches a stable state during the preliminary lighting time (sufficient time for changes in the luminous flux resulting from the temperature rise of the test LED when it is turned on to become stable).

b) Read each measured output value for the test LED and the luminous-flux standard LED shown on the photometer.

6.10.5 Precautions to be observed

The precautions to be observed are as follows:

a) Make sure that you use a luminous-flux standard LED that has the same configuration as and an emission spectrum distribution equivalent to the test LED to which the values have been added by the standard light source as a luminous-flux standard LED.

   If the configuration and emission spectrum distribution of the luminous-flux standard LED are not equivalent to those of the test LED, use the following formula to correct them as needed – particularly if the photometer is a filter-type (e.g. $V(\lambda)$ photometer):

$$\Phi_{vT} = \alpha \cdot k \cdot \Phi_{vS} \cdot \frac{I_{vT}}{I_{vS}}$$

where

α is the self-absorption correction factor;

k is the colour correction factor.

NOTE 1 Details on how to obtain the self-absorption correction factor can be found in Annex B.

NOTE 2 Details on how to obtain the colour correction factor can be found in Annex C.

b) The light receiving luminous flux and the optical output of the photometer shall be in direct proportion to each other. If they are not in direct proportion to each other, they shall be corrected.

c) The diameter of the integrating sphere shall be sufficiently larger than the test device in principle. The size of the light shielding plate should be the minimum required to completely block the light source viewed from the photometer window. The plate should be fixed on the line connecting the centre of the integrating sphere and the photometer window at a point that is a third to half the radius from the centre. All parts of the inner surface of the integrating sphere shall be diffusing surfaces that provide as uniform a reflectivity as possible (lambertian surface).

Errors may be included in the result of the photometry depending on how close the relative spectral sensitivity curve (in which the spectral reflection factor of the integrating sphere paint, the spectral transmittance of the diffuse transmission plate at the photometer window, and the relative spectrum of the photometer are combined to form a photometry system) is to the standard luminous efficiency curve. Therefore, these errors shall be evaluated and corrected.

d) For details other than those provided in a), b), and c) above, see 6.1.

6.10.6 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.11 Radiant flux (Φ_e) measurement

6.11.1 Purpose

The purpose of this measurement is to measure the total radiant flux of the LED under established conditions.

6.11.2 Measurement principle

Alternately illuminate a radiant-flux standard LED whose total radiant flux (Φ_{eS}) is known and the test LED at the centre of the integrating sphere and read the output value from each radiometer.

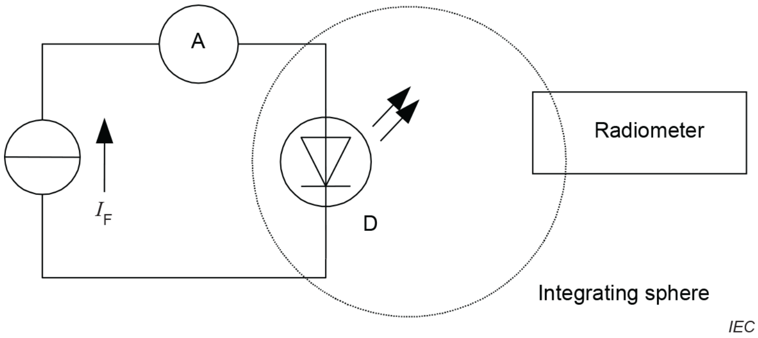
With I_{eS} as the optical output of the radiometer when the radiant-flux standard LED is illuminated under established conditions and I_{eT} as the output of the radiometer when the test LED is illuminated, the radiant flux Φ_{eT} of the test LED will be as follows.

$$\Phi_{eT} = \Phi_{eS} \cdot \frac{I_{eT}}{I_{eS}}$$

If the values of Φ_{eT} and Φ_{eS} differ greatly, it may be particularly appropriate to have a filter whose attenuation is known between the radiometer and the photometer window.

6.11.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 25 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 25 – Circuit diagram for Φ_e measurement

The sensor window inside the integrating sphere should be designed to be sufficiently small for the area of the internal surface. However, if it is difficult to design such an integrating sphere because of the spherical diameter of the integrating sphere as well as the shape and type of the light receiving portion of the radiometer, a radiometer with bundled fibres whose attenuation and wavelength sensitivity have been sufficiently corrected can be used for the measurement.

If it is obvious that no radiation is being emitted in the reverse direction, the test LED can be installed at the incident window to perform a 2π space measurement.

6.11.4 Measurement procedure

The measurement procedure is as follows:

a) Perform the measurement by alternately placing the test LED and the radiant-flux standard LED in the centre of the integrating sphere.

   Start the photometry when the radiant flux has reached a stable state during the preliminary lighting time (sufficient time for changes in the radiant flux resulting from the temperature rise of the test LED when it is turned on to become stable).

e) Read each measured output value for the test LED and the radiant-flux standard LED shown on the radiometer.

6.11.5 Precautions to be observed

The precautions to be observed are as follows:

a) Make sure that you use a radiant-flux standard LED that has the same configuration as and an emission spectrum distribution equivalent to a sufficiently calibrated test LED and a radiometer.

   If the configuration and emission spectrum distribution of the radiant-flux standard LED are not equivalent to those of the test LED, use the following formula to correct them as needed.

$$\Phi_{vT} = \alpha \cdot k \cdot \Phi_{vS} \cdot \frac{I_{vT}}{I_{vS}}$$

   where

   α is the self-absorption correction factor;

k is the colour correction factor.

NOTE 1 Details on how to obtain the self-absorption correction factor can be found in Annex B.

NOTE 2 Details on how to obtain the colour correction factor can be found in Annex C.

When using an optical power meter with a wavelength sensitivity compensation function for the radiometer, correction with the colour correction factor can be omitted if a correction with the corresponding wavelength is performed for each measurement.

b) The diameter of the integrating sphere shall be sufficiently larger than the test LED in principle. The size of the light shielding plate should be the minimum required to completely block the light source viewed from the photometer window. The plate should be fixed on the line connecting the centre of the integrating sphere and the photometer window at a point that is a third to half the radius from the centre. All parts of the inner surface of the integrating sphere shall be diffusing surfaces that provide as uniform a reflectivity as possible (lambertian surface).

c) For details other than those provided in a) and b) above, see 6.1.

6.11.6 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.12 Luminous intensity (I_V) measurement

6.12.1 Purpose

The purpose of this measurement is to measure the luminous intensity of the LED under established conditions.

6.12.2 Measurement principle

The luminous intensity measurement shall conform to the measurement of the CIE-averaged LED intensity. This measurement is performed by turning on a luminous-intensity standard LED whose averaged LED intensity (I_v) is known and the test LED and comparing them alternately under two defined visual (solid angle) conditions.

With I_{vS} as the luminous intensity of the luminous-intensity standard LED, i_{vS} as the read value of the photometer output, and i_{vT} as the read value of the photometer output when the test LED is illuminated, the luminous intensity of the test LED (I_v) will be as follows.

$$I_v = \frac{i_{vT}}{i_{vS}} \cdot I_{vS}$$

The measurement distance should be between the tip of the LED and the reference surface of the light receiving portion of the photometer as shown in Figure 26.

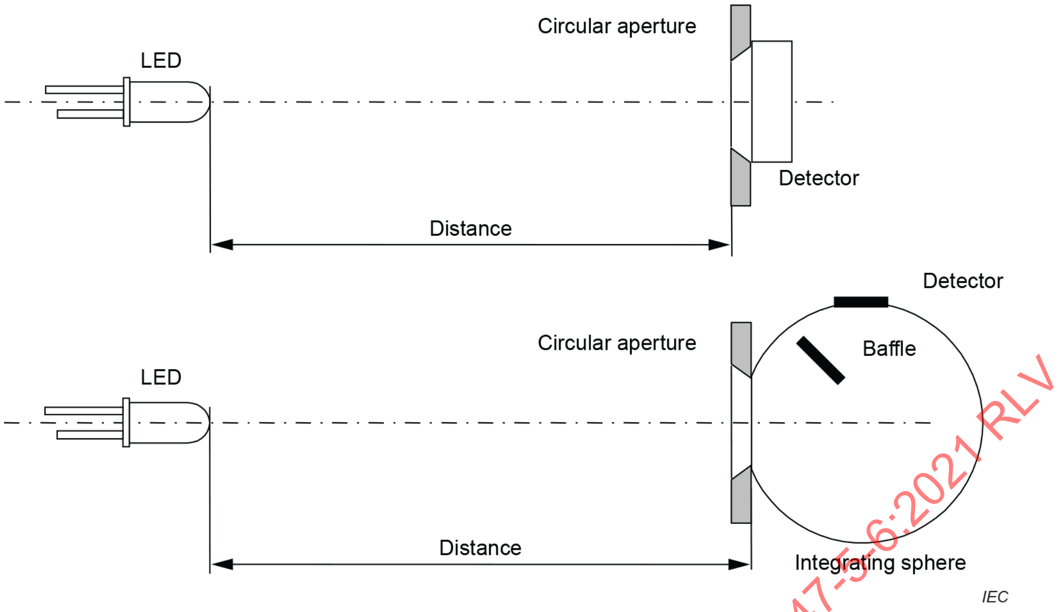


Figure 26 – Schematic diagram for I_V measurement

If the reference surface of the photometer for the measurement distance is not set, take the front surface of the light receiving portion as the reference surface.

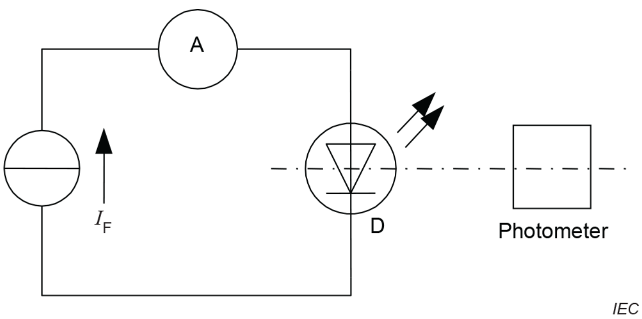
Table 3 shows the view angle conditions for CIE-averaged LED intensity.

Table 3 – CIE averaged LED intensity measurements

	Circular aperture mm^2	**Distance** mm	**View angle** sr
Condition A	100	316	0,001
Condition B		100	0,01

6.12.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 27 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 27 – Circuit diagram for I_V measurement

6.12.4 Measurement procedure

The measurement procedure is as follows:

a) Set the luminous-intensity standard LED or the test LED in accordance with its external structure. Set the photometer and the test LED at a position where the vertical central axis of the acceptance surface of the photometer is, in principle, coincident with the structural central axis or the optical central axis of the test LED.

b) Set the photometric distance between the LED and the acceptance surface of the photometer to one of the values shown in Table 3 in accordance with the relevant condition.

c) Apply the specified forward current (I_F) to the luminous-intensity standard LED and the test LED alternately to obtain the luminous intensity by reading the photometer.

If the emission spectrum distribution of the luminous-intensity standard LED is not equivalent to that of the test LED, perform corrections with the colour correction factor as needed – particularly if the photometer is a filter-type (e.g. $V(\lambda)$ photometer).

NOTE Details on how to obtain the colour correction factor can be found in Annex B.

6.12.5 Precautions to be observed

The precautions to be observed are the following.

a) In actual measurements, the structural central axis based on the external structure of the test LED is not necessarily coincident with the optical central axis. It is advisable to clarify to which axis the obtained measured value belongs.

b) For details other than those provided in a) above, see 6.1.

6.12.6 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F) and current-carrying time;

– distance (visual) condition;

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.13 Radiant intensity (I_e) measurement

6.13.1 Purpose

The purpose of this measurement is to measure the radiant intensity of the LED under established conditions.

6.13.2 Measurement principle

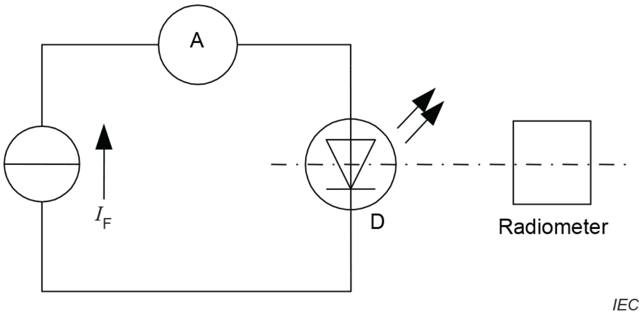
The radiant intensity measurement shall conform to the visual (solid angle) conditions and the conditions for the positional relation between the light receiving portion and the LED, as specified for the measurement of CIE-averaged LED intensity in 6.12. This measurement is performed by alternately turning on a radiant-intensity standard LED whose radiant intensity (I_e) is known and the test LED and comparing them.

With I_{eS} as the radiant intensity of the radiant-intensity standard LED, i_{eS} as the read value of the radiometer output, and i_{eT} as the read value of the radiometer output when the test LED is illuminated, the radiant intensity of the test LED (I_e) will be as follows.

$$I_e = \frac{i_{eT}}{i_{eS}} \cdot I_{eS}$$

6.13.3 Measuring circuit

The measuring circuit should be designed as shown in Figure 28 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 28 – Circuit diagram for I_e measurement

6.13.4 Measurement procedure

The measurement procedure is as follows:

a) Set the radiant-intensity standard LED or the test LED in accordance with its external structure. Set the radiometer and the test LED at a position where the vertical central axis of the acceptance surface of the optical receiver is, in principle, coincident with the structural central axis or the optical central axis of the test LED.

b) Set the photometric distance between the LED and the acceptance surface of the radiometer to one of the values shown in Table 3 in accordance with the relevant condition.

c) Apply the specified forward current to the radiant-intensity standard LED and the test LED alternately to obtain the radiant intensity by reading the radiometer output. When using an optical power meter with a wavelength sensitivity compensation function for the radiometer, make sure that you calibrate it with the corresponding wavelength for each measurement.

In actual measurements, the structural central axis based on the external structure of the test LED is not necessarily coincident with the optical central axis. It is advisable to clarify to which axis the obtained measured value belongs.

For details other than those provided in a), b) and c) above, see 6.1.

6.13.5 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F) and current-carrying time;

– distance (visual) condition;

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X).

6.14 Luminance (L_v) measurement

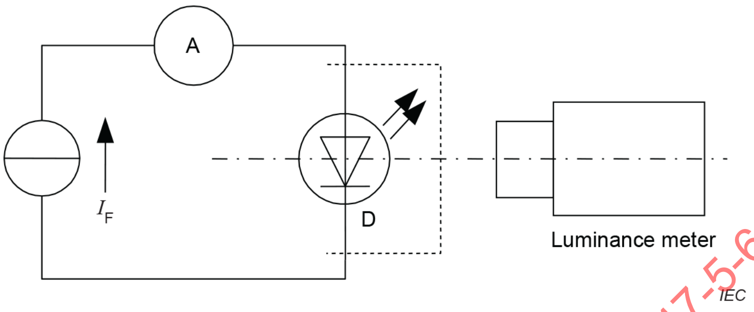
6.14.1 Purpose

The purpose of this measurement is to measure the luminance under established conditions using either a LED flat illuminator that has a light emitting part with a large area in particular and a flat emitting pattern or a LED dot-matrix display.

6.14.2 Measuring circuit

The measuring circuit should be designed as shown in Figure 29 in principle.

Commonly used LED flat illuminators usually have multiple LED dies. Figure 29 shows an example of a LED flat illuminator with a single LED die. The actual driving circuitry should be configured in accordance with the number of LED dies to be used and the LED connection topology.



Key

I_F forward DC

D light emitting diode being measured

Figure 29 – Circuit diagram for L_v measurement

6.14.3 Measurement procedure

The measurement procedure is as follows:

a) Set the test LED in accordance with its external structure. Set the luminance meter and the test LED at a position where the vertical central axis of the acceptance surface of the luminance meter is coincident with the normal in the emitting face of the test LED.

b) Set the distance between the emitting face of the test LED and the acceptance surface of the luminance meter so that the solid angle, which is determined by the size of the diameter of the measurement spot on the specified emitting face, will be appropriate.

c) Apply the specified forward current (I_F) to the test LED to obtain the luminance (L_v) by reading the luminance meter.

Care should be taken when measuring luminance to ensure that the brightness in the view of the luminance meter is uniform and that the field of view is completely filled with the emission of light. If the luminance of the emitting face is not uniform, take the average value as the luminance.

It is advisable to clarify on which part of the emitting face the luminance was measured.

The luminance meter shall be calibrated on a regular basis. For details on calibration, refer to Annex D.

For details other than those provided in a), b), and c) above, see 6.1.

6.14.4 Measurement conditions to be defined

The measurement conditions to be defined are the following:

– forward current (I_F);

– photometric distance and solid angle;

– ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);
– position on the emitting face;
– measured surface.

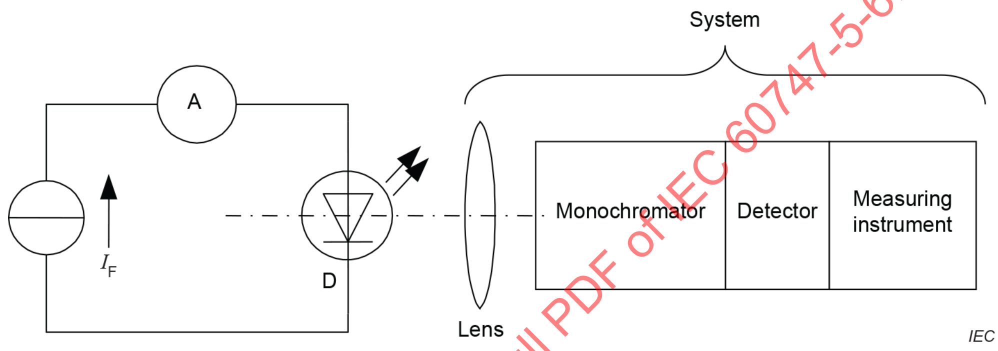
6.15 Emission spectrum distribution, peak emission wavelength (λ_p), and spectral half bandwidth ($\Delta\lambda$) measurement

6.15.1 Purpose

The purpose of this measurement is to measure the emission spectrum distribution, peak emission wavelength, and spectral half bandwidth of the LED under established conditions.

6.15.2 Measuring circuit

The measuring circuit should be designed as shown in Figure 30 in principle.



Key

I_F forward DC

D light emitting diode being measured

Figure 30 – Circuit diagram for λ_p measurement

The emission spectrum of LEDs may differ greatly in distribution due to their position in the emitting face and directivity angle. Therefore, the measurement can, depending on the intended use, be performed by using a light receiving system in 2π space through an integrating sphere as shown in Figure 31. Particularly for measurements with a LED in which multiple LED dies are contained within a single package or with a dual-wavelength emission type LED using an excited luminescence layer in the LED die, use the system shown in Figure 31 unless otherwise specified.