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INTERNATIONAL STANDARD

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

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FOREWORD

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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- withdrawn,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: $\rho = \rho_r + \rho_d$

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: $\tau = \tau_r + \tau_d$.

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:

$$Q_{\mathrm{e}} = \int_{\Delta t} \Phi_{\mathrm{e}} \, \mathrm{d}t$$

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

$$\Phi_\mathrm{e} = \frac{\mathrm{d}Q_\mathrm{e}}{\mathrm{d}t}$$

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

$$I_\mathrm{e} = \frac{\mathrm{d}\Phi_\mathrm{e}}{\mathrm{d}\Omega}$$

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

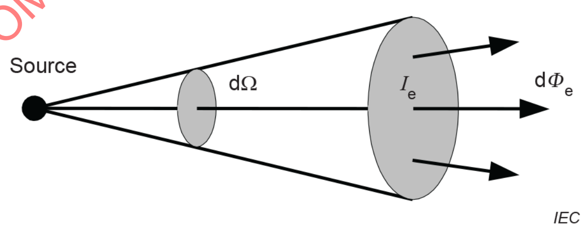


Figure 1 – Radiant intensity

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:

$$\Phi_\mathrm{e} = \iint_{\Omega} I_\mathrm{e}(\vartheta,\varphi) \sin\vartheta \, \mathrm{d}\varphi \, \mathrm{d}\vartheta .$$

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 60050-845:2020, 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

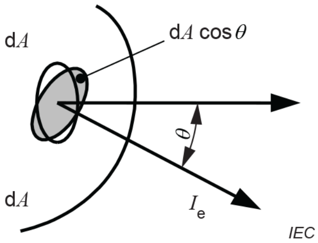


Figure 2 – Radiance

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

[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 ($W \cdot m^{-2}$).

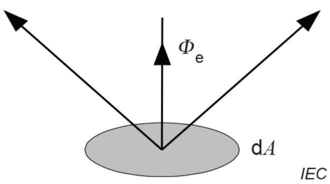


Figure 3 – Radiant exitance

[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

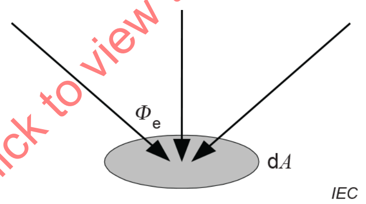


Figure 4 – Irradiance

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

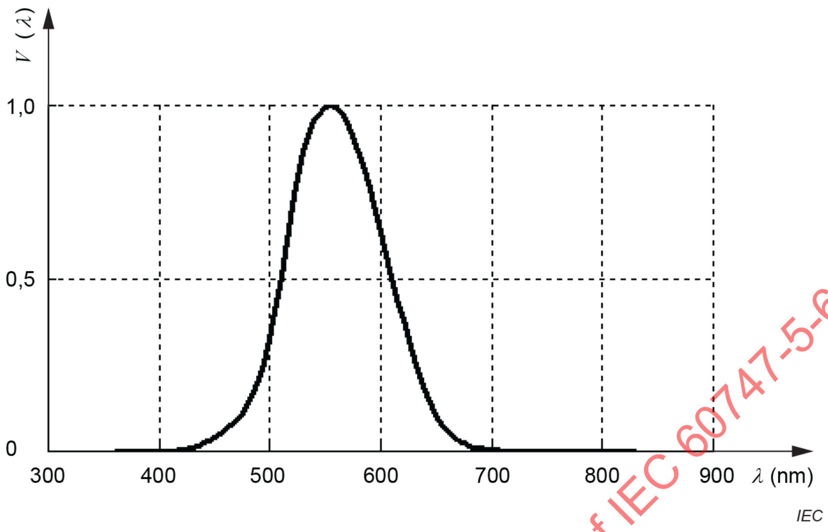


Figure 5 – Spectral luminous efficiency

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 ($\mathrm{lm \cdot m^{-2}}$).

[SOURCE: IEC 60050-845:2020, 845-21-081, modified – The symbol M has been removed.]

3.3.9
illuminance
$\boldsymbol{E}_\mathrm{v}$
density of incident luminous flux with respect to area at a point on a real or imaginary surface

$$E_\mathrm{v} = \frac{\mathrm{d}\Phi_\mathrm{v}}{\mathrm{d}A}$$

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

$$E_\mathrm{v} = K_\mathrm{m} \int_0^\infty E_{\mathrm{e},\lambda}(\lambda) V(\lambda) \mathrm{d}\lambda$$

where K_m is maximum luminous efficacy, $E_{\mathrm{e},\lambda}(\lambda)$ 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 ($\mathrm{lx = lm \cdot m^{-2}}$).

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

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

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

3.4.3
real thermal resistance
$R_{\mathrm{th(j\text{-}X)real}}$
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)

$$R_{\text{th(j-X)real}} = \frac{T_{\text{j}} - T_{\text{X}}}{P - \Phi_{\text{e}}}$$

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.

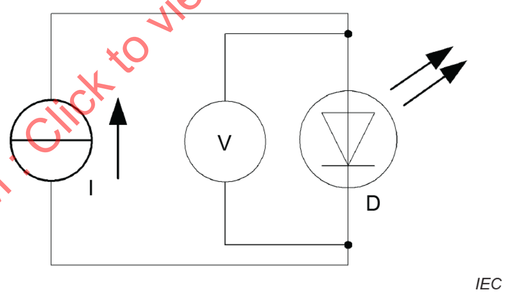
6.2 Forward voltage (V_F) measurement

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

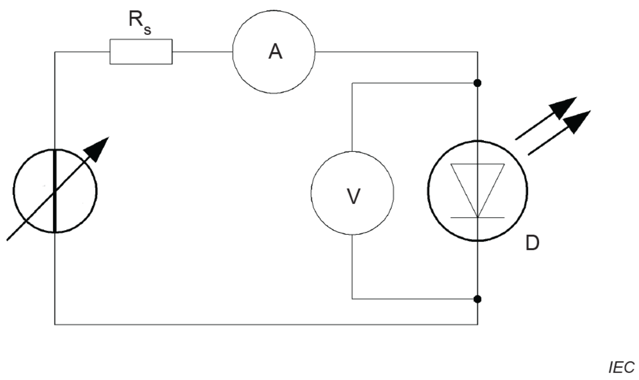
6.2.3 Requirements

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

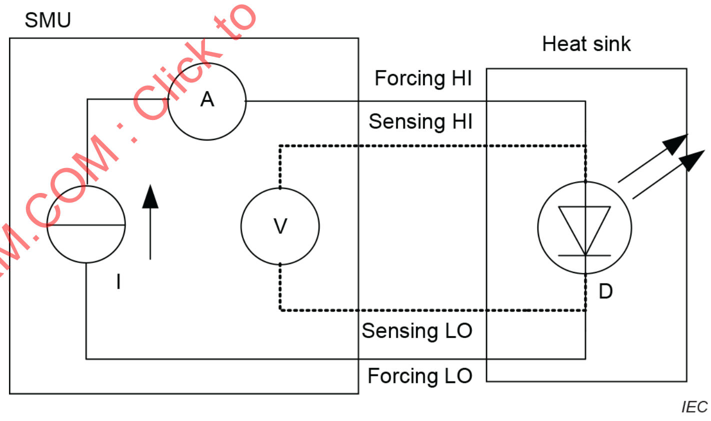
V voltmeter

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

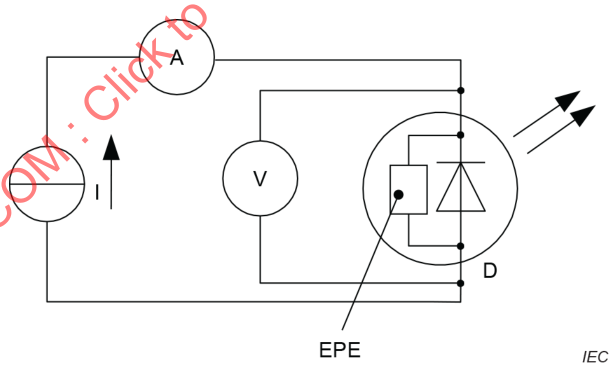
6.3.1 Purpose

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

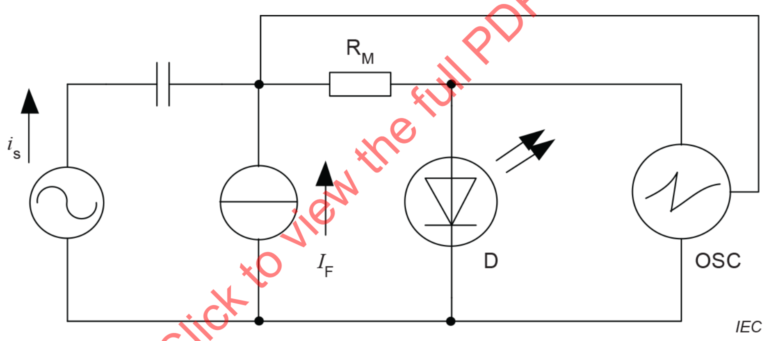
6.4.1 Purpose

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:

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

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).

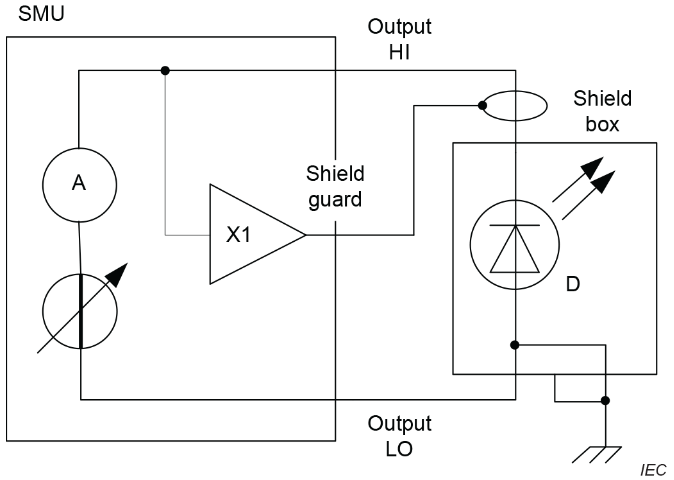
6.5 Reverse current (I_R) measurement

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.

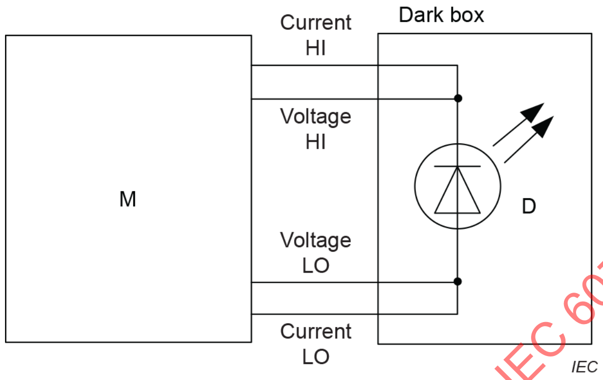
6.6.2 Measurement using LCR meter

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).

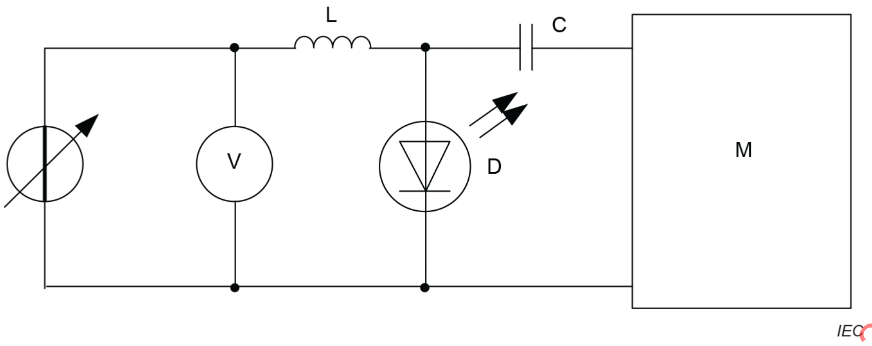
6.6.3 Measurement using AC bridge

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 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.

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

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.

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

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}.

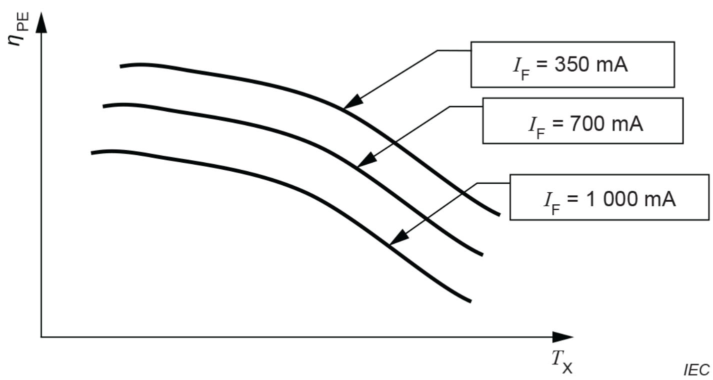


Figure 14 – An example of the temperature dependence of η_{PE}

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.

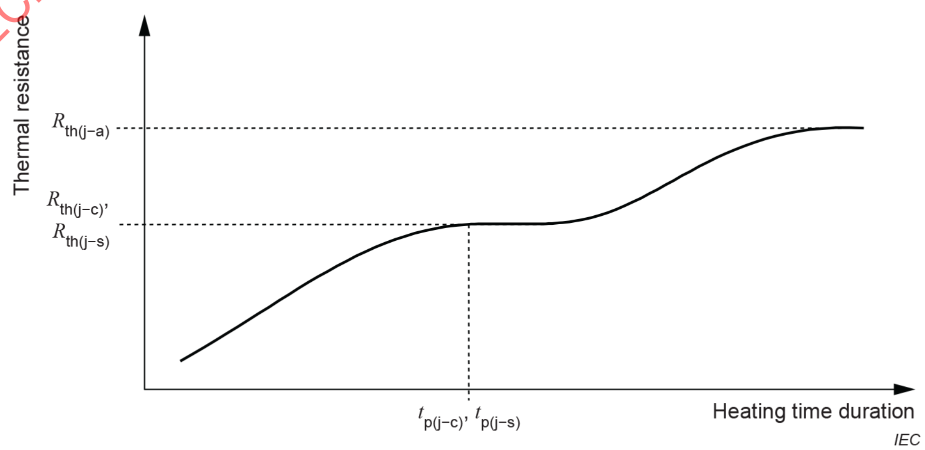


Figure 15 – Heating time duration dependence of the measured thermal resistance

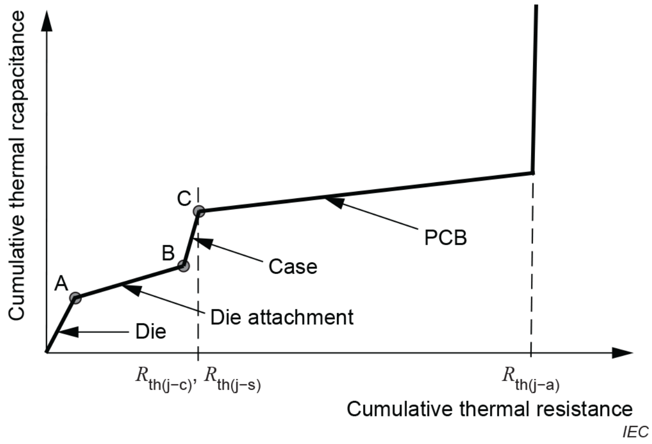


Figure 16 – Cumulative thermal capacitance versus cumulative thermal resistance characteristics (structural function)

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.

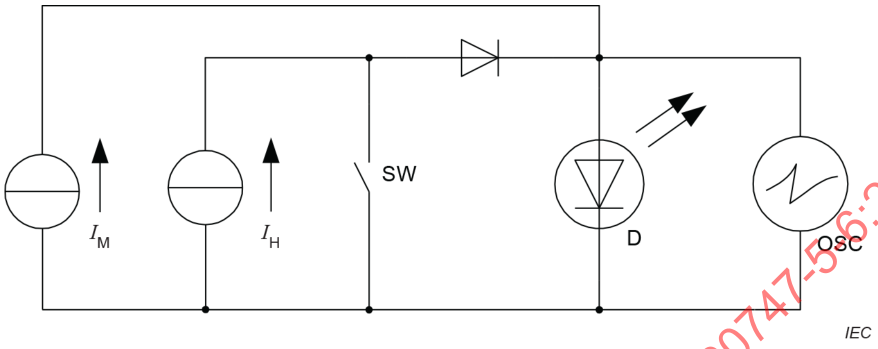
NOTE In the case of LED with resistor, even though the measured temperature coefficient includes the temperature dependence of the resistor, the measured value is still considered to be the temperature coefficient of the LED.

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.

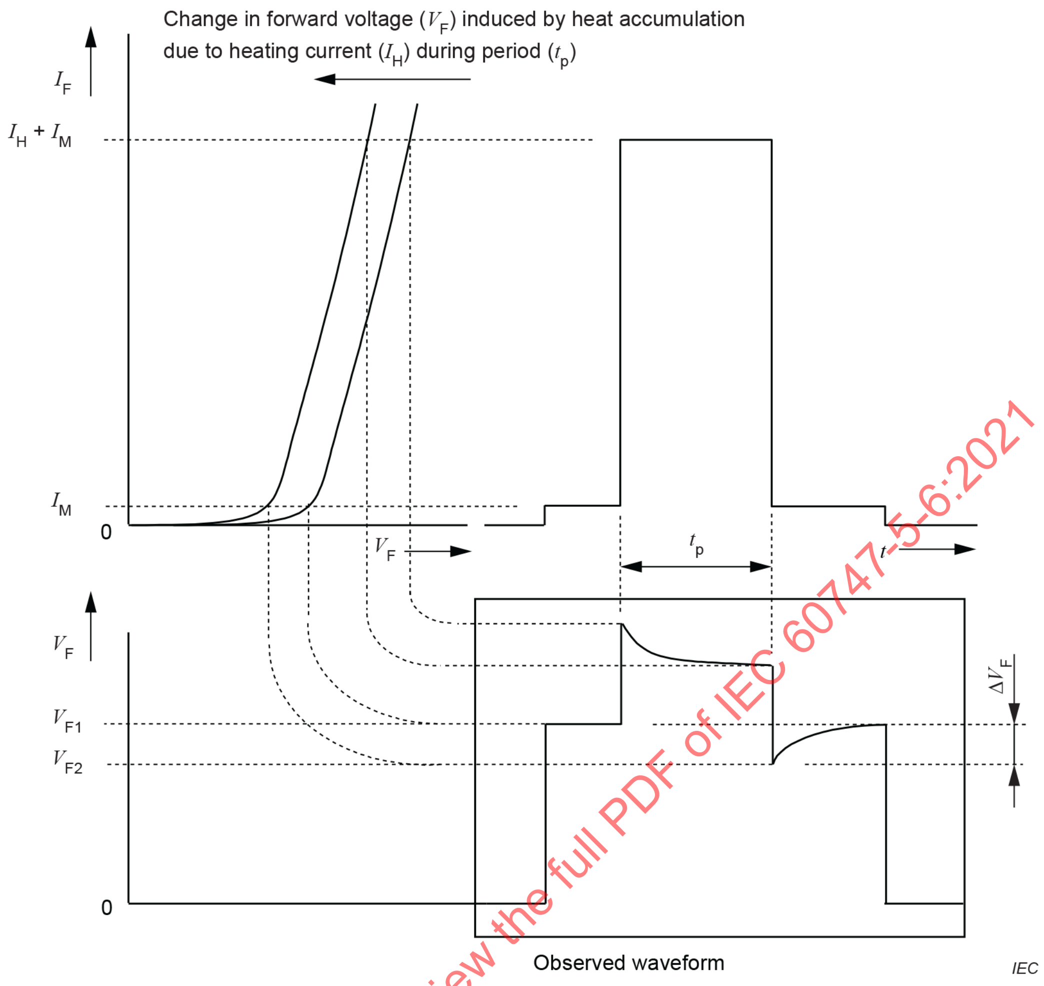


Figure 18 – Change in V_F during the measurement

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).

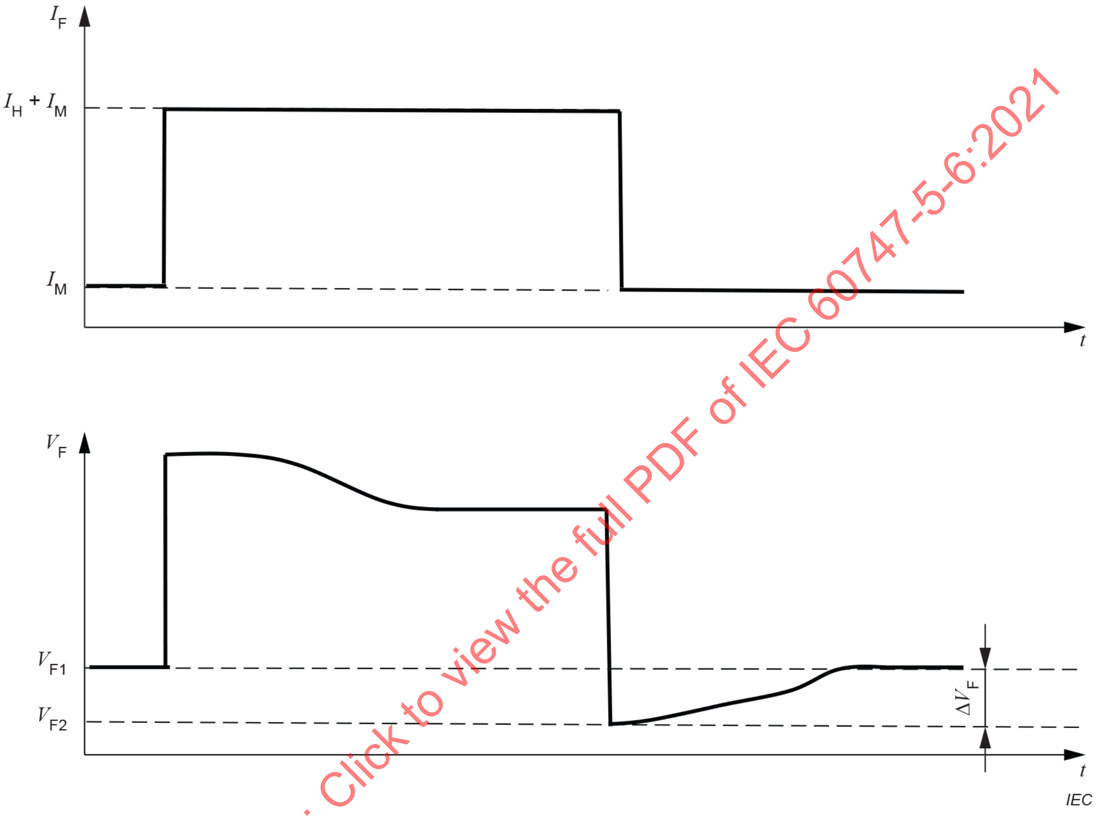


Figure 19 – Example of the time variation in V_F

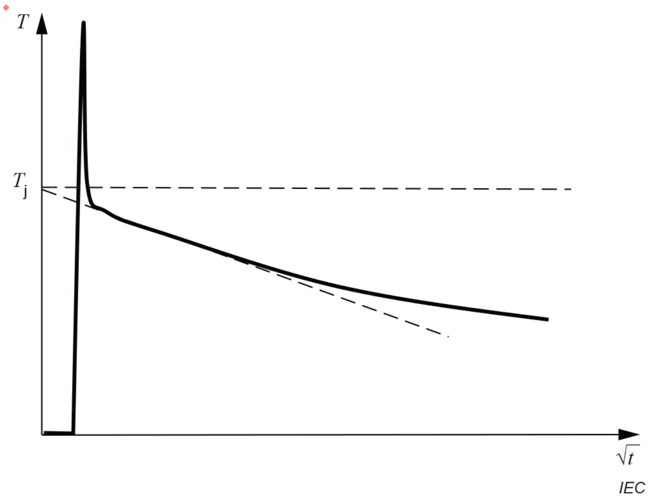


Figure 20 – Transient vibration waveform immediately after the heating is off

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).

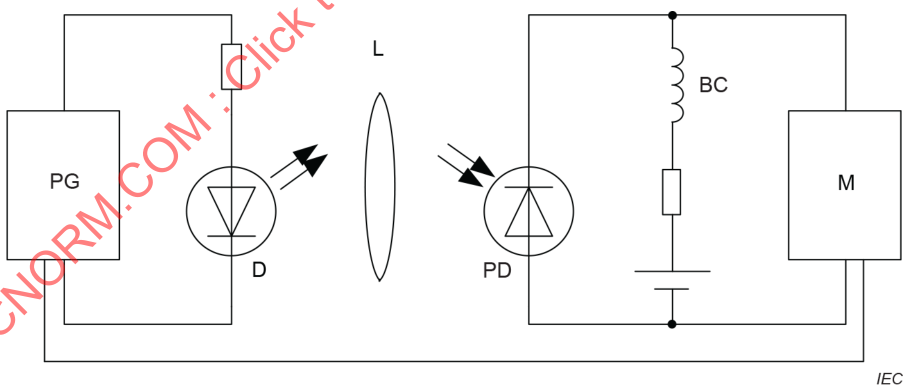
6.8 Response time measurement

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).

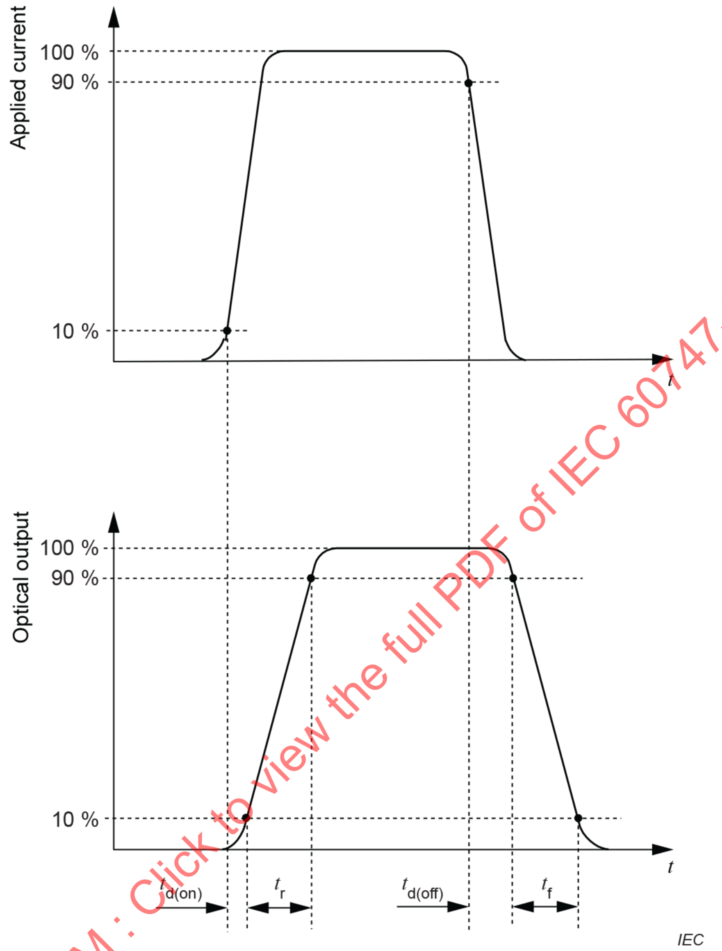


Figure 22 – Waveform of response time measurement

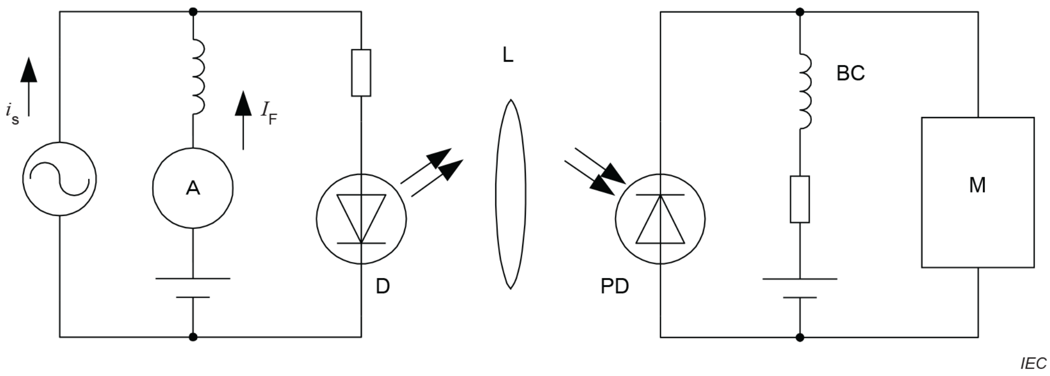
6.9 Frequency response and cut-off frequency (f_c) measurement

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

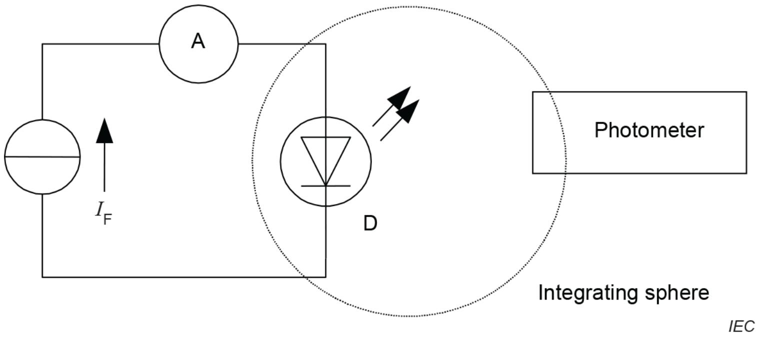
Alternately illuminate a luminous-flux standard LED whose total flux (Φ_{vS}) is known and the test LED at the centre of the integrating sphere and read the output value from each photometer. With I_{vS} as the optical output of the photometer when the luminous-flux standard LED is illuminated under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

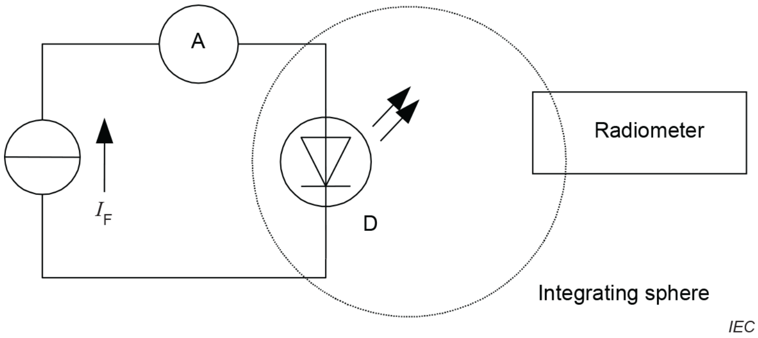
With I_{eS} as the optical output of the radiometer when the radiant-flux standard LED is illuminated under established conditions and I_{eT} as the output of the radiometer when the test LED is illuminated, the radiant flux Φ_{eT} of the test LED will be as follows.

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

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.

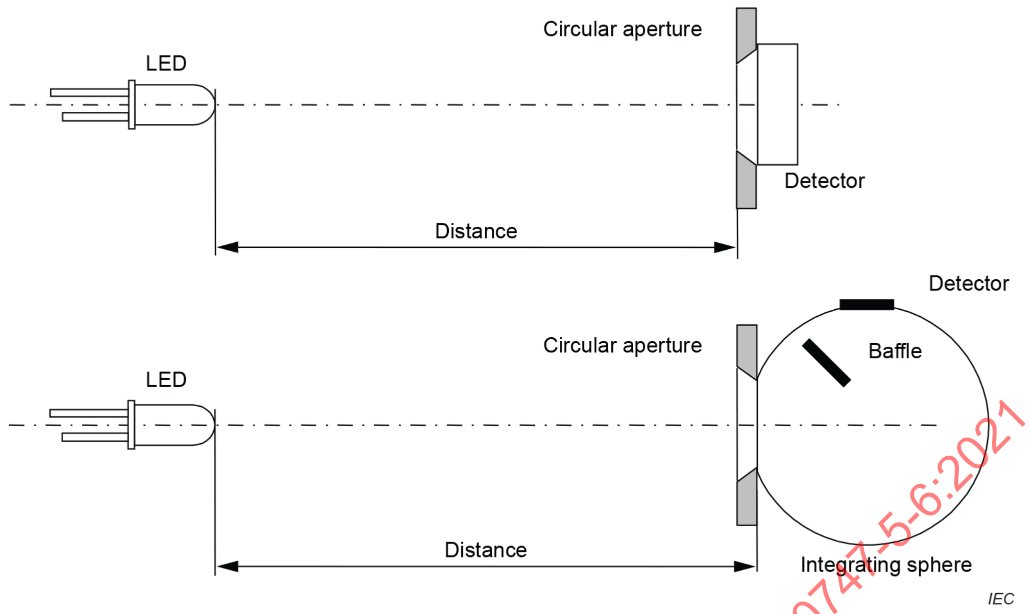


Figure 26 – Schematic diagram for I_V measurement

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.

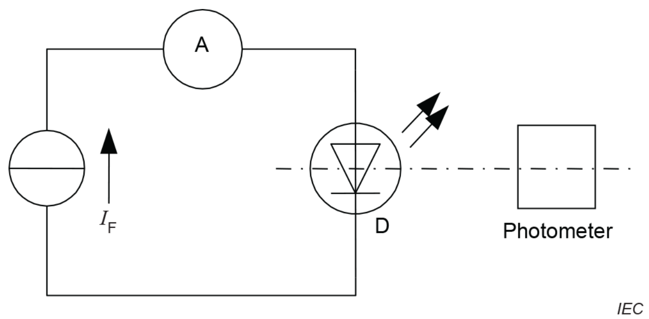
Table 3 shows the view angle conditions for CIE-averaged LED intensity.

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

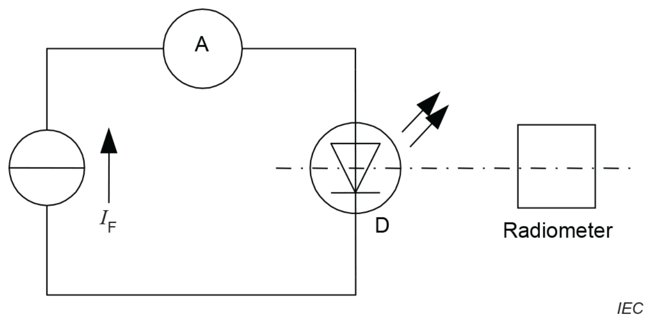
The radiant intensity measurement shall conform to the visual (solid angle) conditions and the conditions for the positional relation between the light receiving portion and the LED, as specified for the measurement of CIE-averaged LED intensity in 6.12. This measurement is performed by alternately turning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

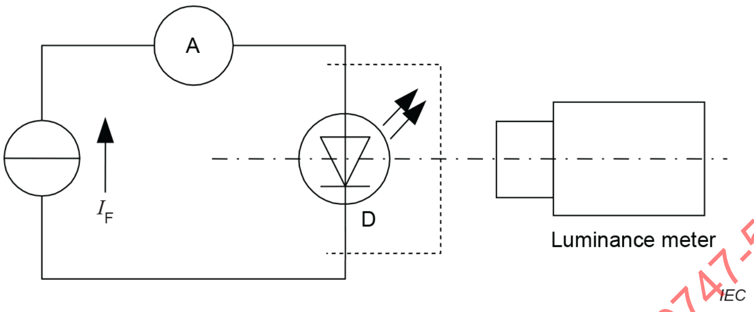
6.14.1 Purpose

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.

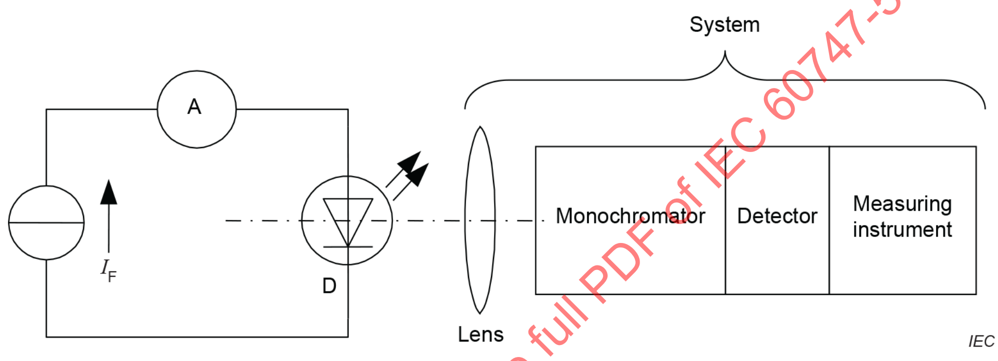
6.15 Emission spectrum distribution, peak emission wavelength (λ_p), and spectral half bandwidth ($\Delta\lambda$) measurement

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.



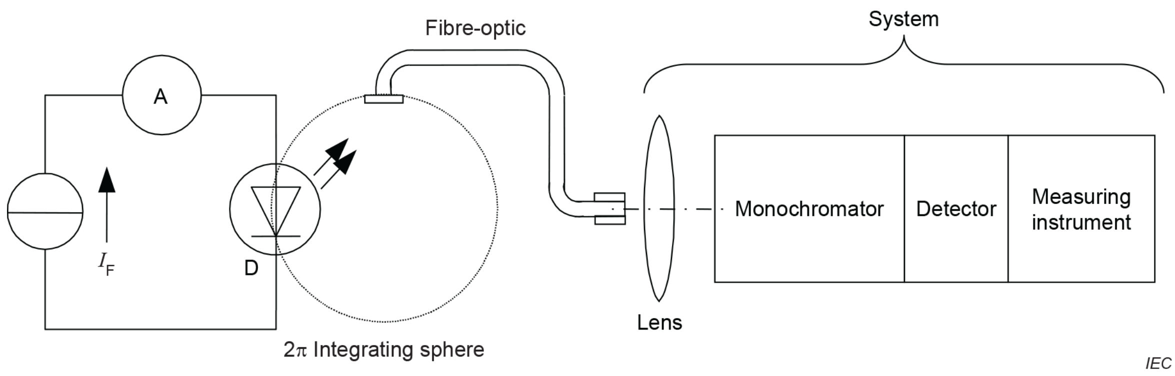
Key

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.



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).

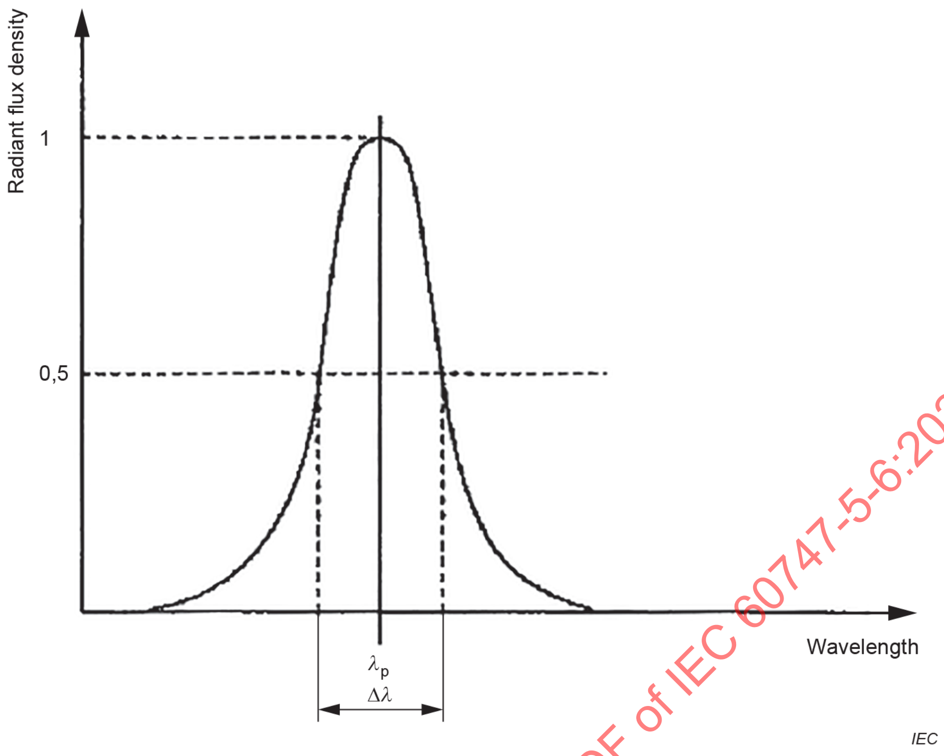


Figure 32 – Schematic diagram of $\Delta\lambda$ measurement

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.

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

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.

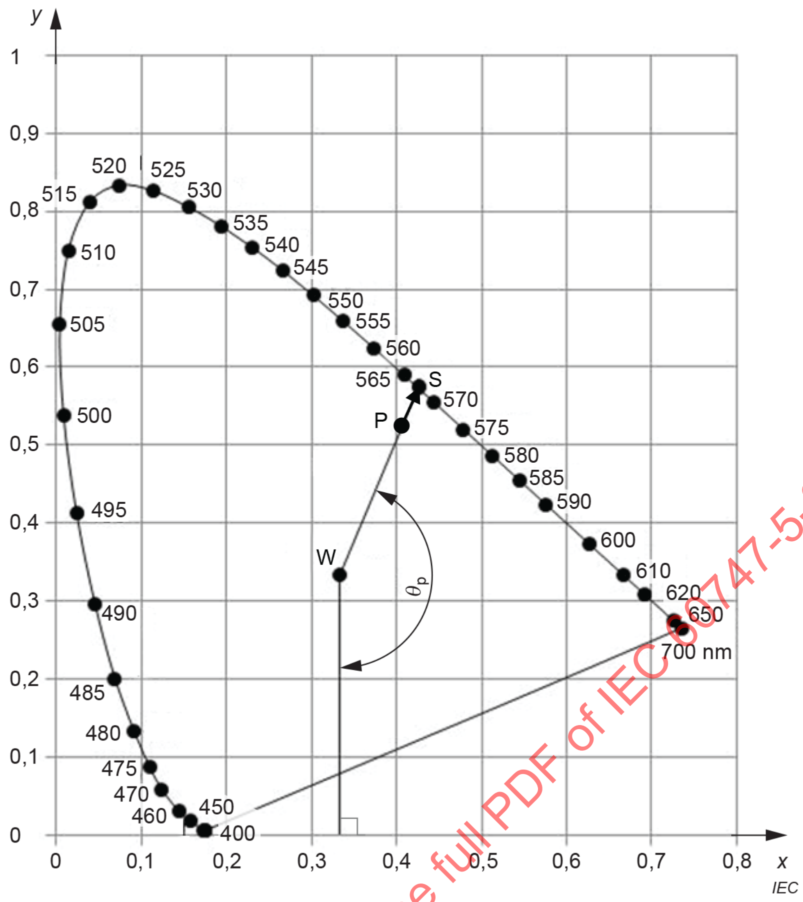


Figure 33 – Chromaticity

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:

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

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

$$\theta_D = 0° \text{ or } 180° \text{ where } x_P = 0{,}333$$

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.

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).

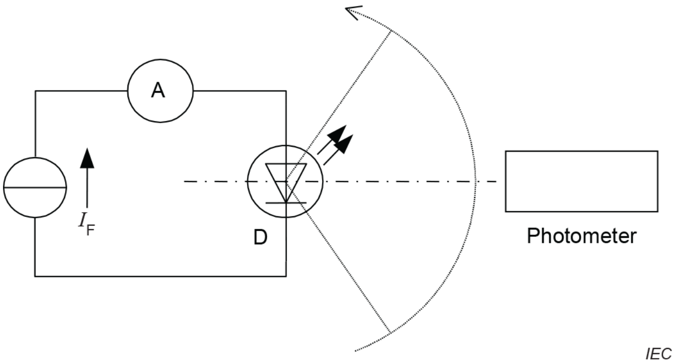
6.17 Directional characteristics and full width half maximum of an intensity measurement

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 maximum of an intensity ($2\theta_{1/2}$).

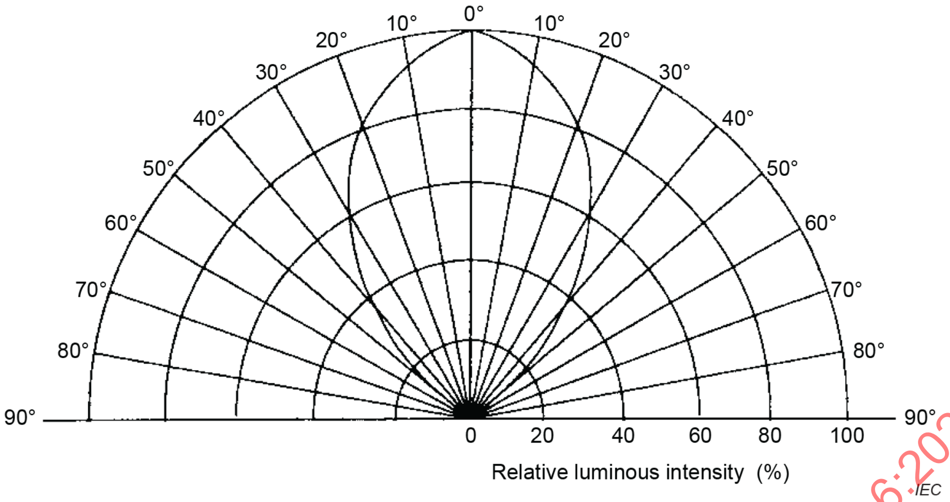


Figure 35 – Directional characteristics (example 1)

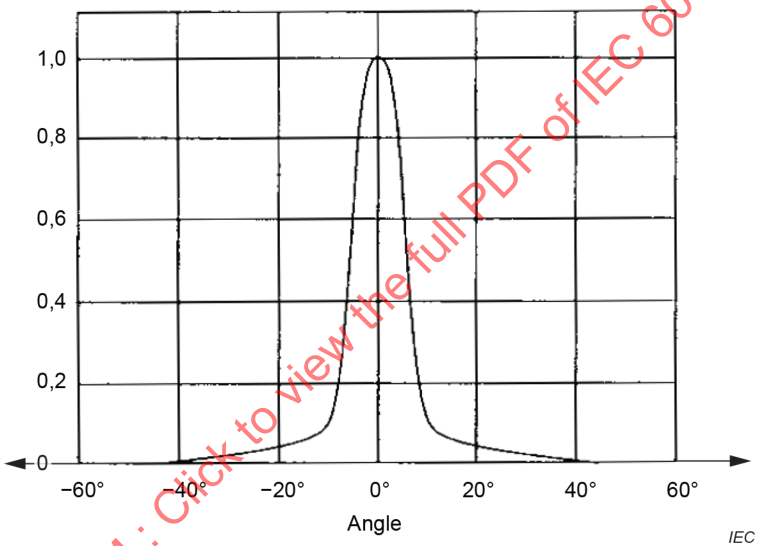


Figure 36 – Directional characteristics (example 2)

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).

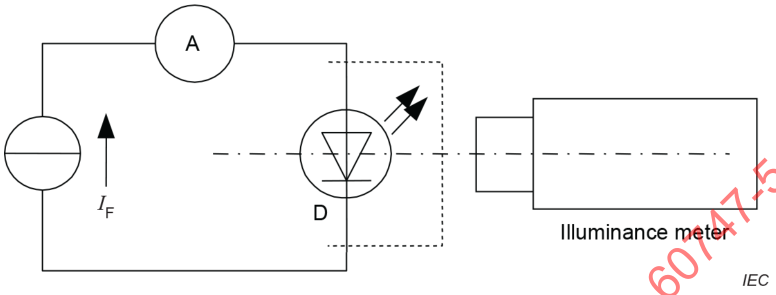
6.18 Illuminance (E_V) measurement

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 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 illuminance meter.

The 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 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 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 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 shall undergo the screening test and obtain the quality certifications for Classification III as defined in Table 5, and 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	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) 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	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	IEC 60749-12	Same as Group 3	18	1	13	1	8	1	○	○	○	○	○	○
		Mechanical shock	IEC 60749-10								○	○	○	○	○	○
		Acceleration, steady state	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						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) 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] 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 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] 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	Types of LED: b) LED flat illuminator	Types of LED: c) LED numeric display and alpha-numeric display	Types of LED: d) LED dot-matrix display	Types of LED: e) IR LED	Types of 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) IR LED	f) UV LED
B [k]	B_1	Size	Outline		Outline	9	1	9	1	9	○	○	○	○	○	○	○
	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	○	○	○	○		○	○
		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 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) IR LED	f) UV LED
	$B_{(CRRL)}$ [k]	Certificate of test results for Subgroups B_1 to B_7	–	–	–	–	–	–	–	–	○	○	○	○	○	○

[a] 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 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)

[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) 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						○
	$C_{(CRRL)}$ [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.

[e] Certificate of test results (CRRL).

8.3 Quality evaluation test

8.3.1 General

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 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 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 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

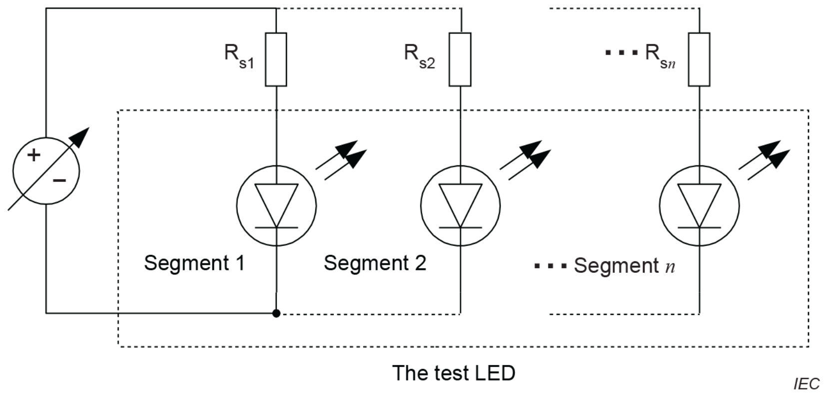
The purpose of this test is to evaluate the resistance characteristics of the test LED when electrical and thermal stresses are applied to it over a prolonged period of time.

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)	$V(\lambda)$	λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$
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)	$V(\lambda)$	λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$	λ (nm)	$V(\lambda)$
680	0,017 000 0	720	0,001 047 0	760	0,000 060 0	800	0,000 003 7
681	0,015 903 8	721	0,000 976 6	761	0,000 056 0	801	0,000 003 5
682	0,014 837 2	722	0,000 911 1	762	0,000 052 2	802	0,000 003 2
683	0,013 810 7	723	0,000 850 1	763	0,000 048 7	803	0,000 003 0
684	0,012 834 8	724	0,000 793 2	764	0,000 045 4	804	0,000 002 8
685	0,011 920 0	725	0,000 740 0	765	0,000 042 4	805	0,000 002 6
686	0,011 068 3	726	0,000 690 1	766	0,000 039 6	806	0,000 002 4
687	0,010 273 4	727	0,000 643 3	767	0,000 036 9	807	0,000 002 3
688	0,009 533 3	728	0,000 599 5	768	0,000 034 4	808	0,000 002 1
689	0,008 846 2	729	0,000 558 5	769	0,000 032 1	809	0,000 002 0
690	0,008 210 0	730	0,000 520 0	770	0,000 030 0	810	0,000 001 8
691	0,007 623 8	731	0,000 483 9	771	0,000 028 0	811	0,000 001 7
692	0,007 085 4	732	0,000 450 1	772	0,000 026 1	812	0,000 001 6
693	0,006 591 5	733	0,000 418 3	773	0,000 024 4	813	0,000 001 5
694	0,006 138 5	734	0,000 388 7	774	0,000 022 7	814	0,000 001 4
695	0,005 723 0	735	0,000 361 1	775	0,000 021 2	815	0,000 001 3
696	0,005 343 1	736	0,000 335 4	776	0,000 019 8	816	0,000 001 2
697	0,004 995 8	737	0,000 311 4	777	0,000 018 5	817	0,000 001 1
698	0,004 676 4	738	0,000 289 2	778	0,000 017 2	818	0,000 001 0
699	0,004 380 1	739	0,000 268 5	779	0,000 016 1	819	0,000 001 0
700	0,004 102 0	740	0,000 249 2	780	0,000 015 0	820	0,000 000 9
701	0,003 838 5	741	0,000 231 3	781	0,000 014 0	821	0,000 000 8
702	0,003 589 1	742	0,000 214 7	782	0,000 013 1	822	0,000 000 8
703	0,003 354 2	743	0,000 199 3	783	0,000 012 2	823	0,000 000 7
704	0,003 134 1	744	0,000 185 0	784	0,000 011 4	824	0,000 000 7
705	0,002 929 0	745	0,000 171 9	785	0,000 010 6	825	0,000 000 6
706	0,002 738 1	746	0,000 159 8	786	0,000 009 9	826	0,000 000 6
707	0,002 559 9	747	0,000 148 6	787	0,000 009 2	827	0,000 000 6
708	0,002 393 2	748	0,000 138 3	788	0,000 008 6	828	0,000 000 5
709	0,002 237 3	749	0,000 128 8	789	0,000 008 0	829	0,000 000 5
710	0,002 091 0	750	0,000 120 0	790	0,000 007 5	830	0,000 000 5
711	0,001 953 6	751	0,000 111 9	791	0,000 007 0		
712	0,001 824 6	752	0,000 104 3	792	0,000 006 5		
713	0,001 703 6	753	0,000 097 3	793	0,000 006 0		
714	0,001 590 2	754	0,000 090 8	794	0,000 005 6		
715	0,001 484 0	755	0,000 084 8	795	0,000 005 3		
716	0,001 384 5	756	0,000 079 1	796	0,000 004 9		
717	0,001 291 3	757	0,000 073 9	797	0,000 004 6		
718	0,001 204 1	758	0,000 068 9	798	0,000 004 3		
719	0,001 122 7	759	0,000 064 3	799	0,000 004 0		