

INTERNATIONAL STANDARD

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



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INTERNATIONAL STANDARD

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 5-6: Optoelectronic devices – Light emitting diodes

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- withdrawn,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.

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

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 $\lambda_1 = 400 \text{ nm}$ to $\lambda_2 = 750 \text{ nm}$ is recommended.

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

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

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

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

3.1.13**infrared-emitting diode**

IR LED

light emitting diode that emits infrared radiation

3.1.14

infrared radiation

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

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

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

IR-B: 1,4 µm to 3 µm;

IR-C: 3 µm to 1 mm.

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

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

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

3.1.15

ultraviolet-emitting diode

UV LED

light emitting diode that emits ultraviolet radiation

3.1.16

ultraviolet radiation

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

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

UV-A: 315 nm to 400 nm;

UV-B: 280 nm to 315 nm;

UV-C: 100 nm to 280 nm.

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

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

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

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

3.2.1

radiant energy

Q_e

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

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

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

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

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

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

[SOURCE: IEC 60050-845:2020, 845-21-041]

3.2.2

radiant flux

Φ_e

change in radiant energy with time

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

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

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

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

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

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

3.2.3

radiant intensity

I_e

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

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

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

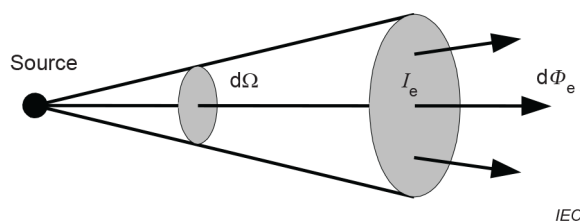


Figure 1 – Radiant intensity

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

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

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

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

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

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

3.2.4 radiance

L_e

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

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

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

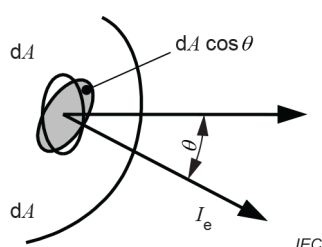


Figure 2 – Radiance

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

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

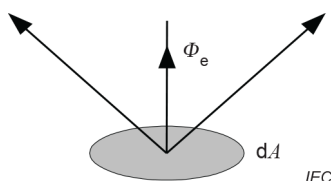


Figure 3 – Radiant exitance

[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

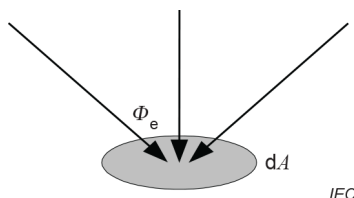


Figure 4 – Irradiance

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

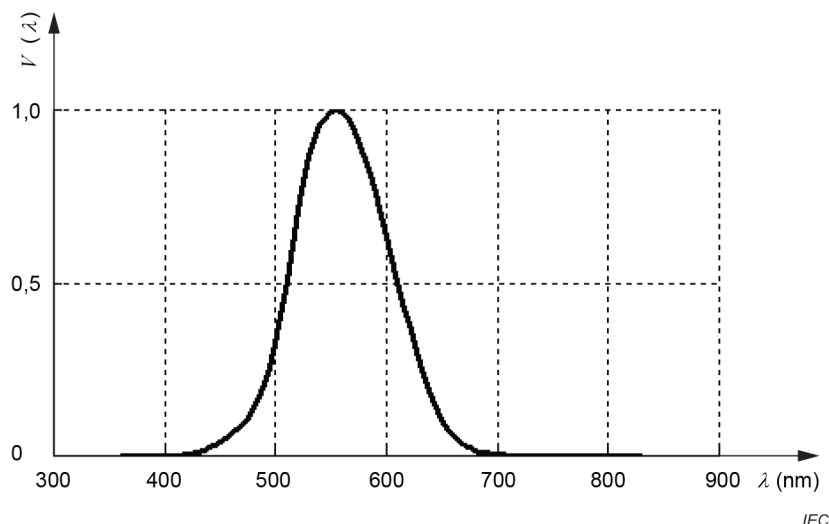


Figure 5 – Spectral luminous efficiency

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 ($\lambda = 555$ 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:

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

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 $\Phi_{e,\lambda}(\lambda)$ 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:

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

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

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

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

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

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

[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

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

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

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

Note 2 to entry: The luminance is expressed in candela per square metre ($\text{cd} \cdot \text{m}^{-2} = \text{lm} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}$).

[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

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

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

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

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

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

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

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

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

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

3.3.9

illuminance

E_v

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4.3

real thermal resistance

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

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

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

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

3.5 Abbreviations

PCB printed circuit board
AC alternating current
DC direct current

4 Absolute maximum ratings

Absolute maximum ratings are shown in Table 1. They are specified at the ambient temperature or the reference point temperature $T_X = (25 \pm 3) ^\circ C$, 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 $T_X = (25 \pm 3) ^\circ\text{C}$, 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	$I_F = \dots \text{ mA}$	–			V	○	○	○	○	○	○
Reverse current	I_R	see 6.5	$V_R = \dots \text{ V}$	–	–		μA	○	○	○	○	○	○
Luminous flux ^b	Φ_v	see 6.10	$I_F = \dots \text{ mA}$				lm	○	○	○	○		
Radiant flux ^c	Φ_e	see 6.11	$I_F = \dots \text{ mA}$				mW					○	○
Luminous intensity ^{b, d}	I_v	see 6.12	$I_F = \dots \text{ mA}$				mcd	○	○	○			
Radiant intensity ^c	I_e	see 6.13	$I_F = \dots \text{ mA}$				mW/sr					○	○
Luminance ^d	L_v	see 6.14	$I_F = \dots \text{ mA}$				cd/cm ²		○	○	○		
Peak emission wavelength ^e	λ_p	see 6.15	$I_F = \dots \text{ mA}$				nm	○	○		○	○	○
Spectrum width of half value	$\Delta\lambda$	see 6.15	$I_F = \dots \text{ mA}$	–		–	nm	○	○	○	○	○	○
Dominant emission wavelength ^e	λ_d	see 6.16	$I_F = \dots \text{ mA}$				nm	○	○	○	○		
Chromaticity ^f	x, y	see 6.16	$I_F = \dots \text{ mA}$				–	○	○	○	○		
Cut-off frequency ^{f, g}	f_c	see 6.9	$I_F = \dots \text{ mA}$ $I_p(f_0) = \dots \text{ mA}$ $f_0 = \dots \text{ MHz}$	–			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	$P_D = \dots \text{ mW}$	–		–	K/W	○				○	○
	$R_{th(j-X)real}$	see 6.7	$P_D = \dots \text{ mW}$	–		–	K/W	○				○	○
Power efficiency f, j	η_{PE}	IEC 60747-5-8	$I_F = \dots \text{ mA}$	–		–	–	○				○	○
Full width half maximum of an intensity ^k	$2\theta_{1/2}$	see 6.17	$I_F = \dots \text{ mA}$		–		°	○				○	○

^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 $\geq 0,5 \text{ W}$ and power efficiency $\geq 10 \%$.
^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 $(25 \pm 3) ^\circ\text{C}$ 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.

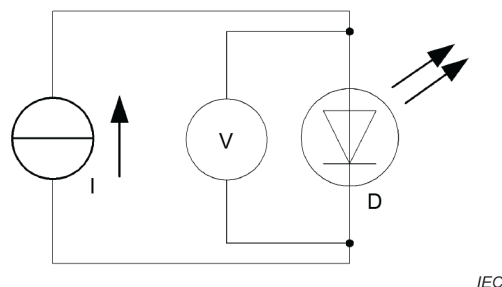
6.2 Forward voltage (V_F) measurement

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

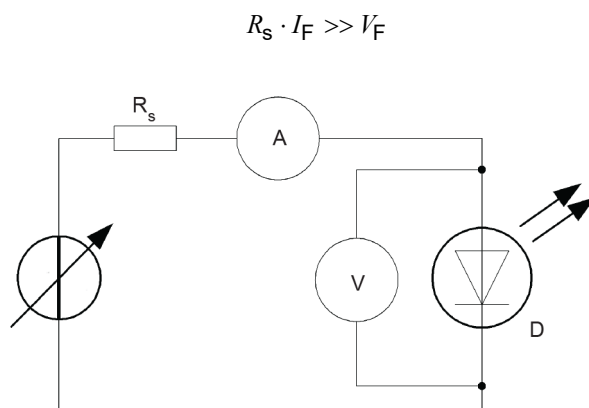
Figure 6 – Circuit diagram for V_F measurement

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.



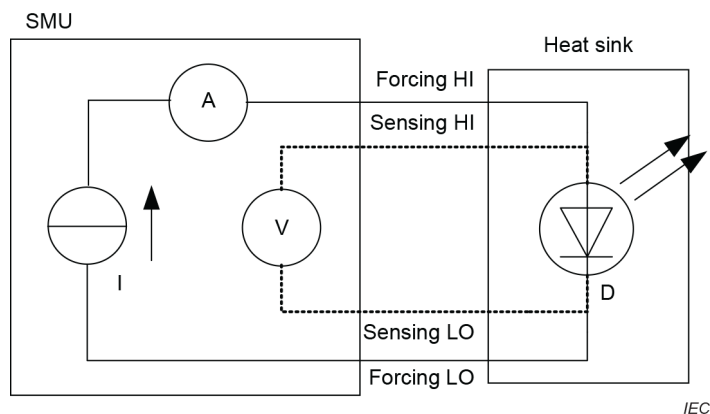
IEC

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.



IEC

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