

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**Dispositifs à semiconducteurs –
Partie 5-6: Dispositifs optoélectroniques – Diodes électroluminescentes**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2016 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

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

About IEC publications

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

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

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

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

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

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**Dispositifs à semiconducteurs –
Partie 5-6: Dispositifs optoélectroniques – Diodes électroluminescentes**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.080.99

ISBN 978-2-8322-3209-5

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	7
1 Scope.....	9
2 Normative references.....	9
3 Terms and definitions	10
3.1 General terms and definitions	10
3.2 Terms and definitions relating to the measurement of the quantity of radiation	12
3.3 Terms and definitions relating to the measurement of the photometric quantity.....	14
4 Absolute maximum ratings	17
5 Electrical and optical characteristics.....	18
6 Measuring method	19
6.1 Basic requirements	19
6.1.1 Measuring conditions	19
6.1.2 Measuring instruments and equipment.....	20
6.1.3 Essential requirements.....	21
6.1.4 General precautions.....	21
6.2 Forward voltage (V_F) measurement	22
6.2.1 Purpose	22
6.2.2 Circuit diagram	22
6.2.3 Requirements	22
6.2.4 Measurement procedure.....	23
6.2.5 Precautions to be observed	24
6.2.6 Specified conditions	24
6.3 Reverse voltage (V_R) measurement.....	24
6.3.1 Purpose	24
6.3.2 Circuit diagram	24
6.3.3 Measurement procedure.....	24
6.3.4 Precautions to be observed	24
6.3.5 Specified conditions	25
6.4 Differential resistance (r_f) measurement	25
6.4.1 Purpose	25
6.4.2 Circuit diagram	25
6.4.3 Requirements	25
6.4.4 Measurement procedure.....	25
6.4.5 Precautions to be observed	26
6.4.6 Specified conditions	26
6.5 Reverse current (I_R) measurement.....	26
6.5.1 Purpose	26
6.5.2 Circuit diagram	26
6.5.3 Provisions.....	27
6.5.4 Measurement procedure.....	27
6.5.5 Precautions to be observed	27
6.5.6 Specified conditions	27
6.6 Measurement of capacitance between terminals (C_t).....	27
6.6.1 General	27

6.6.2	Measurement using LCR meter	27
6.6.3	Measurement using AC bridge.....	28
6.7	Measurement of junction temperature and thermal resistance ($R_{th(j-X)}$).....	29
6.7.1	Purpose	29
6.7.2	Measurement principle	29
6.7.3	Measurement procedure.....	30
6.7.4	Precautions to be observed	33
6.8	Response time measurement	34
6.8.1	Purpose	34
6.8.2	Circuit diagram	34
6.8.3	Provisions.....	34
6.8.4	Measurement procedure.....	34
6.8.5	Precautions to be observed	35
6.8.6	Specified conditions	35
6.9	Frequency response and cut-off frequency (f_c) measurement.....	36
6.9.1	Purpose	36
6.9.2	Circuit diagram	36
6.9.3	Provisions.....	37
6.9.4	Measurement procedure.....	37
6.9.5	Precautions to be observed	38
6.9.6	Specified conditions	38
6.10	Luminous flux (Φ_V) measurement.....	38
6.10.1	Purpose	38
6.10.2	Measurement principle	38
6.10.3	Measuring circuit.....	38
6.10.4	Measurement procedure.....	39
6.10.5	Precautions to be observed	39
6.10.6	Measurement conditions to be defined.....	40
6.11	Radiant power (Φ_e) measurement	40
6.11.1	Purpose	40
6.11.2	Measurement principle	40
6.11.3	Measuring circuit.....	40
6.11.4	Measurement procedure.....	41
6.11.5	Precautions to be observed	41
6.11.6	Measurement conditions to be defined.....	42
6.12	Luminous intensity (I_V) measurement.....	42
6.12.1	Purpose	42
6.12.2	Measurement principle	42
6.12.3	Measuring circuit.....	43
6.12.4	Measurement procedure.....	44
6.12.5	Precautions to be observed	44
6.12.6	Measurement conditions to be defined.....	44
6.13	Radiant intensity (I_e) measurement	44
6.13.1	Purpose	44
6.13.2	Measurement principle	44
6.13.3	Measuring circuit.....	45
6.13.4	Measurement procedure.....	45
6.13.5	Measurement conditions to be defined.....	45
6.14	Luminance (L_V) measurement.....	45

6.14.1	Purpose	45
6.14.2	Measuring circuit.....	46
6.14.3	Measurement procedure.....	46
6.14.4	Measurement conditions to be defined	46
6.15	Emission spectrum distribution, peak emission wavelength (λ_p), and spectral half bandwidth ($\Delta\lambda$) measurement.....	47
6.15.1	Purpose	47
6.15.2	Measuring circuit.....	47
6.15.3	Measurement procedure.....	48
6.15.4	Measurement conditions to be defined	48
6.16	Chromaticity measurement	49
6.16.1	Purpose	49
6.16.2	Measurement principle	49
6.16.3	Measuring circuit.....	51
6.16.4	Measurement procedure.....	51
6.16.5	Measuring conditions to be defined	51
6.17	Directional characteristics measurement.....	51
6.17.1	Purpose	51
6.17.2	Measuring circuit.....	51
6.17.3	Measurement procedure.....	52
6.17.4	Measuring conditions to be defined	53
6.18	Illuminance (E_V) measurement	54
6.18.1	Purpose	54
6.18.2	Measuring circuit.....	54
6.18.3	Measurement procedure.....	54
6.18.4	Measuring conditions to be defined	54
7	Items to be indicated on the package	54
8	Quality evaluation	55
8.1	Classification of quality evaluations	55
8.1.1	General	55
8.1.2	Classification I	55
8.1.3	Classification II	55
8.1.4	Classification III	55
8.1.5	Precautions to be observed	55
8.2	Quality evaluation test.....	60
8.2.1	General	60
8.2.2	Specimens.....	60
8.3	Lot quality inspection	60
8.3.1	General	60
8.3.2	Specimens.....	60
8.4	Periodical quality inspection	60
8.4.1	General	60
8.4.2	Specimens.....	60
8.4.3	Inspection period	60
8.5	Easing of the lot quality inspection standards.....	61
8.6	Periodical evaluation maintenance tests	61
8.6.1	Test items and specimens	61
8.6.2	Test period	61
8.7	Long-term storage products.....	61

8.8	Continuous current test	61
8.8.1	General	61
8.8.2	Initial measurement.....	61
8.8.3	Test circuits	61
8.8.4	Test conditions	62
8.8.5	Post-treatment	62
8.8.6	Final measurement	62
Annex A (normative)	Standard luminous efficiency	63
Annex B (normative)	How to obtain the self-absorption correction factor	66
B.1	Purpose	66
B.2	LED light sources for self-absorption measurement.....	66
B.3	Method	66
Annex C (normative)	How to obtain the colour correction factor	68
C.1	Purpose	68
C.2	Method	68
C.2.1	Luminous flux and luminous intensity measurement.....	68
C.2.2	Radiant power and radiant intensity measurement	69
Annex D (normative)	Calibration of the luminance meter.....	70
D.1	Purpose	70
D.2	How to perform the calibration	70
Annex E (normative)	Colour-matching function of the XYZ colour system	72
Annex F (normative)	Spectral chromaticity coordinates	77
Annex G (normative)	Illuminometer calibration.....	82
G.1	Purpose	82
G.2	How to perform the calibration	82
Bibliography		83
Figure 1 – Radiant intensity		12
Figure 2 – Radiance.....		13
Figure 3 – Radiant exitance		14
Figure 4 – Irradiance.....		14
Figure 5 – Spectral luminous efficiency		15
Figure 6 – Circuit diagram for V_F measurement		22
Figure 7 – Circuit diagram for V_F measurement with a constant voltage source and a current-limiting resistor		23
Figure 8 – Circuit diagram for V_F measurement using an SMU		23
Figure 9 – Circuit diagram for V_R measurement.....		24
Figure 10 – circuit diagram for r_f measurement		25
Figure 11 – Circuit diagram for I_R measurement.....		26
Figure 12 – Circuit diagram for C_t measurement		27
Figure 13 – Circuit diagram for C_t measurement		28
Figure 14 – Circuit diagram for measurement of change in V_F		30
Figure 15 – Waveform of change in V_F		32
Figure 16 – Transient change in thermal resistance (double-logarithmic plots)		33
Figure 17 – Circuit diagram for response time measurement.....		34
Figure 18 – Waveform of response time measurement.....		36

Figure 19 – Circuit diagram for f_c measurement.....	37
Figure 20 – Circuit diagram for Φ_V measurement.....	39
Figure 21 – circuit diagram for Φ_e measurement.....	41
Figure 22 – Schematic diagram for I_V measurement.....	43
Figure 23 – Circuit diagram for I_V measurement.....	43
Figure 24 – circuit diagram for I_e measurement.....	45
Figure 25 – Circuit diagram for L_V measurement.....	46
Figure 26 – Circuit diagram for λ_p measurement.....	47
Figure 27 – Circuit diagram for λ_p measurement.....	48
Figure 28 – Schematic diagram of $\Delta\lambda$ measurement.....	48
Figure 29 – Chromaticity	50
Figure 30 – Circuit diagram for chromaticity measurement	52
Figure 31 – Directional characteristics (example 1).....	53
Figure 32 – Directional characteristics (example 2).....	53
Figure 33 – Circuit diagram for E_V measurement.....	54
Figure 34 – Circuit diagram for continuous current test	62
Figure B.1 – Schematic diagram for self-absorption measurement	66
Figure D.1 – Schematic diagrams for calibration	71
Figure G.1 – Schematic diagram for calibration	82
Table 1 – Absolute maximum ratings	18
Table 2 – Electrical and optical characteristics	19
Table 3 – CIE averaged LED intensity measurements.....	43
Table 4 – Items for the screening test and their conditions(reference)	55
Table 5 – Quality evaluation tests (1 of 2)	56
Table 6 – Lot quality inspection	58
Table 7 – Periodical quality inspection.....	59
Table A.1 – Definitive values of the spectral luminous efficiency function for photopic vision $V(\lambda)$ (1 of 3).....	63
Table E.1 – Colour-matching function of the XYZ colour system (1 of 5).....	72
Table F.1 – Spectral chromaticity coordinates (1 of 5).....	77

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 5-6: Optoelectronic devices – Light emitting diodes

FOREWORD

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

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

This first edition of IEC 60747-5-6, together with IEC 60747-5-4, IEC 60747-5-5 and IEC 60747-5-7, cancels and replaces IEC 60747-5-1, IEC 60747-5-2 and IEC 60747-5-3, published in 1997, and their amendments. This edition constitutes a technical revision.

This edition includes significant technical changes to the clauses for light emitting diodes in IEC 60747-5-1:1997, IEC 60747-5-2:1997 and IEC 60747-5-3:1997, including their amendments.

The text of this standard is based on the following documents:

FDIS	Rapport de vote
47E/529/FDIS	47E/535/RVD

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

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

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

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

The types of LED are divided into the following five classes:

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

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, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

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, *Sampling procedures for inspection by attributes*

3 Terms and definitions

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

3.1 General terms and definitions

3.1.1

integrating sphere

hollow sphere whose internal surface is a diffuse reflector, as non-selective as possible

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

3.1.2

diffuse reflector

reflector composed of a surface with diffuse reflection

3.1.3

diffuse reflection

diffusion by reflection in which, on the macroscopic scale, there is no regular reflection

[SOURCE: IEC 60050-845:1987, 845-04-47]

3.1.4

diffuse transmission

diffusion by transmission in which, on the macroscopic scale, there is no regular transmission

[SOURCE: IEC 60050-845:1987, 845-04-48]

3.1.5

diffuse reflectance

R_d

ratio of the diffusely reflected part of the (whole) reflected flux, to the incident flux

Note 1 to entry: $R = R_r + R_d$

Note 2 to entry: The results of the measurements of R_r and R_d depend on the instruments and the measuring techniques used.

[SOURCE: IEC 60050-845:1987, 845-04-62]

3.1.6

diffuse transmittance

T_d

ratio of the diffusely transmitted part of the (whole) transmitted flux, to the incident flux

Note 1 to entry: $T = T_r + T_d$

Note 2 to entry: The results of the measurements of T_r and T_d depend on the instruments and the measuring techniques used.

[SOURCE: IEC 60050-845:1987, 845-04-63]

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 or luminous exitance, and L the radiance or luminance.

[SOURCE: IEC 60050-845:1987, 845-04-57]

3.1.8

spectral reflectance

$R(\lambda)$

ratio between the spectral radiant flux of wavelength λ that is reflected by an object and the spectral radiant flux of wavelength λ that is absorbed by the object

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

3.1.9

spectral transmittance

$T(\lambda)$

ratio between the spectral radiant flux of wavelength λ that is transmitted by an object and the spectral radiant flux of wavelength λ that is absorbed by the object

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

3.1.10

spectral distribution

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

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

3.1.11

spectral sensitivity

$S(\lambda)$

light sensitivity as a function of wavelength

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

3.1.12 distribution temperature

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

Note 1 to entry: The unit used is: K.

[SOURCE: IEC 60050-845:1987, 845-04-14]

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

3.2.1 radiant energy

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

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

Note 1 to entry: The unit used is: J (1 J = 1 W · s).

[SOURCE: IEC 60050-845:1987, 845-01-27]

3.2.2 radiant flux

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

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

Note 1 to entry: The unit used is: W.

[SOURCE: IEC 60050-845:1987, 845-01-24, modified – The formula has been added.]

3.2.3 radiant intensity

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

$$I_e = \frac{d\Phi_e}{d\Omega} \text{ (d}\Omega\text{: solid angle)}$$

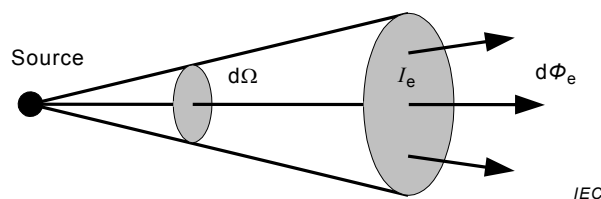


Figure 1 – Radiant intensity

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

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

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

3.2.4 radiance

L_e

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

where

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

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

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

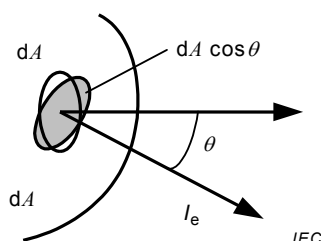


Figure 2 – Radiance

Note 1 to entry: The unit used is: W/(sr·m²).

[SOURCE: IEC 60050-845:1987, 845-01-34, modified – omitting the part about Notes]

3.2.5 radiant exitance

M_e

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

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

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

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

[SOURCE: IEC 60050-845:1987, 845-01-47]

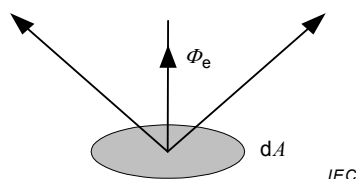


Figure 3 – Radiant exitance

3.2.6 irradiance

E_e
quotient of the radiant flux $d\Phi_e$ incident on an element of the surface containing the point, by the area dA of that element

$$E_e = \frac{d\Phi_e}{dA} \quad (dA: \text{small area})$$

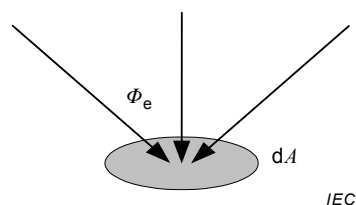


Figure 4 – Irradiance

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

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

[SOURCE: IEC 60050-845:1987, 845-01-37]

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

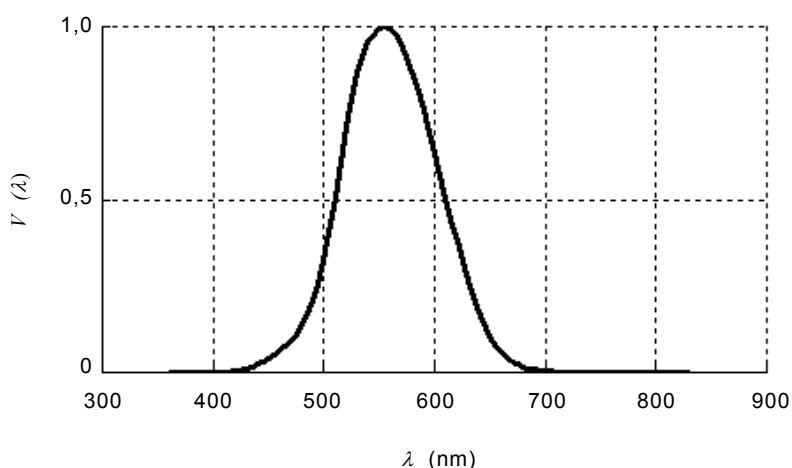
3.3.1 photometric standard lamp

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



IEC

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 numeric scheme for the spectral luminous efficiency, respectively.

3.3.3 maximum spectral luminous efficiency

K_m

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

Note 1 to entry: 683 (1 m/W) ($\lambda = 555$ nm) is the value adopted by the CIPM.

3.3.4 luminous flux

Φ_v

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

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

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

where

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

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

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

3.3.5 quantity of light

Q_v

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

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

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

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

3.3.6

luminous intensity

I_V

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

$$I_V = \frac{d\Phi_V}{d\Omega} \quad (d\Omega: \text{solid angle})$$

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

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

Note 3 to entry: A luminous intensity of 1 cd is defined as $1/(60 \times 10^4)$ of the perpendicular oriented luminous intensity on a 1-m² flat surface of a black-body whose temperature is equivalent to the freezing point of platinum under a pressure of 101,325 N/m².

Note 4 to entry: The unit used is: cd (1 cd = 1 lm·sr⁻¹).

[SOURCE: IEC 60050-845:1987, 845-01-31, modified – Two notes to entry have been added.]

3.3.7

luminance

L_V

quantity defined by the formula

$$L_V = \frac{d\Phi_V}{dA \cdot \cos\theta \cdot d\Omega},$$

where

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

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

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

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

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

[SOURCE: IEC 60050-845:1987, 845-01-35, modified – The note has been removed and a new note has been added.]

3.3.8

luminous exitance

M_V

quotient of the luminous flux $d\Phi_V$ leaving an element of the surface containing the point, by the area dA of that element

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

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

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

Note 3 to entry: The unit used is: lm/m^2 .

[SOURCE: IEC 60050-845:1987, 845-01-48, modified – Note 2 to entry has been added.]

3.3.9 illuminance

E_v
quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element

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

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

Note 2 to entry: The spatial definition of illuminance is shown in Figure 4; however, symbol ϕ_e should be changed to ϕ_v .

Note 3 to entry: The unit used is: lx (1 lx = 1 lm/m^2).

[SOURCE: IEC 60050-845:1987, 845-01-38, modified – Note 2 to entry has been added.]

4 Absolute maximum ratings

Absolute maximum ratings are shown in Table 1. They are specified at the ambient temperature or the reference point temperature $T_X = (25 \pm 3) ^\circ\text{C}$, unless otherwise stated.

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

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

Table 1 – Absolute maximum ratings

Item	Symbol	Conditions	Ratings	Unit	To be applicable for LEDs of type				
					a)	b)	c)	d)	e)
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 five types of LED as described in Clause 1:

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

Table 2 – Electrical and optical characteristics

Item	Symbol	Measuring method	Conditions	Characteristics			Unit	To be applicable for				
				min.	typ.	max.		a)	b)	c)	d)	e)
Forward voltage	V_F	see 6.2	$I_F =$ mA	–			V	○	○	○	○	○
Reverse current	I_R	see 6.5	$V_R =$ V	–	–		µA	○	○	○	○	○
Luminous intensity	I_V	see 6.12	$I_F =$ mA				mcd	○		○		
Radiant intensity ^b	I_e	see 6.13	$I_F =$ mA				mW/sr					○
Luminance ^c	L_v	see 6.14	$I_F =$ mA				cd/cm ²		○		○	
Peak emission wavelength	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	λ_d	see 6.16	$I_F =$ mA				nm	○				
Chromaticity ^d	X,Y	see 6.16	$I_F =$ mA				–	○				
Cut-off frequency ^{d,e}	f_c	see 6.9	$I_F =$ mA $I_p(f_0) =$ mA $f_0 =$ MHz	–			MHz					○
Thermal resistance ^{d,f}	$R_{th(j-X)}$	see 6.7	$P_D =$ mW	–		–	K/W	○				○

^a These values are specified for each segment.

^b Either radiant intensity or luminous flux is specified.

^c Either luminance or luminous intensity is specified.

^d These items are specified when necessary.

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

^f 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.

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

6 Measuring method

6.1 Basic requirements

6.1.1 Measuring conditions

The measuring conditions are the following:

a) Temperature

If not specified, measurements shall be made at an ambient (T_a) or reference point temperature (T_X) of $(25 \pm 3)^\circ\text{C}$ in a condition of free air.

b) Humidity

When humidity condition is not specified, relative humidity shall be between 45 % and 85 %.

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

- a) when no serious influence affects a measurement result;
- b) when no serious influence affects a judgment of result.

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

6.1.2.4 Standard light source

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

6.1.2.5 Measuring instruments for photometry

One of the following instruments shall be used:

- a) A 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 ($I(\lambda)$ 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. 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.

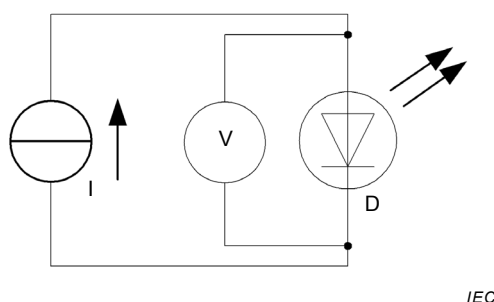
6.2 Forward voltage (V_F) measurement

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.



IEC

Key

I constant current source

V voltmeter

D light-emitting diode being measured

Figure 6 – Circuit diagram for V_F measurement

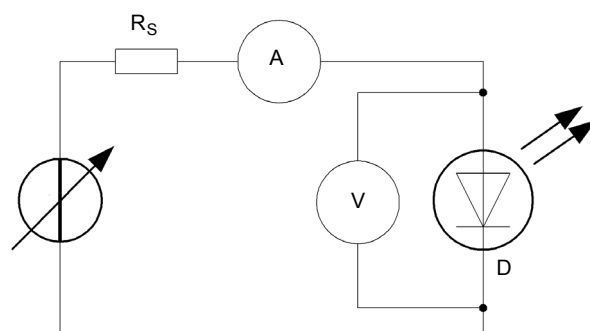
6.2.3 Requirements

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

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

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.

$$R_S \cdot I_F \gg V_F$$



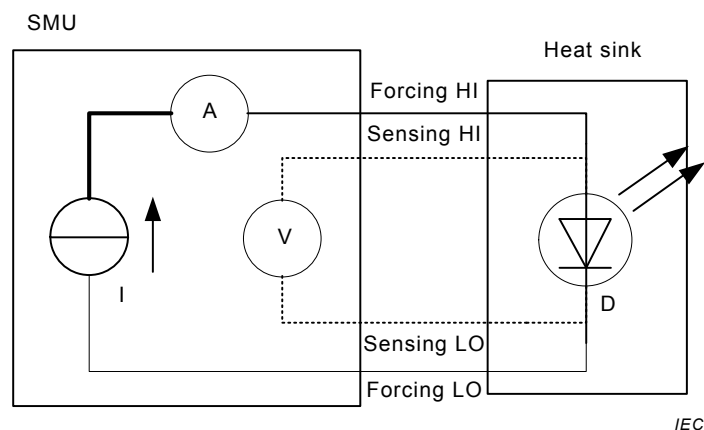
IEC

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

6.2.4 Measurement procedure

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

6.2.5 Precautions to be observed

See 6.1.

6.2.6 Specified conditions

The specified conditions are as follows:

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

6.3 Reverse voltage (V_R) measurement

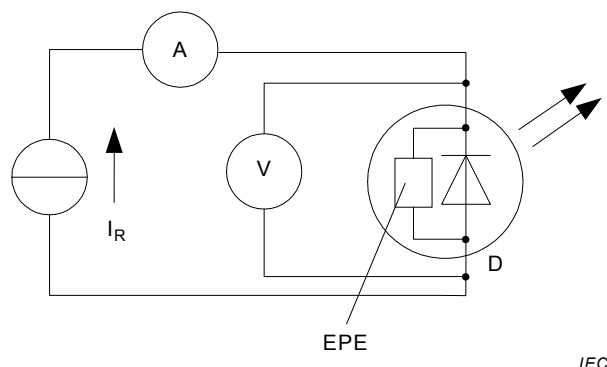
6.3.1 Purpose

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

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

6.3.2 Circuit diagram

The circuit diagram is shown in Figure 9.



Key

- I_R 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

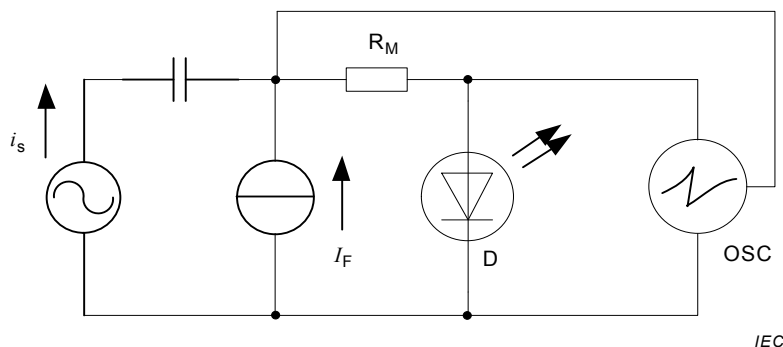
6.4.1 Purpose

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

NOTE Generally the series resistance of an 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 current
- I_F forward DC current
- 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 current is superimposed on the specified DC current.

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 current and AC current 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.

- The frequency of AC current to be superimposed should be around 10 kHz so that it will not affect the measurement.
- The forward current including AC current should be as high as possible within the rated value.
- 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 current to be superimposed, or the amplitude modulation factor ($M = (\max(i_s))/I_F$);
- ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_x).

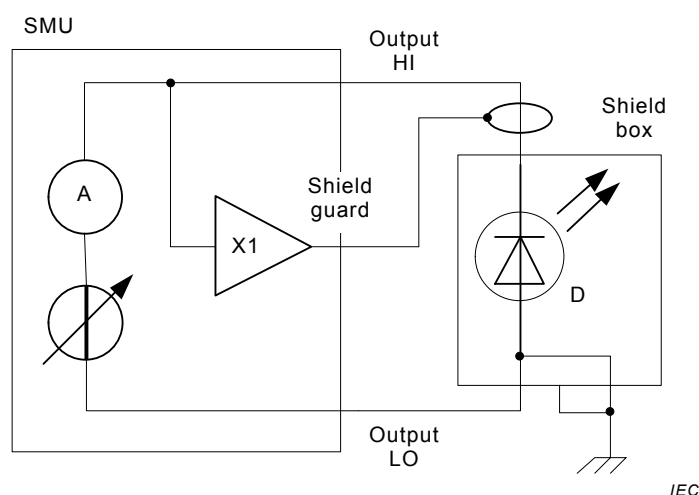
6.5 Reverse current (I_R) measurement

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

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.

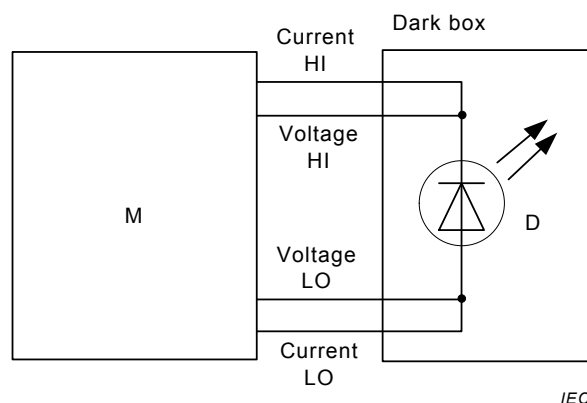
6.6.2 Measurement using LCR meter

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).

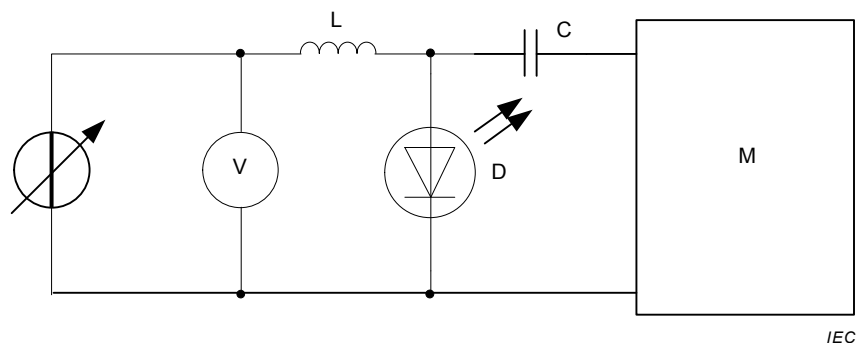
6.6.3 Measurement using AC bridge

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 1MHz is used;
- ambient temperature (T_a), case temperature (T_c) or reference point temperature (T_X).

6.7 Measurement of junction temperature and thermal resistance ($R_{th(j-x)}$)

6.7.1 Purpose

To measure the junction temperature and thermal resistance of the LED under established conditions.

6.7.2 Measurement principle

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

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

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

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

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

a) Saturated thermal resistance

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

b) Transient thermal resistance

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

6.7.3 Measurement procedure

6.7.3.1 Measurement of temperature coefficient of forward voltage (V_F)

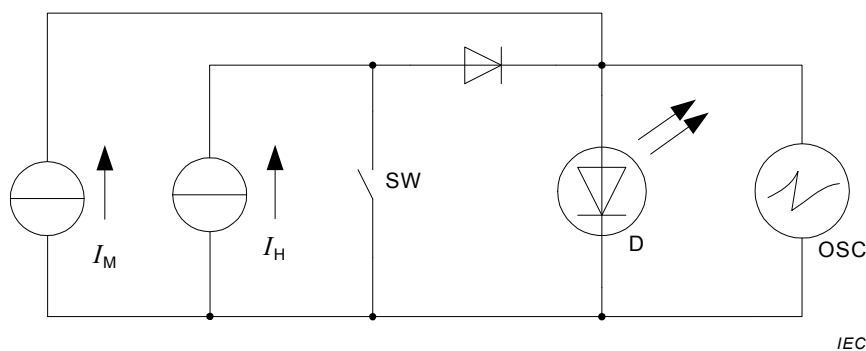
The relationship between the forward voltage (V_F) and junction temperature (T_j) is obtained as the temperature coefficient by the following procedure.

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

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

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

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



Key

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

Figure 14 – Circuit diagram for measurement of change in V_F

6.7.3.3 Thermal resistance measurement

6.7.3.3.1 Transient thermal resistance measurement

The switch is closed beforehand.

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

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

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

The switch is then closed.

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

6.7.3.3.2 Saturated thermal resistance measurement

Close the switch beforehand.

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

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

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

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

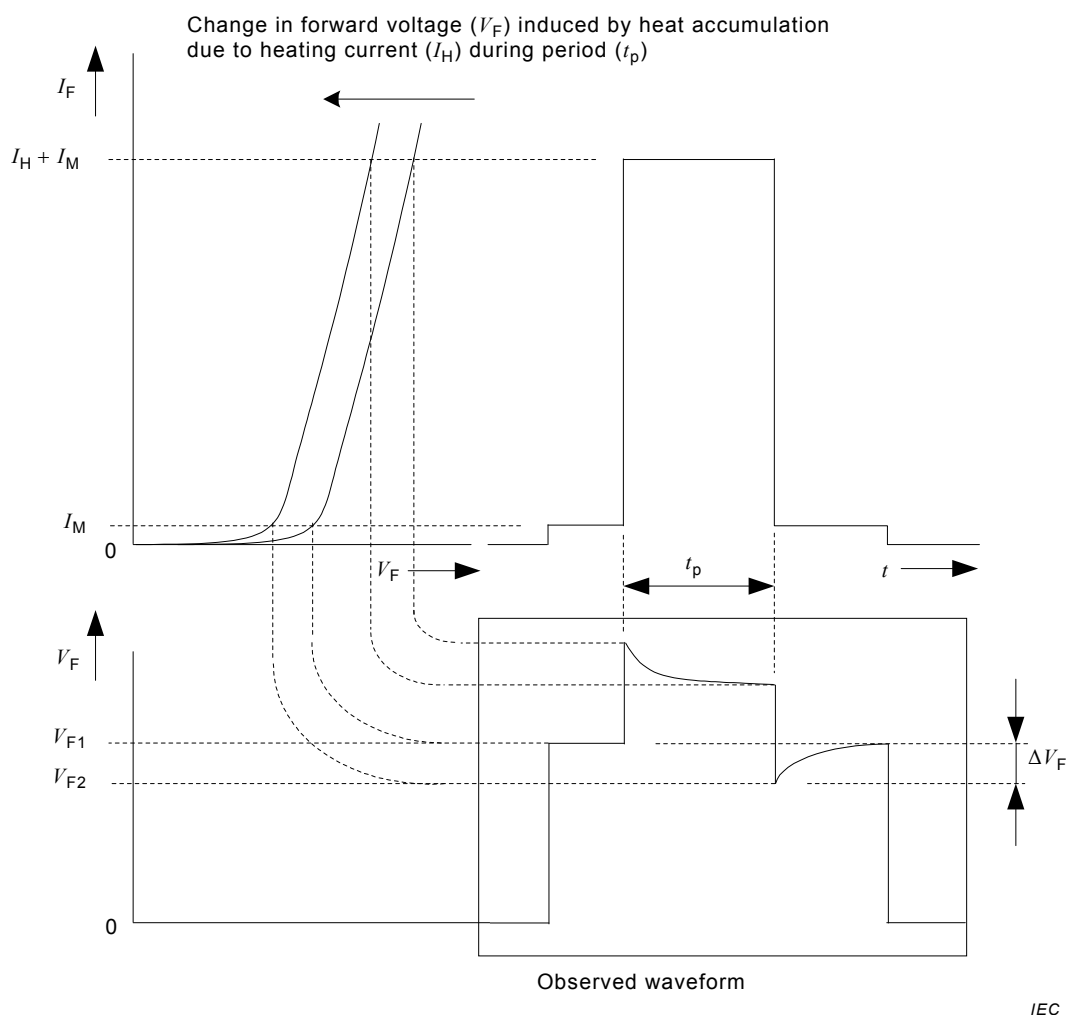


Figure 15 – Waveform of change in V_F

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

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

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

6.7.3.4 Calculation of thermal resistance

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

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

where

T_j is the junction temperature;

T_X is the reference point temperature;

P is the total power dissipation;

b is the temperature coefficient of the forward voltage;

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

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

Two saturated regions are observed in this example.

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

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

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

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

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

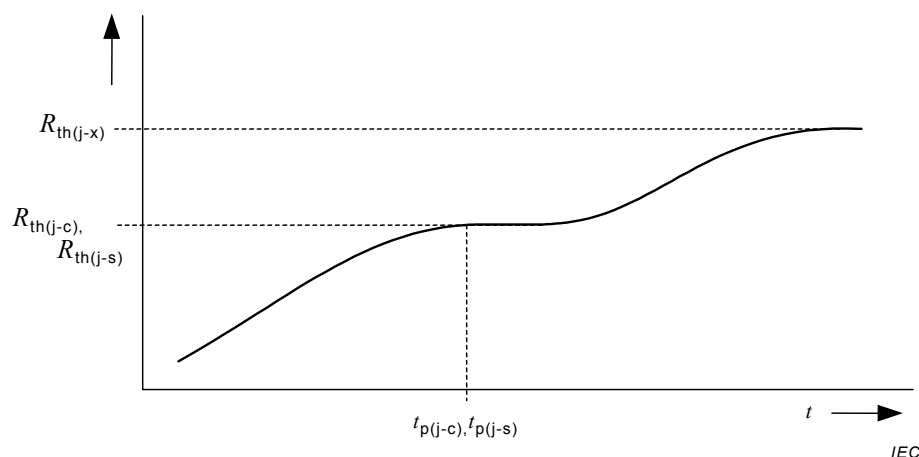


Figure 16 – Transient change in thermal resistance (double-logarithmic plots)

6.7.4 Precautions to be observed

The precautions to be observed are as follows.

- Heating current (I_H) shall be set as high as possible so as to ensure the detection sensitivity of forward voltage difference ΔV_F before and after heating.
- For details other than those provided in a) above, see 6.1.

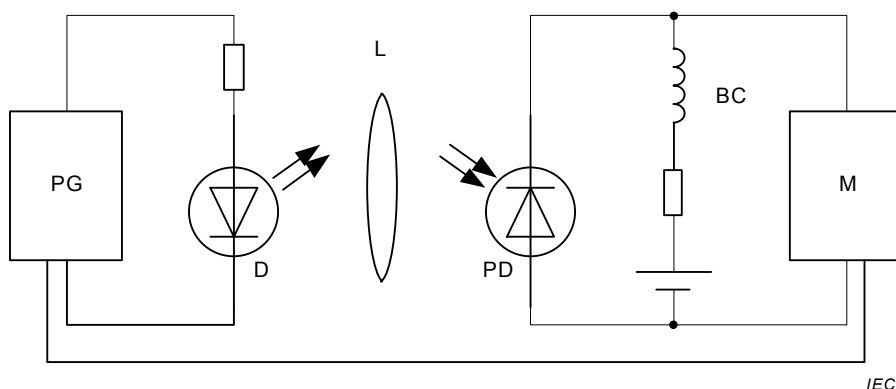
6.8 Response time measurement

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 17.



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 17 – Circuit diagram for response time measurement

6.8.3 Provisions

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

The rise and fall times of the pulse generator and the optical pulse measurement system should be sufficiently lower than the response time of the test LED. The responsiveness 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.

- Apply the specified forward current pulse to the test LED.
- 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 18 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:

- a) ambient temperature (T_a), case temperature (T_c), or reference point temperature (T_X);
- b) input pulse signal (pulse current, pulse width, duty ratio).

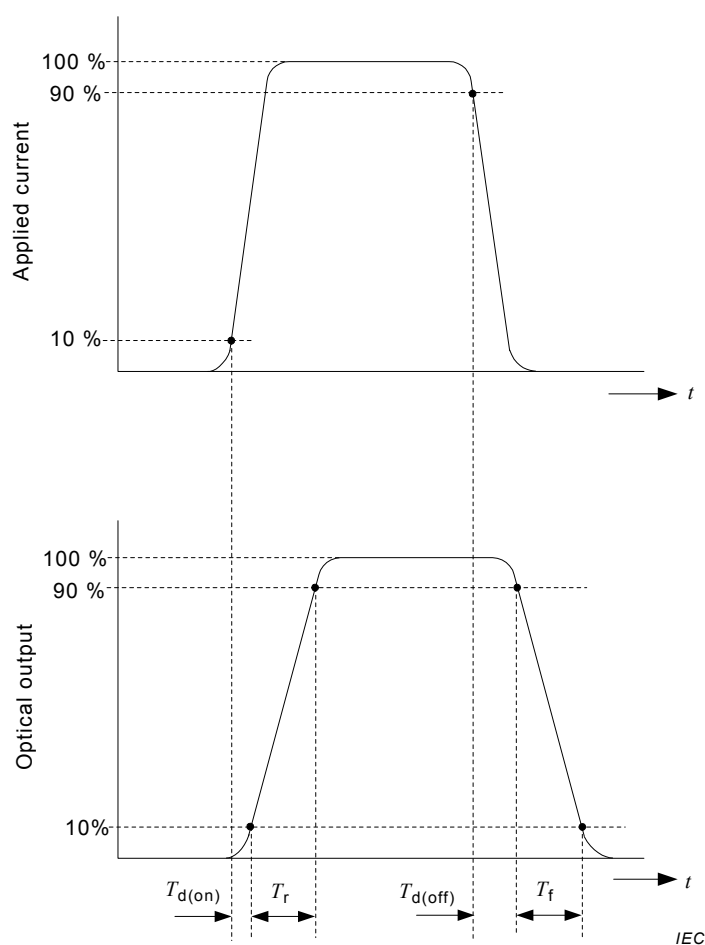


Figure 18 – Waveform of response time measurement

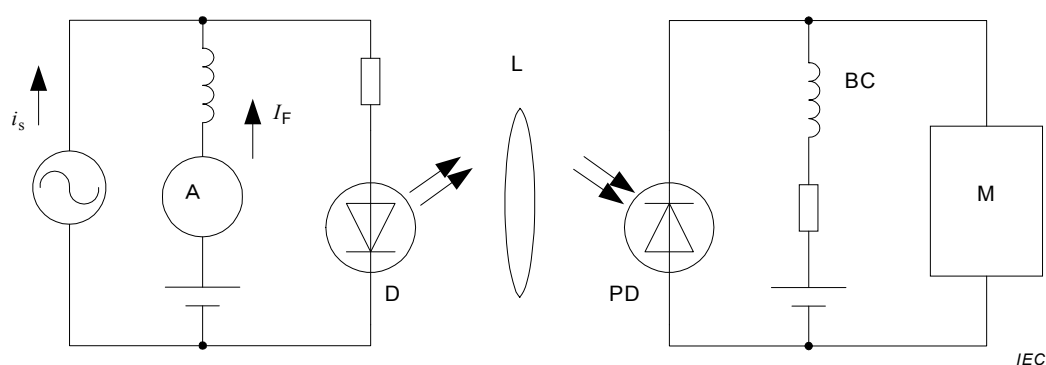
6.9 Frequency response and cut-off frequency (f_c) measurement

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 19 in principle.

**Key**

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

Figure 19 – Circuit diagram for f_c measurement**6.9.3 Provisions**

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

The responsiveness 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.

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 current 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 current, $i_p(f)$, 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 ($f_0 \leq f_c/100$) 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.

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

6.9.5 Precautions to be observed

The precautions to be observed are as follows.

- 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.
- The linearity of the optical signal measurement system should be corrected to within the measurement range of the measured value before use.
- 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.
- 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 ($\max(|i_s|)$) or modulation factor ($M = (\max(|i_s|))/I_F$) of the AC signal current.

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

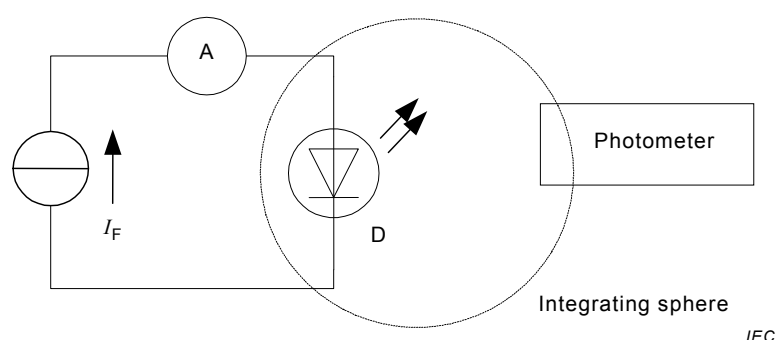
Alternately illuminate a luminous-flux standard LED whose total flux (Φ_{VS}) is known and the test LED at the centre of the integrating sphere and read the output value from each photometer. With I_{VS} as the optical output of the photometer when the luminous-flux standard LED is illuminated under established conditions and I_{VT} as the optical output of the photometer when the test LED is illuminated, the total flux $\Phi_{VT}(1m)$ 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 20 in principle.

**Key**

I_F forward DC current

D light-emitting diode being measured

Figure 20 – Circuit diagram for Φ_V measurement

It is preferable that a monochromator-method or polychromator-method photometer 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.

- 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).
- 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.

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

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

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

where

α is the self-absorption correction factor;

k is the colour correction factor.

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

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

- b) The light receiving luminous flux and the optical output of the photometer shall be in direct proportion to each other. If they are not in direct proportion to each other, they need to be corrected.
- c) The diameter of the integrating sphere shall be sufficiently larger than the test device in principle. The size of the light shielding plate should be the minimum required to completely block the light source viewed from the photometer window. The plate should be fixed on the line connecting the centre of the integrating sphere and the photometer window at a point that is a third to half the radius from the centre. All parts of the inner surface of the integrating sphere shall be diffusing surfaces that provide as uniform a reflectivity as possible (Lambertian surface).

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

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

6.11 Radiant power (Φ_e) measurement

6.11.1 Purpose

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

6.11.2 Measurement principle

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

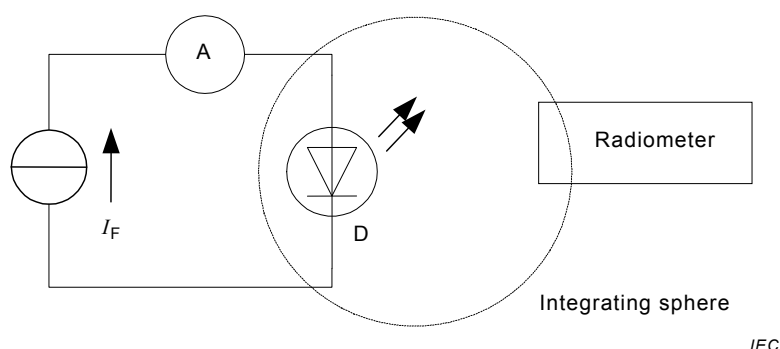
With I_{eS} as the optical output of the radiometer when the radiant-power standard LED is illuminated under established conditions and I_{eT} as the output of the radiometer when the test LED is illuminated, the radiant power Φ_{eT} of the test LED will be as follows.

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

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 21 in principle.

**Key**

I_F forward DC current

D light-emitting diode being measured

Figure 21 – 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.

- Perform the measurement by alternately placing the test LED and the radiant-power standard LED in the centre of the integrating sphere.
Start the photometry when the radiant power has reached a stable state during the preliminary lighting time (sufficient time for changes in the radiant power resulting from the temperature rise of the test LED when it is turned on to become stable).
- Read each measured output value for the test LED and the radiant-power standard LED shown on the radiometer.

6.11.5 Precautions to be observed

The precautions to be observed are as follows.

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

If the configuration and emission spectrum distribution of the radiant-power 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:

- a) forward current (I_F);
- b) 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 22.

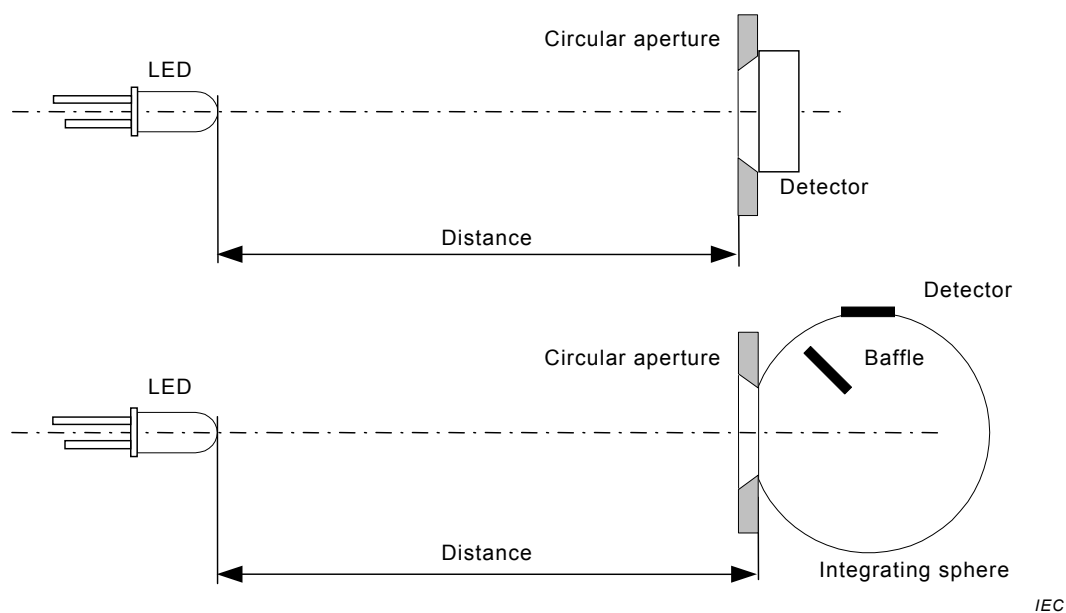


Figure 22 – Schematic diagram for I_V measurement

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.

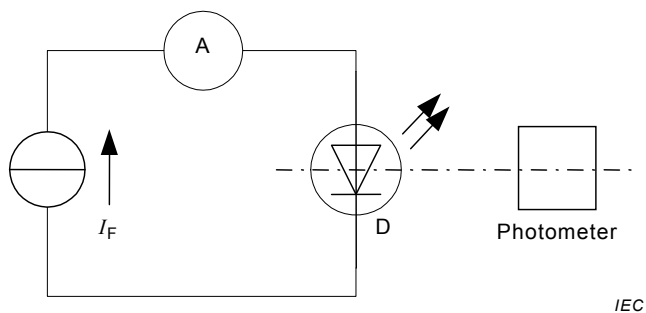
Table 3 shows the view angle conditions for CIE-averaged LED intensity.

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 23 in principle.



Key

I_F forward DC current

D light-emitting diode being measured

Figure 23 – 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:

- a) forward current (I_F) and current-carrying time;
- b) distance (visual) condition;
- c) 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

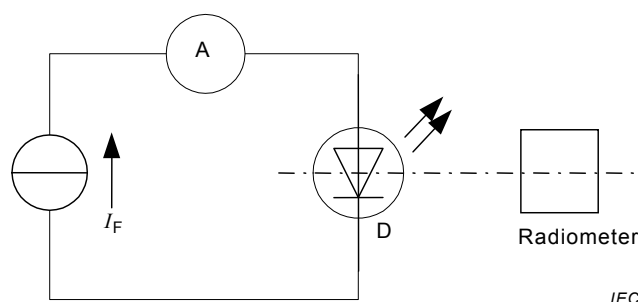
The radiant intensity measurement shall conform to the visual (solid angle) conditions and the conditions for the positional relation between the light receiving portion and the LED, as specified for the measurement of CIE-averaged LED intensity in 6.12. This measurement is performed by alternately turning on a radiant-intensity standard LED whose radiant intensity (I_{es}) 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 24 in principle.



Key

I_F forward DC current

D light-emitting diode being measured

Figure 24 – circuit diagram for I_e measurement

6.13.4 Measurement procedure

The measurement procedure is as follows.

- 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.
- 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.
- 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

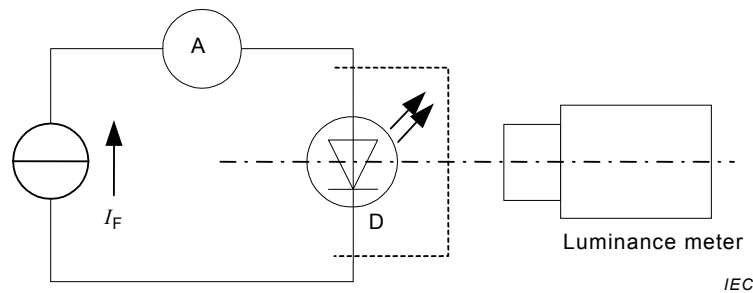
6.14.1 Purpose

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

6.14.2 Measuring circuit

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

Commonly-used LED flat illuminators usually have multiple LED dies. Figure 25 shows an example of an 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 current

D light-emitting diode being measured

Figure 25 – Circuit diagram for L_v measurement

6.14.3 Measurement procedure

The measurement procedure is as follows.

- 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.
- 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.
- 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_{rp});

- d) position on the emitting face;
- e) measured surface.

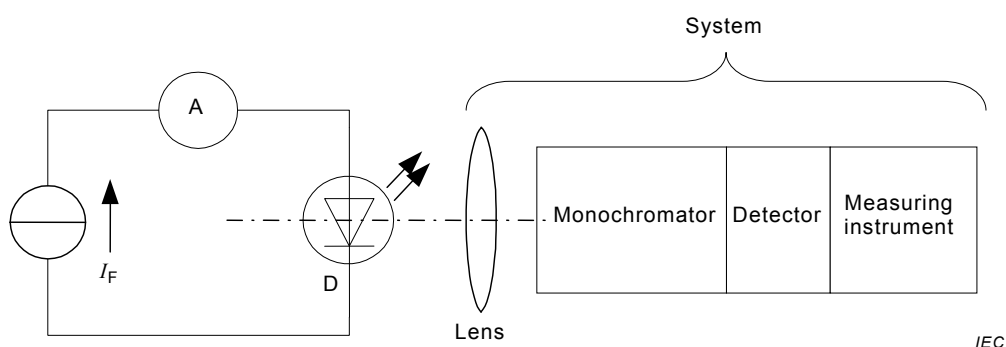
6.15 Emission spectrum distribution, peak emission wavelength (λ_p), and spectral half bandwidth ($\Delta\lambda$) measurement

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 26 in principle.



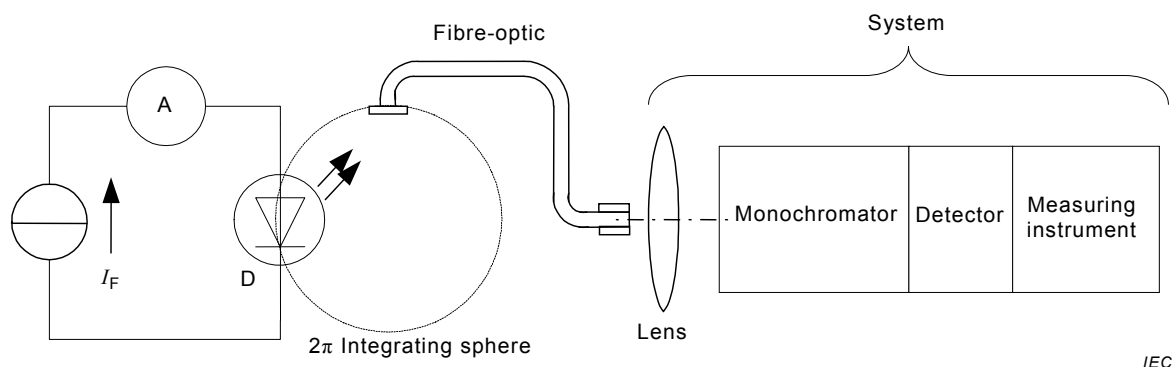
Key

I_F forward DC current

D light-emitting diode being measured

Figure 26 – 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 27. Particularly for measurements with an 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 27 unless otherwise specified.



Key

I_F forward DC current

D light-emitting diode being measured

Figure 27 – Circuit diagram for λ_p measurement

6.15.3 Measurement procedure

The measurement procedure is the following.

- 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.
- 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 28).
- Obtain the wavelength corresponding to the maximum value of the emission spectrum (peak emission wavelength (λ_p)) from the emission spectrum distribution (see Figure 28).
- 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 28).

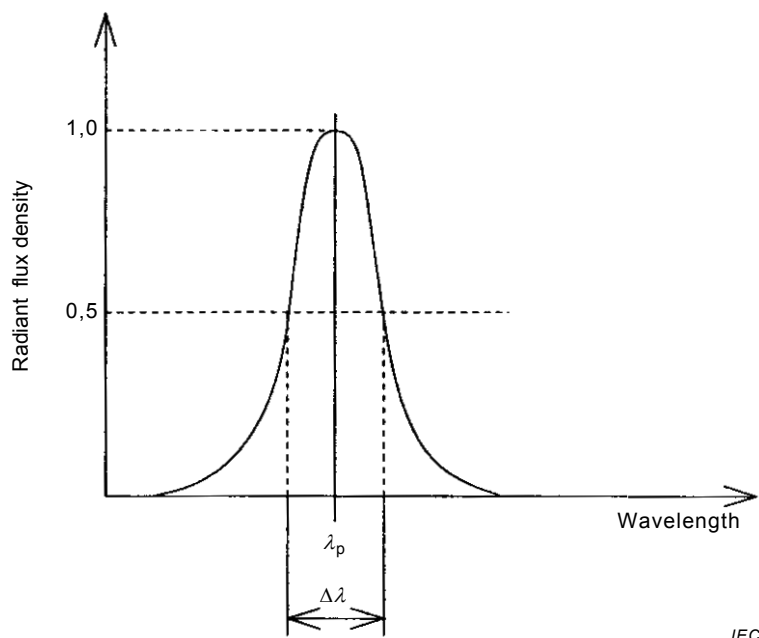


Figure 28 – Schematic diagram of $\Delta\lambda$ measurement

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

The 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).