

BSI Standards Publication

Electronic displays

Part 1-31: Generic — Practical information on the use of light measuring devices

Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

National foreword

This Published Document is the UK implementation of IEC TR 62977-1-31:2021+A1:2022. It supersedes PD IEC TR 62977-1-31:2021, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee EPL/47, Semiconductors.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

This publication is not to be regarded as a British Standard.

© The British Standards Institution 2023
Published by BSI Standards Limited 2023

ISBN 978 0 539 18996 4

ICS 31.120; 31.260

Compliance with a Published Document cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 May 2021.

Amendments/corrigenda issued since publication

Date	Text affected
30 April 2023	Implementation of IEC amendment 1:2022

AVA Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

IEC TR 62977-1-31

Edition 1.0 2022-03

TECHNICAL REPORT

colour inside

AMENDMENT 1

Electronic displays –
Part 1-31: Generic – Practical information on the use of light measuring devices

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.120; 31.260

ISBN 978-2-8322-9716-2

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

® Registered trademark of the International Electrotechnical Commission

Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

This page is left deliberately blank.

Documents
Document Sharing Hub

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms, definitions, and abbreviated terms 9
3.1 Terms and definitions 9
3.2 Abbreviated terms 10
4 General information on LMDs for photometry and colorimetry 10
4.1 General 10
4.2 Photometry and colorimetry for electronic displays 10
4.3 LMDs for luminance and chromaticity measurements 11
4.3.1 Configuration of LMDs 11
4.3.2 Input optics of LMDs 13
4.3.3 Electronic system of LMDs 13
4.3.4 Calibration of LMDs 14
4.3.5 Maintenance of LMDs 14
4.4 Setup conditions for measurement 14
4.4.1 LMDs 14
4.4.2 DUTs 14
4.4.3 Environment 14
5 Influence of LMD properties on luminance and chromaticity measurements 14
5.1 General 14
5.2 Repeatability 15
5.2.1 General 15
5.2.2 Example of the repeatability of an LMD 15
5.3 Accuracy 16
5.3.1 General 16
5.3.2 Example of the accuracy of an LMD 16
5.3.3 Linearity 16
5.3.4 Range change 17
5.4 Luminance range 17
5.5 Spectral properties of the spectroradiometer 17
5.5.1 General 17
5.5.2 Wavelength accuracy and spectral bandwidth 17
5.6 Spectral properties of the filter-type luminance meter and colorimeter 23
5.6.1 General 23
5.6.2 Spectral responsivity 23
5.6.3 Methods to reduce the measurement difference 25
5.7 Angular response of LMDs 26
5.7.1 General 26
5.7.2 Subtended angles 26
5.7.3 Consideration of the input optics 27
5.8 Measurement field 28
5.8.1 General 28
5.8.2 Number of pixels within the measurement field 29
5.9 Polarization 29

AVA Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

5.9.1 General 29
5.9.2 Polarization dependence of LMDs 30
5.10 Temporal synchronization 31
5.10.1 General 31
5.10.2 Temporal synchronization of the LMD and DUT 31
6 Influence of LMD properties on measurements of the optical characteristics of electronic displays 32
6.1 General 32
6.2 Contrast ratio 32
6.2.1 General 32
6.2.2 Calculated influence of LMD properties on the contrast ratio measurements 32
6.3 Electro-optical transfer function (EOTF) 35
6.3.1 General 35
6.3.2 Calculated influence of the LMD properties on the EOTF measurements 35
6.4 Chromaticity gamut area 36
6.4.1 General 36
6.4.2 Calculated influence of LMD properties on the chromaticity gamut area measurements 36
6.5 Viewing direction characteristics 38
6.5.1 General 38
6.5.2 Calculated influence of the LMD properties on the viewing direction characteristics measurements 38
6.5.3 Measurement field at an oblique direction 40
6.6 Spatial uniformity 41
6.6.1 General 41
6.6.2 Calculated influence of LMD properties on uniformity and non-uniformity measurements 41
6.7 Response time 43
6.7.1 General 43
6.7.2 Measurement of the response time 43
6.8 Flicker 46
6.8.1 General 46
6.8.2 Measurement method of the flicker 46
6.8.3 Low-pass filter of LMDs 47
Annex A (informative) Photometry and colorimetry 49
A.1 General 49
A.2 Photometry 49
A.3 Colorimetry 49
A.3.1 General 49
A.3.2 Standard colorimetric observer 50
A.3.3 Tristimulus values 50
A.3.4 Chromaticity diagram and colour space 50
Annex B (informative) Method for reducing the measurement difference of colorimeters 53
B.1 General 53
B.2 Matrix calibration methods for colorimeters 53
B.2.1 Matrix calibration process 1: RGB calibration 53
B.2.2 Matrix calibration process 2: RGBW calibration 54

AVA Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

Annex C (informative) Input data in Clause 5 and Clause 6, and calculation methods in 5.8 and 6.5 56
C.1 General 56
C.2 Characteristics of DUTs 56
C.2.1 Spectral radiances of the DUTs 56
C.2.2 Directional characteristic of the DUT 57
C.2.3 Temporal modulation characteristics of the DUT 57
C.2.4 EOTF characteristics of the DUTs 57
C.2.5 Uniformity characteristics of the DUTs 58
C.3 Characteristics of the filter-type LMDs 59
C.3.1 Spectral responsivities of the filter-type LMDs 59
C.3.2 Specifications of filter-type LMDs 61
C.4 Influence of the number of pixels within the measurement field 63
C.5 Validity of the viewing direction dependence obtained by a simplified method 64
Annex D (informative) Instabilities of DUTs in measurement 66
D.1 General 66
D.2 DUT instabilities 66
Bibliography 68

Figure 1 – Block diagrams of three types of LMDs 12
Figure 2 – Example of configurations for the input optics and detector 12
Figure 3 – Example of input optics for the luminance meters 13
Figure 4 – Block diagram of a typical electronic system 13
Figure 5 – Examples of the repeatability of an LMD as a function of luminance 15
Figure 6 – Examples of the accuracy of an LMD as a function of luminance 16
Figure 7 – Calculated relative luminance difference as a function of wavelength error 19
Figure 8 – Calculated relative luminance difference as a function of spectral bandwidth 20
Figure 9 – Calculated chromaticity differences as a function of wavelength error 21
Figure 10 – Calculated chromaticity differences as a function of spectral bandwidth 22
Figure 11 – Calculated relative luminance difference as a function of f_1' 24
Figure 12 – Calculated chromaticity differences as a function of f_1', xyz 25
Figure 13 – Angular aperture and measurement field angle 27
Figure 14 – Calculated relative luminance difference and chromaticity difference as a function of the angular aperture 27
Figure 15 – Diagram of light rays in object space telecentric and non-telecentric optical design 28
Figure 16 – Calculated chromaticity difference as a function of the number of pixels 29
Figure 17 – Measured luminance variation as a function of the rotation angle of the polarizer 30
Figure 18 – Calculated relative luminance differences as a function of sampling period 32
Figure 19 – Total measurement times for 0,3 % repeatability (2σ) in three LMDs 36
Figure 20 – Calculated relative difference, ΔGA_{xy}, by spectroradiometers 37
Figure 21 – Calculated relative difference, ΔGA_{xy}, by colorimeters 38
Figure 22 – Cone of light rays for calculating the tristimulus values measured by an LMD with the angular aperture, α, and an optical axis at an inclination angle, θ_{LMD} 39

AVA Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

Figure 23 – Calculated luminance and chromaticity dependence as a function of the inclination angle for the 2°, 6°, and 10° angular apertures 40
Figure 24 – Measurement field and test pattern 41
Figure 25 – Calculated non-uniformity difference by the filter-type colorimeters 43
Figure 26 – Measurement setups for response time measurements 44
Figure 27 – Response curves measured at different sampling rates 44
Figure 28 – Measured response subjected to various low-pass filterings 45
Figure 29 – Measured response curves switched from the 10 % to 90 % level 46
Figure 30 – Schematic measured temporal luminance modulation of the LCD with a common voltage offset 47
Figure 31 – Conceptual pseudo-temporal luminance modulation 48
Figure 32 – Simulated luminance modulations with and without high frequency noise 48
Figure C.1 – Spectral radiances 56
Figure C.2 – Inclination angle dependence 57
Figure C.3 – Temporal modulation of the luminance 57
Figure C.4 – EOTF characteristics 58
Figure C.5 – Spectral responsivity of the colorimeter 61
Figure C.6 – Repeatability of three LMD models 62
Figure C.7 – Three positions of a circular measurement field relative to the RGB stripes 63
Figure C.8 – Configuration to measure DUT emission by the LMD at the inclination angle, θ_{LMD} 64
Figure C.9 – Inclination angle dependence calculated by two methods using an LMD with an angular aperture of 10° 65
Figure D.1 – Changes of luminance and chromaticity after switching the grey levels 66
Figure D.2 – Changes of luminance after switching from the black to grey level 67

Table 1 – DUT characteristics for the calculations 33
Table 2 – Calculated results of the contrast ratio by three LMDs 34
Table 3 – Calculated durations of the EOTF measurements 36
Table 4 – Chromaticity gamut area of three DUTs 37
Table 5 – Non-uniformity of DUTs 42
Table 6 – Rise times calculated from a measured response subjected to various low-pass filterings 45
Table 7 – Rise times measured by LMDs of various $V(\lambda)$ fidelities 46
Table C.1 – Measured luminance and chromaticity at the nine positions of DUT-1 58
Table C.2 – Measured luminance and chromaticity at the nine positions of DUT-2 59
Table C.3 – Specifications of filter-type LMDs 62
Table D.1 – Luminance and chromaticity transition 66
Table D.2 – Luminance changes in two measurements 67

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

ELECTRONIC DISPLAYS –

Part 1-31: Generic – Practical information on the use of light measuring devices

FOREWORD

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

IEC TR 62977-1-31 has been prepared by IEC technical committee 110: Electronic displays. It is a Technical Report.

The text of this Technical Report is based on the following documents:

DTR	Report on voting
110/1258/DTR	110/1281A/RVDTR

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

The language used for the development of this Technical Report is English.

Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

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

A list of all parts in the IEC 62977 series, published under the general title *Electronic displays*, can be found on the IEC website.

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

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

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

Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

INTRODUCTION

Measurements of the optical characteristics of electronic displays are primarily affected by three factors: measuring procedures, displays (devices under test: DUTs), and light measuring devices (LMDs), for which there are many international standards supporting consistent and comparable measurements. Most of them, however, provide only limited information on LMDs, making it difficult to appropriately select and use the LMD for the measurement objective. The purpose of this document is to provide best practices and suggestions which are missing in the standards.

This document addresses how the major properties of a typical LMD affect the measurement results. It is often impractical and unnecessary to consider the influences of all properties of LMDs and all characteristics of DUTs as well as their interactions and influences on the measurement results. Therefore, the multiple interaction effects that exist are beyond the scope of this document. Due to the rapid innovation and abundance of LMDs, covering all types of LMDs is also outside the objectives of this document.

Documents
Document Sharing Hub

Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

ELECTRONIC DISPLAYS –

Part 1-31: Generic – Practical information on the use of light measuring devices

1 Scope

This part of IEC 62977 provides practical information on light measuring devices (luminance meters, colorimeters, and spectroradiometers) with luminance measuring optics for the characterization of electronic displays.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

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

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

NOTE CIE Electronic international lighting vocabulary (e-ILV) is also available at http://cie.co.at/e-ilv.

3.1.1
repeatability
<of an LMD> closeness of agreement between indications or measured quantity values obtained by replicated measurements over a short period of time using a specific LMD under conditions specified by the LMD manufacturer

Note 1 to entry: Repeatability of an LMD is usually expressed numerically by statistical quantities, such as standard deviation, variance, or coefficient of variation (relative standard deviation) under the specified conditions of measurement.

Note 2 to entry: The influence on measurement repeatability caused by fluctuations of the measured light source and by the measurement procedure is assumed to be negligible when the manufacturer specifies the repeatability of an LMD. Manufacturers often specify the type of light source and measurement conditions used for determining the repeatability of an LMD.

Note 3 to entry: Measurement precision is the closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions. Measurement repeatability is measurement precision under a set of repeatability conditions of measurement that includes the same measurement procedures, same operators, same measuring system, same operating conditions, same location, and replicate measurements on the same or similar objects over a short period of time. Measurement reproducibility is measurement precision under a set of reproducibility conditions of measurement that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects [1], [2][1].

[1] Numbers in square brackets refer to the Bibliography.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

3.1.2
accuracy
<of an LMD> difference between a measured quantity value and an accepted reference value when using a specific LMD under conditions specified by the LMD manufacturer

Note 1 to entry: This term is a quantity with a numerical value and is usually expressed as a range specification.

Note 2 to entry: The accepted reference value is a value that serves as an agreed-upon reference for comparison, and which is derived as:

a) a theoretical or established value, based on scientific principles;

b) an assigned or certified value, based on experimental work of some national or international organization;

c) a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group;

d) (when a), b) and c) are not available) the expectation of the (measurable) quantity, i.e. the mean of a specified population of measurements [3].

Note 3 to entry: The influence on measurement accuracy caused by fluctuations of the measured light source and by the measurement procedure is assumed to be negligible when the manufacturer specifies the accuracy of an LMD. Manufacturers often specify the type of light source and other measurement conditions used for determining the accuracy of an LMD.

Note 4 to entry: Measurement accuracy is the closeness of agreement between a measured quantity value and the true quantity value of a measurand [1], [2]. The accuracy of measurement is not a quantity value while the accuracy of an LMD is a quantity value; thus, the term "accuracy" conventionally used for the specification of LMDs means something different than that used for measurement.

3.2 Abbreviated terms

CIE	Commission Internationale de l'Éclairage (International Commission on Illumination)
CMF	colour-matching function
DUT	device under test
EOTF	electro-optical transfer function
LCD	liquid crystal display
LED	light emitting diode
LMD	light measuring device
ND	neutral density
OLED	organic light emitting diode
PWM	pulse width modulation
RGB	red, green, and blue
RGBW	red, green, blue, and white
Vsync	vertical synchronizing signal

4 General information on LMDs for photometry and colorimetry

4.1 General

Clause 4 describes the principles of photometry and colorimetry, configuration, calibration, and maintenance of LMDs, as well as setup conditions for measurement.

4.2 Photometry and colorimetry for electronic displays

Photometry is the measurement of quantities referring to radiation as evaluated according to a given spectral luminous efficiency (see IEV 845-25-013). Colorimetry is the measurement of colour stimuli based on a set of conventions (see IEV 845-25-014). Details on the calculation formulae and specific conditions applied to electronic display measurement are shown in Annex A.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

4.3 LMDs for luminance and chromaticity measurements

4.3.1 Configuration of LMDs

The configurations of three types of LMDs are described as follows:

1) Luminance meter

A luminance meter is an instrument for measuring luminance (see IEV 845-25-021). A block diagram of the setup of a typical luminance meter is shown in Figure 1a): it consists of input optics, a detector unit for measuring the luminance, L_v, and an electronic system. An example of the configuration of the input optics and the detector unit is shown in Figure 2a), where a lens is used for the input optics. The input optics collects the light emitted from the DUT and converges it onto the detector. An optical compensation filter is arranged in front of the detector. The combination of the spectral characteristics of the filter, input optics, and detector approximates the spectral luminous efficiency function, $V(\lambda)$. A neutral density (ND) filter can be inserted into the optical path, for example when the LMD's dynamic range is insufficient and results in detector saturation. The detector receives the light and converts the optical signal to an electronic one, from which the electronic system calculates the luminance, L_v, as in [4], indicates it on an instrument display, and/or sends the result to an external system.

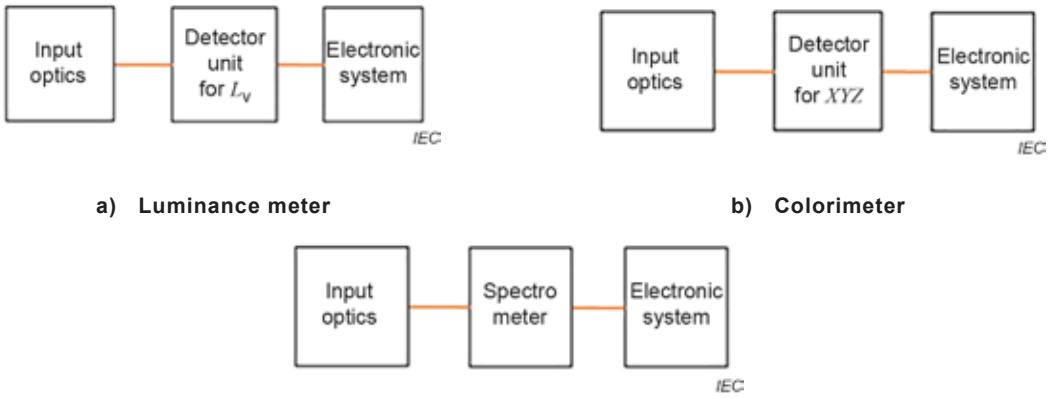
2) Colorimeter

A colorimeter is an instrument for measuring colorimetric quantities, such as the tristimulus values of a colour stimulus (see IEV 845-25-022). A block diagram of the most common setup for a colorimeter is shown in Figure 1b): it is conceptually similar to a luminance meter. A colorimeter has a detector unit for measuring the tristimulus values instead of one for the luminance. A colorimeter for both luminance and chromaticity measurements employs the same type of input optics as the luminance meter, as described in 4.3.1 1). An example of the configuration of the input optics and the detector unit is shown in Figure 2b), where the detector unit has three pairs of optical compensation filters and detectors. The input optics is connected to the detector unit by a three-branch optical fibre. The combined spectral characteristics of those components approximates the CIE colour-matching functions (CMFs). The electronic system calculates the tristimulus values, X, Y, and Z, where Y is practically identical to L_v (see Annex A).

3) Spectroradiometer

A spectroradiometer is an instrument for measuring radiometric quantities in narrow wavelength intervals over a given spectral region (see IEV 845-25-007). A block diagram of the general setup of a spectroradiometer is shown in Figure 1c). A spectroradiometer for spectral radiance measurements, and luminance and chromaticity calculations therefrom, employs the same type of input optics as the luminance meter, as described in 4.3.1 1). An example of the configuration of the input optics and the spectrometer is shown in Figure 2c), where the input optics is connected to the spectrometer by an optical fibre. The example spectrometer consists of an input slit, a grating, for example a concave grating [5], and an array detector, where the output of the detector is related to the spectral radiance of the DUT. The obtained spectral radiance, $L_e(\lambda)$, is converted to the luminance, L_v, or tristimulus, values, X, Y, and Z, using $V(\lambda)$ or CMFs data, which are often stored in look-up tables [6], [7].

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

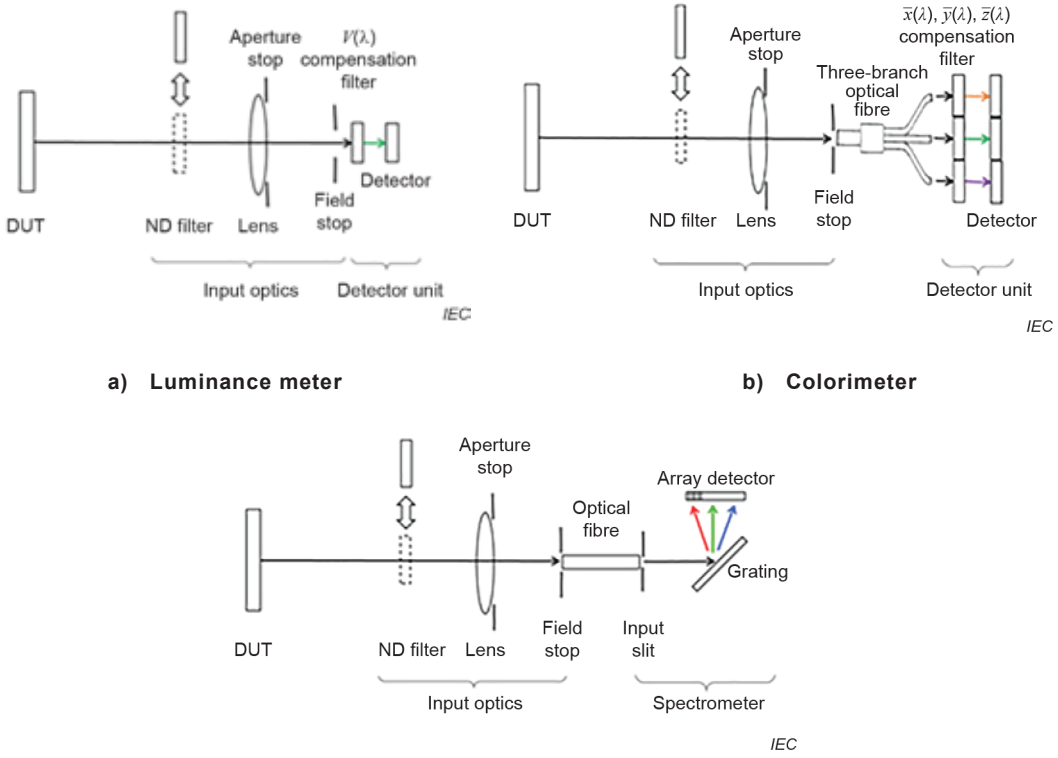


a) Luminance meter

b) Colorimeter

c) Spectroradiometer

Figure 1 – Block diagrams of three types of LMDs



a) Luminance meter

b) Colorimeter

c) Spectroradiometer with spectrometer using grating and array detector

Figure 2 – Example of configurations for the input optics and detector

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

4.3.2 Input optics of LMDs

An LMD has an input optics system which collects the light emitted or reflected from a DUT. There are various types of imaging as well as non-imaging input optics, for example fixed-focus lens, variable-focus lens, and optical fibre. For luminance measurements, imaging optics is often used. Figure 3 shows an example of the input optics with an imaging lens, an aperture stop (aperture), a field stop, and a detector behind the field stop, together with the DUT and detector. Related optical properties are described in the following sentences. The aperture stop is an opening that defines the area over which the average optical emission is measured (see IEV 845-25-086). The entrance pupil is a virtual image of the aperture stop as viewed from the object space, and its position and size depend on the measurement distance. The angular aperture is the angle subtended by the entrance pupil. The field stop which is positioned on the image plane limits the measurement field of the DUT. The measurement field angle is the angle subtended by the measurement field at the entrance pupil.

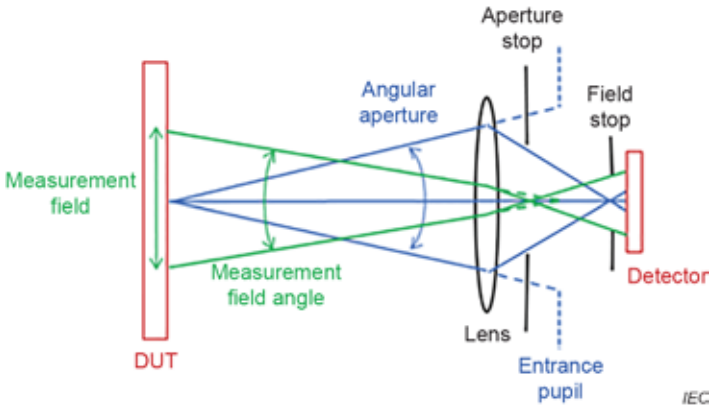


Figure 3 – Example of input optics for the luminance meters

4.3.3 Electronic system of LMDs

An LMD has an electronic system for processing the electronic signal from the detector [8] in order to deliver the measured values. Among the various types of systems, Figure 4 shows a typical one consisting of an analogue circuit amplifying the signal from the detector, an A/D converter converting the amplified signal into a digital signal, a data processor converting the digital signal to the measurement value, and a system controller controlling the whole system including the memory, display, and interface of the external devices.

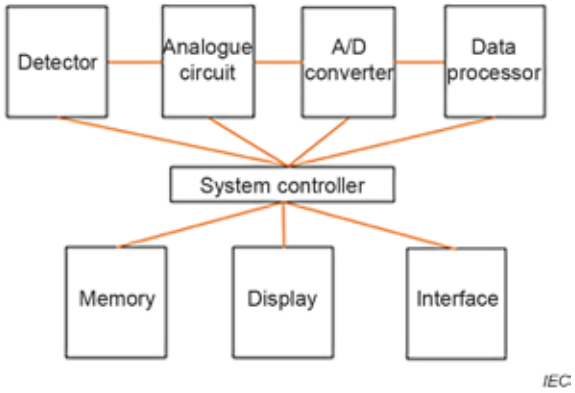


Figure 4 – Block diagram of a typical electronic system

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

4.3.4 Calibration of LMDs

Luminance meters and colorimeters are usually calibrated to a reference source with a light source and a plane diffuser, which are traceable to a national standard recognized by a national authority as the basis for assigning quantity values to other measurement standards [1], [2]. These light sources are often incandescent lamps, for example tungsten-halogen lamps, designed to approximate the CIE standard Illuminant A. It is sometimes possible to use other types of light sources, for example LEDs, for LMDs specifically designed for display measurement. For a spectroradiometer, the wavelengths are usually calibrated to a light source emitting one or more line spectra, and the spectral radiance is calibrated to the reference source described above [9]. The temporal stability of these light sources is strictly managed by manufacturers to meet their specifications.

4.3.5 Maintenance of LMDs

The performance of LMDs depends on ambient conditions, especially temperature and humidity. Careful storage, handling, and operation of LMDs are recommended in accordance with instructions provided by the manufacturer. Since deterioration caused by ageing is inevitable, periodic inspections, adjustments, and calibration by the manufacturer are recommended.

4.4 Setup conditions for measurement

4.4.1 LMDs

Most LMDs are unstable immediately after switching the power on, and they therefore need some warm-up time to achieve their specified accuracy and repeatability. Most optical instabilities are due to thermal effects and thus have a long time constant. Checking the measurement stability before regular measurements is recommended in order to verify the appropriate warm-up time.

4.4.2 DUTs

Short-term instabilities in the optical output of DUTs are often caused by their electronic system while long-term instabilities are mostly caused by thermal effects which can have long time constants. Measured instabilities of DUTs are exemplified in Annex D. Checking for such DUT instabilities is recommended in order to adapt the measurement procedure accordingly. The combined long-term stability of the LMD and DUT can be confirmed by comparing the results measured with the same settings at the beginning and at the end of the measurement session.

4.4.3 Environment

For consistent and comparable measurements, environmental conditions should meet the requirements of the LMDs and DUTs. Carefully checking the environmental conditions described in the respective instruction manuals before measurement is recommended.

5 Influence of LMD properties on luminance and chromaticity measurements

5.1 General

Clause 5 describes the LMD properties disclosed by the manufacturer or required by the display measurement standards, and their influence on the luminance and chromaticity measurement results. This information is helpful for the selection and use of the LMD suitable for the measurement objectives [10]. Some input data for calculations are shown in Annex C.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

5.2 Repeatability

5.2.1 General

Repeatability of an LMD as defined in 3.1.1 is one of the dominant performance factors of an LMD. It is usually given as the relative standard deviation, σ_R, for luminance, L_V, and standard deviation, σ, for CIE 1931 chromaticity coordinates, x, y, with a coverage factor, K, i.e., $K\,\sigma_R$ and $K\,\sigma$, respectively, where $\sigma_R = \sigma / \overline{L}_V$, $\overline{L}_V$ is the average luminance, and K = 1 or 2 in most cases. For both, the smaller the value, the higher the repeatability of the LMD. Those values are essentially positive.

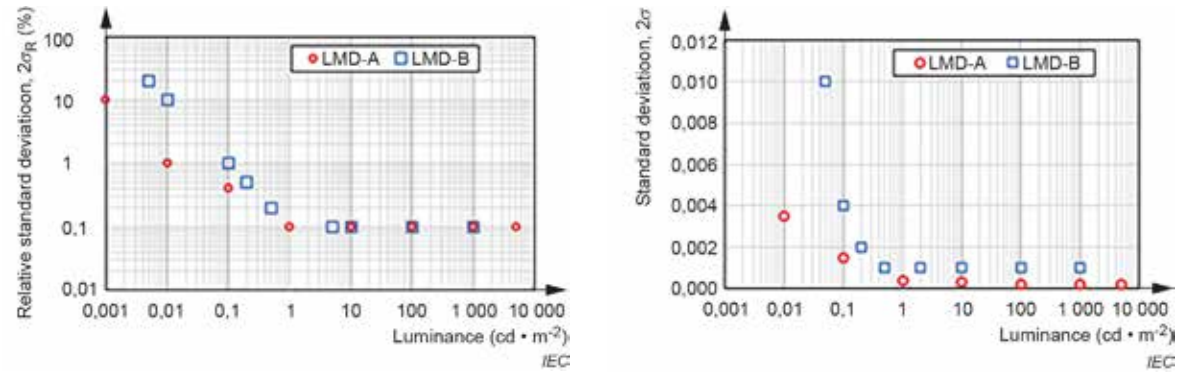
The conditions for evaluating the repeatability of an LMD with respect to the specifications given by the manufacturer, for example the light source, luminance, number of measurements, and statistical evaluation method used, are often defined by the manufacturer specifically for each LMD model and often documented in the data sheet. They are often specific to each model even by the same manufacturer. Checking such conditions is recommended when comparing the performance of different models.

In actual measurements, experimentally checking whether the measurement repeatability, which is affected not only by the repeatability of the LMD but also the instabilities of the DUT and others, meets the requirements of the measurement objectives is recommended, and if not, improving the measurement system and procedure to meet such requirements is recommended.

NOTE The number of significant digits is determined by the internal numerical calculation, and the rounding strategy using measurement precision for tristimulus values is shown in A.3.3. The number of digits indicated on the display and transmitted to the external devices is usually specific to each LMD and is often determined in relation to the number of significant digits and by considering the repeatability of the LMD.

5.2.2 Example of the repeatability of an LMD

Figure 5 exemplifies the repeatability of an LMD for luminance and chromaticity at different luminance levels for two LMD models by the same manufacturer under the same conditions specified by the manufacturer. The difference between the two models increases from a negligible level in the high luminance range to a significant level in the low luminance range.



a) Luminance, L_V

b) Chromaticity coordinates, x, y

Figure 5 – Examples of the repeatability of an LMD as a function of luminance

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

5.3 Accuracy

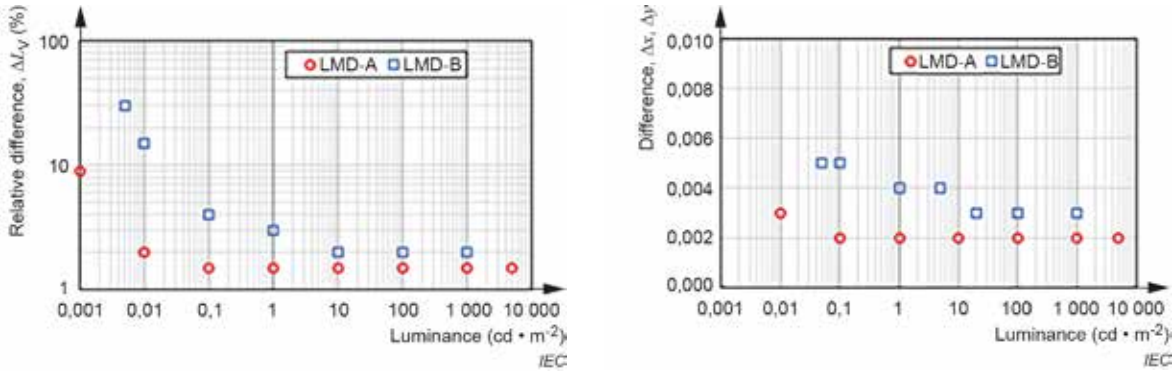
5.3.1 General

Accuracy of an LMD as defined in 3.1.2 is one of the dominant LMD performance factors of an LMD. It is usually specified as a range: ± maximum difference or ± standard deviation with a coverage factor of K, where K is 1 or 2 in most cases. It is usually expressed as a relative value (%) for luminance and a nonrelative value for the chromaticity coordinates. The smaller the absolute value, the more accurate the LMD.

The conditions for evaluating the accuracy of an LMD with respect to the specification given by the manufacturer, for example the light source, luminance, and statistical method used, are often defined by the manufacturer specifically for each LMD model and documented in the data sheet. They are often specific to each model even for the same manufacturer. Checking such conditions is recommended when comparing the performance of different models. Note that the definition of accuracy includes systematic errors that remain when the measured value is obtained by averaging multiple measurements.

5.3.2 Example of the accuracy of an LMD

Figure 6 exemplifies the accuracy of an LMD for luminance, ΔL_V, and for chromaticity coordinates, Δx, Δy, at different luminance levels for two LMD models by the same manufacturer under the same conditions specified by the manufacturer. Note that Figure 6 shows the positive value only. The difference between the two models increases from a negligible level in the high luminance range to a significant level in the low luminance range.



a) Luminance, L_V

b) Chromaticity coordinates, x, y

Figure 6 – Examples of the accuracy of an LMD as a function of luminance

5.3.3 Linearity

Linearity is the degree to which the change in the output quantity of the LMD is proportional to the change in the input quantity, i.e., the responsivity is constant over a specified range of inputs [10]. The measured values of L_V, X, Y, Z, and $L_e(\lambda)$ have an inherent linearity error due to factors mostly in the detector and electronic system. For most LMDs, the linearity is not specified separately. It is included in the accuracy of an LMD specified over a luminance range.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

5.3.4 Range change

The deviation due to range change is the systematic deviation arising when the LMD is switched from one range to an adjacent range [10]. The LMD changes the integration time, the amplifier gain, and/or inserts the neutral density (ND) filter in order to expand the luminance range, which usually leads to inter-range discontinuities. Note that this range switching error is likely to occur independently in the individual X, Y, and Z detectors of the colorimeter, and that the range-switching luminance level is likely to be different between increasing and decreasing luminance. The errors associated with range change are not necessarily disclosed in the specifications of LMDs. They are usually included in the accuracy specified over the luminance range.

In actual measurements, fixing the measurement sequence is often taken into consideration, i.e., from low to high luminance, from high to low luminance, or both, to average the two values of the same luminance in opposite sequences. This is to minimize total measurement time or to achieve higher precision in measurements such as tone-rendering (also known as electro-optical transfer function: EOTF), colour gamut volume, and colour accuracy [11].

5.4 Luminance range

Luminance range is usually specified by LMD manufacturers in terms of a lower and an upper limit for a guaranteed range and/or an indicated range. All measured values within the guaranteed range are guaranteed to meet specifications of the LMD whereas measured values within the indicated range are obtainable and do not necessarily meet the specifications. Both luminance ranges are typically specific to a particular LMD.

Measured values beyond the upper limit of the guaranteed range are likely to be unobtainable or inaccurate due to saturation or poor linearity of the detector and/or analogue circuit, while measured values below the lower limit of the guaranteed range are likely to be inaccurate due to poor repeatability and/or poor linearity. Checking that the operation conditions of the LMD are properly met for measurement near the lower limit is recommended. For some colorimeters, the lower luminance limit in chromaticity measurements is higher than that in luminance measurements. When measuring below the guaranteed lower limit, it is helpful to consult with the manufacturer.

The dynamic range of an LMD is usually defined as the ratio of the upper and lower limit. It is a major figure of merit when selecting LMDs for measurement of the contrast ratio of a DUT.

5.5 Spectral properties of the spectroradiometer

5.5.1 General

A spectroradiometer measures the spectral radiance of a DUT. Subclause 5.5 addresses the influence of the major spectral properties of spectroradiometers on the measured values for the array spectroradiometers shown in Figure 2c).

5.5.2 Wavelength accuracy and spectral bandwidth

5.5.2.1 General

Wavelength accuracy and spectral bandwidth are two of the major spectral properties of a spectroradiometer. Some wavelength error is inevitable and usually varies by wavelength. Its permissible value is the wavelength accuracy specified by the manufacturer. Spectral bandwidth characterizes the spectral bandwidth of the measured signal for monochromatic inputs. It usually varies by wavelength, and its permissible value is specified by the manufacturer. These spectral properties of the spectroradiometer affect the measured spectral radiance as well as the luminance and chromaticity calculated therefrom. The influence of these spectral properties on the measured values also depends on the spectral radiance of DUTs, as shown below by simulated measurements.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022

NOTE 1 In actual LMDs, the spectral properties of the spectroradiometer are not as simple as those in the calculations, and the DUTs are not only those used in the calculations. The actual results are likely to be different from the calculations.

NOTE 2 Stray light in a spectral measurement system is light that reaches the detector which is at a wavelength other than the wavelength intended to be measured (see IEV 845-25-116). This spectral stray light in the array spectrometer (see 4.3.1) is described in detail in [9] and its influence on the measured values of luminance and chromaticity can be usually mitigated by various technologies. [A1] When spectral stray light affects the measured values of luminance and chromaticity, spectral stray light correction can be applied. [12]. [A1] The LMD property for this spectral stray light is often specified by the manufacturer with evaluation conditions specific to each LMD model.

[A1] NOTE 3 The influence of spectral bandwidth on chromaticity measurements of narrow spectral linewidth light is shown in Annex E. [A1]

5.5.2.2 Calculation method and DUT/LMD parameters

1) Spectral radiance of DUTs: Calculations are performed for three types of DUTs whose spectral radiances, $L_e(\lambda)$, of red, green, blue, and white test patterns are shown in C.2.1. They are taken as the reference spectral radiances, $L_{e,\,ref}(\lambda)$.

2) Wavelength error and spectral bandwidth: For simplicity, the wavelength error, $\delta\lambda$, is assumed to be the same over the wavelength range, and six wavelength errors: ±0,2 nm, ±0,5 nm, and ±1 nm, are chosen for calculation. The respective measured spectral radiances are obtained by $L_e(\lambda - \delta\lambda)$. For simplicity, spectral response to the monochromatic input is assumed to be Gaussian with a bandwidth, bw, which is the same over the wavelength range. Five bandwidths: 2 nm, 4 nm, 6 nm, 8 nm, and 10 nm are chosen for the calculation. The respective measured spectral radiances are obtained by the convolution of the reference spectral radiance, $L_{e,\,ref}(\lambda)$, and the simulated Gaussian spectral responses. The influence of the wavelength error and spectral bandwidth is calculated independently.

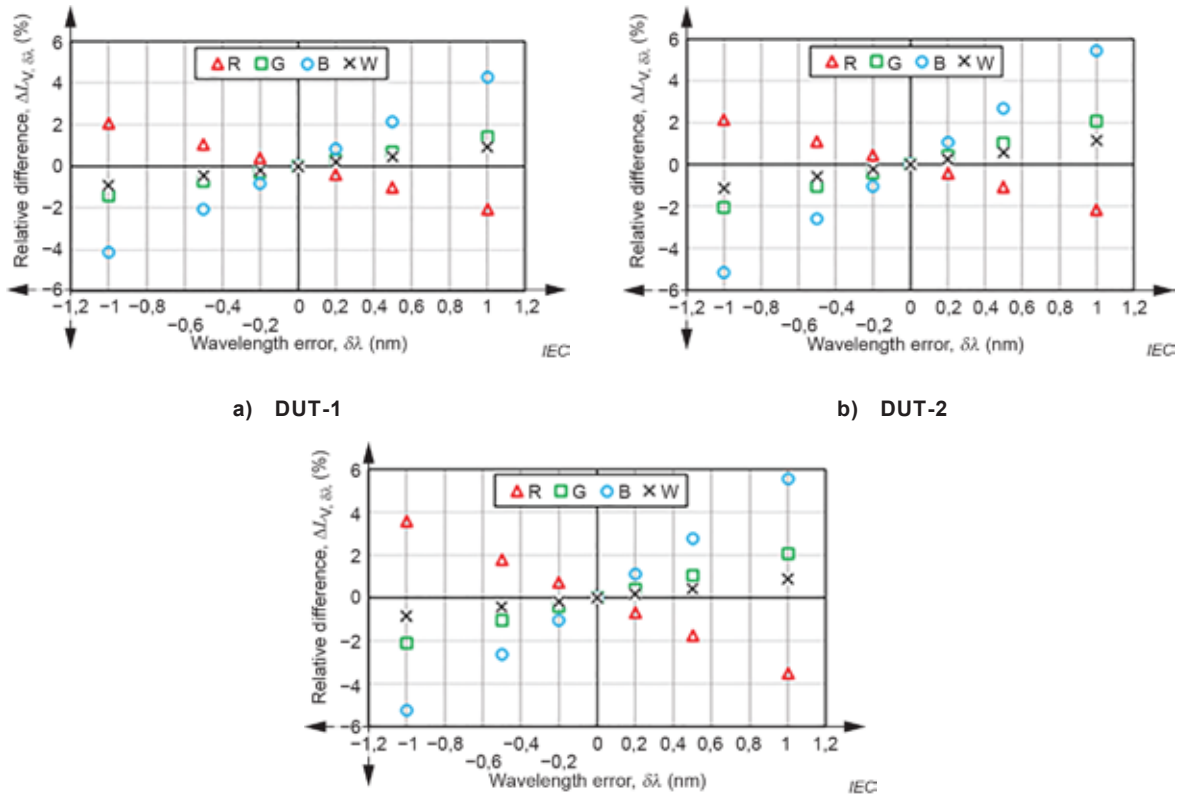
3) Calculation of luminance and chromaticity: The tristimulus values, X, Y, and Z, and the chromaticity, (x, y), are calculated by Formulae (A.2) to (A.7), while Y is practically identical to L_v (see Annex A). The measured values, $L_{v,\,meas}$, x_{meas}, and y_{meas}, are obtained by substituting the measured spectral radiance of the DUT in the formulae. Their references, $L_{v,\,ref}$, x_{ref}, and y_{ref}, are obtained by substituting the reference spectral radiances in the formulae. The differences of the measured values from the reference values indicate the influence of the wavelength error and spectral bandwidth of the spectroradiometer on the measured values.

5.5.2.3 Calculation results

5.5.2.3.1 Luminance

Figure 7 shows the calculated relative luminance difference, $\Delta L_{v,\,\delta\lambda}$ (%), as a function of the wavelength error, $\delta\lambda$, for the four displayed colours: red, green, blue, and white. As shown, the larger the wavelength error, the larger the difference. The difference depends on the displayed colour, where the difference in red, green, and blue is larger than in white. It also depends on the spectral radiance of the DUT, however, the trends of the difference are not so different among these DUTs.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022



a) DUT-1

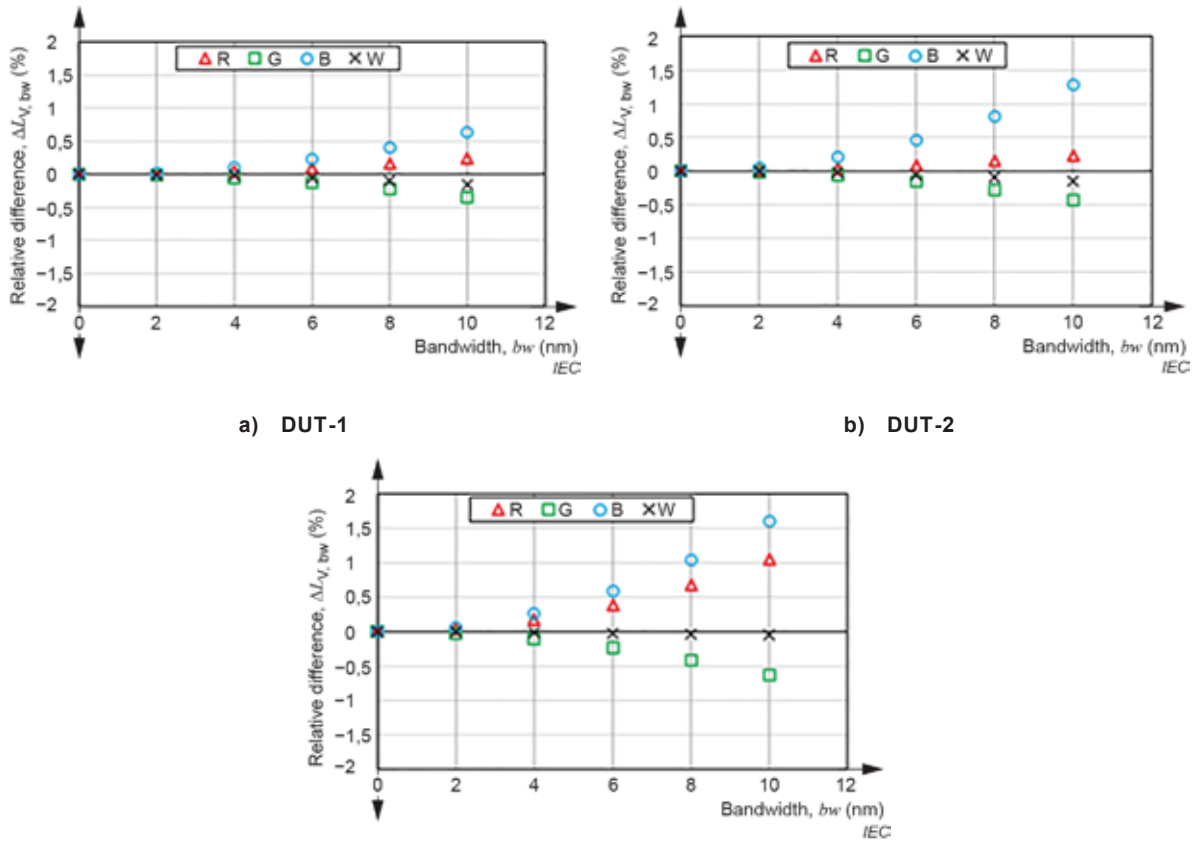
b) DUT-2

c) DUT-3

Figure 7 – Calculated relative luminance difference as a function of wavelength error

Figure 8 shows the calculated relative luminance difference, $\Delta L_{v,bw}$, as a function of the bandwidth, bw, for the four displayed colours: red, green, blue, and white. As shown, the larger the bandwidth, the larger the difference, and the difference also depends on the displayed colour. The difference in red, green, and blue is larger than in white. It depends also on the spectral radiance of the DUT; the trends of the difference are larger in DUT-3 than in the others.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022



a) DUT-1

b) DUT-2

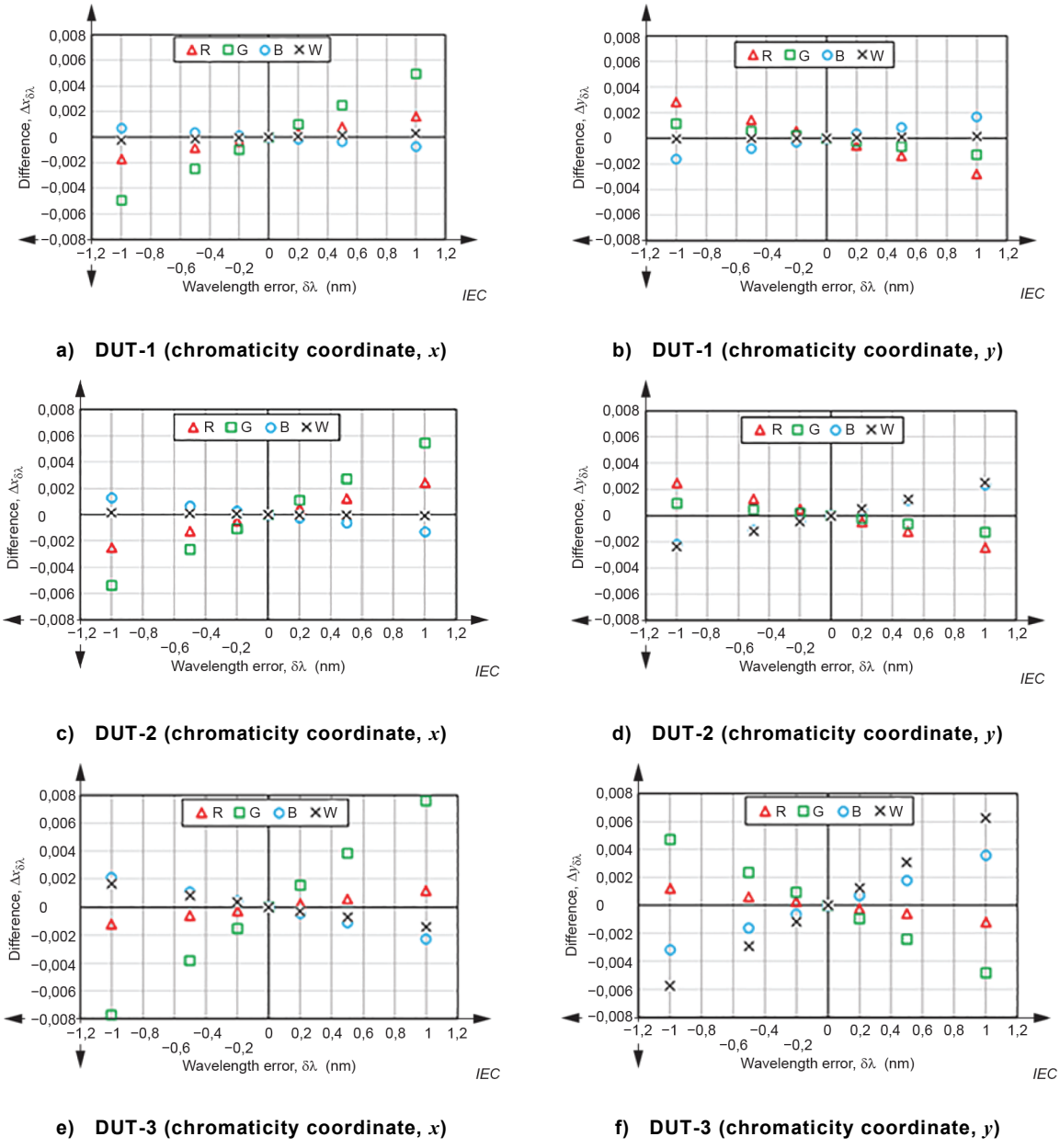
c) DUT-3

Figure 8 – Calculated relative luminance difference as a function of spectral bandwidth

5.5.2.3.2 Chromaticity

Figure 9 shows the calculated chromaticity coordinate differences, $\Delta x_{\delta\lambda}$, $\Delta y_{\delta\lambda}$, as a function of the wavelength error, $\delta\lambda$. The differences depend on the displayed colour and the spectral radiance of the DUTs.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022



a) DUT-1 (chromaticity coordinate, x)

b) DUT-1 (chromaticity coordinate, y)

c) DUT-2 (chromaticity coordinate, x)

d) DUT-2 (chromaticity coordinate, y)

e) DUT-3 (chromaticity coordinate, x)

f) DUT-3 (chromaticity coordinate, y)

Figure 9 – Calculated chromaticity differences as a function of wavelength error

Figure 10 shows the calculated chromaticity coordinate differences, Δx_{bw}, Δy_{bw}, as a function of the bandwidth, bw. The differences depend on the displayed colour and the spectral radiance of the DUTs.

Documents
Document Sharing Hub
Full document details: PD IEC/TR 62977-1-31:2021+A1:2022