

BS ISO 12646:2015



BSI Standards Publication

Graphic technology — Displays for colour proofing — Characteristics

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 12646:2015. It supersedes BS ISO 12646:2008+A1:2010 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PAI/43, Graphic technology.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2015. Published by BSI Standards Limited 2015

ISBN 978 0 580 75285 8

ICS 37.100.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2015.

Amendments issued since publication

Date	Text affected
------	---------------

INTERNATIONAL
STANDARD

ISO
12646

Third edition
2015-07-15

**Graphic technology — Displays for
colour proofing — Characteristics**

*Technologie graphique — Affichages pour la réalisation d'épreuves en
couleur — Caractéristiques*



Reference number
ISO 12646:2015(E)



COPYRIGHT PROTECTED DOCUMENT

© ISO 2015, Published in Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Requirements	2
4.1 General.....	2
4.2 Uniformity of luminance and chromaticity.....	3
4.2.1 General.....	3
4.2.2 Evaluation of tone uniformity.....	3
4.2.3 Tonality evaluation (uniformity).....	3
4.3 Viewing cone characteristics.....	3
4.4 Reflective characteristics.....	4
5 Test methods	5
5.1 General.....	5
5.2 Preparation and display set-up.....	5
5.3 Viewing angle dependent tonality evaluation (“ Δ Gamma”).....	5
5.4 Measurement conditions.....	6
5.4.1 Photometric and colorimetric measurements.....	6
5.4.2 Measurements as a function of viewing direction.....	8
Bibliography	11

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 130, *Graphic technology*.

This third edition cancels and replaces the second edition (ISO 12646:2008), which has been technically revised to improve the compatibility with the requirements of soft proofing defined in ISO 14861.

Introduction

The ability to match colour images displayed on colour displays to the images produced when the same digital file is rendered by proofing and printing systems (commonly referred to as “soft” proofing) is increasingly expected in graphic arts. Obtaining such a match is not simple and to be fully accurate requires careful control of many aspects of the process. The primary purpose of this International Standard is to make recommendations with respect to the soft proof displays requirements. If these are met, it is then possible for a soft proofing system such as defined in ISO 14861 to accurately colour match to the hard copy proof. Hence, this International Standard is intended for display manufacturers in order to qualify their display for use in graphic arts proofing systems.

The appearance of a colour image on a colour display is influenced by many physical factors other than controlled ambient viewing conditions. Among the most important of these are uniformity, size and resolution (in order to permit rendition of the proof at close to its normal size and with the finest detail visible on the hard copy at normal viewing distances), variation of electro-optical properties with viewing direction, freedom from flicker and glare (specular reflections with distinct images), the opto-electronic calibration of the display, and the settings of its display driver software. In this regard, to be acceptable in a proofing system that provides a reasonable level of image quality, the display needs to also exhibit these properties at an acceptable quality.

Note that even for displays of the highest quality, the appearance of the displayed image will be limited by the accuracy of the colour transformation used for converting the digital file from its encoded colour space to that required for display purposes.

This International Standard specifies requirements for displays to be used in soft proofing systems defined by ISO 14861. ISO 14861 primarily focuses on applications where the displayed image will be compared to a hard copy in an adjacent viewing cabinet or where the viewing cabinet intentionally contains the display. Furthermore, in order to address the different needs for the soft proofing use cases, two different conformance levels (class A and class B) will be defined in this International Standard.

However, in some practical situations, the image on the screen is evaluated in the absence of a hard copy. This International Standard might be used as reference, but this is not required. Users of this International Standard will also benefit from CIE Publication 122 which provides an overview of the relationship between digital and colorimetric data. Those unfamiliar with the evaluation of displays will also find it helpful to read IEC 61223-2-5 which contains much useful detailed information about evaluation and testing of image display devices.

Graphic technology — Displays for colour proofing — Characteristics

1 Scope

This International Standard specifies requirements for two conformance levels for the characteristics of displays to be used for soft proofing of colour images. Included are requirements for uniformity and variations of electro-optical properties with viewing direction for different driving signals.

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.

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

3 Terms and definitions

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

3.1 calibration

set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system or values represented by a material measure of a reference material and the corresponding values realized by standards

[SOURCE: ISO International Vocabulary of Basic and General Terms in Metrology]

Note 1 to entry: However, in typical graphic arts, use cases calibration is understood as an active process where a display or a printer is adjusted such that it produces the defined aim values.

3.2 colorimeter

instrument for measuring colour values such as the tristimulus values of a colour stimulus

[SOURCE: ISO 12637-2:2008, 2.18]

3.3 design viewing direction DVD

direction for which specific electro-optical characteristics of the display have been optimized

Note 1 to entry: Examples of important electro-optical characteristics are maximum luminance and maximum contrast in definite direction.

3.4 gamma

best-fit parameter which relates the display normalized output luminance to a normalized input digital value presented to the display system including its hardware and software components as given in Formula (1):

$$L = (S)^{\gamma} + O$$

where

- L is the normalized output luminance;
- S is the normalized input digital value;
- O is the offset.

3.5

ON-state

condition in which the display is switched on

Note 1 to entry: This definition is important for light-valve-like displays which might emit a significant light intensity even when displaying the darkest image ($R = G = B = 0$) in the ON-state.

3.6

spectrophotometer

instrument for measuring the reflectance or transmittance of light (or other radiation) by an object at one or more wavelengths in the spectrum

[SOURCE: ISO 105-A08:2001, 2.24]

3.7

viewing cone

VC

conical space originating at the display surface that includes all viewing directions with a specified angle of inclination, θ (3.8)

3.8

viewing angle

θ

angle between the normal to the display and the *design viewing direction* (3.3)

4 Requirements

4.1 General

All display tests should be performed for a display calibrated to a luminance of 160 cd/m² and a chromaticity corresponding to a D50 ($x = 0,3457$ and $y = 0,3585$) illuminant with a 2° observer at a gamma of 2,2. The display shall display a "white" image consisting of the maximum value in each channel, red, green, and blue (255 for 8-bit). It shall be reported if other calibration aims were used.

NOTE 1 This calibration condition is typical of the conditions used in the graphic arts industry and ensures that the results of different tested displays can be compared because uniformity can be dependent to some extent on the chosen gamma, luminance, and white point settings.

If a display to be tested will be used solely in a specific soft proofing system where no display calibration is used, but only the state of the display is characterized, the calibration can be omitted. The luminance, the white point chromaticity (as expressed in CIE_{xy} units), and tone reproduction curve (as expressed by a single gamma value or as a set of tabulated values) shall be reported.

The display shall be tested in a stable condition. In order to establish the individual stabilization time, each display to be tested shall be operated in the calibration mode for 12 h in a room with controlled temperature conditions. The room temperature shall not change more than $\pm 0,5$ °C and shall be in the range of 18 °C to 28 °C.

The stabilization time (warm up time) is achieved when the luminance change is less than 2 % (compared to the average of the measurements of the last 9 h of the 12 h period) and the white point is within $\pm 0,005$ for CIE $\Delta x, \Delta y$ of the calibrated conditions. If the display will not achieve stable conditions, it shall not be used.

The warm up behaviour of a display shall be reported with a graph of luminance and CIE Δx , Δy in measured values and in percentage compared to the average of the last 9 h of the 12 h period.

NOTE 2 When using viewing condition P2, according to ISO 3664, a luminance of 160 cd/m² correlates with an illuminance of 500 lux illuminating a perfect reflecting diffusor.

4.2 Uniformity of luminance and chromaticity

4.2.1 General

The uniformity of a soft proofing system is vital and shall be checked for solid colours and for tonality (gradation) changes of the screen. If the informative requirements of 4.2.2. or 4.2.3 are not met, this shall be reported. Therefore, the following method is normatively required in ISO 14861. However, since there are soft proofing solutions that are able to perform a spatial resolved uniformity correction, this International Standard makes the uniformity assessment informative.

It shall be reported and if hardware based, look up table display corrections are turned on (if present).

4.2.2 Evaluation of tone uniformity

The CIELAB values of a uniform 5 × 5 grid are calculated using the measurement of the centre patch at maximum driving as the reference white illuminant. Note that this method may result in some CIEL* values being greater than 100. 24 readings are compared with the centre colour for three different driving levels, namely white, at the maximum driving level (R = G = B = 255 for 8-bit displays), grey at about half maximum driving level (R = G = B = 127 for 8-bit displays), and dark grey at about one fourth of maximum driving level (R = G = B = 63 for 8-bit displays) by means of the DE00 colour difference formulae. For the white and the grey driving levels, the DE00 colour differences should be equal or less than four.

4.2.3 Tonality evaluation (uniformity)

Utilizing luminance (cd/m²) measurements of grey at half maximum driving level (R = G = B = 127 for 8-bit displays) and white at max driving level (R = G = B = 255 for 8-bit displays) the grey/white ratio should be calculated for the 25 regions. For the non-central regions, new ratios, T_i , with $i = \{1, \dots, 24\}$ should be computed by dividing the individual grey/white ratios, R_i , with $i = \{1, \dots, 24\}$ by the grey/white ratio of the centre, R_c , subtracting one and calculate the absolute value of the number. This measure of the deviation from uniform tonality should be less than 10 %, i.e. $\max(T_i), i = \{1, \dots, 24\}$ should be less than 0,10.

$$T_i = \text{abs}(R_i / R_c - 1), (i = 1, \dots, 24) \quad (1)$$

The uniformity of tonality, determined as $\max(T_i)$, with $i = \{1, \dots, 24\}$, should be less than 0,1.

4.3 Viewing cone characteristics

The instrumentation setup and measurement geometry for viewing cone measurements shall be as defined in 5.4.2.

Based on the viewing cone which is visible for an observer viewing a display centred with one eye at a given viewing distance (default: 500 mm), the maximal viewing angles θ_{\max} (θ_{\max}) shall be calculated for the horizontal, diagonal and vertical directions. In addition, θ_{\max} for the four 45° angles (starting at 45° being 90° apart from each other) shall be calculated. The maximum inclination (θ_{\max}) depends on screen size, screen aspect ratio (ratio of display width and height), and viewing distance and will be calculated as follows:

$$\theta_{\max, \text{horizontal}} = \arctan(W2 / VD) * 180^\circ / \pi \quad (2)$$

$$\theta_{\max, \text{vertical}} = \arctan(H2 / VD) * 180^\circ / \pi \quad (3)$$

$$\theta_{\max, \text{diagonal}} = \arctan(D2 / VD) * 180^\circ / \pi \quad (4)$$

$$\theta_{\max, 45} = \arctan(D45_2 / VC) * 180^\circ / \pi \quad (5)$$

where

$W2$ is the half of the display width in mm;

$H2$ is the half of the display height in mm;

$D2$ is half of the display diagonal in mm;

VD is the viewing distance in mm;

$D45_2$ is half of the 45° diagonal calculated by $D45_2 = H2 / \sin(45^\circ * \pi / 180^\circ)$.

EXAMPLE For a 15 inch laptop display with an aspect ratio of 1,6 (display height = 202 mm, display width = 323 mm, diagonal = 15" * 25,4 = 381 mm), seen from 500 mm viewing distance $\theta_{\max, \text{horizontal}}$ is 17,9°, $\theta_{\max, \text{vertical}}$ is 11,4°, $\theta_{\max, \text{diagonal}}$ is 20,9°, and $\theta_{\max, 45}$ is 15,9°.

All viewing angles theta up to theta_max are assessed in steps of 10° (or smaller). Theta_max is rounded according to the assessed step width. It shall be reported if the intended viewing distance exceeds 500 mm.

NOTE 1 It is important to note that the viewing distance a user might choose might be different (often between 500 mm and 800 mm). The tolerances have been defined with a default viewing distance of 500 mm in mind. This viewing distance represents the lower range which is typical for desktop application soft proofing.

A display suitable for graphic arts soft proofing should exhibit low colour deviations for all driving levels over the visible viewing cone. A stable colour over the visible viewing cone is assessed by calculating DE00 for all viewing angles up to theta_max for each azimuth angle. The colour deviation shall be less DE00 of 10 for white at maximum driving level (R = G = B = 255 for 8-bit displays) and grey at about half maximum driving level (R = G = B = 127 for 8-bit displays) and should be less DE00 of 10 for dark grey at about one fourth of maximum driving level (R = G = B = 63) and for a driving level which results in a luminance level equal to 1 % of the calibrated luminance (default 1,6 cd/m²).

NOTE 2 The state of technology does not allow displays to be produced with little or no colour deviation over the viewing cone. A maximum deviation of DE00 of 10 is a reasonable tolerance for this deviation. Also the gradation across the viewing cone can vary for some types of displays. This can be observed visually by "washed out" looking mid-tones. The practice shows that those displays still can be used with good success for graphic arts work. Although for demanding users, displays with a more stable gradation are needed. This situation was the reasoning for introducing two classes for this single criterion. When technology evolves tighter, tolerances can be used.

The viewing angle dependent gradation difference (Delta Gamma) as defined in 5.3 shall be equal or less than "ΔGamma" of 10 % for grey at about half of maximum driving level (R = G = B = 127 for 8-bit displays). Displays not passing the "ΔGamma" criteria, but all other normative criteria of this International Standard are categorized as class B displays. Displays passing all criteria are categorized as class A displays.

4.4 Reflective characteristics

The reflective properties of the display surface in the power off shall be judged visually in a darkroom using a point source. The reflection of the point source off the screen should appear hazy and should smoothly decrease as one turns away from the direction of specular reflection.

5 Test methods

5.1 General

For each patch displayed (sequentially at the image centre), the measured spectral radiance and/or CIEXYZ values shall be recorded. CIELAB values are calculated, if needed. (refer to ISO 13655 for calculation) The white point used shall be reported.

The display is calibrated and profiled to the target values defined for a specific application.

NOTE The measurement device should be calibrated if possible, for example, by the manufacturer. If this is not possible, the inter-instrument agreement between two devices or comparison to a visual in-house reference like a proof print can help to estimate that the measuring device is functioning correctly.

5.2 Preparation and display set-up

Prior to calibration and any measurement, the display shall be switched on and allowed to warm as defined in 4.1. All measurements shall be carried out on the calibrated and characterized display according to 4.1. The information (e.g. calibration process, software used, ICC profiles) necessary to describe and repeat the measurements shall be reported with the data.

If not otherwise required, all measurements shall be carried out at the design viewing direction and in contact with the faceplate. If no design viewing direction is stated by the vendor, the normal to the display surface shall be used instead.

5.3 Viewing angle dependent tonality evaluation (“ΔGamma”)

To ensure a stable image appearance, it is vital that the gradation varies as little as possible over the viewing angle and area of the display. The Delta Gamma (tone reproduction) is assessed by first calculating a normalized, “relative” luminance value for grey for the centre of the display and for each viewing direction or point to compare against. The relative luminance Y_{rel} is calculated as the ratio between the luminance at grey of about half maximum driving level ($R = G = B = 127$ for 8-bit displays) to the luminance of white at maximum driving level ($R = G = B = 255$ for 8-bit displays). To assess if the gradation is stable, a so-called “ΔGamma” value is calculated using Formula (5).

$$\text{“}\Delta\text{Gamma”} \sim [Y_{rel}(\text{test colours}, \theta, \phi)] / [Y_{rel}(\text{reference colours @ DVD})] - 1$$

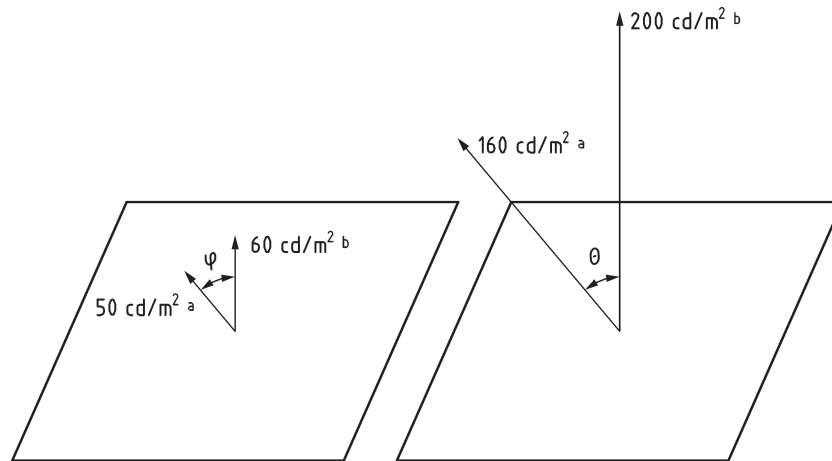
with

$$Y_{rel} = Y_{grey} / Y_{white}$$

(6)

An example is presented in [Figure 1](#).

NOTE A stable gradation could be expressed as a gamma change (see given example). Here, the gradation is assessed by calculating the percentage how a normalized grey luminance differs from the normalized grey luminance of the reference angle (at design viewing direction). To make it easy to communicate this value to the practitioner, this can be called “ΔGamma”, including quotation marks, to make clear that this is not a real gamma difference, but only related to a gamma difference.



Key

a
$$Y_{rel}(Testcolours, \varphi, \theta) = \frac{50}{160} = 0,312 \sim \gamma = 1,68$$

b
$$Y_{rel}(reference\ colours@DVD) = \frac{60}{200} = 0,3 \sim \gamma = 1,74$$

NOTE $\frac{0,312}{0,3} - 1 = 0,0417 \rightarrow \Delta\text{Gamma} = 4,2\%$

Figure 1 — Example calculation of “Delta Gamma”

5.4 Measurement conditions

5.4.1 Photometric and colorimetric measurements

The following requirements pertain to measurements either at the faceplate (contact measurement) or telespectroradiometrically. The measurement at the faceplate of the display shall be carried out using either a spectroradiometer or a colorimeter. The measurement at some distance from the faceplate of the display shall be carried out in a dark room with the configuration shown in [Figure 2](#). For both cases, the optical axis of the instrument shall be in line with the design viewing direction.

Spectroradiometers and spectrophotometers shall comply with the following requirements:

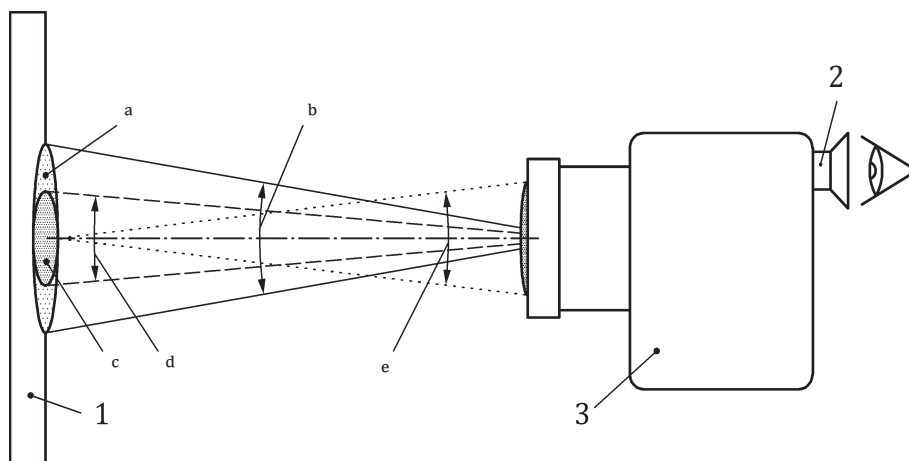
- a) the wavelength range shall include the interval from 400 nm to 720 nm;
- b) the angular angle of the sensing cone, i.e. the angle region over which the efflux is sensed by the receiver, shall not be more than a half angle of 5° and should not be more than a half angle of 2,5° (see [Figure 2](#));
- c) for telespectroradiometric measurements, the distance, *d*, shall be chosen such that the number of pixels sampled during measurement is at least 150. For measurement at the face plate, the area measured for each sample shall have a diameter of no less than 4 mm and shall contain at least 150 pixels.
- d) the chromaticity accuracy when measuring an incandescent source shall be $CIExy = \pm 0,002$ at luminance levels between 0,5 cd/m² and at least 800 cd/m².
- e) the 2*k* uncertainty of the wavelength where *k* is the coverage factor defined in ISO 15790 should be less than 0,5 nm and shall be less than 1 nm as described in the wavelength standard (incandescent reference source with colour temperature of 2 856K ± 50K with certified values of spectral radiance or irradiance tabulated at 5 nm intervals for an average half-power bandwidth of between 4 nm and 5 nm);

- f) the reference for spectral data shall be based on computed data at 5 nm intervals where the spectral response function is triangular with a 5 nm bandwidth at the half-power point.
- g) the resolution of the measuring device shall be smaller or equal to 10 nm (FWHM) and should be smaller or equal to 5 nm (FWHM). If the measurements are taken at sampling intervals smaller than 5 nm, the procedure for widening the bandwidth specified in ISO 13655 shall be used for deriving and reporting data at 5 nm intervals;
- h) at a luminance greater than 80 cd/m² and at a spectral distribution corresponding to that of the white state of the display, the repeatability of the spectroradiometer shall be less than 0,001 for CIE $u'v'$ and 0,5 % of the luminance level being measured;
- i) for flat panel displays only, the polarization error of the instrument is limited as follows: the luminance, measured at five azimuthal positions of the instrument, spaced 30° apart, shall be within 5 % of the average of the five measurements, and CIE_{xy} chromaticity shall be within 0,002 of the five measurements.

Tristimulus colorimeters shall comply with the following requirements:

- a) the angular angle of the sensing cone, i.e. the angle region over which the efflux is sensed by the receiver, shall not be more than a half angle of 5° and should not be more than a half angle of 2,5° (see [Figure 2](#));
- b) for measurement at some distance, the distance, d , shall be chosen such that the number of pixels sampled during measurement is at least 150. For measurement at the face plate, the area measured for each sample shall have a diameter of no less than 4 mm and shall contain at least 150 pixels.
- c) the repeatability (stability) shall be less than 0,001 for CIE_{xy} and 0,5 % for the luminance using a stable light source having a luminance higher than 80 cd/m².
- d) the chromaticity accuracy when measuring an incandescent source shall be CIE_{xy} = ±0,002 at luminance levels between 0,5 cd/m² and at least 800 cd/m².

NOTE CIE standard source A is chosen for traceability measurements because of its practicality and ease of realization.



Key

- 1 DUT, object of measurement
- 2 viewport
- 3 LMD, receiver
- a Field of view.
- b Angular field of view.
- c Measurement field.
- d Measurement field angle.
- e Aperture angle.

NOTE Refer to CIE Publication No. 69 for more details. In case of LCD-DUT, the angular aperture shall be $<5^\circ$ ($\pm 2,5^\circ$) per IEC 61747.

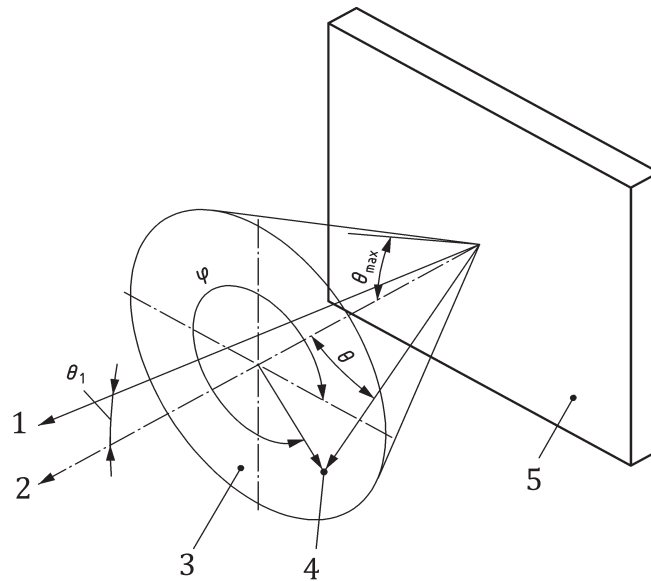
Figure 2 — Set-up for non-contact measurements (adapted from IEC 61747)

5.4.2 Measurements as a function of viewing direction

5.4.2.1 Angle definitions

For the purpose of these measurements, the following definitions apply. The azimuth angle, φ , is measured anti-clockwise from the three o'clock position (see [Figure 3](#)). The viewing angle, θ , is measured from the surface normal, n .

NOTE For more information on coordinates and viewing, see ISO 9241-302:2008.



Key

- 1 design viewing direction
- 2 surface normal (n)
- 3 viewing cone
- 4 point defining the measurement direction with respect to θ and φ
- 5 flat panel displays
- θ angle of inclination of measurement direction with respect to the surface normal
- θ_1 angle of inclination of the normal with respect to the Design Viewing Direction
- θ_{\max} maximum angle of inclination with respect to the surface normal
- φ angle of azimuth of measurement direction

Figure 3 — Spherical coordinate system

5.4.2.2 Viewing cone

Measurements of the directional luminance and colorimetric distribution shall be carried out in a darkroom at the centre of the display using conoscopical measurements or other instrumentation capable of measuring the colorimetric properties for different angles of azimuth and inclination (see IEC 61223-2-5).

The measurement shall be carried out at a defined position within the so-called viewing cone (see [Figure 3](#), key 4). The viewing cone is limited by the maximum angle of inclination, θ_{\max} , a single “one-eyed” observer can see.

NOTE 1 The viewing cone described corresponds to the viewing direction range class II of ISO 9241-302:2008.

NOTE 2 If two persons are to view the display simultaneously, the resulting viewing angles might be addressed and evaluated separately. This is not part of this International Standard.

NOTE 3 The viewing directions under which the periphery of the monitor (i.e. edge and corner locations), as seen by the observer, are obtained from the viewing direction to the centre of the monitor by the viewing distance and by the dimensions of the monitor screen area as explained in detail, for example, in ISO 13406-2 (see ISO 13406-2, Clause 7).

With that geometry defined, four or eight viewing directions can be calculated according to the vantage point situation.

The actual measurements for evaluation of the variation of luminance, contrast, and chromaticity with viewing direction are then carried out at the centre location of the screen area. The variation of optical properties with viewing direction at this location is assumed to be identical to the variation at all other locations. This assumption is justified by metrological verification and on the fact that these variations are dominated by crystal optics. So if the dark state of the display screen (no voltage, only cell gap and cell thickness variations obvious) and medium states of gray (with electrical addressing and driving) are uniform across the screen area (this is evaluated from one viewing direction, usually from the normal direction), then also the variations with viewing direction at all other locations are the same (i.e. beyond the limits of metrological detection).

Bibliography

- [1] ISO 3664, *Graphic technology and photography — Viewing conditions*
- [2] ISO 9241-1, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 1: General introduction*
- [3] ISO 9241-2, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 2: Guidance on task requirements*
- [4] ISO 9241-302:2008, *Ergonomics of human-system interaction — Part 302: Terminology for electronic visual displays*
- [5] ISO 9241-303:2011, *Ergonomics of human-system interaction — Part 303: Requirements for electronic visual displays*
- [6] ISO 9241-304:2008, *Ergonomics of human-system interaction — Part 304: User performance test methods for electronic visual displays*
- [7] ISO 9241-305:2008, *Ergonomics of human-system interaction — Part 305: Optical laboratory test methods for electronic visual displays*
- [8] ISO 9241-306:2008, *Ergonomics of human-system interaction — Part 306: Field assessment methods for electronic visual displays*
- [9] ISO 9241-307:2008, *Ergonomics of human-system interaction — Part 307: Analysis and compliance test methods for electronic visual displays*
- [10] ISO 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*
- [11] ISO 11664-2, *Colorimetry — Part 2: CIE standard illuminants*
- [12] ISO 12641, *Graphic technology — Prepress digital data exchange — Colour targets for input scanner calibration*
- [13] ISO 12647 (all parts), *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints*
- [14] ISO 14861, *Graphic technology — Requirements for colour soft proofing systems*
- [15] ISO 15076-1, *Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2004-10*
- [16] ISO 15930-7, *Graphic technology — Prepress digital data exchange using PDF — Part 7: Complete exchange of printing data (PDF/X-4) and partial exchange of printing data with external profile reference (PDF/X-4p) using PDF 1.6*
- [17] IEC 61223-2-5, *Evaluation and routine testing in medical imaging departments — Part 2-5: Constancy tests — Image display devices*
- [18] IEC 61966-4, *Multimedia systems and equipment — Colour measurement and management — Part 4: Equipment using liquid crystal display panels*
- [19] IEC 61966-2-1, *Multimedia systems and equipment — Colour measurement and management — Part 2-1: Colour management — Default RGB colour space — sRGB*
- [20] BECKER. M. *Viewing-Cone Analysis of LCDs: A Comparison of Measuring Methods*. SID Digest, San Diego, 1996
- [21] PUBLICATION CIE 116, *Industrial Colour-Difference Evaluation*

- [22] PUBLICATION CIE 122, The relationship between digital and colorimetric data for computer controlled CRT displays
- [23] PUBLICATION CIE 159, A Colour Appearance Model for Colour Management Systems: CIECAM02

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards-based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

Useful Contacts:

Customer Services

Tel: +44 845 086 9001

Email (orders): orders@bsigroup.com

Email (enquiries): cservices@bsigroup.com

Subscriptions

Tel: +44 845 086 9001

Email: subscriptions@bsigroup.com

Knowledge Centre

Tel: +44 20 8996 7004

Email: knowledgecentre@bsigroup.com

Copyright & Licensing

Tel: +44 20 8996 7070

Email: copyright@bsigroup.com



...making excellence a habit.™