IEC 62977-3-7

Edition 1.0 2022-01

INTERNATIONAL STANDARD

colour inside

Electronic displays –
Part 3-7: Evaluation of optical performance – Tone characteristics

IEC 62977-3-7:2022-01(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.120

ISBN 978-2-8322-1070-7

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ELECTRONIC DISPLAYS –

Part 3-7: Evaluation of optical performance – Tone characteristics

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The text of this International Standard is based on the following documents:

Draft	Report on voting
110/1371/FDIS	110/1397/RVD

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

The language used for the development of this International Standard is English.

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

A list of all parts in the IEC 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 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- withdrawn,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.

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INTRODUCTION

Images as formed by electronic displays have lateral variations of for example hue, saturation and intensity of visual stimuli. For displays of gradual smooth transitions no unwanted contours and no quantization artefacts should be visible. Therefore, the displays should render the required gradation of an image through tone reproduction. Tone is the variation in luminance, ideally with constant hue and saturation, at (r, g, b) input (n, 0, 0), (0, n, 0), (0, 0, n), and (n, n, n), respectively, where n:{0, 1,…N}, and N + 1 is the number of quantization levels. Similarly, colour saturation tone is defined as the luminance variation, ideally with constant hue, but with varying saturation of the input (= 1 – min (r, g, b) / max (r, g, b)), for input (N, n, n), (n, N, n), and (n, n, N). Tone can also be defined for complementary colour (r, g, b) input (0, n, n), (n, 0, n), (n, n, 0) and (n, N, N), (N, n, N), and (N, N, n), respectively. This is conceptually shown in Figure 1 which is the hue saturation lightness/intensity (HSL or HSI) model with RGB inputs for single colour tone, grey tone and colour saturation tone signal, where the lightness is defined as 0,5 × ((max (r, g, b) + min (r, g, b)). Note that this colour space is different from the device RGB colour space. Grey and RGB tone reproduction, and their additive relation, are fundamental optical properties of displays since they affect the fidelity with which colour is rendered from the input code values.

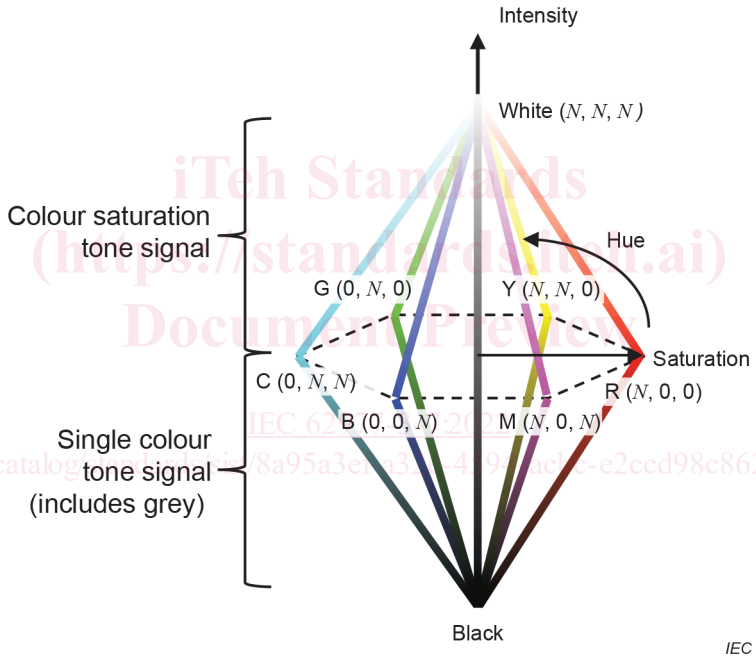


Figure 1 – Hue saturation lightness (HSL) colour model

In contemporary displays, nonlinear transformations into perceptually equidistant spaces are required to reduce visual artefacts while maintaining data economy. Also, the transformations linearize the opto-electrical transfer function, the nonlinearity of which is beneficial for reduction of artefacts such as quantization noise, banding, contouring, as well as for quantization efficiency.

The variation of electro-optical transfer functions (EOTFs) with viewing direction introduces further complications. The resulting impact omnidirectional image quality is more multifaceted compared to the viewing direction dependence of contrast, peak luminance, and colour of a limited number of patches.

This document describes methods for the measurement of EOTF and evaluation, and points out necessary precautions and diagnostics. The document is a reference for forthcoming standards to make the work of the involved experts more efficient and to avoid duplication of efforts.

ELECTRONIC DISPLAYS –

Part 3-7: Evaluation of optical performance – Tone characteristics

1 Scope

This part of IEC 62977 specifies the standard measurement and evaluation of optical performance for grey and colour tone reproduction of electronic displays under darkroom conditions. This document describes the measuring methods and evaluation of tone rendering of neutral grey, primary and secondary input colours. This document applies to displays with unbounded input signals.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62977-2-1:2021, *Electronic displays – Part 2-1: Measurements of optical characteristics – Fundamental measurements*

IEC TS 62977-3-1:2019, *Electronic displays – Part 3-1: Evaluation of optical performances – Colour difference based viewing direction dependence*

IEC 62341-6-3, *Organic light emitting diode (OLED) displays – Part 6-3: Measuring methods of image quality*

IEC 61966-2-1, *Multimedia systems and equipment – Colour measurement and management – Part 2-1: Colour management – Default RGB colour space – sRGB*

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:

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

3.1.1
electro-optical transfer function
EOTF
nonlinear decoding
variation of the optical output of electronic visual displays in terms of for example luminance and chromaticity, as a function of the input signals

Note 1 to entry: The input signals could be R, G, B, C, M, Y, and grey for (r, g, b) input (n, 0, 0), (0, n, 0), (0, 0, n), (0, n, n), (n, 0, n), (n, n, 0), and (n, n, n), respectively, where n:{0,1,...N}, and N + *1* is the number of quantization levels per primary colour.

Note 2 to entry: The EOTFs for the C, M and Y inputs are optional.

Note 3 to entry: Generally, nonlinear decoding is the reciprocal of nonlinear encoding, but custom decoding is also available in many display products ("gamma" pre-sets).

3.1.2
nonlinear encoding [4], [7][1]
signal transform mostly expressed by a combination of a linear function for low input values and a power function with a single exponent above a certain level of input values as an opto-electrical transfer function (OETF) [4]

Note 1 to entry: It is used in image acquisition devices such as digital cameras for mapping scene luminance to digital code values prior to encoding, transmission, and/or compression.

Note 2 to entry: In conventional non-constant luminance systems, the nonlinear decoding is done in the RGB domain, whereas it is done in the YC_bC_r domain for constant luminance systems.

Note 3 to entry: The reason for the linear transformation for low input values is that the steepness of the power function is too close to zero (infinite), leading to artefacts (e.g. excessive noise).

3.1.3
display gamma
exponent of the power function specifying the target EOTF of a display

Note 1 to entry: Deviations from the ideal power function are possible and should be specified.

Note 2 to entry: Generally, the display gamma value is calculated from an EOTF with the luminance of the black level subtracted (de-biasing). Gamma is only defined if the de-biased EOTF obeys a power law, the exponent of which is the gamma. The gamma value of an ideal display is the same for R, G, B, C, M, Y and grey tone.

3.1.4
colour saturation tone function
variation of the optical output of electronic visual displays in terms of for example luminance and chromaticity, as a function of input signals with at least one RGB input kept at its maximum value and the remaining R, G or B inputs being varied and of equal value

Note 1 to entry: An ideal display renders constant colorimetric hue for the inputs.

Note 2 to entry: When the luminance at maximum saturation is subtracted from the colour saturation tone function (bias correction), and the resulting function obeys a power law, its exponent is called colour saturation gamma.

Note 3 to entry: The input signals could be R, G, B, C, M, and Y for (r, g, b) input (N, n, n), (n, N, n), (n, n, N), (n, N, N), (N, n, N), and (N, N, n), respectively, where n:{0,1,...N}, and N + 1 is the number of quantization levels per primary colour.

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

3.1.5
display bit depth
number of quantization levels, assuming binary-encoded levels

Note 1 to entry: It is the number of display bits or $\log_2$[number of addressable shades] in the tone rendering.

Note 2 to entry: The actual number of renderable shades is often reduced when white balancing is done by gain control [4], [7].

Note 3 to entry: Display colour depth is the sum of the bit depths of the rendered primary colours (RGB). Primary colours can have different bit depths, for example 5-, 6- and 5-bit RGB depth for 16-bit colour depth.

3.1.6
tone additivity function
sum of the R, G, and B tones divided by the grey tone

Note 1 to entry: An ideal display has unity additivity for all inputs.

3.1.7
unbounded input signal
input signal for which there is neither any host-side colour management nor any handshaking taking place between the host and the DUT

3.2 Abbreviated terms

ABC	automatic brightness control
ALL	average light level
ALS	ambient light sensor
APL	average picture level
CIELAB	CIE 1976 $L^*a^*b^*$ colour space
CMY	cyan, magenta, and yellow
DUT	device under test
EOTF	electro-optical transfer function
GOGO	gain-offset-gamma-offset
HSI	hue saturation intensity (device dependent colour space, also called HSL (hue saturation lightness))
JND	just noticeable difference
LMD	light measuring device
OETF	opto-electrical transfer function
OOTF	opto-optical transfer function
RGB	red, green, and blue
RGBCMY	red, green, blue, cyan, magenta, and yellow
SLET	stray light elimination tube
sRGB	a standard RGB colour space as defined in IEC 61966-2-1 (sRGB has the same colour gamut as the gamut of Recommendation ITU-R BT.709 [11])

4 Standard measuring equipment

4.1 Video signal generator

A digital video signal generator or a computer with digital RGB outputs, each with at least 8-bit depth, shall be used. The signal bit depth supported by the DUT shall be reported according to Clause 7.

4.2 Measuring equipment and conditions

Refer to IEC 62977-2-1:2021, 5.3.4.

4.3 Test equipment setup

The setup of a non-close-up light measuring device (LMD) is shown in Figure 2 in the case of a perpendicular direction measurement. The optical axis of the LMD shall be centred on the screen and perpendicular to the plane of the display screen. The general conditions of the measuring equipment, such as angular aperture, shall follow IEC 62977-2-1. A close-up type LMD as shown in Figure 3 can be used only for measurements perpendicular to the DUT. A close-up LMD shall have input optics with a well-defined measurement field angle similar to that of non-close-up LMDs. The accuracy of the close-up type LMD shall be verified by a non-close-up spectroradiometer.

The measuring layout for viewing directional measurement shall be applied by moving the LMD or by rotation of the display in the horizontal viewing direction as shown in Figure 4a) and b), where a vertical arrangement for a vertical viewing direction is also possible. Alternatively, the spherical coordinate system as shown in Figure 4c) shall be applied (refer to IEC TS 62977-3-1:2019, 6.1, and IEC 62977-2-1:2021, 5.6 and 6.10). The directional measurement shall be done with a non-close-up measurement.

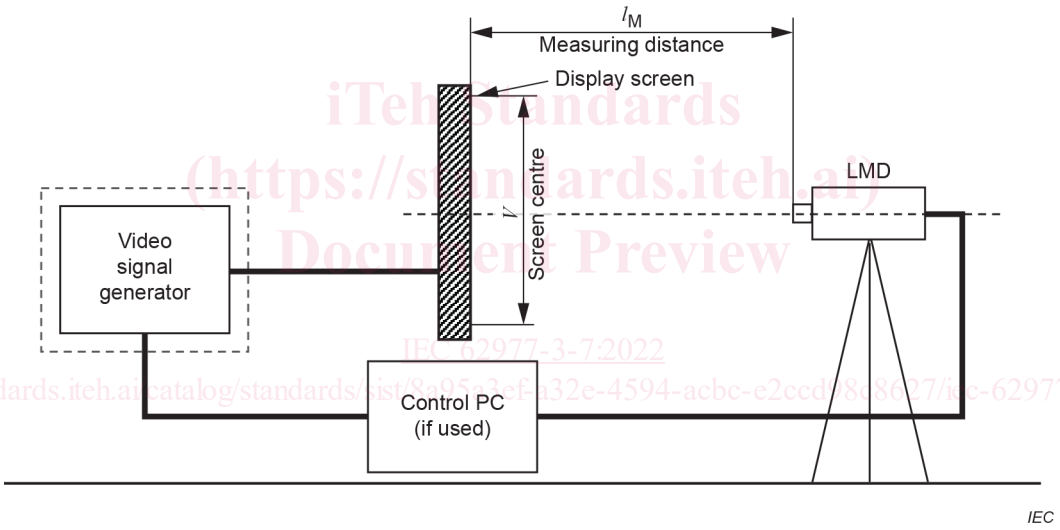


Figure 2 – Measuring layout for non-close-up measurement

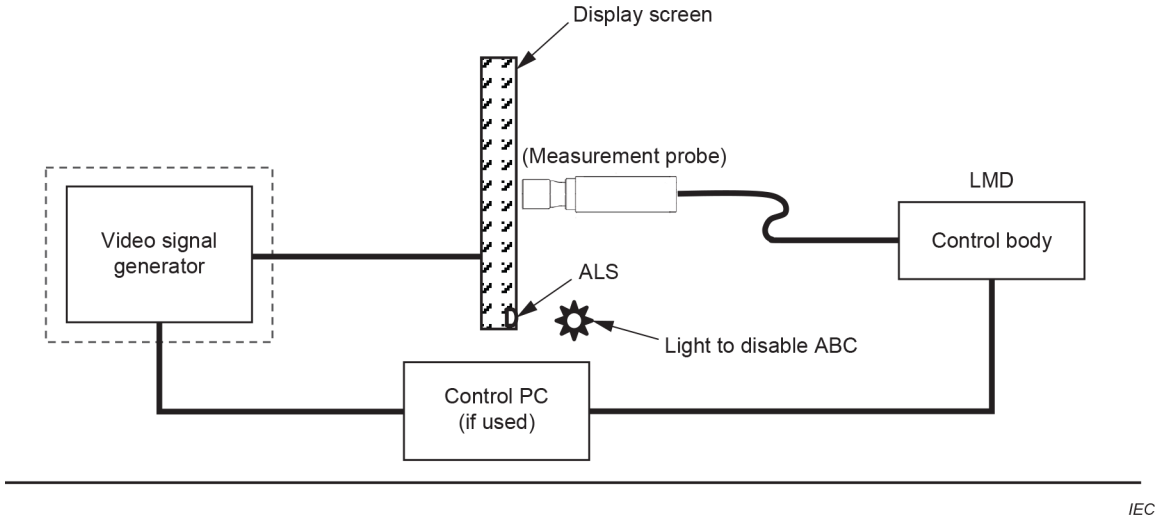
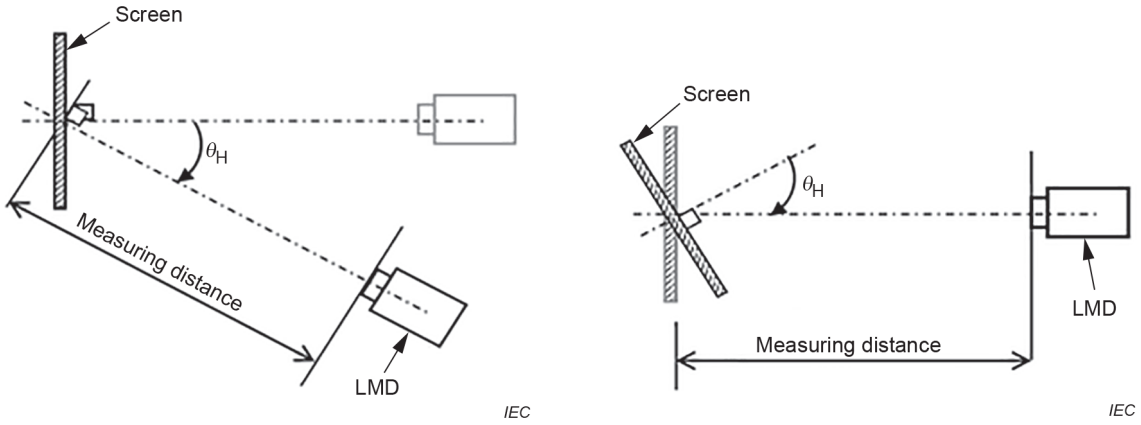
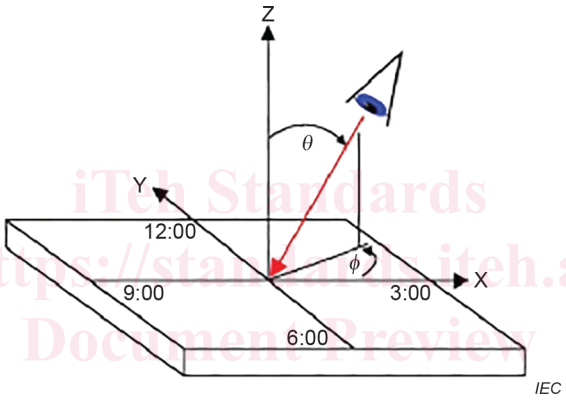


Figure 3 – Measuring layout for close-up type LMD



a) Measurement by moving the LMD (top view) **b) Measurement by rotating the DUT (top view)**



c) Measurement in spherical coordinate system

Figure 4 – Setup for viewing directional measurements

5 Standard measuring conditions

5.1 Standard measuring environmental conditions

Refer to IEC 62977-2-1:2021, 5.1, where the standard environmental conditions are defined as follows:

- temperature: 25 °C ± 3 °C,
- relative humidity: 25 % to 85 %,
- atmospheric pressure: 86 kPa to 106 kPa.

When different environmental conditions are used, they shall be noted in the report.

5.2 Standard measuring darkroom conditions

Refer to IEC 62977-2-1:2021, 5.2.