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Electronic displays

Part 3-4: Evaluation of optical performances — High dynamic range displays

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

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Part 3-4: Evaluation of optical performances – High dynamic range displays

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ELECTRONIC DISPLAYS –

Part 3-4: Evaluation of optical performances – High dynamic range displays

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Draft	Report on voting
110/1493/FDIS	110/1509/RVD

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

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INTRODUCTION

High dynamic range (HDR) systems enable more natural images that contain wider variations in brightness. For the wider dynamic range, newly designed electro-optical transfer function (EOTF) replaces the BT.1886 function of standard dynamic range (SDR) HDTV. High dynamic range (HDR) systems utilize non-linear signal encoding that enables reproduction over a wider range of light levels, from subtle grey differences at very low luminance levels up to very bright highlights. This very wide range of light levels occurs in both natural as well as synthetic imagery. In particular, in order to render the native image according to the intent of the content creator, signal codewords of SMPTE ST 2084 [2][1] HDR EOTF, also known as the perceptual quantizer (PQ), are mapped to absolute luminance values within the mastering peak luminance as specified in metadata of the HDR content, versus an SDR signal level which indicates relative brightness according to the display luminance. In this case, tone mapping would be necessary when the display luminance cannot make the darker and the brighter luminance because HDR content preserves details in the darkest and brightest areas of a picture that are lost when using SDR standards (see 3.1.4) [20] such as Recommendation ITU-R BT.709 [12]. The tone mapping curve can depend upon the display manufacturer.

This document intends to describe the measurement and evaluation of the optical performance of HDR displays as a reference for forthcoming standards to make the work of the involved experts more efficient and to avoid duplication of efforts.

There are unique requirements to evaluate HDR displays, and particular attention is given to the measurements, so that they are done properly. For example,

1) very low luminance levels will be measured, with careful control of stray light from both the display as well as ambient light sources;
2) to measure high light output levels, measurements timing and test pattern need to be carefully controlled to correctly and accurately capture peak or high luminance levels since HDR displays can have a peak luminance time limit, and many HDR displays have luminance loading limits;
3) for HDR content, 10 bits or higher bit-depth should be used for sufficient luminance quantization;
4) the HDR test signal has SMPTE ST 2086 [3] HDR static metadata assigned to fixed values. Other metadata is not used in this document.

Proper source content is critical to evaluating HDR performance of the displays including the driver (and interface). In SDR displays, it is possible to separate these issues from the evaluation of “panels”, but for HDR displays it is not possible to separate these issues because HDR displays include one or more internal blocks that process the HDR video signal, such as EOTF and tone mapping, etc., in addition to essential driving stages for the display panel.

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

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ELECTRONIC DISPLAYS –

Part 3-4: Evaluation of optical performances – High dynamic range displays

1 Scope

This part of IEC 62977 specifies the standard evaluation methods for determining the optical characteristics of HDR electronic display modules and systems. These methods apply to emissive and transmissive direct-view displays that render real 2D images on a flat panel or on a curved panel with a local radius of curvature larger than 1 500 mm. This document evaluates the optical characteristics of these displays under darkroom conditions. This document applies to the testing of display performance in response to HDR digital input signals that are absolute luminance encoded such as the HDR signal comprising RGB component values of Recommendation ITU-R BT.2020 colorimetry with SMPTE ST 2084 [2] PQ luminance encoding and SMPTE ST 2086 [3] metadata.

NOTE A flat panel or flat panel display is a display with a planar surface that emits light from the surface. The display can consist of light valves modulating a backlight or be self-luminous. Emissive/transmissive/reflective hybrid displays can be non-planar panels or non-planar panel displays.

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 62977-2-2:2020, *Electronic displays – Part 2-2: Measurement of optical characteristics – Ambient performance*

CIE 015:2004, *Colorimetry*

Recommendation ITU-R BT.2020-2, *Parameter values for ultra-high definition television systems for production and international programme exchange*

Recommendation ITU-R BT.2100-2, *Image parameter values for high dynamic range television for use in production and international programme exchange*

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 https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

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3.1.1
HDR peak luminance
maximum stable white luminance of the display using the HDR test signal (see 3.1.14) under the required measuring condition

3.1.2
dynamic range
range of the lowest to the highest luminance expressed by the ratio of the highest luminance to the lowest luminance that the display can render by a non-zero signal value

Note 1 to entry: The unit of the dynamic range can be expressed in terms of the number of stops using the formula Log_2[dynamic range].

3.1.3
high dynamic range
HDR
span of image luminance and contrast described in Recommendation ITU-R BT.2100

3.1.4
standard dynamic range
range of relative luminance with an unbounded input signal (generally exhibiting a power law dependence with input signal to be displayed in accordance with the luminance range of the display) that is normally possible for a conventional video display and content, whereby the standard dynamic range signal for SDTV, HDTV and UHDTV is encoded with the format defined in Recommendation ITU-R BT.601 [13], Recommendation ITU-R BT.709 [12] and Recommendation ITU-R BT.2020, respectively

3.1.5
average picture level
APL
average input level of all signal pixels relative to the maximum signal setting expressed as a percentage

Note 1 to entry: Post-EOTF APL is also called ALL (average light level), and calculated by averaging of post-EOTF signal pixels (linear values).

3.1.6
code value
digital input value of an image signal component representing a signal pixel expressed in a specified format such as RGB

3.1.7
opto-electrical transfer function
OETF
optical to signal transfer function which is used in image acquisition devices such as digital cameras for mapping scene luminance to digital code values prior to encoding, transmission, or compression

Note 1 to entry: If OETF and EOTF consist of or are close to a power function (such as generally used in SDR systems), the function is called nonlinear encoding (gamma correction) and nonlinear decoding (inverse gamma correction), respectively, where its exponent is called gamma or gamma value.

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.

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3.1.8
electro-optical transfer function
EOTF
mathematical function for the inverse OETF (and system gamma for power law functions), usually used for display systems such as TVs and monitors, that maps digital code values to displayed luminance

Note 1 to entry: Generally, EOTF is also called nonlinear decoding, which is the inverse of nonlinear encoding, but custom decoding is also available in many display products.

3.1.9
optical-to-optical transfer function
OOTF
mathematical function that maps the captured luminance by a camera to the displayed luminance by a display device according to the rendering intent or peak luminance of the display

3.1.10
white boosting
increase in the luminance of displayed white image elements beyond what is expected for R + G + B primary colour additivity, and a corresponding decrease in colour saturation

Note 1 to entry: Luminance boosting such as white boosting can influence the tone curve according to colour saturation that is deviated from the display gamma curve.

3.1.11
HDR display
display that can accommodate, properly process, and display the PQ-encoded HDR content defined in Recommendation ITU-R BT.2100

Note 1 to entry: An HDR display can also display SDR content by changing the EOTF and its related functions such as tone mapping and system gamma.

3.1.12
HDR content
image content mastering with OETF which is described in Recommendation ITU-R BT.2100

3.1.13
HDR tone mapping
mapping of the HDR test signal to the performance envelope of a display, whereby the display system maps one set of tone ranges to another to approximate the appearance of the content, when the content requires a wider dynamic range beyond the display's capability to reproduce the full range of light intensities ranging from the darkest to the highest target luminance levels

Note 1 to entry: HDR tone mapping can include dynamic range global or local clipping or roll-off while preserving the chromaticity of the original image (see 6.6), perceptual colour rendering, or other forms of colour gamut mapping which are dependent on the display mode.

Note 2 to entry: An HDR DUT can use different static and/or dynamic metadata as input to the tone mapping algorithms.

3.1.14
HDR test signal
test signal referred to as an HDR10 implementation that has been adopted by the display industry to describe an uncompressed signal that uses the PQ EOTF from Recommendation ITU-R BT.2100 and HDR static metadata defined in SMPTE ST 2086 [3]

Note 1 to entry: An explanation can be found in 4.1. For the purpose of controlled metrology, the test signal is used with a single set of signal parameters that is unique compared to other signals described in display-referred (refer to Chapter 20 in [1]) whose signal represents the intent of the content creator that includes defined parameters for the non-linearity, min/max luminance, and the colour encoding of the signal container, whereby the encoded signal values can be directly transformed to absolute CIE XYZ.

Note 2 to entry: For the definitions of HDR test signals such as display-referred, signal container, etc., and for background information see Chapter 20 in IDMS ver.1.1:2021 [1].

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3.1.15
Maximum Content Light Level
MaxCLL
metadata which indicates the maximum light level value of any single pixel of the entire playback sequence

Note 1 to entry: For MaxCLL, the unit is equivalent to cd/m^2 when the brightest pixel in the entire video stream has the chromaticity of the white point of the encoding system used to represent the video stream. Since the value of MaxCLL is computed with a max() mathematical operator, it is possible that the true CIE Y luminance value is less than the MaxCLL value.

3.1.16
Maximum Frame-average Light Level
MaxFALL
metadata which indicates the maximum frame average value within a temporal sequence of frames

Note 1 to entry: For MaxFALL, the unit is equivalent to cd/m^2 when the maximum frame average of the entire stream corresponds to a full-screen of pixels that has the chromaticity of the white point of the encoding system used to represent the video stream. The frame-average computation used to compute the MaxFALL value is performed only on the active image area of the image data.

3.1.17
$\Delta E_{00,D50}$
colour difference calculated based on adaptation to D50 using CIE 1931 colour-matching functions (CMFs)

Note 1 to entry: This colour difference is different from CIE ΔE_{00}.

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

ABC	auto brightness control
ACR	ambient contrast ratio
ALC	ambient light control
APL	average picture level
BRCR	bright room contrast ratio
CAT	chromatic adaptation transform
CIELAB	CIE 1976 (L*a*b*) colour space
CMF	colour-matching function
DRCR	darkroom contrast ratio
DUT	device under test
EOTF	electro-optical transfer function
HDR	high dynamic range
OETF	opto-electrical transfer function
OLED	organic light emitting diode
OOTF	optical-to-optical transfer function
PQ	perceptual quantizer (PQ tone curve as defined in Recommendation ITU-R BT.2100)
RGBCMY	red, green, blue, cyan, magenta and yellow
SDR	standard dynamic range
SLET	stray light elimination tube

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4 Standard measuring equipment

4.1 Video signal generator

A digital video signal generator is used, and the HDR test signal is implemented as follows. All code values of the test signal shall be PQ encoded with BT.2020 colorimetry and 10-bit full-range. The DUT should support a 10-bit or greater signal and colour range signal input of Recommendation ITU-R BT.2020. This shall be included as “Supported” or ”Not supported” in the test report of Clause 7. It is important that for each measurement result, metadata conditions are defined, checked and reported; otherwise, the results might not be reproducible. The static HDR metadata format shall be reported as described in 7.1 (refer to Section 20.1.1 and Section 20.1.5 in IDMS ver.1.1:2021 [1], [12], [15]). The HDR test signal format is defined as:

SMPTE ST 2084 EOTF, 10-bit RGB full range, BT.2020 primary encoding,

SMPTE ST 2086 metadata: The default metadata is set to P3D65, 4 000 cd/m^2 peak

MaxCLL no data, MaxFALL no data

If the DUT exceeds the default metadata settings, these can be modified accordingly as long as they are clearly reported.

The input signal or input data, in this document, means the transferred code values by the OETF of PQ HDR defined in Recommendation ITU-R BT.2100 and Report ITU-R BT.2390 [17].

4.2 Conditions of measuring equipment

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

Additional conditions of the measuring equipment shall comply with IEC 62977-2-1.

4.3 Measuring equipment block diagram

Refer to IEC 62977-2-1. An example of block diagram is shown in Figure 1. The optical axis of the optical test equipment shall be centered on the screen and perpendicular to the display surface.

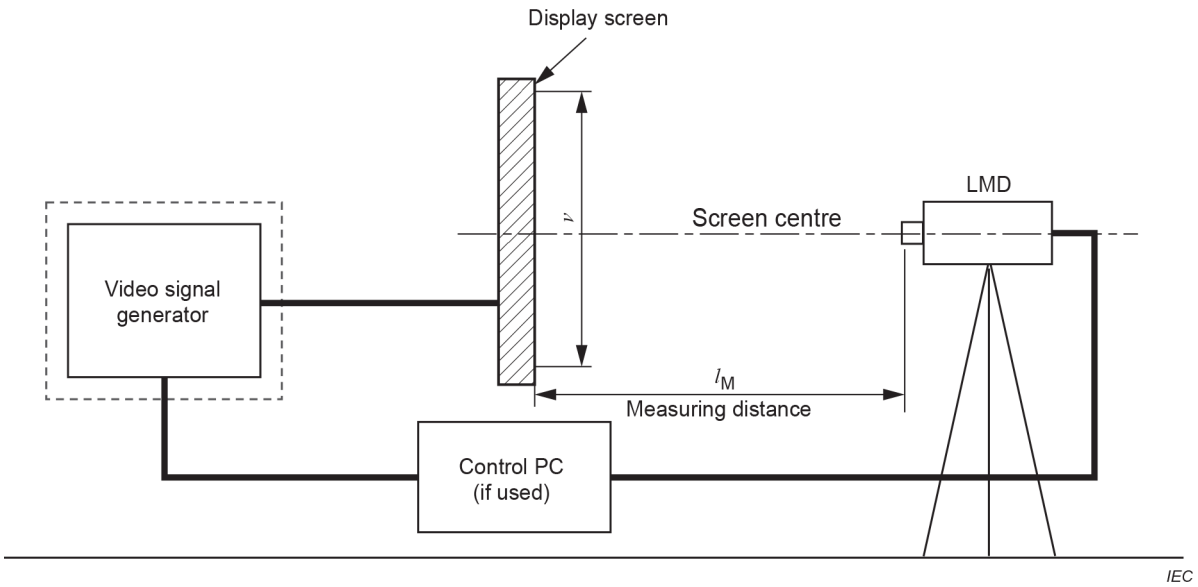

Figure 1 – Measuring layout for non-contact measurement

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