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Electronic displays –
Part 2-1: Measurements of optical characteristics – Fundamental measurements

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FOREWORD

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

FDIS	Report on voting
110/1256/FDIS	110/1275/RVD

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

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

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- withdrawn,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.

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INTRODUCTION

This document describes the common optical measurement methods applicable in the field of electronic display devices, which can overlap with some of the parts of existing documents developed within TC 110 (IEC 61747-30-1 [1] [1], IEC 62341-6-1, IEC 61988-2-1 [2], IEC 62715-5-1 [3]), that describe the optical measurement methods of the individual technologies, such as LCD, OLED, PDP and others. This document on common optical measurement methods is intended to be used as the reference document in future documents and in revisions of existing documents (e.g. IEC 61747-30-1, IEC 62341-6-1, IEC 61988-2-1, IEC 62715-5-1). The existing documents will be revised in their maintenance time to refer to this document to the largest extent possible.

All documents in IEC TC 110 that are concerned with the measurement of optical properties of electronic displays refer to a set of methods and procedures that are similar to each other, or sometimes even identical. This document is intended to identify these methods and to describe them, together with suitable precautions and diagnostics, as a reference for forthcoming documents to make the work of the involved experts more efficient and to avoid duplication of efforts.

Introduction of the common optical measurement method (COMM) is also related to a structure where each kind of optical measurement finds its unambiguous position for identification of similarities to other methods or for clarification of distinctions. This structural classification together with a general taxonomy is supposed to make the process of document production easier, faster and thus more effective.

The above characteristics are summarized in Table 1. The display characteristics that are addressed in this part of IEC 62977 are indicated by a check mark √ in the table.

Table 1 – Summary of display characteristics

Variables	**Time**		**Location** (x, y)	**Direction** (θ, ϕ)	**Test pattern, electrical driving, input signal**	**Illumination conditions**	**Temperature, humidity**
Data sampling condition	**Fast**	**Slow**	**Slow** √	**Slow**	**Slow** √		
Evaluation							
Results	transitions from one optical state to another state	temporal stability (uniformity)	uniformity √	uniformity, √	static pattern, √ characteristic function (electro-optic transfer function, EOTF) characteristic values (e.g. threshold, saturation)	darkroom, √ indoor, outdoor	standard environment √
Evaluation 1st order	turn-on, turn-off, delay (latency) time periods, temporal modulations				luminance, √ contrast, √ chromaticity, √ threshold, saturation values, steepness of transitions, etc.		
Evaluation 2nd order	flicker prediction, moving picture response time, etc.				EOTF from which the exponent gamma is evaluated chromaticity/ colour gamut area, √ colour gamut volume, √		

1 Numbers in square brackets refer to the Bibliography.

ELECTRONIC DISPLAYS –

Part 2-1: Measurements of optical characteristics – Fundamental measurements

1 Scope

This part of IEC 62977 specifies standard measurement conditions and measuring methods for determining the optical characteristics of electronic display modules and systems. These methods apply to emissive and transmissive direct view displays that render real 2D images on a flat panel. This document evaluates the optical characteristics of these displays under darkroom conditions. This document applies to the testing of display performance in response to standard analogue or digital input signals that are not absolute luminance encoded. The input signal is relative RGB without metadata information that codes for real luminance, colour space or colour coordinates. These methods are limited to input signals with typical OETFs such as defined in IEC 61966-2-1, ITU BT. Rec. 601, ITU BT. Rec.709, and ITU BT. Rec.2020. The tests in this document are not approved for use with HDR input signals.

NOTE A flat panel or flat panel display is a display with a flat surface and minimal depth that emits visible light from the surface. The display is subdivided into an array of electronically driven pixels which can be light valves modulating a backlight, or self-luminous. Emissive/transmissive/reflective hybrid displays can be flat panel or flat 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 60050-845, *International Electrotechnical Vocabulary – Part 845: Lighting* (available at www.electropedia.org)

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

IEC 62341-6-1, *Organic light emitting diode (OLED) displays – Part 6-1: Measuring methods of optical and electro-optical parameters*

IEC TR 62977-2-3, *Electronic display devices – Part 2-3: Measurements of optical properties – Multi-colour test patterns*

ISO 9241-305, *Ergonomics of human-system interaction – Part 305: Optical laboratory test methods for electronic visual displays*

ISO 15076-1:2010, *Image technology colour management – Architecture, profile format and data structure – Part 1: Based on ICC.1:2010*

ISO/CIE 11664-1, *Colorimetry – Part 1: CIE standard colorimetric observers*

ISO/CIE 11664-4, *Colorimetry – Part 4: CIE 1976 L*a*b* colour space*

CIE 15:2004, *Colorimetry, 3rd edition*

CIE 168:2005, *Criteria for the evaluation of extended-gamut colour encodings*

CIE 233:2019, *Calibration, characterization and use or array spectroradiometers*

ITU-R BT.601, *Studio encoding parameters of digital television for standard 4:3 and wide screen 16:9 aspect ratios*

ITU-R BT.709, *Parameters values for the HDTV standards for production and international programme exchange*

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

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-845 and the following 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
signal pixel
smallest encoded picture element in the input image

Note 1 to entry: Signal pixel is defined as the unit of signal resolution.

3.1.2
pre-gamma average picture level
average input level of all signal pixels relative to an equivalent white pixel driven by a digital RGB input

Note 1 to entry: Unless otherwise stated, the pre-gamma average picture level (APL) will simply be referred to as average picture level in this document.

Note 2 to entry: The APL will normally be expressed as a percentage, where a full white screen at maximum drive level would be 100 % APL.

Note 3 to entry: The pre-gamma APL is also called gamma-corrected APL in IEC 62087-2 [4]. In addition, it is noted that the tone rendering curve may not have a power law function with a well-defined exponent (gamma).

3.1.3
APL loading
influence of average picture level on display performance, for example luminance

3.1.4
chromaticity difference
geometric distance between two colour coordinates in a CIE chromaticity diagram, usually the CIE 1976 chromaticity diagram

3.1.5
chromaticity gamut area
colour gamut area
maximum area of chromaticity reproducible by a display

Note 1 to entry: "Colour gamut area" has been used in textbooks, industry, and the market for a long time. However, the CIE (eilv.cie.co.at) indicates that the term "colour gamut" should be regarded as a volume in a colour space. Therefore, a two-dimensional representation should be described as a chromaticity gamut area.

3.1.6
direct view
non-projection display technology where the image rendering surface is viewed directly without any optical components between the viewer and the surface

3.2 Abbreviated terms

APL	average picture level
CAT	chromatic adaption transform
CCT	correlated colour temperature
CIE	Commission Internationale de L'Eclairage (International Commission on Illumination)
CIELAB	CIE 1976 (L*a*b*) colour space
CMY	cyan, magenta, and yellow
DUT	device under test
EOTF	electro-optic transfer function
HDR	high dynamic range
LCD	liquid crystal display
LED	light-emitting diode
LMD	light measuring device
OETF	opto-electronic transfer function
RGB	red, green, and blue
RGBCMY	red, green, blue, cyan, magenta, and yellow
SDR	standard dynamic range
sRGB	a standard RGB colour space defined in IEC 61966-2-1
SPD	spectral power distribution
UCS	uniform chromaticity scale

4 General

4.1 Measured basic quantities

The basic quantities for luminance and chromaticity can be measured directly, for example with photometers and colorimeters, or they can be obtained from measured spectra (i.e. the spectral power distribution (SPD)) by a spectroradiometer. Spectroradiometers are generally more accurate than photometers or colorimeters, and should be used when higher accuracy is needed. Photometers and colorimeters allow for fast data acquisition as required for evaluation of optical transitions (e.g. "switching times"). The acquisition of the spectral power distribution is usually restricted to steady optical states.

4.2 Electrical driving of the display (depending on the nature of the display)

The electrical driving conditions of the display are as follows:

– driving voltage (waveform), current, frequency, etc.;
– RGB input (analogue, digital);
– test pattern (independent of display electrical interface).

4.3 Data acquisition timing and display driving

4.3.1 Stationary measurements

After application of a new driving state (test pattern), a delay (wait) period is introduced for the optical response to settle to a steady state before the measurement is carried out.

4.3.2 Properties of display under test

The physics of the display itself or the signal processing measures can affect the optical response (image), for example via luminance loading (luminance dependence on APL). The display to be measured shall be checked for this effect and the test patterns used during the measurement procedure shall be chosen and applied accordingly.

5 Standard measuring conditions

5.1 Standard measuring environmental conditions

Measurements shall be carried out under the standard environmental conditions:

– 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

The luminance contribution from unwanted background illumination reflected off the test display shall be less than 1/20 of the display's black state luminance. The reflected background luminance can be approximated by turning off the display. When the reflected background luminance and total (reflected plus black) luminance are greater than the sensitivity limit of the LMD, then it is possible to calculate the black luminance by subtracting the background luminance from the total luminance. If the reflected background luminance or total luminance are similar to the sensitivity limit of the LMD, this shall be reported. In cases where the display has a very low luminance black state, a stray light elimination tube (according to ISO 9241-305) should be used to minimize the contribution of the background illumination. This method can be used to estimate the reflected luminance from the black state luminance.

NOTE Blackout curtains are a solution for reducing the reflection from the DUT.

5.3 Standard setup conditions

5.3.1 General

Standard setup conditions are given in 5.3. Any deviations from these conditions shall be reported.

5.3.2 Adjustment of display

The display shall be configured to the specified settings, and the settings recorded in the test report. These settings shall be held constant for all measurements. It is important, however, to make sure that not only the adjustments are kept constant, but also that the resulting physical quantities remain constant during the measurement. This is not automatically the case because of, for example, warm-up effects or auto-dimming features. Any automatic luminance or gain control shall be turned off. Otherwise it should be noted in the report. The ambient light (or brightness) control (ABC), which can reduce the display luminance level with dim ambient illumination, shall be turned off. If that is not possible, it is recommended to set it to turn on no lower than 300 lx to minimize the influence of the ABC. The state of the ABC shall be reported. In addition, if the display has an auto-dimming feature which reduces the display luminance of a static image after a prolonged time, then at least an 8 s black frame shall be rendered prior to rendering and measuring the desired test pattern. The measurements shall be completed before the dimming feature is triggered. When the display has the option to be set for different viewing modes, the viewing mode shall be defined by the test specification, and be used with consistency for all measurements. Additional viewing modes can also be measured. The viewing mode used during testing shall be reported. The display should be operated in a mode that does not have overscan.

5.3.3 Starting conditions of measurements

Measurements shall be started after the displays and measuring instruments achieve stability. The DUT shall be turned on first and operated for at least 30 min prior to the measurement. Some display technologies may need a loop of colour patterns rendered on the screen during the warm-up period. Sufficient warm-up time has been achieved when the luminance of the test feature to be measured varies by less than ±3 % over the entire measurement period (e.g. uniformity measurements) for a given display image.

5.3.4 Conditions of measuring equipment

5.3.4.1 General conditions

Optical properties of displays shall generally be expressed in photometric or colorimetric units using the CIE 1931 standard colorimetric 2° observer (according to ISO/CIE 11664-1). Luminance can be measured by a photometer, and CIE tristimulus values (X, Y, Z) or CIE chromaticity coordinates by a colorimeter. A spectroradiometer can also obtain photometric and colorimetric values through a numerical conversion of the measured spectral radiance data (see for example [5]). The following requirements are given for these instruments.

The LMD shall be a luminance meter, colorimeter, or a spectroradiometer. For DUTs that have sharp spectral peak full-width-at-half-maximums (FWHMs) smaller than 20 nm, such as LCDs with fluorescent lamp backlights or LEDs with narrow-peak phosphors, quantum-dot phosphors, or narrow-spectrum OLEDs, a spectroradiometer should be used. A filter colorimeter should generally not be used for light sources with sharp spectral peaks. If a colorimeter is used, it shall be calibrated with the measured colorimetry values obtained from a narrow bandwidth spectroradiometer. Even with this procedure, the colorimeter will give lower accuracy results than the spectroradiometer. Report the characteristics of the spectroradiometer (as given in CIE 233) which is used for calibration. For light sources with sharp spectral peaks, the maximum bandwidth of the spectroradiometer shall be ≤ 5 nm. In those cases, the wavelength accuracy shall be within ±0,3 nm. The spectroradiometer shall be capable of measuring spectral radiance over at least the 380 nm to 780 nm wavelength range, with a maximum bandwidth of 10 nm for smooth broadband spectra (i.e. broad spectrum with no sharp spikes).

Care should be taken to ensure that the LMD has enough sensitivity and dynamic range to perform the required task. Before measuring the DUT, it is recommended to check the LMD specification.

The following additional best practices shall be followed:

a) The LMD shall be focused on the image plane of the display and generally aligned perpendicularly to the display surface at the centre of the active display area, unless stated otherwise.

b) The relative uncertainty and repeatability of all the measuring devices shall be maintained by following the instrument supplier's recommended calibration schedule.

c) If the light level of the display is temporally modulated, then the LMD integration time shall be synchronized with the vertical frame synchronization signal. If the LMD is not capable of synchronizing, then the LMD integration time shall be at least 200 cycles of the fundamental Fourier Transform frequency light of the modulated light in order to measure the luminance to better than 5 %. An initial assessment of the suitability of the LMD for temporally modulated signals can be made by a repeatability measurement with at least five measurements.