

SEMI D72-1014

TEST METHODS FOR COLOR PROPERTIES OF ELECTRONIC PAPER DISPLAYS

This Standard was technically approved by the Flat Panel Display – Metrology Global Technical Committee.
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1 Purpose

1.1 Electronic paper displays use reflective technology to create images and need no power to hold images because of their bistable nature. There are more and more applications of color electronic paper displays on the market nowadays, and for convenient reading, some of electronic paper displays are equipped with front light. It is necessary to standardize the test methods for measuring color and optical properties of electronic paper displays under front light on or off.

2 Scope

2.1 Standardize the measurement methods, including light sources, illumination conditions and measuring geometries, and define the parameters for color properties of electronic paper display.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Standard is suitable for use with color electrophoretic displays, cholesteric-LCDs, and other displays with bistable nature which are reflective electronic paper displays under the front light on or off.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI D68 — Test Methods for Optical Properties of Electronic Paper Displays

4.2 CIE Standard¹

CIE 15:2004 3rd edition — Colorimetry

4.3 ICDM Standard²

Information Display Measurements Standard (IDMS v1.03)

4.4 IEC Standard³

IEC 61747-6-2 — Measuring Methods for Liquid Crystal Display Modules – Reflective Type

4.5 ISO Standard⁴

ISO 12647-3 — Graphic Technology – Process Control for the Production of Half-Tone Colour Separations, Proofs and Production Prints – Part 3: Coldset Offset Lithography on Newsprint

4.6 VESA Standard⁵

VESA 2.0 — Flat Panel Display Measurements Standard

¹ International Commission on Illumination, <http://www.cie.co.at/>

² International Committee for Display Metrology, http://www.icdm-sid.org/icdm_main.html

³ International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland; Telephone: 41.22.919.02.11, Fax: 41.22.919.03.00, <http://www.iec.ch>

⁴ International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland; Telephone: 41.22.749.01.11, Fax: 41.22.733.34.30, <http://www.iso.org>

⁵ Video Electronics Standards Association, <http://www.vesa.org>

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *DUT* — display under test

5.1.2 *EPD* — electronic paper display

5.1.3 *ILU* — integrated lighting unit (e.g., an edge-lit front light plate)

5.1.4 *LMD* — light-measuring device

5.2 Definitions

5.2.1 *bistability* — ability to hold the image without applied voltage.

5.2.2 *contrast ratio* — ratio of the DUT brightness at white state to that at black state.

5.2.3 *gamut area* — area enclosed by the chromaticity coordinates of the display primary colors.

5.2.4 *gamut area ratio* — ratio of the gamut area to the area defined by a particular specification in a color space coordinate.

5.2.5 *uniformity* — characterizes the change in brightness or color difference over the display area of the DUT.

5.2.6 *viewing direction* — direction from which the observer looks at the point of interest on the DUT. Viewing direction dependence characterizes the change in brightness, contrast ratio, and color relative to their values at the normal viewing direction.

6 Summary of Test Method

6.1 The test methods provide procedures for measuring the optical properties of color electronic paper display (EPD) with the integrated lighting unit (ILU) off or on.

6.1.1 For the measurements of device under test (DUT) with the ILU off, EPDs are viewed as reflective displays. The light reflected from the EPD will generally be measured in terms of photometric or colorimetric units; photometric reflectance for a luminance photometer, or CIE 1931 tristimulus values (X, Y, Z) for a colorimeter. A spectroradiometer may also obtain photometric and colorimetric values through a numerical conversion of the measured spectral reflectance data. Measurement specifications on reflective displays must include the illumination conditions during measurement. The measurement illumination consists of one or more light sources, each with specified spectral distribution and illumination geometry. The key steps include:

6.1.1.1 Measuring the spectral reflectance factors of the reference white standard, black standard, and DUT set to the desired full-screen color with a spectroradiometer.

6.1.1.2 Measuring the CIE tristimulus values of the reference white standard, black standard, and DUT set to the desired full-screen color with a colorimeter.

6.1.1.3 Measuring the bistability by measuring the spectral reflectance factors or the CIE tristimulus values at two different times after switching the DUT to the desired full-screen color.

6.1.1.4 Measuring the uniformity of the DUT set to the desired full-screen color by measuring the spectral reflectance factors or the CIE tristimulus values of the nine measurement positions.

6.1.1.5 Measuring the viewing-direction dependence of contrast ratio, color difference and lightness difference at horizontal or vertical angles.

6.1.2 For the measurements of DUT with the ILU on, EPDs are viewed as emissive displays. The light emitted from the EPD with ILU switched on will generally be measured in terms of photometric or colorimetric units; luminance for a luminance meter, or CIE 1931 tristimulus values (X, Y, Z) for a colorimeter. A spectroradiometer may also obtain photometric and colorimetric values through a numerical conversion of the measured spectral radiance data. The measurements have to be carried out under darkroom conditions. The key steps include:

6.1.2.1 Measuring the spectral radiance of the DUT set to the desired full-screen color with a calibrated spectroradiometer.

6.1.2.2 Measuring the CIE tristimulus values of the DUT set to the desired full-screen color with a calibrated colorimeter.

6.1.2.3 Measuring the bistability by measuring the spectral radiance or the CIE tristimulus values at two different times after switching to the desired full-screen color.

6.1.2.4 Measuring the uniformity of the DUT set to the desired full-screen color by measuring the spectral radiance or the CIE tristimulus values at nine measurement positions.

6.1.2.5 Measuring the viewing-direction dependence of contrast ratio, color difference and luminance at horizontal or vertical angles.

7 Environmental Conditions

- Temperature: $25^{\circ}\text{C} \pm 3^{\circ}\text{C}$
- Humidity: 25% to 85% RH
- Illumination of surrounding: dark room ≤ 1 lx
- No reflection or low reflection objects of surroundings

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

8 Apparatus

8.1 Light Source

8.1.1 If the ILU of the EPD is turned off, standard directional, ring light, or hemispherical illumination conditions shall be used. The illumination spectra should approximate CIE Illuminant D50 or D65, or A (incandescent lamp, e.g., tungsten halogen lamp). When different light sources are used, they shall be noted in the report.

8.1.1.1 Directional illumination simulates sunlight or small indoor light sources. It is produced by approximately parallel rays incident on the DUT. The maximum deviation of the rays from the optical axis shall not exceed 5° , and the illumination across the cross-section of the beam shall be uniform to within 5%. For $45^{\circ} \times 0^{\circ}$ geometry, DUT is illuminated at an angle of 45° from the normal to DUT surface and viewed normal to DUT surface or within 10° to the normal.

8.1.1.2 Ring light illumination is a special case of directional illumination with rotational symmetry about the display's surface normal and centered on the measurement spot. For $45^{\circ} \text{ a:} 0^{\circ}$ geometry, DUT is illuminated at 45° circumferential incidence from the normal to DUT surface and viewed normal to DUT surface or within 10° to the normal.

8.1.1.3 Uniform hemispherical diffuse illumination simulates outdoor skylight or indoor diffuse background illumination. It is produced by an integrating sphere with the DUT inside, or a sampling sphere with the DUT at the exit port.

8.2 Light-Measuring Device (LMD)

8.2.1 Spectroradiometers are used for the measurement of spectral reflectance factor (ILU off) or radiance (ILU on). Its wavelength intervals, $\Delta\lambda$ shall not be greater than 10 nm over the wavelength range from 380 to 780 nm.

8.2.2 Colorimeters are used for the measurement of CIE 1931 tristimulus values (X, Y, Z).

8.2.3 Luminance meters are used for the measurement of photometric reflectance (ILU off) or luminance (ILU on).

8.3 Reflection Standards

8.3.1 For the spectral reflection measurement, one reference white standard and one reference black standard of calibrated spectral reflectance factor $R_{WS}(\lambda)$ and $R_{BS}(\lambda)$ respectively for the same measurement geometry as in the test configuration shall be used.

8.3.2 For the filter photometric reflection measurement, one reference white standard and one reference black standard of calibrated CIE tristimulus values (X_{WS} , Y_{WS} , Z_{WS}) and (X_{BS} , Y_{BS} , Z_{BS}) respectively for the same measurement geometry as in the test configuration shall be used.

8.3.3 Diffuse reflectance standards are highly Lambertian, and are optically flat to $\pm 1\%$ over the visual region of the spectrum. White standards have a diffuse reflectance of 98% or more; black standards have a diffuse reflectance of 2% or less.

9 Measurement Geometry

9.1 Viewing-Direction Coordinate System

9.1.1 The display is at the center of an x-y-z coordinate system, with x-y the display surface, and z the display normal (see Figure 1). The direction of a directed light source and the direction of the LMD (or viewer) are parameterized by azimuth angle φ about the surface normal (rotating anti-clockwise, starting from $\varphi=0$ at 3 o'clock, which is also the x-direction), and angle of inclination θ to the normal z.

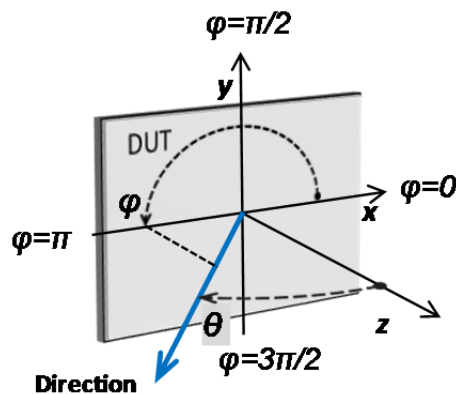


Figure 1

Representation of the viewing direction, or direction of measurement, defined by the angle of inclination, and the angle of rotation (azimuth angle) in a polar coordinate system.

9.2 Reflection Measurement Geometry

9.2.1 This geometry is used when the ILU is off so that measurement illumination is required. About the geometry of the diffuse illumination and directional illumination, refer to SEMI D68 in §§ 9.1 and 9.2.

9.2.2 Viewing-Direction Dependent Reflection

9.2.2.1 Different viewing directions can be achieved by varying the inclination θ_d of the LMD in a horizontal x-z plane between ($\theta_d=-\pi/2$, $\varphi=\pi$) and ($\theta_d=\pi/2$, $\varphi=0$). The direct source is inclined in the y-z plane by ($\theta_s=\pi/4=45^\circ$, $\varphi=\pi/2$) so that light source reflections are excluded from the measurement (see Figure 2). The viewing direction rotation θ_d can be achieved either by rotating the LMD as shown in Figure 2, or by rotating the DUT about the y-axis, with the directed source fixed to the DUT and rotating with it.

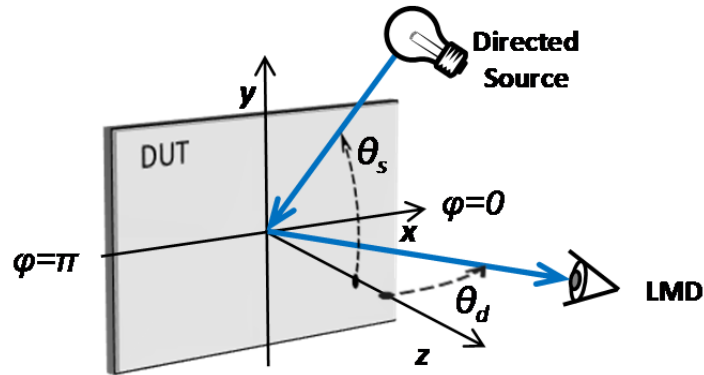


Figure 2
Horizontal viewing direction geometry with directional illumination; θ_s is source inclination in y-z-plane; θ_d is viewing direction in x-z-plane.

9.2.2.2 The vertical viewing direction (vertical relative to the display) can be measured with the same geometry after rotating the display by 90° about the z-axis (see Figure 3).

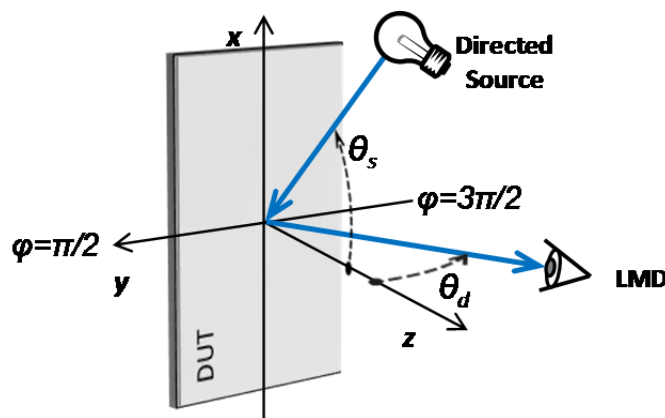


Figure 3
Vertical Viewing Direction Geometry with Directional Illumination
Illumination and Measurement Geometry for Vertical Viewing Direction

9.2.2.3 Different viewing directions can be achieved by varying the detector inclination θ_d in a y-z plane between $(\theta_d = -\pi/2, \varphi = \pi/2)$ and $(\theta_d = \pi/2, \varphi = 3\pi/2)$. The direct source is inclined in the x-z plane by $(\theta_s = \pi/4 = 45^\circ, \varphi = 0)$ so that light source reflections are excluded from the measurement (see Figure 3).

9.3 Luminance Measurement Geometry

9.3.1 This measurement geometry is used when the ILU is on so that no other measurement illumination is required.

9.3.2 Normal Viewing Direction

9.3.2.1 The LMD should view the DUT along the line in normal direction to the DUT (see Figure 4). The angular uncertainty of the normal direction is less than $\pm 0.3^\circ$. The measurement field angle is 2° or less.