IEC 61747-30-5

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INTERNATIONAL STANDARD

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Liquid crystal display devices –
Part 30-5: Optical measuring methods of transmissive transparent LCD modules

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IEC 61747-30-5:2019-01(en)

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LIQUID CRYSTAL DISPLAY DEVICES –

Part 30-5: Optical measuring methods of transmissive transparent LCD modules

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

FDIS	Report on voting
110/1047/FDIS	110/1070/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.

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A list of all the parts in the IEC 61747 series, under the general title *Liquid crystal display devices*, can be found on the IEC website.

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- withdrawn,
- replaced by a revised edition, or
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LIQUID CRYSTAL DISPLAY DEVICES –

Part 30-5: Optical measuring methods of transmissive transparent LCD modules

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1 Scope

This part of IEC 61747 specifies the standard measurement conditions and measuring methods for determining the optical properties of transparent liquid crystal display modules which operate in a transmissive mode.

More specifically, this document focuses on three particular aspects of the transparent properties, i.e. transmittance, haze, and image distortion.

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 61747-1-2, *Liquid crystal display devices – Part 1-2: Generic – Terminology and letter symbols*

IEC 61747-30-1, *Liquid crystal display devices – Part 30-1: Measuring methods for liquid crystal display modules – Transmissive type*

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

ISO 11664-2, *Colorimetry – Part 2: CIE standard illuminants*

ISO 14782, *Plastics: Determination of haze for transparent materials*

3 Terms, definitions, symbols and units

For the purposes of this document, the terms, definitions, symbols and units given in IEC 61747-1-2, as well as 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
transparent liquid crystal display module
direct-view liquid crystal display module that can show the information on the screen and allow real objects to be viewed through the screen

3.2
on-screen property
visual properties when the focus of the viewer is on the display screen

3.3
through-screen property
visual properties when the focus of the viewer is on the object behind the display screen

3.4
transmittance
ratio of the transmitted radiant or luminous flux to the incident flux in the given conditions

[SOURCE: IEC 60050-845:1987, 845-04-59, modified – The text in brackets after the term has been omitted.]

3.5
transmitted haze
percentage of transmitted light that is scattered more than 2,5° from the direction of the incident beam relative to the total transmitted light

3.6
sharpness
apparent blurring of the border between two adjacent areas with different brightness

3.7
colour shift
change in chromaticity of an object when viewed through transparent liquid crystal display devices

3.8
contrast ratio offset
change in contrast ratio of the reference object when viewed through transparent liquid crystal display devices

3.9
MTF
modulation transfer function
ratio of the final to the initial signal amplitude as a function of the spatial frequency of the initial signal

[SOURCE: IEC 60050-881:1983, 881-04-65, modified – The abbreviated term "MTF" has been added, and the Note to entry, omitted.]

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4 Measurement conditions

4.1 Standard measurement environmental conditions

Measurements shall be carried out under standard environmental conditions:

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

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

4.2 Standard measurement darkroom conditions

The luminance contribution from unwanted background illumination reflected off the test display shall be less than 1/20 the display's black state luminance. If this condition is not satisfied, then background subtraction is required and it shall be noted in the test report. In addition, if the sensitivity of the light measure device (LMD) is inadequate to measure at these low levels, then the lower limit of the LMD shall be noted in the test report.

4.3 Standard measurement locations

Luminance, radiance distribution and/or tristimulus values may be measured at several specified positions on the surface of the device under test (DUT), see Figure 1. Unless otherwise specified, measurements are carried out in the centre of each circle. Care shall be taken to ensure that the measuring spots on the display do not overlap.

Any deviation from the above-described standard positions shall be added to the detail specification.

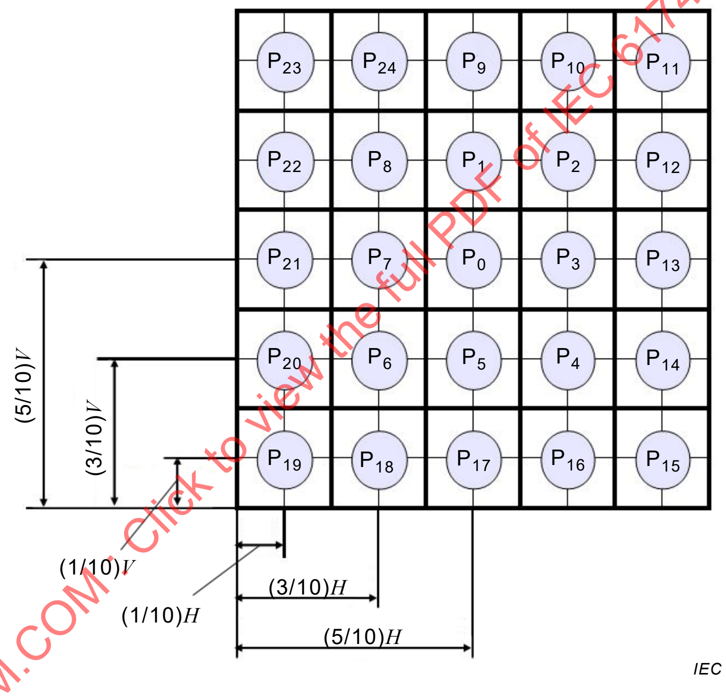

Figure 1 – Measurement points

5 Measurement methods of on-screen properties

5.1 Measurement equipment and its setup

Three different instruments may be applied to measure the light transmitted and/or reflected by the DUT: a luminance meter, colorimeter or spectroradiometer. The optical system is shown schematically in Figure 2 and will allow for measurement of well-defined spot sizes (measurement field) on the DUT.

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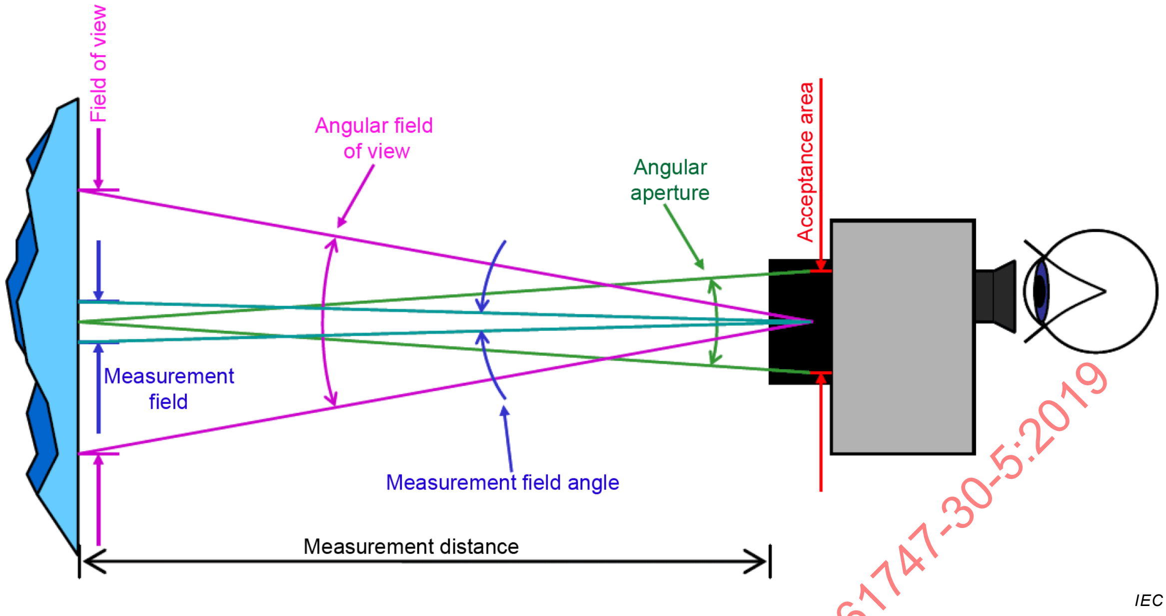

Figure 2 – Measurement equipment and its configuration

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When the measure matrix displays, the above-mentioned meters should be set to a circular or rectangular field of view that includes more than 500 pixels on the display, and measured perpendicular to the screen surface (the standard measurement direction). Total angular aperture of detection by these meters: angular aperture shall be less than 5° and the measurement field angle should be less than 2° (see Figure 2). This can be obtained, for example, by having a measuring distance of 50 cm between the meters and the display area centre (recommended) (see Figure 2). If measuring segmented displays, the measurement field should be located completely inside a single segment, and should not include any of its surroundings.

For DUTs not equipped with their own source of illumination, an external backlight source should be used to provide uniform illumination to the DUT.

The isolated directed light source is the preferred directed source. If the display exhibits strong asymmetric scatter, then integrating spheres with the sample port close to the screen shall be used (e.g., Figure 3).

Measure the following parameters of the light source:

a) spectrum of emission;
b) luminance, L;
c) temporal stability of the luminance, $L(t)$;
d) luminance distribution with viewing angle, $L(\theta, \phi)$.

Unless otherwise specified, it is recommended to use a spectrally smooth broadband light source that approximates the spectrum of CIE-D_{65}.

5.2 Measurement methods

For on-screen properties, such as luminance, chromaticity, viewing angle, reflection and so on, the test methods specified in IEC 61747-30-1 shall apply.

The choice of the appropriate tests depends on the application of the display modules. The relevant specification shall state which tests are applicable.

6 Measurement methods of through-screen properties

6.1 Luminous transmittance and its uniformity

6.1.1 Purpose

The purpose of this method is to determine the transmittance and the uniformity of transmittance of a transparent LCD panel under test.

6.1.2 Measurement conditions

For this measurement, the following conditions shall be applied.

a) Apparatus: an integrating sphere with standard light source; a light measurement device that can measure the luminance; driving power source, and driving signal equipment. The measurement geometry is as shown in Figure 3.

b) Standard environmental conditions for measurements: darkroom conditions; standard setup conditions.

c) The distance between the light measurement device and integrating sphere should be consistent during the test, for example, set at 50 cm.

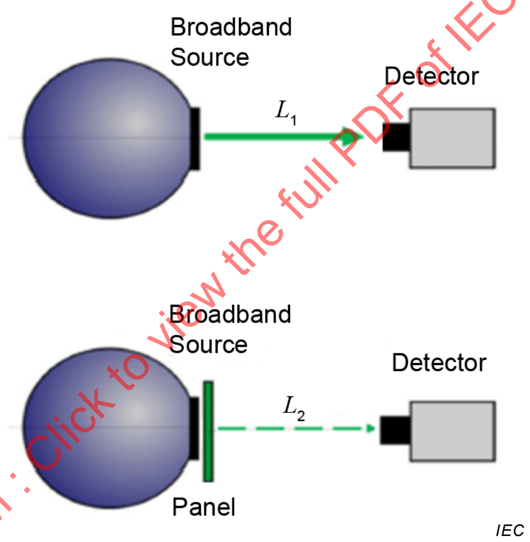

Figure 3 – Measurement configuration with light source

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6.1.3 Measurement methods

The transmittance of the liquid crystal display device is obtained by comparing the luminous value of the DUT to the light source. It shall be ensured that all conditions remain constant during the measurement of both luminance values (temperature, illumination, etc.).

Proceed as follows:

a) allow the apparatus sufficient time to reach thermal equilibrium before making any measurements;

b) measure the luminance of the light source L_1 at the centre position P_0;

c) mount the transparent LCD panel in front of the light source;

d) apply a full-screen white signal at a 100 % grey level;

e) measure the transmitted luminance L_2 at position P_0.

Calculate the luminous transmittance, τ, as a percentage, using Equation (1):

$$\tau = \frac{L_2}{L_1} \tag{1}$$

To achieve transmittance uniformity, proceed as follows.

1) Measure the luminous transmittance at specific points, P_i. Either 5 or 9 measurement points shall be used. For 5 points, use P_0, P_{11}, P_{15}, P_{19}, and P_{23}. For 9 points, use P_0, P_9, P_{11}, P_{13}, P_{15}, P_{17}, P_{19}, P_{21}, and P_{23}.
2) The average transmittance is as per Equation (2) or (3):

$$\tau_{av} = \frac{1}{5}(\tau_0 + \tau_{11} + \tau_{15} + \tau_{19} + \tau_{23}) \tag{2}$$

or

$$\tau_{av} = \frac{1}{9}(\tau_0 + \tau_9 + \tau_{11} + \tau_{13} + \tau_{15} + \tau_{17} + \tau_{19} + \tau_{21} + \tau_{23}) \tag{3}$$

3) The transmittance non-uniformity (TNU) is calculated from the individual transmittance τ_i and the average luminance τ_{av} in accordance with Equation (4):

$$TNU = \left[\max\left(\left| \frac{\tau_{av} - \tau_i}{\tau_{av}} \right| \right) \right] \times 100\,\% \tag{4}$$

The measuring distance and other factors that can affect the measurement result should be reported.

6.2 Transmitted haze

6.2.1 Purpose

The purpose of this method is to evaluate the transmitted haze of a transparent LCD module. ISO 14782 shall be applied for this test item.

6.2.2 Measurement conditions

Standard measuring is implemented under the standard environmental conditions.

6.2.3 Test apparatus

Proceed as follows.

a) The apparatus shall consist of a stabilized light source, an associated optical system, an integrating sphere with ports, and a photometer comprising a photodetector, signal processor and display unit or recorder (see Figure 4).
b) The light source and the photometer shall be used in conjunction with a filter to provide an output corresponding to the photopic standard luminous efficiency $V(\lambda)$ (as defined in IEC 60050-845:1987, 845-01-57). $V(\lambda)$ is identical to the colour-matching function $\bar{y}(\lambda)$; reference shall be made to ISO 11664-1 under CIE standard illuminant D_{65} as specified in ISO 11664-2. By measuring the spectral power distribution of the light source in advance using the detector, the measured spectral information is used to determine the equivalent result for a D65 light source. The output of the photodetector shall be proportional to the incident flux, to within 1 % of the incident flux, over the range used. The spectral and photometric characteristics of the light source and photometer shall be kept constant during measurements.

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c) The light source and its associated optical system shall produce a parallel light beam, no ray of which shall make an angle of more than 0,05 rad (3°) with the beam axis. This beam shall not be vignetted at either port of the integrating sphere.

d) The design of the instrument shall be such that the reading is zero in the absence of the light beam.

e) The integrating sphere used to collect the transmitted light may be of any diameter (but preferably no less than 150 mm in order to be able to accommodate large specimens), as long as the total port area does not exceed 3,0 % of the internal reflecting area of the sphere.

f) The integrating sphere shall have an entrance port, an exit port, a compensation port and a photodetector port (see Figure 4). The entrance and exit ports shall be centred on the same great circle of the sphere, and there shall be an angle of (3,14 ± 0,03), rad (180° ± 2°) between the centres of the ports. The exit port shall subtend an angle of (0,140 ± 0,002), rad (8° ± 0,1°) at the centre of the entrance port. The exit and compensation ports shall be the same size. The entrance and compensation ports and the photodetector shall not lie on the same great circle of the sphere. The compensation port shall be positioned at an angle of less than 1,57 rad (90°) from the entrance port. The compensation port is used to compensate for changes in the efficiency of the integrating sphere, which depends on the area of the inner surface, the number of ports and the way in which they are covered.

g) When the beam is unobstructed by a transparent LCD module, its cross section at the exit port shall be approximately circular, sharply defined and concentric with the exit port, leaving around it an annulus which subtends an angle of (0,023 ± 0,002), rad (1,3° ± 0,1°) at the centre of the entrance port. It is important to verify whether the unobstructed beam diameter and centring at the exit port are maintained, especially if the source aperture and focus are changed. The tolerance of ±0,002 rad (±0,1°) stated for the angle subtended by the annulus corresponds to an uncertainty of ±0,6 % in a haze reading. This is relevant to the assessment of the precision of this test method.

h) The position of the photodetector on the integrating sphere shall be at an angle of (1,57 ± 0,26) rad (90° ± 15°) to the entrance port. The photodetector shall be fitted with baffles to prevent light from the specimen falling directly on it. Light traps shall be provided for the exit and compensation ports to absorb the beam completely when no specimen is present, or the instrument design shall obviate the need for light traps for the exit and compensation ports.

i) The tristimulus value Y[1] of the surfaces of the interior of the integrating sphere, the baffles and the white reference (a working reference normally provided by the instrument manufacturer) shall be 90 % or more and shall not vary by more than ±3 %. When direct measurement of the reflectance of the inner surface of the integrating sphere is difficult, the measurement may be made on a surface prepared from the same material in the same condition as the inner surface.

j) The specimen holder shall be designed to hold the transparent LCD module rigidly in a plane, perpendicular to within ±2° to the light beam and as close as possible to the integrating sphere in order to ensure that all the light passing through the specimen, including scattered light, is collected. The holder shall also be designed so that flexible specimens, such as film, are kept flat. It is recommended that thin, flexible film be held around the edge in a double-ring clamp or be stuck to the holder by means of double-sided adhesive tape. Double-sided adhesive tape can also be used for thicker specimens that will not fit in the double-ring clamp. The use of a vacuum pump and vacuum plate to mount the specimen on the holder is also recommended.

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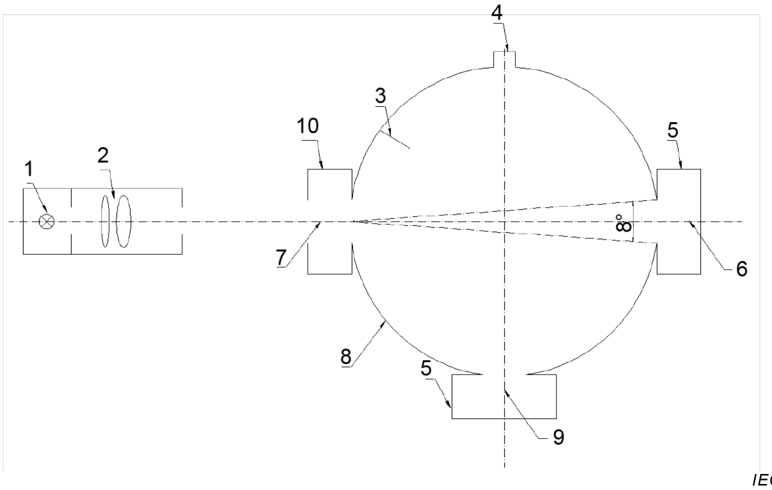
1 Tristimulus value for the 2° observer.



Key

1 lamp
2 lens
3 baffle
4 photodetector
5 light trap
6 exit port
7 entrance port
8 integrating sphere
9 compensation port
10 specimen holder

Figure 4 – Schematic arrangement of the apparatus (TOP view)

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6.2.4 Procedure

Proceed as follows:

a) allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made;

b) mount a transparent LCD module in the sample holder;

c) make the 4 measurements set out in Table 1 at specific points, P_i. Either 5 or 9 measurement points shall be used. For 5 points, use P_0, P_{11}, P_{15}, P_{19}, and P_{23}. For 9 points, use P_0, P_9, P_{11}, P_{13}, P_{15}, P_{17}, P_{19}, P_{21}, and P_{23};

d) carry out the procedure 3 times.

Table 1 – Measurements

	Entrance port	Exit port	Compensation port
τ_1		White reference	Light trap
τ_2	Transparent LCD module	White reference	Light trap
τ_3		Light trap	White reference
τ_4	Transparent LCD module	Light trap	White reference

6.2.5 Results

Calculate the haze value, H, as a percentage, using Equation (5):

$$H = \left(\frac{\tau_4}{\tau_2} - \frac{\tau_3}{\tau_1} \right) \times 100 \tag{5}$$

where

τ_1 is the intensity of the incident light;

τ_2 is the intensity of all the light transmitted by the specimen;

τ_3 is the intensity of the light scattered by the instrument;

τ_4 is the intensity of the light scattered by the instrument and the specimen.

6.2.6 Reporting

The following information shall be noted in the measurement report:

a) all details necessary for complete identification of the material or product tested;
b) average thickness of a transparent LCD module;
c) haze value, i.e. the average of the results for a transparent LCD module;
d) type of light source used;
e) details of any incident likely to have affected the results;
f) date of the test.

6.3 Colour shift

6.3.1 Purpose

The purpose of this method is to evaluate the colour shift of the object through a transparent LCD module.

6.3.2 Measurement conditions

Measurements shall be carried out under the standard environmental and darkroom conditions.

6.3.3 Test apparatus

Test apparatus shall be as follows.

a) The apparatus shall consist of a standard light source, an integrating sphere with two ports, a colorimeter or spectroradiometer that can measure the CIE 1931 chromaticity coordinates (x, y); a reference object; a driving power supply; and a driving signal generator which is used to light the transparent LCD modules (see Figure 5). The position of the integrating sphere and light measurement device should remain unchanged during the test.

   NOTE The accuracy of the colour shift can be affected by the quality of the colorimeter or spectroradiometer.

b) The reference object used in this test shall be standard white reflectance.
c) The distance between the light measurement device and the transparent LCD modules shall be consistent during the test, for example set at 50 cm. Keep the reference object on the light-trap port and the transparent LCD modules on the exit port during the test.

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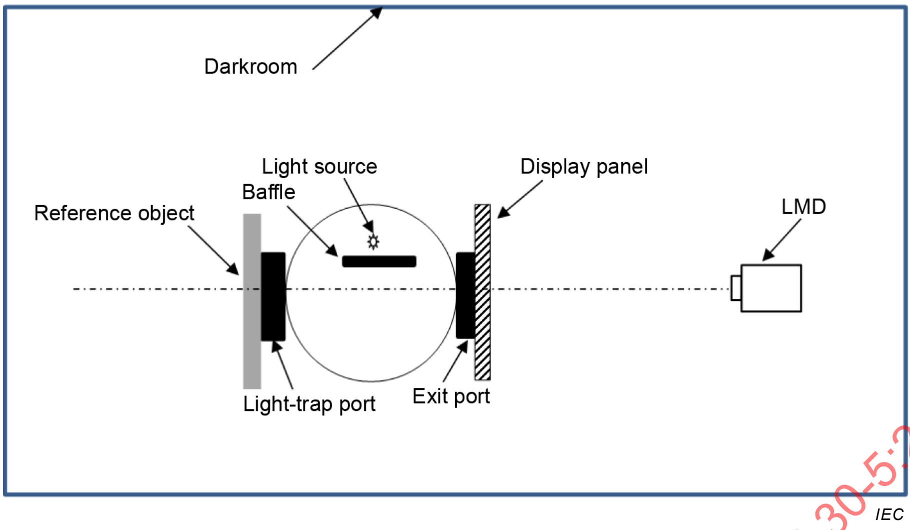

Figure 5 – Measurement system and its configuration

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d) Keep the illumination of the reference object surface constant during the test (e.g. (2 000 ± 100) lx).

e) It is recommended to use a sphere diameter of about 30 cm (minimum); if other sizes are used, these shall be reported.

6.3.4 Procedure

Proceed as follows:

a) allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made;

b) measure the CIE 1931 chromaticity coordinates (x_1, y_1) of the standard white reflectance at the centre point when there is no display module;

c) mount a transparent LCD module on the exit port and apply a white signal level of 100 % over the entire screen;

d) measure the CIE 1931 chromaticity coordinates (x_2, y_2) of the standard white reflectance at the centre point through the transparent LCD module;

e) calculate the colour shift using Equations (6) and (7):

$$u' = \frac{4x}{3-2x+12y}, \quad v' = \frac{9x}{3-2x+12y} \tag{6}$$

$$\Delta u'v' = \sqrt{(u'_2 - u'_1)^2 + (v'_2 - v'_1)^2} \tag{7}$$

f) record the measurement results, as shown in Table 2.

6.3.5 Reporting

The following information shall be noted in the measurement report:

a) type of light source used;

b) size and detail information of a transparent LCD module;

c) measurement distance between display module and LMD;

d) colour shift results of a transparent LCD module;

e) date of the test;

f) any other details that could influence the test results (e.g., the illumination of the reference object surface, the measurement aperture) should be reported.

Table 2 – Measurement results

	Colour coordinates of standard white reflectance	
	CIE 1931	CIE 1976
Without transparent display	$W(x_1, y_1)$	$W(u'_1, v'_1)$
With transparent display	$W(x_2, y_2)$	$W(u'_2, v'_2)$
Colour shift	–	$\Delta u'v'$

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6.4 Contrast ratio offset

6.4.1 Purpose

The purpose of this method is to evaluate the change of contrast ratio of the reference objects through transparent LCD devices.

6.4.2 Measurement conditions

Measurements shall be carried out under the standard environmental and darkroom conditions.

6.4.3 Test apparatus

Test apparatus shall be as follows.

a) The apparatus shall consist of a standard light source, an integrating sphere with two ports; a light measurement device that can measure luminance; a reference object; a driving power supply; and a driving signal generator which is used to light the transparent LCD modules (see Figure 5). The position of the integrating sphere and the light measurement device should remain unchanged during the test.

b) The reference object used in this test shall be a black and white board (see Figure 6).

c) The distance between the light measurement device and the transparent LCD modules shall be consistent during the test, for example set at 50 cm. Keep the reference object on the light-trap port and the transparent LCD modules on the exit port during the test.

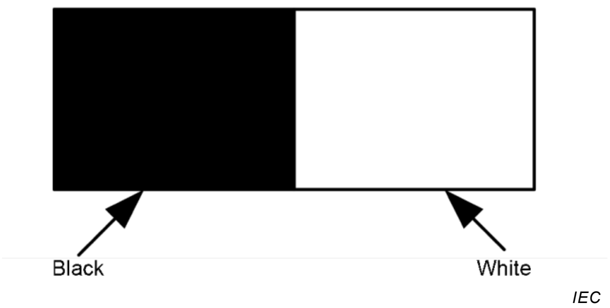

Figure 6 – Reference object and its configuration

6.4.4 Procedure

Proceed as follows:

a) allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made;

b) translate the reference object by measuring the luminance of the white and black parts of the board when there is no transparent LCD module;

c) mount a transparent LCD module on the exit port and apply a white signal level of 100 % over the entire screen;

d) measure the luminance of the white and black parts of the board through the transparent LCD module, the same as in 6.4.4 b);

e) record the measurement results, as shown in Table 3.

Table 3 – Data summary for contrast offset

	Standard colour board		**Contrast ratio**	**Contrast ratio offset**
	White	**Black**	***CR***	
Without transparent display	L_W	L_B	$CR = L_W/L_B$	-
With transparent display	L_{W1}	L_{B1}	$CR_1 = L_{W1}/L_{B1}$	$\frac{\lvert CR_1 - CR \rvert}{CR}$

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6.4.5 Reporting

The following information shall be noted in the measurement report:

a) type of light source used;

b) size and detail information of a transparent LCD module;

c) the spectral reflectance of the black and white board;

d) measurement distance between the LMD and display modules under test;

e) details of any incident likely to influence the results (e.g., the illumination spectrum and geometry on the reference object surface);

f) date of the test.

6.5 Sharpness

6.5.1 Purpose

The purpose of this method is to evaluate the sharpness of the object behind a transparent LCD module.

6.5.2 Measuring conditions

Measurements shall be carried out under the standard environmental and darkroom conditions.

6.5.3 Test apparatus

a) The apparatus shall consist of a standard light source, an integrating sphere with two ports, a two-dimensional LMD, such as a CCD image colorimeter, a reference object (the surface reflectance and material should be standard reflectance board, or standard colour board), a driving power supply and a driving signal generator, which is used to light the transparent LCD modules (see Figure 5). The diameter of the sphere should be set according to the size of the DUT. The position of the integrating sphere and light measurement device should remain unchanged during the test.

A two-dimensional LMD can measure the map of lumina reflectance. That should be noted in the report, as in the example shown in Table 4.

Table 4 – Example of reported specification of two-dimensional LMD

CCD resolution	4 096 × 2 048	
CCD A/D dynamic range	More than 12 bits = 4 096 grey scale levels	
Wavelength range	380 nm to 780 nm	
System accuracy	Luminance accuracy	±3 %
	Chromaticity accuracy	±0,003

b) The reference object used in this test shall be in the shape of black and white stripes. The direction of the stripes will be different according to different pixel structures; Figure 7 shows an example. The stripe width D shall be chosen from the list given below according to the size and application of the transparent LCD modules:

5 mm, 10 mm, 15 mm, 20 mm, etc.

c) The distance between the light measurement device and the transparent LCD modules shall be consistent during the test, for example, set at 50 cm. Keep the reference object on the light-trap port and the transparent LCD modules on the exit port during the test.

NOTE Due to matrix scatter, the sharpness value can be a function of the measurement setup (e.g. distance of the reference object behind the display).

6.5.4 Procedure

Proceed as follows:

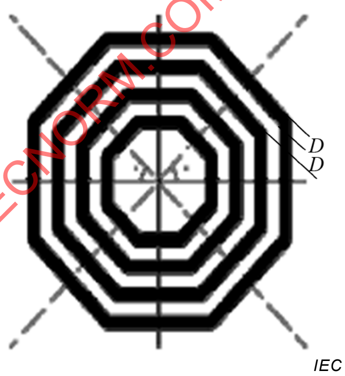
a) allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made;

b) mount the reference object on the light-trap port; measure the luminance of the reference object along the horizontal, vertical or diagonal direction when there is no transparent LCD module. Obtain a luminance curve of the reference object;

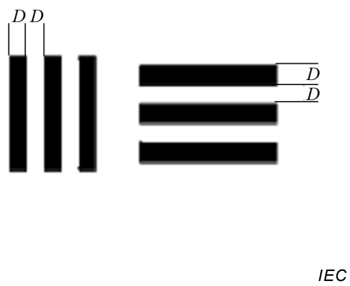
c) mount a transparent LCD module on the exit port; apply a white signal level of 100 % over the entire screen;

d) measure the luminance of the reference object along the same direction through the transparent LCD module. Obtain another luminance curve of the reference object;

e) compare the brightness of the two curves of the reference object.



a) **Configuration a)**



b) **Configuration b)**

Figure 7 – Example reference object and its configuration

6.5.5 Results

Luminance curves of the reference object are the relative luminance profiles taken across the white and black stripes. Normally the profiles are taken by averaging the luminance profiles over several camera rows for a better signal-to-noise ratio. Theoretically, the luminance curve

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of the reference object is a square wave and will change into a sinusoidal wave through the transparent LCD module (see Figure 8).

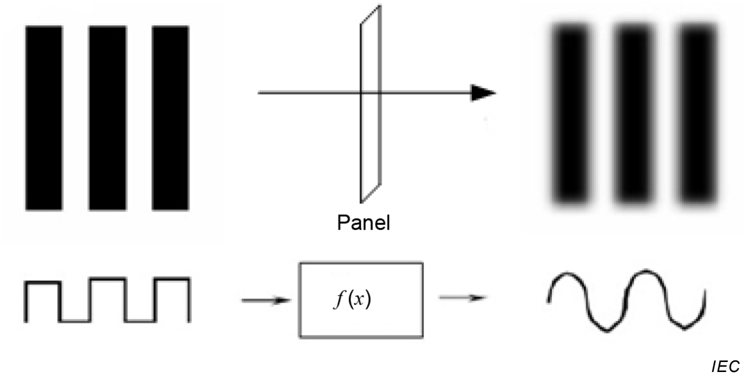

Figure 8 – Luminance curve of reference object

Calculate k and the sharpness value, S, using Equations (8) and (9):

$$K = \left(\frac{\sum_{i=1}^{n} DP_{\text{i}}}{2n} \right) \times \frac{1}{D} \tag{8}$$

$$S = \frac{\sum_{i=1}^{n} \left(\frac{DW_{\text{i}}}{K} + \frac{DB_{\text{i}}}{K} \right)}{2n} \times \frac{1}{D} \times 100\ \% \tag{9}$$

where

n is the number of pairs in the black and white stripe;

D is the original width of a single black or white stripe;

DW_{i} is the measured width of white stripes which is measured at the point where the brightness is 90 % of the range between peak and bottom profile through a transparent LCD module;

DB_{i} is the measured width of black stripes which is measured at the point where the brightness is 10 % of the range between peak and bottom profile through a transparent LCD module;

DP_{i} is the measured width of black and white stripes without a transparent LCD module;

K is the affect factor of the luminance meter.

Figure 9 shows the definition of the above parameters.

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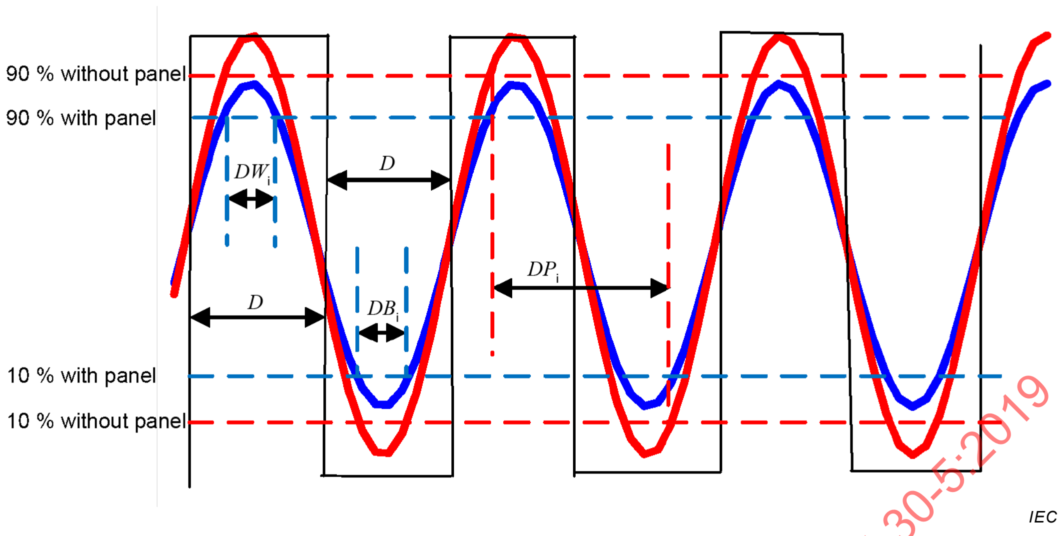

Figure 9 – Definition of test parameters

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6.5.6 Reporting

The following information shall be noted in the measurement report:

a) type of light source used;
b) size and detail information of a transparent LCD module;
c) measuring distance between display module and LMD;
d) stripe width of reference object;
e) sharpness value of a transparent LCD module;
f) detail of any incident likely to have influenced the results (e.g., the illumination of reference object surface);
g) date of the test.

6.6 MTF and Michelson contrast ratio

6.6.1 Purpose

The purpose of this method is to evaluate the matrix diffraction of the transparent LCD. As we know, there are various diffraction artefacts, and the location and intensity of the diffraction artefact can be varied by a pixel design of the transparent display. For some transparent display applications, therefore, the new test pattern and metric to quantify the location and intensity shall be carefully determined. We use MTF to evaluate the matrix diffraction phenomenon.

6.6.2 Measurement conditions

Measurements shall be carried out under the standard environmental and darkroom conditions.

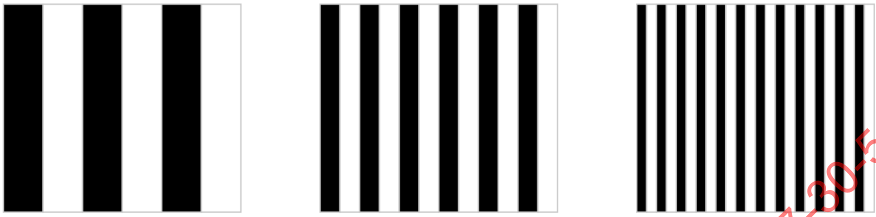
6.6.3 Measurement methods

Proceed as follows.

a) The apparatus shall consist of a standard light source; an integrating sphere with two ports; a charge-coupled device (CCD) or equivalent LMD; a reference object with specified test pattern; a driving power supply; and a driving signal generator which is used to light the transparent LCD modules (see Figure 5).

b) The reference object used in this test shall be in the shape of black and white stripes with a stable or gradually changing width. The relationship between stripe width D and spatial frequency V is shown in Equation (10). The stripe width should be chosen based on what level of detail needs to be viewed on the object. For a stable spatial frequency, the test pattern in Figure 7 can apply. For a gradually changing spatial frequency, Figure 10 shows an example.

$$D = \frac{1}{2V} \tag{10}$$



(a) Low resolution (b) Middle resolution (c) High resolution

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Figure 10 – Reference object and its configuration

c) Allow the apparatus sufficient time to reach thermal equilibrium before the measurements are made.

d) Measure the luminance profile of the reference object when there is no transparent LCD module.

e) Mount a transparent LCD module on the exit port and apply a white signal level of 100 % over the entire screen.

f) The distance between the light measurement device and the transparent LCD modules shall be consistent during the test, for example set at 50 cm. Keep the reference object on the light-trap port and the transparent LCD modules on the exit port during the test.

g) Measure the luminance profile of the reference object through transparent LCD module.

h) Calculate the MTF using the Equations (11) to (13):

$$M(n) = \frac{L_{max}(n) - L_{min}(n)}{L_{max}(n) + L_{min}(n)} \tag{11}$$

$$M(n)' = \frac{L'_{max}(n) - L'_{min}(n)}{L'_{max}(n) + L'_{min}(n)} \tag{12}$$

$$MTF = \frac{M(n)'}{M(n)} \tag{13}$$

where

$L_{max}(n)$ is the maximum luminance of the n^{th} black and white stripe measured without transparent LCD module;

$L_{min}(n)$ is the minimum luminance of the n^{th} black and white stripe measured without transparent LCD module;

$M(n)$ is the modulation contrast of the n^{th} black and white stripe measured without transparent LCD module;

$L'_{max}(n)$ is the maximum luminance of the n^{th} black and white stripe measured through transparent LCD module;

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$L'_{min}(n)$ is the minimum luminance of the n^{th} black and white stripe measured through transparent LCD module;

$M'(n)$ is the modulation contrast of the n^{th} black and white stripe measured through transparent LCD module.

i) Due to the role of diffraction, the value of MTF will vary when the width of the black and white stripes is gradually changed. We define the number of black and white stripe pairs within a unit length as stripe frequency, the higher the stripe frequency, the smaller the MTF value. Figure 11 shows an example of the relationship between stripe frequency and MTF.

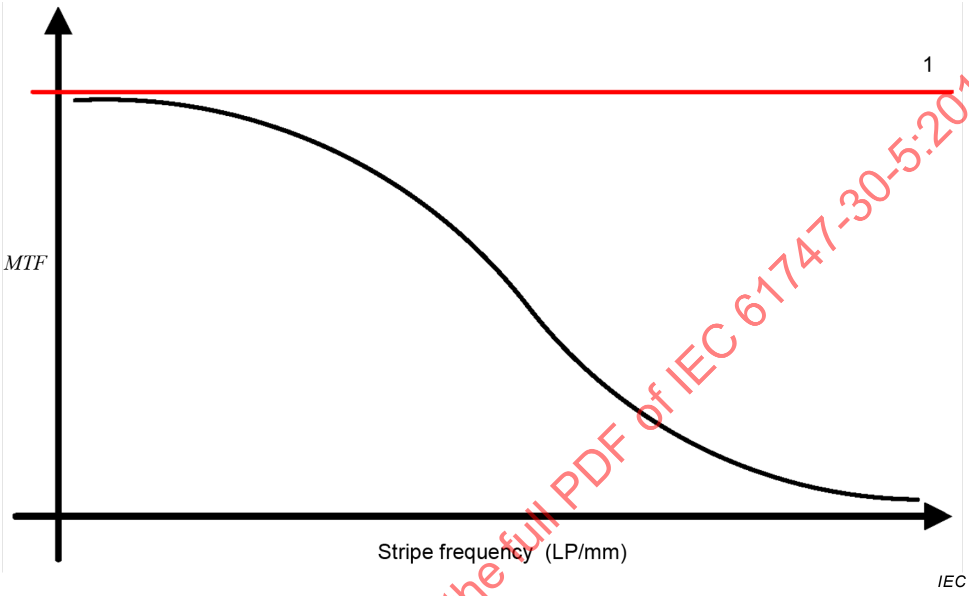

Figure 11 – Relationship between stripe frequency and MTF

6.6.4 Reporting

The following information shall be noted in the measurement report:

a) the measurement result and calculated data;

b) the size and detail information of a transparent LCD module;

c) measuring distance between LMD and display modules under test;

d) detail of any incident likely to have influenced the results (e.g., the illumination of reference object surface;

e) date of the test.

7 Contrast ratio and colour coordinates with the incident illumination originating from objects behind the screen

7.1 Purpose

The purpose of this method is to measure the contrast ratio and colour coordinates with the incident illumination originating from objects behind the transparent display module.

When an object is located behind the screen and the emitted light or reflected light reaches the viewer through the transparent display, the contrast ratio or colour gamut of the display image can be deteriorated because the incident light mixes with the light from the transparent display itself (Figure 12).

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It is important to evaluate the contrast ratio or colour coordinates of the display with an object behind the screen (Figure 12). Figure 13 shows the case with LCDs. If the background is totally dark or in a darkroom, white state is given by light from a backlighting system transmitting through an LC layer. As there is no additional light, the viewer can enjoy the intrinsic display performance. When the background is bright, the light from the object can be mixed up with the light from the backlighting system. In the case of LCDs, black state absorbs all the incident light, giving a high contrast ratio. However, in the case of emissive type displays, as black state is transparent, black state does not absorb the incident light, giving rather low contrast ratio. For white state, in the case of LCDs, the light from the background is mixed up, deteriorating the colour coordinates as the colour of the light coming from background objects is generally different from that coming from the backlighting system. In the case of emissive type displays, emitted light is mixed up with the light coming from the backlighting system, and sometimes the displayed image is not recognizable.

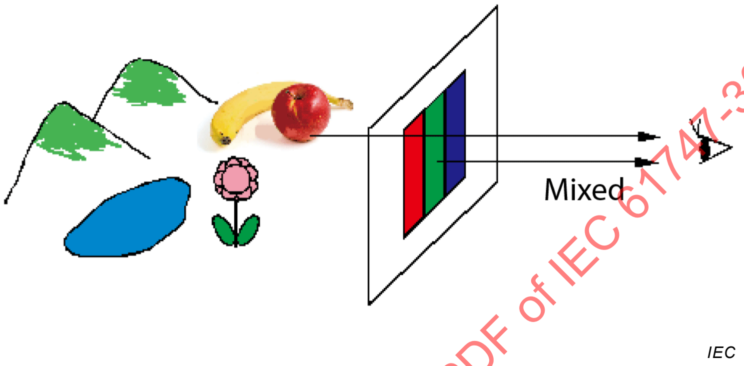

Figure 12 – Geometry of the transparent display and the bright background object

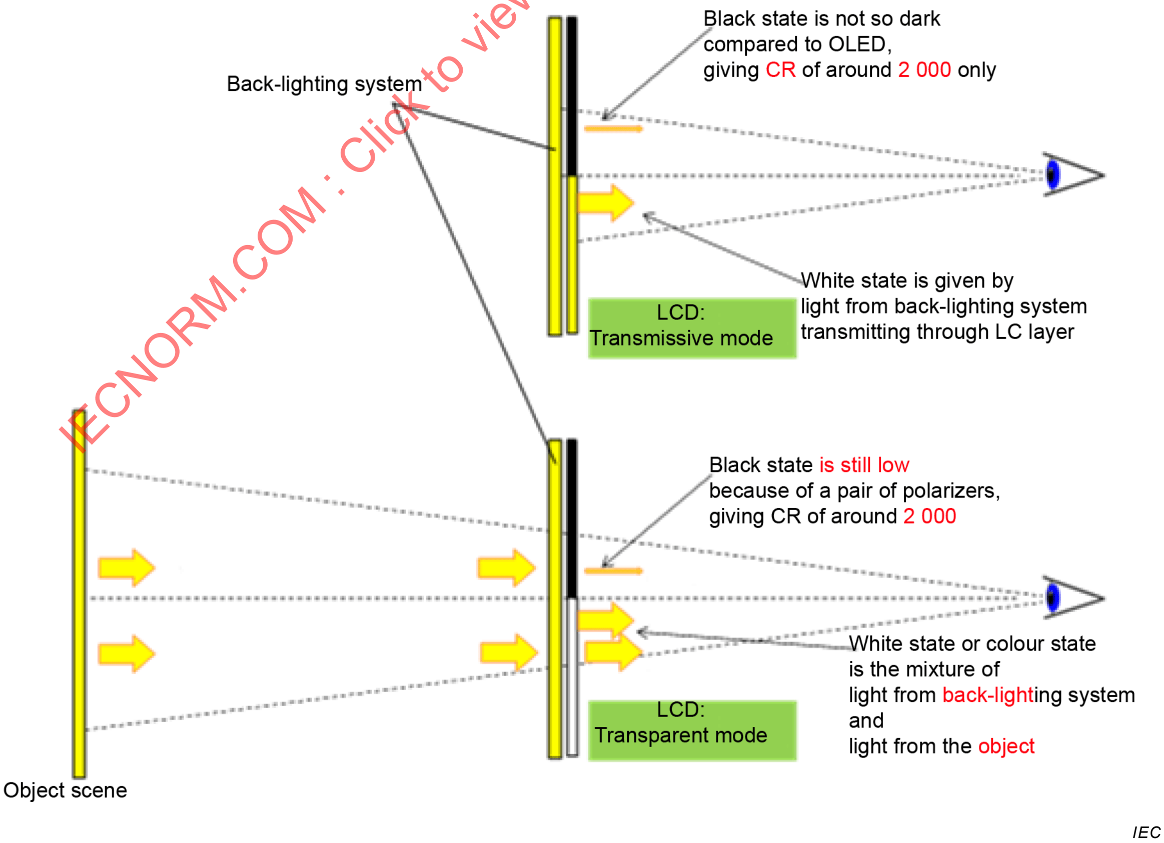

Figure 13 – Case with bright backgrounds

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