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Edition 1.0 2019-08

INTERNATIONAL STANDARD

Liquid crystal display devices –
Part 30-3: Measuring methods for liquid crystal display modules – Motion artefact measurement of active matrix liquid crystal display modules

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LIQUID CRYSTAL DISPLAY DEVICES –

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FOREWORD

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International Standard IEC 61747-30-3 has been prepared by IEC technical committee 110: Electronic displays.

This first edition cancels and replaces the first edition of IEC 61747-6-3 published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) added test positions and areas;
b) revised standard measuring conditions;
c) added calculation of the standard deviation of the line-spread function of the eye;
d) added requirements for high speed camera;

e) changed “LCDs” to “transmissive TFT LCDs” in Clause 1.

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

FDIS	Report on voting
110/1103/FDIS	110/1130/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.

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

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

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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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LIQUID CRYSTAL DISPLAY DEVICES –

Part 30-3: Measuring methods for liquid crystal display modules – Motion artefact measurement of active matrix liquid crystal display modules

1 Scope

This part of IEC 61747 applies to transmissive type active matrix liquid crystal displays.

This document defines general procedures for quality evaluation related to the motion performance of transmissive thin film transistor (TFT) LCDs. It defines artefacts in the moving image and methods for motion artefact measurement.

NOTE Motion blur measurement methods and analysis methods introduced in this document are not universal tools for all the different LCD motion enhancement technologies due to their complexity. Users' attention is drawn to this fact.

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

ISO 11664-4, *Colourimetry – Part 4: CIE 1976 L*a*b* Colour space*

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

NOTE In this document, the term "pixel" is adopted as the unit of the signal resolution. That is, the horizontal and vertical pixel pitch (size) of the DUT is determined based on the spatial distance displayed (scrolled) on the screen corresponding to the inputted signal pixel regardless of the display pixel types.

3.1.1
motion picture response curve
curve representing the convolution of the temporal step response with a moving window function one-frame wide

Note 1 to entry: It shows how the luminance is integrated over time during smooth pursuit eye tracking and combines the effects of the LCD response time and the hold-type characteristics of the device under test.

3.1.2
motion induced edge profile
luminance profile of an intrinsically sharp moving luminance transition when this transition is followed with smooth pursuit eye tracking along its motion trajectory

Note 1 to entry: The profile can be calculated from the motion picture response curve for any given motion speed.

3.1.3
edge blur
blur that becomes visible on an intrinsically sharp transition between two adjacent areas, with a different luminance level, when the transition smoothly moves across the display as a function of time

Note 1 to entry: Preconditions for this type of edge blur are smooth pursuit eye tracking of the object and no obvious flicker, indicating that luminance integration with a frame period is allowed. This blur phenomenon is mainly caused by a slow response time of the liquid crystal cell in combination with the hold-type characteristics.

3.1.4
perceived blurred edge time
time-related equivalent of the perceived blurred edge width

Note 1 to entry: The perceived blurred edge width is derived from the motion induced edge profile by means of filtering the edge profile with the contrast sensitivity function of the human eye.

3.2 Abbreviated terms

BET	blurred edge time
BEW	blurred edge width
CCD	charge-coupled device
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
CMOS	complimentary metal-oxide semiconductor
CSF	contrast sensitivity function
DMTF	dynamic modulation transfer function
DUT	display under test
DVI	digital visual interface
EBET	extended blurred edge time
FFT	fast Fourier transform
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
JND	just-noticeable difference
LCD	liquid crystal display
LMD	light measuring device
LVDS	low-voltage differential signaling
MCD	motion contrast degradation
MPRC	motion picture response curve
MPRT	moving picture response time
MTF	modulation transfer function
PBET	perceived blurred edge time
PBEW	perceived blurred edge width
TFT	thin film transistor
TN-LCD	twisted nematic liquid crystal display
VA-LCD	vertically-aligned liquid crystal display

4 Standard measuring 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.

All visual inspection tests shall be tested at 25 °C ± 3 °C.

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

The illuminance at the measuring spot of the DUT shall be below 1 lx (standard dark room conditions as defined in IEC 61747-30-1).

5 Standard motion blur measuring methods

5.1 General

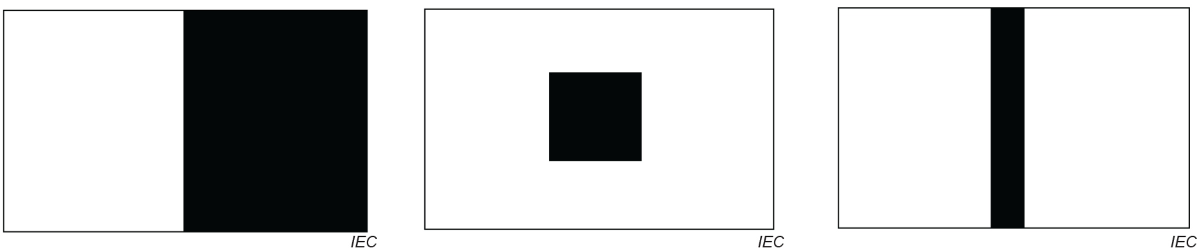
Motion induced object blur is the result of a slow response of the liquid crystal cells and a stationary representation of the temporal image (related to the hold time of the display), in combination with smooth pursuit eye tracking of an object over the display surface. When an object moves across the display and the eye is tracking this object, a spatiotemporal integration of the object luminance is taking place at the human retina. There are several ways to measure and characterize this spatiotemporal integration: via a direct measurement or via an indirect measurement technique. For direct measurement, a pursuit camera system can be used; the indirect measurement is based on measuring the temporal response curves, and from those curves the motion induced object blur that will occur on the retina can be calculated. Both direct and indirect measurements will be described in this document. Possible alternatives to direct measurement are described in Annex A, Annex B and Annex C.

5.2 Direct measurement method

5.2.1 Standard measuring process

5.2.1.1 Test patterns

There are several patterns that can be used to measure motion induced object blur, such as a full test pattern, box test pattern, and line bar test pattern (see Figure 1). The details of the used test pattern(s) shall be reported. When using a pursuit system, the width of the test pattern should be sufficiently wide, for example five times the advancement (step-width) per frame, to capture the total temporal response of the display. It is recommended that a minimum of seven gray shades, including black and white, be used for the gray level of each part of a test pattern in Figure 1. The lightness function L^*, specified in ISO 11664-4, shall be used to space the intermediate gray shades equally on the lightness scale.



a) Full test pattern b) Box test pattern c) Line bar test pattern

Figure 1 – Examples of edge blur test pattern

NOTE LCD input data for gray levels can be obtained by first measuring luminance as a function of input level, i.e. a gray tone-rendering curve, and selecting the input values corresponding most closely to equidistant L^* values.

5.2.1.2 Pursuit detection system

Measuring the edge blur of the LCD module should be done by using a CCD or CMOS camera with the pursuit measurement system shown in Figure 2 and Figure 3. Relevant literature on these systems can be found in [1] to [5], [17], [22] [1].

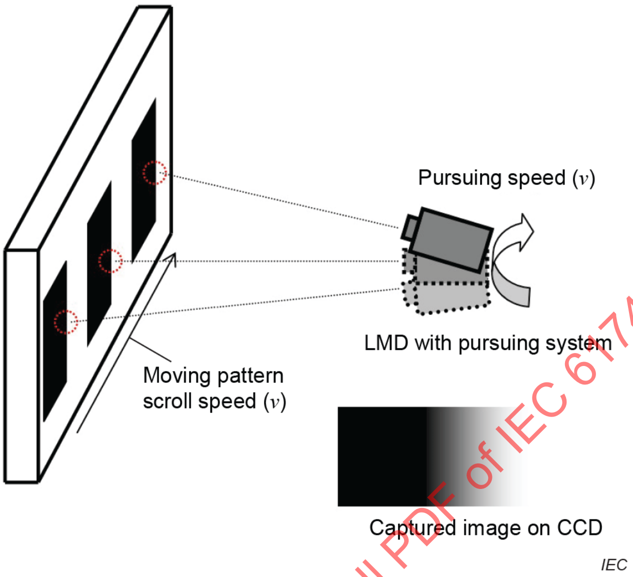


Figure 2 – Example of a pivoting pursuit camera system

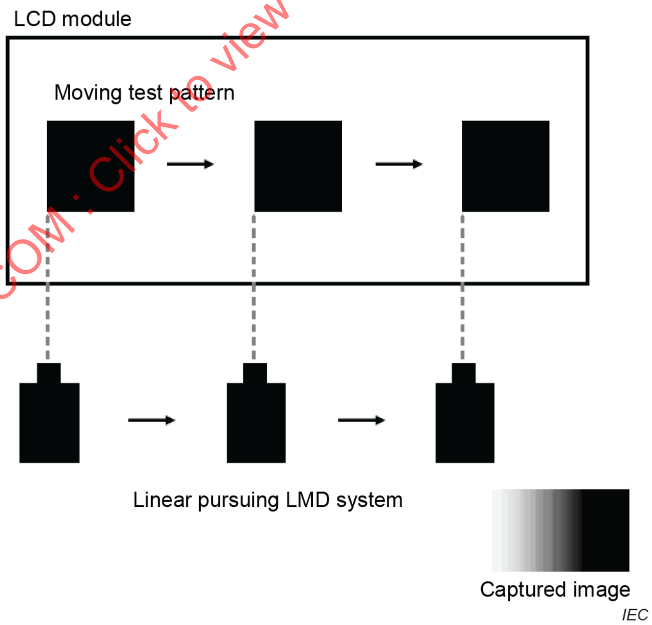


Figure 3 – Example of a linear pursuit camera system

1 Numbers in square brackets refer to the Bibliography.

The following elements are recommended when implementing the pursuit measuring system:

a) LMD: CCD or CMOS type surface measurement devices (CCD camera), with preferably an integrated CIE 1931 photopic luminous sensitivity function (measuring luminance).

b) Scroll speed: the scroll speed of the test pattern and the pursuing speed of the LMD are synchronized accurately to prevent integration errors. Pursuit speed error can be verified by the method in [22]

c) Pursuing system: a pivoting or linear pursuit system as shown in Figure 2 and Figure 3, respectively. The angular rotation is limited to avoid viewing angle–related dependencies (less than ± 5˚).

5.2.1.3 Test position

Since the measurement results of motion blur can be dependent on the measurement position on the display depending on the scanning direction as well as the use of backlight behaviour (scanning backlight/modulation), measurements shall be taken on multiple positions according to Figure 4.

The measurements are taken inside boxes centred on the measurement positions, with a length of $H/5$ and a height of $V/20$.

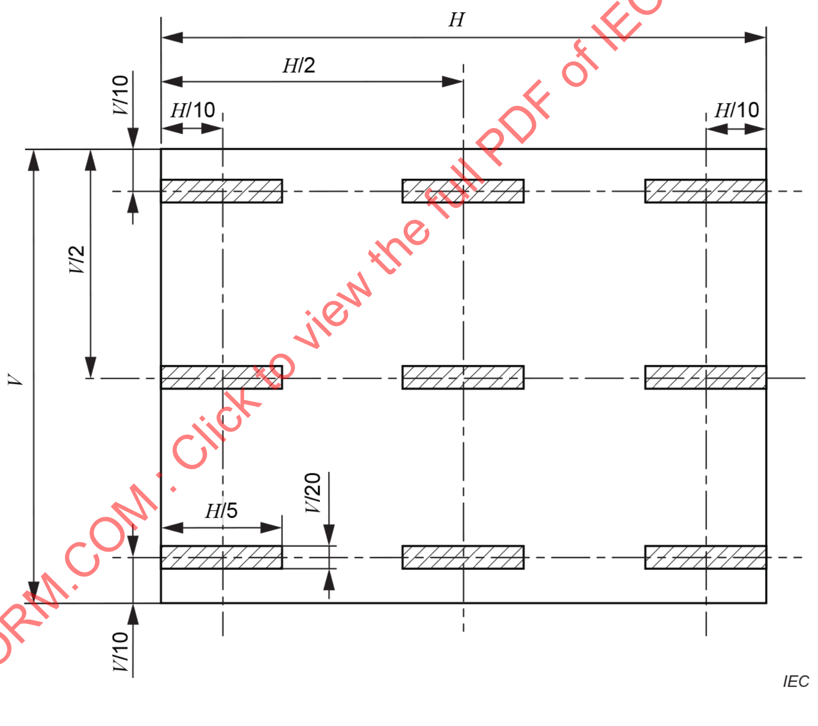


Figure 4 – Measurement regions for landscape orientation

On displays where the (line) scan direction does not coincide with the vertical axis, or displays where the (line) scan direction is unknown, the measurement shall be repeated with the display and measurement positions rotated by 90°, as shown in Figure 5.

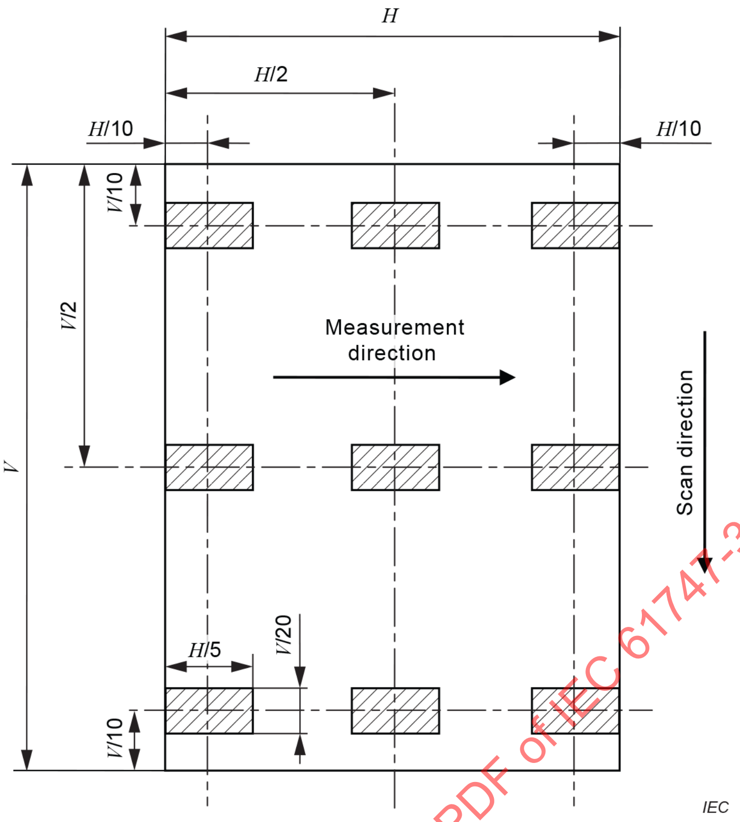


Figure 5 – Measurement regions for portrait orientation

5.2.1.4 Specified conditions

a) Any deviations from the standard measurement conditions shall be reported: the full test pattern shown in Figure 1a) shall be used as the test pattern for this test method. Other test patterns, such as the box test pattern shown in Figure 1b) or the line bar test pattern shown in Figure 1c), can also be used depending on the requirements. The pattern used shall be reported.

NOTE When test patterns other than the standard full test pattern are used, special care is taken because the size of the pattern can alter the luminance level of some of the LCD modules equipped with an automatic luminance level control function, or some long tails of the blurred edge can fall on the adjacent edge, causing ambiguity in the data analysis.

b) The signal level (the start level and the end level) for the test pattern is summarized in Table 1.

Table 1 – Step response data for different luminance transitions

Data per colour (e.g. R, G, B, W)		**End level**					
		L_1	L_2	L_3	..	..	L_N
Start level	L_1	-	$L_{1-2}(t)$	$L_{1-3}(t)$			$L_{1-N}(t)$
	L_2	$L_{2-1}(t)$	-	$L_{2-3}(t)$			$L_{2-N}(t)$
	L_3	$L_{3-1}(t)$	$L_{3-2}(t)$	-			$L_{3-N}(t)$
	..				-		
	..					-	
	L_N	$L_{N-1}(t)$	$L_{N-2}(t)$	$L_{N-3}(t)$			-

c) Standard measuring conditions

1) Scroll speed: The scroll speed shall be set to an angular velocity between 0,01 rad/s and 0,1 rad/s for the design viewing distance of the display. This means the actual scroll speed on the DUT surface will vary with the distance at which the DUT is intended to be viewed.

2) Shutter time of a camera: The shutter time shall be an integer multiple of the DUT frame time.

5.2.2 Analysis method

5.2.2.1 Blurred edge time

The time between the transition from 10 % to 90 % in the luminance transition curve (see Figure 6) is used to represent the blurred edge time, also referred to as moving picture response time (MPRT) [1], [5]. Other ranges, such as 40 % to 60 %, can be used, but they shall be reported.

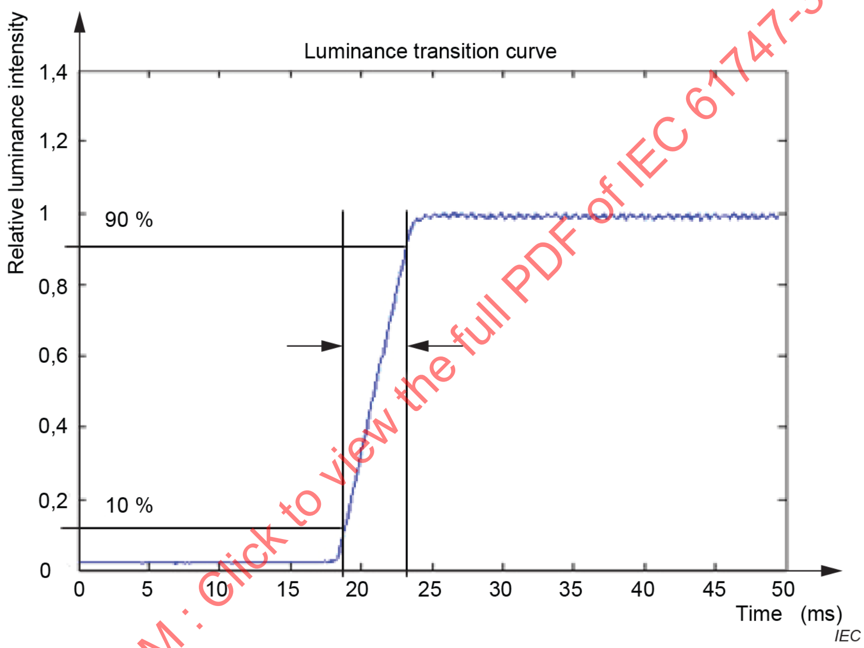


Figure 6 – Example of luminance cross-section profile of blurred edge time

5.2.2.2 Extended blurred edge time (EBET)

The extended blurred edge time (EBET) is defined as BET / 0,8, which linearly extends the BET to the 0 % to 100 % levels (see Figure 7).

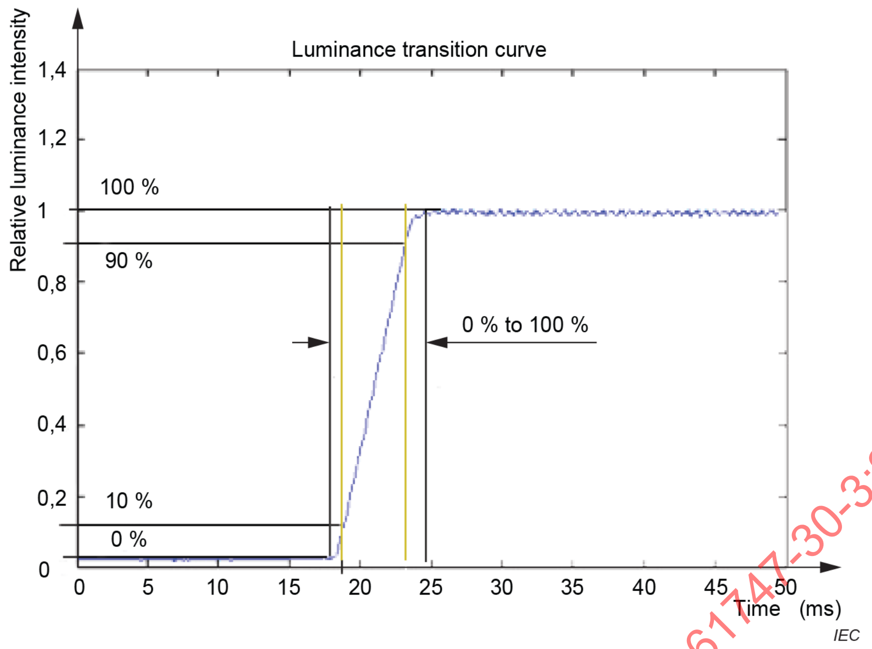


Figure 7 – Example of luminance cross-section profile of extended blurred edge time

5.2.2.3 Perceived blurred edge time (PBET)

The process to obtain a PBET curve is described in [6], and summarized in Figure 8. Luminance blurred edge is converted to a spectrum by a fast Fourier transform (FFT). The spectrum is multiplied by values given by the CSF. After that a PBET curve is obtained by an inverse FFT. The value of the PBET is the distance between the peaks of the PBET curve (expressed in ms).

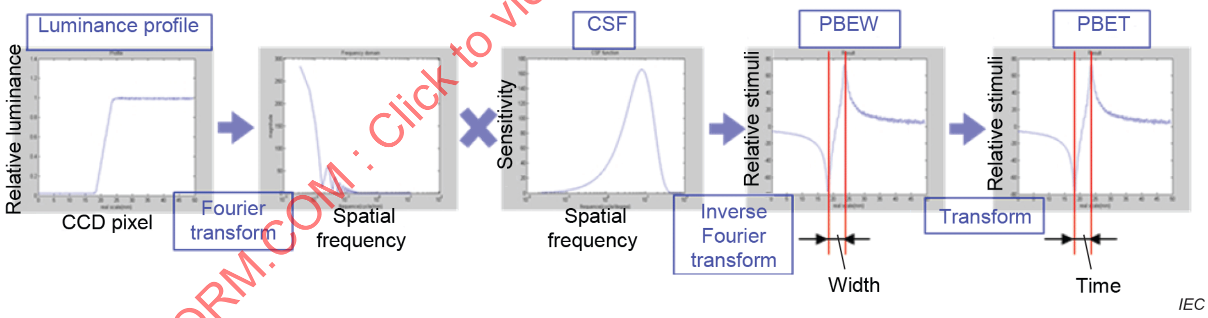


Figure 8 – PBET calculation

The CSF as given in [7] shall be used for CSF calculations.

The CSF formula in [7] is as follows:

$$S(u) = \frac{1}{m_{\mathrm{t}}(u)} = \frac{e^{-2\pi^2\sigma^2u^2}/k}{\sqrt{\dfrac{2}{T}\left(\dfrac{1}{X_0^2}+\dfrac{1}{X_{\max}^2}+\dfrac{u^2}{N_{\max}^2}\right)\left(\dfrac{1}{\eta pE}+\dfrac{\Phi_0}{1-e^{-(u/u_0)^2}}\right)}} \tag{1}$$

where

$S(u)$	is the spatial contrast sensitivity function for binocular vision;
$m_t(u)$	is the modulation threshold;
u	is the spatial frequency;
σ	is the standard deviation of the line-spread function of the eye;
K	is the signal-to-noise ratio (3,0);
T	is the integration time of the eye (0,1 s);
X_0	is the angular size of the object;
X_{max}	is the maximum angular field size of the object (12˚);
N_{max}	is the maximum number of cycles over which the eye can integrate (15 cycles);
η	is the quantum efficiency of the eye (0,03);
p	is the photon conversion factor, depending on the light source; (e.g. 1,2 x 10^6 photon/second/degree^2/troland);
E	is the retinal illumination (Td);
Φ_0	is the spectral density of the neural noise (3,10^{-8} second degree^2);
U_o	is the spatial frequency above which the lateral inhibition ceases (7 cycles/degree).

The magnitude of σ can be estimated according to the following formula:

$$\sigma = \sqrt{\sigma_0^2 + (C_{ab} d)^2} \tag{2}$$

where

σ_0 is a constant, and C_{ab} describes the change in σ for a given pupil diameter d.

It is assumed the pupil diameter is larger than 2 mm (diffraction effects are negligible). In this case, for observers with good overall vision, C_{ab} is 0,008 3° (0,5 arcmin) and σ_0 is 0,0013° /mm (0,08 arcmin/mm).

The retinal illumination E can be calculated as follows:

$$E = \frac{\pi d^2}{4} L \tag{3}$$

where

L is the luminance of the object and d is the pupil diameter in mm.

NOTE The unit of E is troland (Td).

For the calculations, the viewing distance is set to 1,5 times the diagonal screen size of the active display area (approximately three times the height of the display active area).

5.3 Indirect measurement method

5.3.1 Temporal step response

5.3.1.1 General

The temporal step response measurement method is based on [9] to [15]. The edge profile is currently sufficient as a measure for the motion performance, because the relation between the perceived sharpness and the edge blur is only established for continuous backlight-type LCDs (see e.g. [13]). For these LCD types, the BET, EBET, and/or PBET can be derived according to 5.2.2

5.3.1.2 Measurement system

A schematic representation of the measurement set-up to measure the temporal step response is shown in Figure 9.

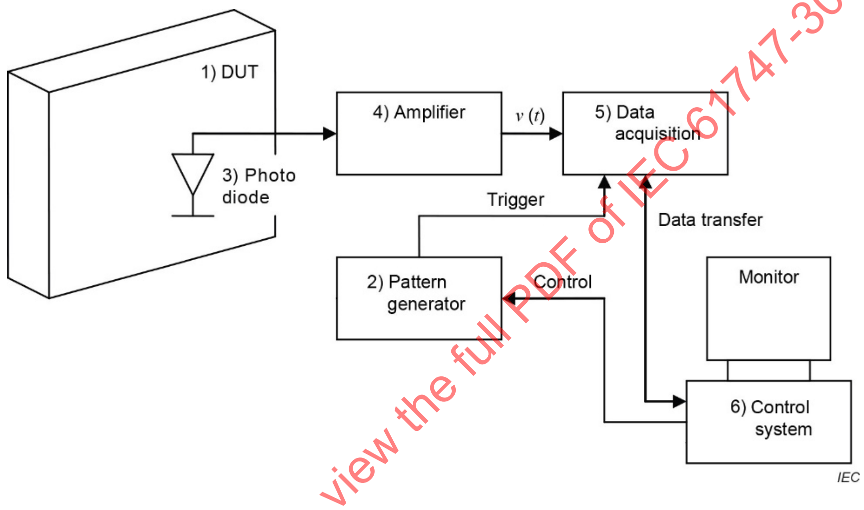


Figure 9 – Set-up to measure the temporal step response

The measurement set-up, presented in Figure 9, comprises the following components:

– The DUT (1), which is the display to be measured.

– A pattern generator (2), which generates the test patterns in the native display resolution and applicable refresh rates. The pattern generator, preferably, has a control terminal or interface, which enables selection of the pattern and start-stop of the measurement procedure. The output of the pattern generator may consist of one or more LVDS(s), DVI(s), or other output terminal(s), which can be connected with the display input terminal(s). The pattern generator should also include a trigger output signal that can be used to start the data acquisition process.

– A fast response photo-diode or other opto-electrical detector (3), with a spectral sensitivity that is matched to the spectral luminous efficiency function $V(\lambda)$ for photopic vision. This detector is used to capture the temporal luminance produced by the DUT.

– A signal amplifier (4), which is used for signal amplification to match the input range of the data acquisition device and for low-pass filtering to attenuate the signal noise.

– A data acquisition device (5) that records the amplified signal $v(t)$ of the photo-diode. The sampling rate shall be at least 10 kHz to enable the acquisition of temporal luminance data with sufficient temporal resolution, and furthermore the sampling rate should be related to the refresh rate of the display to allow time accurate analysis of the data. An oscilloscope or a data-acquisition card can be used to acquire and digitize the time-varying luminance signal.

– A control system (6), for example a personal computer, which can be used to start the measurement procedure, and to collect and process all data.

5.3.1.3 Measurement process

In liquid crystal displays the temporal luminance transition from one level to another depends on the selected input codes. The time required for the transition to be completed has an influence on the perceived motion blur, and therefore several luminance transitions need to be measured. The number of luminance transition levels should be at least seven, and they should be spaced equidistantly on the CIE 1976 lightness scale. In order to determine the appropriate luminance levels, the luminance transfer function of the DUT shall first be measured.

The pattern generator should generate images with gray-level values ranging from 0 to 255 (for an 8-bit display), and the corresponding luminance levels should be measured with the luminance meter. At about the same screen position, the photo-diode (3) signal should be measured in parallel to enable conversion from the time-varying voltage values to luminance values. Next the (seven) luminance levels will be used as start and end levels to measure the temporal step responses of the DUT. In this case the pattern generator will generate the luminance transitions, which will be recorded with the data acquisition device (5) via the photo-diode and amplifier combination.

Multiple traces can be acquired with the control system (6) to enable temporal averaging of the step responses. Furthermore, to ensure accurate and stable start- and end-levels, the step response should be comprised of six frames with the start-level and at least six frames with the end-level. Of course it is also possible and allowed to record the rising and falling luminance transitions in one pass. The measurements can be summarized according to Table 1, where each cell in the table consists of an array with the temporal luminance data. To enable the analysis of motion related colour artefacts, tables are required for each primary colour as well as for white.

5.3.1.4 Data analysis

5.3.1.4.1 Motion picture response curve

From the temporal step response, the motion picture response curve shall be calculated for each transition and each primary colour. This is done with a simple convolution of the step response with a moving window function one-frame wide (see for instance [12]). An example of the convolution process is depicted in Figure 10 (moving window indicated by the yellow arrow), and the result is depicted in Figure 11.

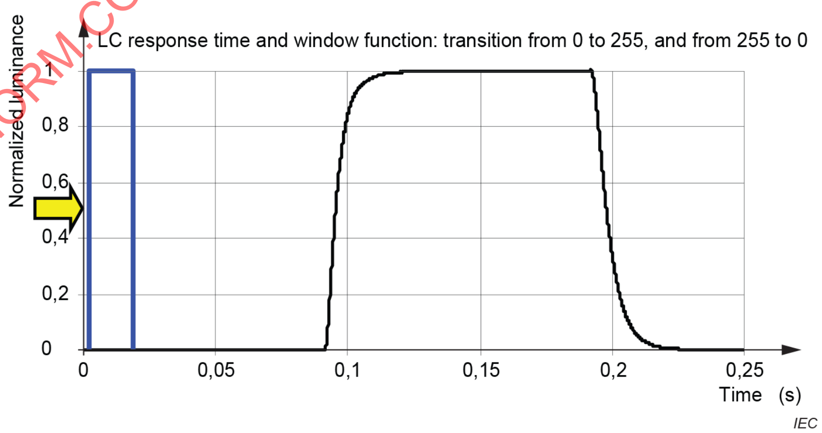


Figure 10 – Example of an LC response time measurement

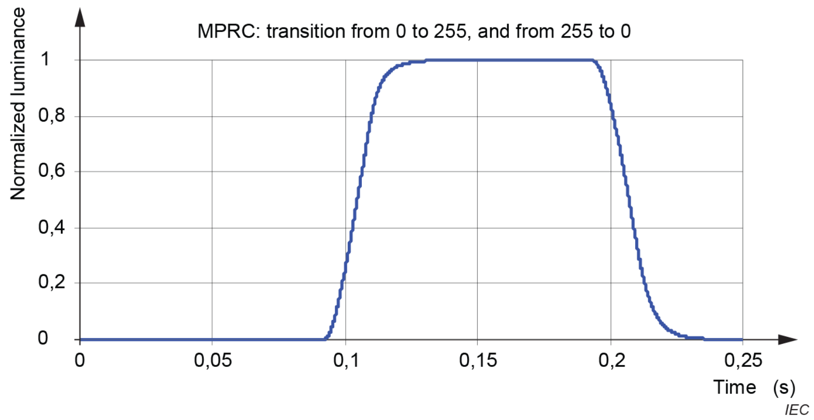


Figure 11 – Example of a motion picture response curve derived from the response measurement presented in Figure 10 and a convolution with a one-frame-wide window function

5.3.1.4.2 Motion induced edge profile

From the motion picture response curves, the edge profiles can be derived for any given object speed. First the motion picture response curves shall be converted from the temporal to the spatial domain using the relation $x_r = -v\ \tau / T_f$, in which x_r is the position of the display pixel, projected on the retina, τ is time, T_f is the frame time, and v is the motion speed expressed in pixels per frame (the minus sign indicates motion from left to right). For each luminance transition, the edge blur profile linearly scales with the motion speed. The higher the motion speed the less pronounced the luminance transition of the edge will be. The visibility of the edge blur depends on the relation between display pixel size and viewing distance, but the luminance contrast and the edge profile also have an effect on the perceived edge blur.

5.3.2 High speed camera

The movement of the visual target is recorded by many individual images taken during oneframe period of the display (i.e. oversampling) followed by numerical processing of the images to realize a pursuit of the target and evaluation of the corresponding blur characteristics.

When a moving block target is used as test pattern, the block-width (w) should be several times the advancement (step-width) per frame, Δ (e.g. $w = 5\Delta$), in order to allow the optical response to settle to a steady state which then serves as reference level for the evaluations (100 % or 0 % level). Under this condition the step response of the display under test is measured. It shall be ensured that the optical response of the DUT is sampled with a sufficient number of images per frame-period. A minimum requirement for the detector shall be 10 times oversampling, i.e. for an effective frame rate of the display of 100 Hz, the sampling frequency is at least 1 000 Hz. The detector shall have settled within 1 % of the stabilised value within the sampling time.

Characteristics for the width of the blurred edges can be obtained for example by the distance between the 10 % and 90 % luminance levels (BEW) for both the rising and falling edge.

The optical transitions should be classified according to the underlying electrical driving conditions (i.e. increasing or decreasing voltage, ON and OFF respectively) rather than by the slope of the optical response to avoid confusion (a normally-black VA-LCD is activated to turn bright, a normally white TN-LCD is activated to turn dark).

6 Test report

6.1 General

Test results shall be reported in conjunction with the test method, the measurement conditions, and the analysis method(s).

6.2 Items to be reported

In the report, the following items at least shall be included:

a) environmental conditions:
   - temperature, humidity, and atmospheric pressure
   - ilumination level
   - other conditions which are different from the standard measuring conditions (Clause 4)

b) display parameters:
   - refresh rate
   - native display resolution / pixel count
   - backlight driving (impulse, stationary, blinking, scanning, other)
   - minimum and peak luminance
   - display's electro-optical transfer function
   - display settings (if applicable)
   - drive mode (when there is an optional driving mode, e.g. “over drives” are installed in the module, the driving mode used for the test shall be reported)

NOTE The driving mode could interfere with the experimental results.

c) measuring method and conditions:
   - measuring device (pursuit detection system, temporal step response, high speed camera)
   - number of bits in the measuring device, used to capture the luminance signal
   - for imaging devices, the number of CCD pixels per display pixel, the f-number, the dynamic range, and the exposure time
   - for pursuit systems, the synchronization accuracy
   - light measuring device (luminance meter, colour analyzer, spectroradiometer, other)
   - scroll speed(s) (for example 8 pixels/frame)
   - gray levels (start levels and end levels, see Table 1)
   - test pattern(s) details
   - other measuring conditions, such as frame frequency, etc.

d) analysis method:
   - parameter (EBET, BET, PBET)
   - threshold for EBET or BET calculation, for example 10 % to 90 %
   - type of CSF and the CSF parameters for PBET calculation

An example for visually reporting the PBET analysis data is shown in Figure 12.

	Ini: 0	Ini: 1	Ini: 2	Ini: 3	Ini: 4	Ini: 5	Ini: 6	Ini: 7	Ini: 8
Fin: 0		9,6	8,8	9	9	9	9,1	9,1	9,3
Fin: 1	8,8		9,9	9,1	9,3	9,1	9,1	9,3	9,3
Fin: 2	9,4	10,3		10	9,4	9,4	9,3	9,4	9,4
Fin: 3	9,3	10	10		9,4	9,4	9,1	9,4	9,4
Fin: 4	9,3	9,6	9,7	9,7		9,6	9,4	9,3	9,4
Fin: 5	9,3	9,7	10,6	11,1	10,3		9,6	9,7	9,6
Fin: 6	9,6	10,3	11,1	10	9,4	9,3		9,4	9,4
Fin: 7	9,4	9,9	10,2	9,4	9,1	9,1	9,1		9,1
Fin: 8	10,9	10,9	11,1	8,8	8,8	8,8	8,7	8,8	

Average	9,5	Standard dev.	0,6
Maximum	11,1	Minimum	8,7

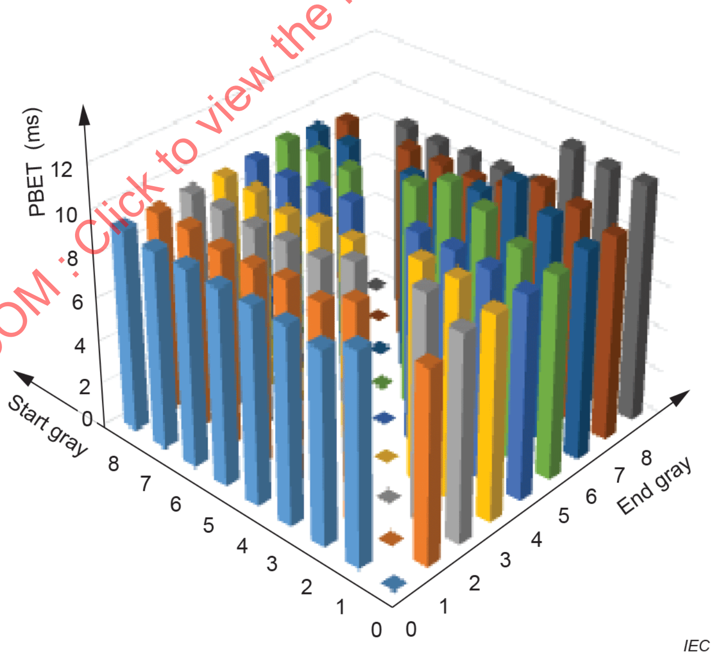


Figure 12 – Example of measurement data reporting

Annex A
(informative)

Subjective test method

This method operates on a pair of images (test and reference), one of which can be a uniform field. The images are defined as digital grayscale images, with an arbitrary size in pixels but subtending 2° or less. Larger images can be handled with suitable extensions to the metric. The images are assumed to be viewed at a specific viewing distance, and the pixels have a known relation to luminance. The output of the metric is a measure of the visibility of the difference between the test and reference images, in units of just-noticeable difference (JND), defined as ΔE_{76} = 2,3 [23].

Annex B
(informative)

Motion contrast degradation

B.1 General

Line spreading is a method to evaluate motion blur magnitude plus contrast degradation as a function of speed, both within a single measurement. It is more efficient and simplified than dual edge methods such as moving edge or box edge blur. It can provide meaningful results for understanding the motion performance of a display. The width and amplitude or luminance of the spreading line are measured.

B.2 Direct measurement

The measurement method is the same as the edge blurring method except for the test pattern (see [8]). Since this method is targeted to measure moving line spreading, a narrow vertical line pattern should be used. An example of the test pattern is shown in Figure B.1.

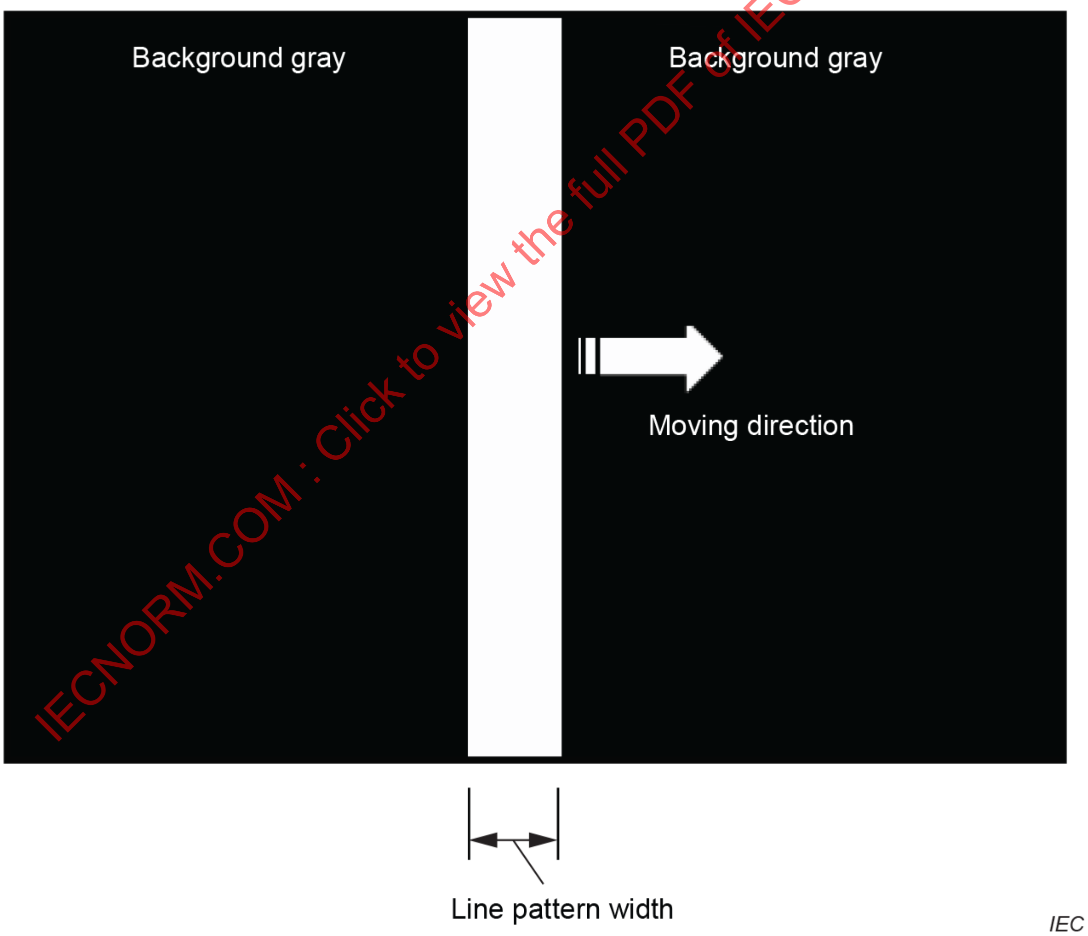
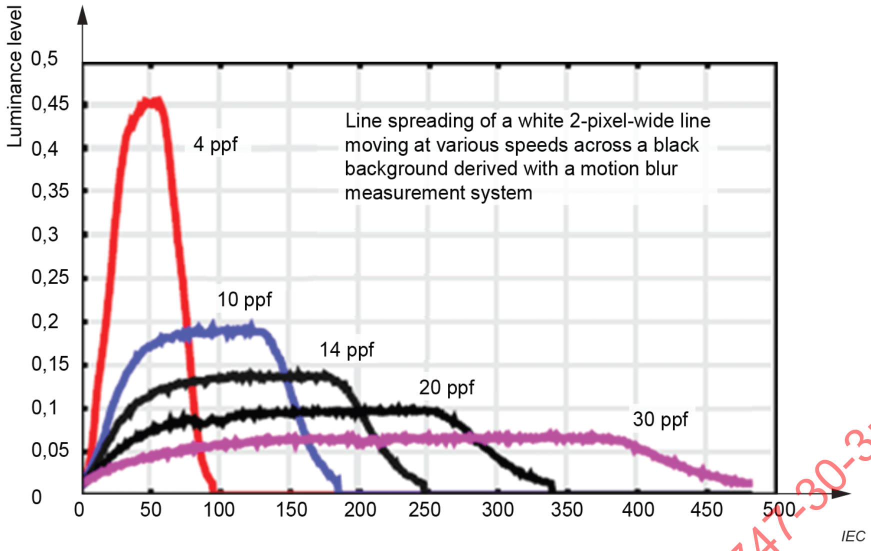


Figure B.1 – Example of motion contrast degradation test pattern

The motion contrast degradation (MCD) characteristics can be analyzed using the line spreading measurement. An example of the results is shown in Figure B.2.



NOTE ppf = pixels per frame.

Figure B.2 – Example of motion contrast degradation due to line spreading

B.3 Indirect measurement

To derive the luminance degradation of a line, the same measurement system and process can be used as described in 5.3.1. In this case the number of frames with line luminance shall be identical to the line width. From the motion picture response curves the line spreading can be calculated for any desired motion speed.