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Liquid crystal display devices –
Part 6-3: Measuring methods for liquid crystal display modules – Motion artifact measurement of active matrix liquid crystal display modules

Dispositifs d'affichage à cristaux liquides –
Partie 6-3: Méthodes de mesure pour les modules d'affichage à cristaux liquides – Mesure de l'artefact de mouvement dans les modules d'affichage à cristaux liquides à matrice active

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CONTENTS

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LIQUID CRYSTAL DISPLAY DEVICES –

Part 6-3: Measuring methods for liquid crystal display modules – Motion artifact measurement of active matrix liquid crystal display modules

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The text of this standard is based on the following documents:

FDIS	Report on voting
110/296/FDIS	110/313/RVD

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

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

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

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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LIQUID CRYSTAL DISPLAY DEVICES –

Part 6-3: Measuring methods for liquid crystal display modules – Motion artifact 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 standard defines general procedures for quality assessment related to the motion performance of LCDs. It defines artifacts in the motion contents and methods for motion artifact measurement.

NOTE Motion blur measurement methods and analysis methods introduced in this standard could not be universal tools for all different LCD motion enhancement technologies due to its complexity. Users shall be notified of these circumstances.

2 Normative references

The following referenced documents are indispensable for the application 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 61747-6, *Liquid crystal and solid-state display devices – Part 6: Measuring methods for liquid crystal modules – Transmissive type*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
motion picture response curve
a curve, representing the convolution of the temporal step response with a moving window function of 1-frame wide. 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

3.2
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 The profile can be calculated from the motion picture response curve for any given motion speed.

3.3
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 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.

3.4
perceived blurred edge time
time-related equivalent of the perceived blurred edge width. The latter one is derived from the motion induced edge profile by means of filtering the edge profile with the contrast sensitivity function of the human eye

4 Abbreviations

For the purpose of this document, the following abbreviations apply.

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
MTF	modulation transfer function
PBET	perceived blurred edge time
PBEW	perceived blurred edge width
TN-LCD	twisted nematic liquid crystal display
VA-LCD	vertically-aligned liquid crystal display

5 Standard measuring conditions

5.1 Temperature, humidity and pressure conditions

The standard environmental condition for the motion artifact measurement is (25 ± 3) °C for temperature, 25 % to 85 % for relative humidity, and 86kPa to 106kPa for air pressure. All visual inspection tests shall be tested in (25 ± 5) °C.

5.2 Illumination condition

The illuminance at the measuring spot of the DUT shall be below 1 lx (standard dark room condition as defined in IEC 61747-6).

6 Standard motion-blur measuring methods

6.1 General

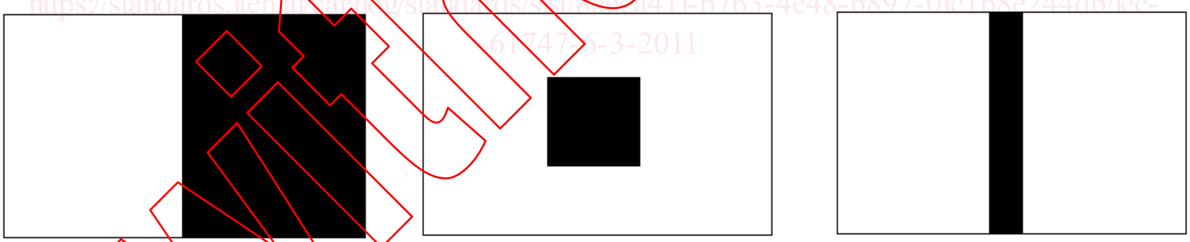
Motion induced object blur is the result of a slow response of the liquid crystal cells and a stationary representation of the temporal image (related to the hold time of the display), in combination with smooth pursuit eye-tracking of an object over the display surface. When an object moves across the display and the eye is tracking this object, a spatiotemporal integration of the object luminance is taken 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 measurements a pursuit camera system can be used, and 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 standard.

6.2 Direct measurement method

6.2.1 Standard measuring process

6.2.2 Test patterns

There are several patterns that can be used to measure motion induced object blur, such as 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, e.g. 5 time 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, are used for gray level of each part of a test pattern in Figure 1. The lightness function, specified in CIE 1976 (L*u*v*) and CIE 1976 (L*a*b*) color spaces, can be used to space the intermediate gray shades equally on the lightness scale. One of gray level data that are available at the LCD modules input, e.g. 0 to 255 for an 8-bit LCD module, also can be used as this gray level.



(A) Full test pattern (B) Box test pattern (C) Line bar test pattern

IEC 1605/11

Figure 1 – Examples of edge blur test pattern

6.2.2.1 Pursuit detection system

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

1 Figures in square brackets refer to the Bibliography.

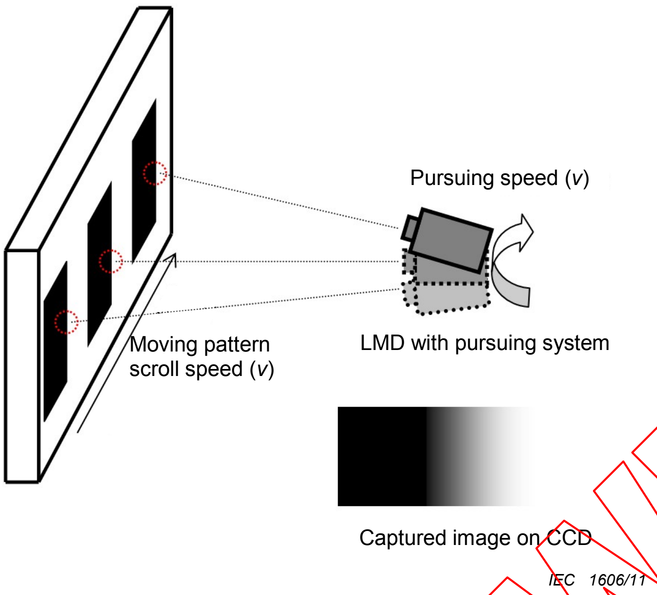


Figure 2 – Example of a pivoting pursuit camera system

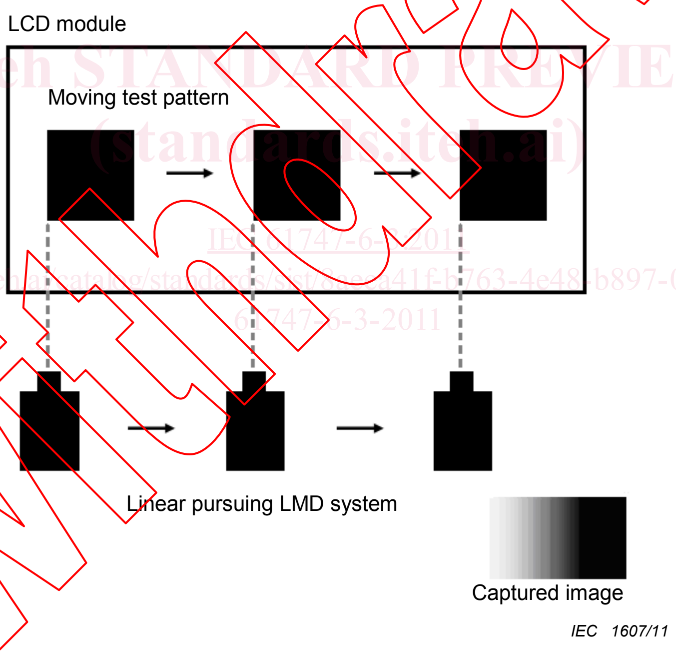


Figure 3 – Example of a linear pursuit camera system

The following guidelines 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 test pattern and the pursuing speed of LMD shall be synchronized accurately to prevent integration errors.

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

6.2.2.2 Specified conditions

a) Any deviations from the standard measurement conditions shall be reported: “Full test pattern” shown in Figure 1(A) shall be used as the test pattern for this test method. Other test patterns, such as “Box test pattern” shown in Figure 1(B) or “Line bar test pattern” shown in Figure 1(C), can be used additionally depending on the requirements. The used patterns shall be reported.

NOTE When other test patterns other than the standard “Full test pattern” are used, special care should be taken because the size of the pattern can alter the luminance level of some of the LCD modules equipped with 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 Table 1.

Table 1 – Step response data for different luminance transitions

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

c) Standard measuring conditions

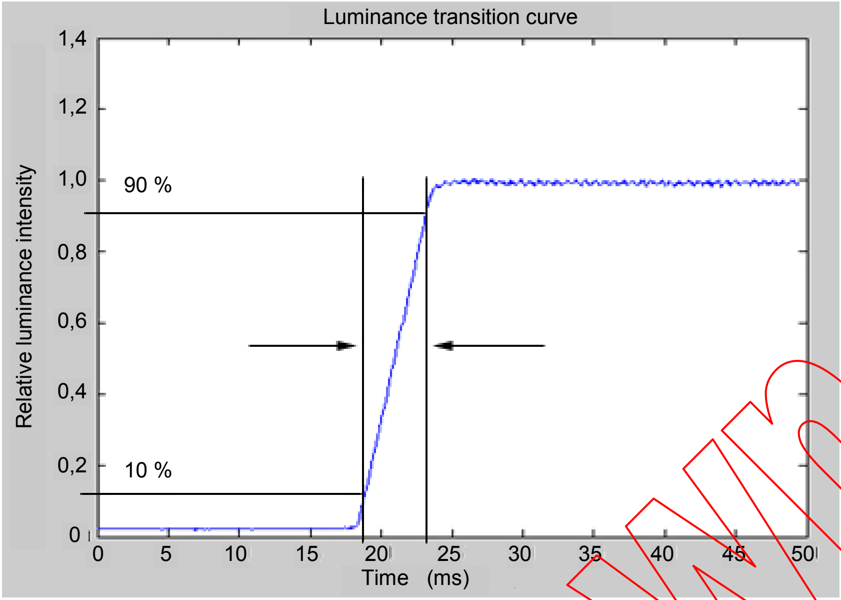
1) Scroll speed : 4, 8, 12 pixel/frame

2) Shutter speed of camera : 1/20 sec.

6.2.3 Analysis method

6.2.3.1 Blurred edge time

The time between the transition from 10 % to 90 % in the luminance transition curve (see Figure 4) is used to represent blurred edge time. Other ranges, such as 40 % to 60 %, can be used, but they shall be reported.

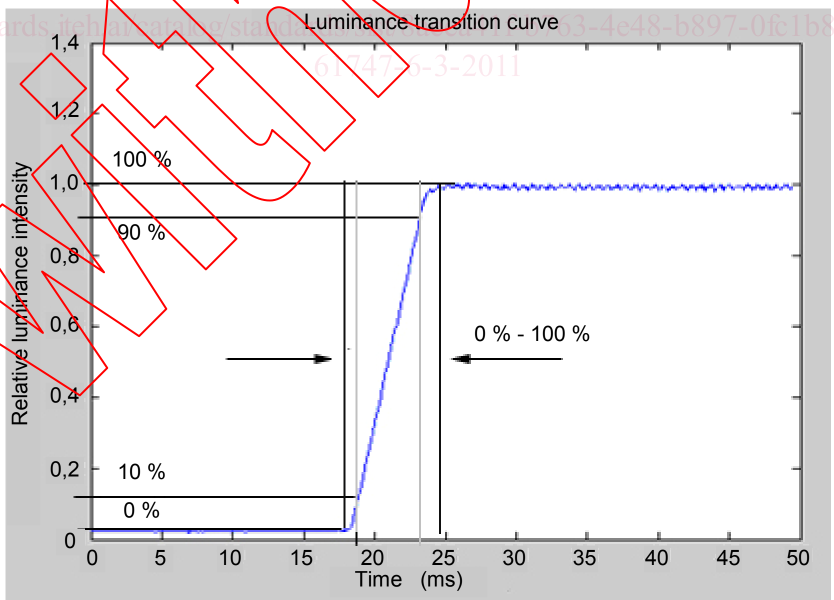


IEC 1608/11

Figure 4 – Example of luminance cross section profile of blurred edge

6.2.3.2 Extended blurred edge time

The extended blurred edge time is defined as EBET = BET/0.8, which linearly extends the BET to the 0 % to 100 % levels (see Figure 5).



IEC 1609/11

Figure 5 – Example of luminance cross-section profile of blurred edge

6.2.3.3 Perceived blurred edge time

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

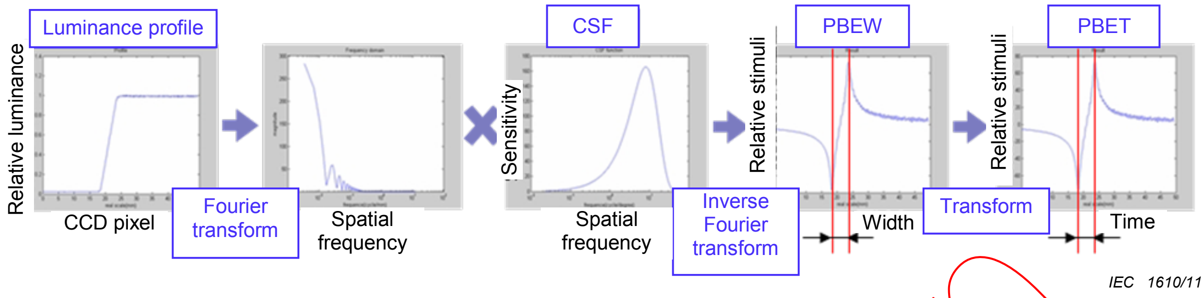


Figure 6 – PBET calculation

NOTE This standard recommends Peter Barten’s CSF (reference [7]), although other CSFs could be used.

Barten’s CSF formulae: $$S(u) = \frac{1}{m_t(u)} = \frac{e^{-2\pi^2\sigma^2u^2} / k}{\sqrt{\frac{2}{T}\left(\frac{1}{X_0^2} + \frac{1}{X_{\max}^2} + \frac{u^2}{N_{\max}^2}\right)\left(\frac{1}{\eta pE} + \frac{\Phi_0}{1 - e^{-(u/u_0)^2}}\right)}}$$

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_O is the angular size of the object;
- X_{max} is the maximum angular filed 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 10^6 photons/sec/deg2/Td) ;
- *E* is the retinal illumination (Td);
- Φ_0 is the spectral density of the neural noise (3,10^{-8} sec deg^2);
- U_o is the spatial frequency above which the lateral inhibition ceases (7 cycles/degree).

For the calculations, the viewing distance is set to 1.5 times the diagonal screen size of the active display area (approximately 3 x height of display active area)

6.3 Indirect measurement method

6.3.1 Temporal step response

The temporal step response measurement method is based on the literature, indicated in the Bibliography, i.e., references [9] to [15].

6.3.1.1 Measurement system

A schematic representation of the measurement set-up to measure the temporal step response is shown in Figure 7.

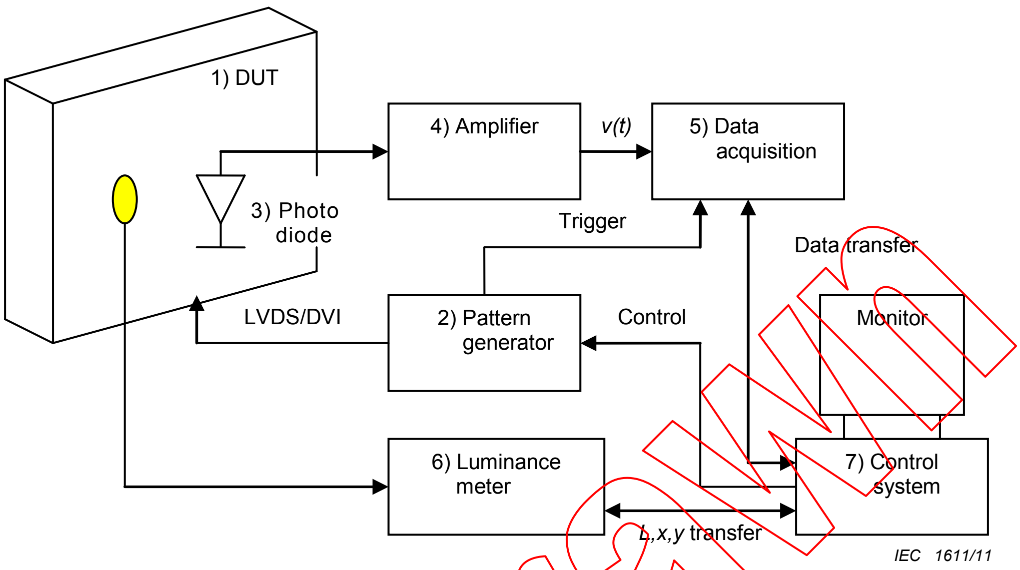


Figure 7 – Set-up to measure the temporal step response

The measurement set-up, presented in Figure 7, comprises of 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, DVI, 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 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 acquiring 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 luminance meter (6) that records the luminance of the display for each input code (0 to 255 for an 8-bit input signal). With this information the time varying photo-diode signal $v(t)$ can be translated to a time varying luminance signal $L(t) = f(v(t))$.

A control system (7), e.g. a personal computer, which can be used to start the measurement procedure, and to collect and process all data.