भारतीय मानक
Indian Standard

IS 15934 (Part 6) : 2014
IEC 61747-6 : 2004

द्रव क्रिस्टल प्रदर्शन उपकरण

भाग 6 द्रव क्रिस्टल मॉड्यूल की मापन विधियाँ — ट्रांसमिसिव प्रकार

Liquid Crystal and Solid State Display Devices

Part 6 Measuring Methods for Liquid Crystal Modules — Transmissive Type

ICS 31.120

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Electron Tubes and Display Devices Sectional Committee, LITD 04

NATIONAL FOREWORD

This Indian Standard (Part 6) which is identical with IEC 61747-6 : 2004 'Liquid crystal and solid-state display devices — Part 6: Measuring methods for liquid crystal modules – Transmissive type' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Electron Tubes and Display Devices Sectional Committee and approval of the Electronics and Information Technology Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are however not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 13406-1 : 1999	Ergonomic requirements for work with visual displays based on flat panels — Part 1: Introduction
ISO 13406-2 : 2001	Ergonomic requirements for work with visual displays based on flat panels — Part 2: Ergonomic requirements for flat panel displays

Only the English language text in the IEC Standard has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

LIQUID CRYSTAL AND SOLID STATE DISPLAY DEVICES

PART 6 MEASURING METHODS FOR LIQ UID CRYSTAL MODULES — TRANSMISSIVE TYPE

1 Scope and object

This part of IEC 61747 gives details of the quality assessment procedures, inspection requirements, screening sequences, sampling requirements and test and measurement procedures required for the assessment of liquid crystal display modules.

This standard is restricted to transmissive liquid crystal display (LCD) modules using either segment, passive or active matrix and achromatic or colour type LCDs (see Clause 3, chromaticity and pixel definitions) that are equipped with their own integrated source of illumination or without their own source of illumination.

For both rear projection-display systems and front projection-display systems, optical performance on the screen is not only determined by the panel performance as described in this standard, but also by the lighting system, such as the projection lens, screen, light filter, etc. Therefore, this standard is not applicable to such projection-display systems. (Nevertheless, for the determination of "on the screen" optical performance of rear projection-display systems, this standard may be used as a guideline).

In order to achieve a useful and uniform description of the performance of the display devices covered in this standard, specifications for commonly accepted relevant parameters are provided and fall into the following categories:

a) general type (e.g. pixel resolution, diagonal, pixel layout);
b) optical (e.g. contrast ratio, response time, viewing direction, cross-talk, etc.);
c) electrical (e.g. power consumption, EMC);
d) mechanical (e.g. module geometry, weight);
e) passed environmental endurance test;
f) reliability and hazard/safety.

In most categories, the specification is self-explanatory. For some, however, notably in the area of optical and electrical performance, the specified value may depend on the measuring method.

The object of this standard is to indicate and list the procedure-dependent parameters and to prescribe the specific methods and conditions that are to be used for their uniform numerical determination.

It is assumed that all measurements are performed by personnel skilled in the general art of radiometric and electrical measurements as the purpose of this standard is not to give a detailed account of good practice in electrical and optical experimental physics. Furthermore, all equipment needs to be suitably calibrated by competent personnel, and records of the calibration data and traceability need to be kept.

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.

ISO 13406-1:1999, *Ergonomic requirements for work with visual displays based on flat panels – Part 1: Introduction*

ISO 13406-2:2001, *Ergonomic requirements for work with visual displays based on flat panels – Part 2: Ergonomic requirements for flat panel displays*

3 Chromaticity and pixel definitions

Several points of view with respect to the preferred terminology concerning "monochrome", "achromatic", "chromatic", "colour", "full-colour", etc. can be encountered in the field amongst spectroscopists, physicists, colour-perception scientists, physical engineers and electrical engineers. In general, all LCDs demonstrate some sort of chromaticity (e.g. as a function of viewing angle, ambient temperature or externally addressable means). Pending detailed official description of the subject, the pre-fix pertaining to the chromaticity of the display will be used to describe the colour capability of the display that is externally (and electrically) addressable by the user. This leads us to the following definitions (see also ISO 13406-1, Chapter 3: Terminology):

a) a monochrome display has no user-addressable chromaticity ("colours"). It may or may not be "black and white" or a-chromatic;

b) a colour display has at least two user-addressable chromaticities ("colours"). A 64-colour display has 64 addressable colours (often made using 2 bits per primary), etc. A full-colour display has at least 6 bits per primary (≥ 260 000 colours).

Within this document, the official definition of pixel is employed, which may or may not include a multitude of constituent dots.

4 Standard measuring conditions

4.1 Standard measurement equipment and setup

4.1.1 High resolution matrix displays ($\geq 320 \times 240$ pixels)

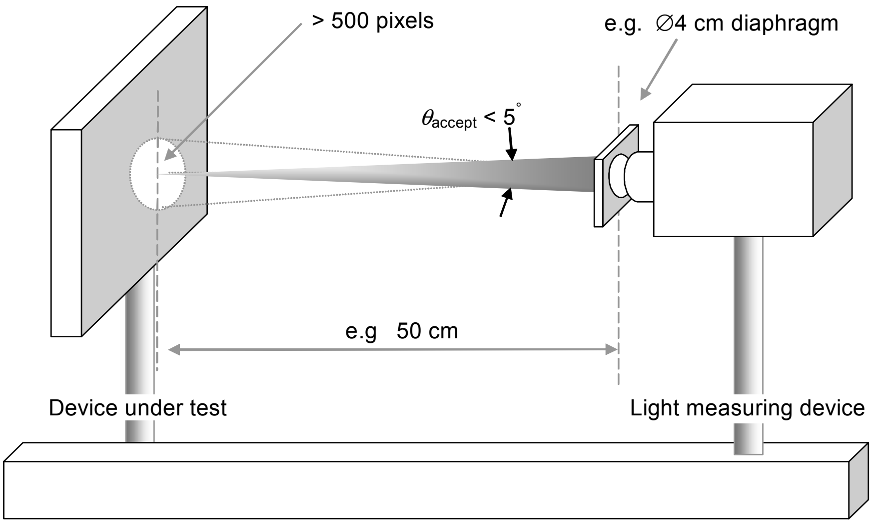
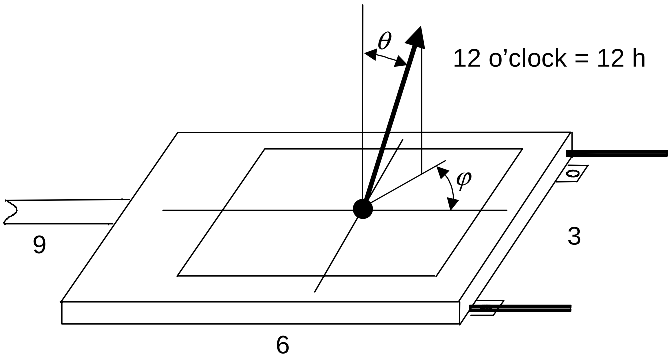


Figure 1 – Measuring system and its configuration

Three different instruments may be applied to the measurements of the light transmitted and/or reflected by the device under test (DUT); a luminance meter, tristimulus photometer or a spectro-radiometer. The optical system is schematically shown in Figure 1 and shall allow for measurement of well-defined spot sizes (field of view) on the DUT. When measuring matrix displays, these meters should be set to a circular or rectangular field of view that includes more than 500 pixels on the display under normal observation (the standard measurement direction). The total acceptance angle of detection by these meters, θ_{accept}, shall be less than 5° (see Figure 1). This can be obtained, for example, by use of a measuring distance between the meters and display area centre of 50 cm (recommended) and a diameter of the detector pupil of 4 cm; see Figure 1. If measuring segment displays, the field of view should be set to a single segment, and not include any of its surroundings.

Viewing direction and angle range are given by polar coordinates θ and φ as defined in Figure 2. $\theta_{\varphi} = 0$ is referred to as the 3 o'clock direction (the "right"), $\theta_{\varphi} = 90$ as the 12 o'clock direction ("upward"), $\theta_{\varphi} = 180$ as the 9 o'clock direction ("left") and $\theta_{\phi} = 270$ as the 6 o'clock ("bottom"). In the standard measurement direction, the photometer observes the DUT under vertical viewing angle ($\theta = 0°$). While scanning θ and/or φ, the centre of the measuring spot on the DUT shall stay fixed.



12 o'clock pertains to "top" of the display area, 3 o'clock to "right" of the display area (as viewed under "normal" operating viewing conditions)

Figure 2 – Definition of polar coordinates θ, φ

Any condition (either measuring spot on the DUT, meter aperture angle, viewing angle, meter spectral sensitivity, resolution etc.) that is not compliant to the required condition described in this shall be recorded in the detail specifications.

If the DUT is not equipped with its own source of illumination, external illumination shall be done in either of two ways:

a) by means of an externally applied diffuse light source with specified (spatial and angular distribution of) luminance and spectrum (this is, for example, used for measurements on direct view displays);
b) by means of an externally applied directional light source with calibrated spatial uniformity of illumination at the plane of the DUT, full opening angle of illumination at the location of the measuring spot in the plane of the DUT of less than 30°, and (if needed) (calibrated) distribution of spectral irradiation in the visible region of radiation (mostly used for measurements on projection-display modules).

In both cases, records of the light source (intensity distribution, temporal stability, opening angle, etc.) and its distance to the device under test shall be added to the detail specification.

The temporal drift in luminance shall be less than 1 % of the stabilized value per minute. Care shall be taken that the temperature of the DUT has stabilized and is not affected by the illumination system. The temperature of the DUT shall be measured and specified.

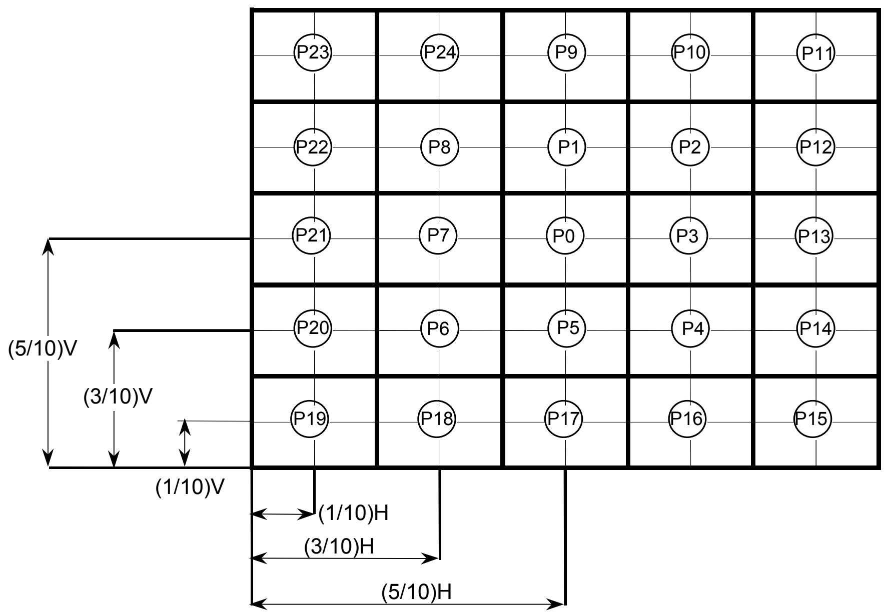
Any deviation from the above described standard measurement equipment or setup shall be added to the detail specification.

4.1.2 Low resolution (< 320 × 240 pixels) and segment display specific remarks

Default measurement conditions are the same as those prescribed for high-resolution matrix displays. However, for low resolution and segment displays the measurement field may contain fewer than 500 pixels. For matrix displays, a minimum of 9 is recommended. For measuring segment displays, the field of view should be set to a single segment, and not include any of its surroundings under any measurement angle.

4.2 Standard measurement positions

4.2.1 Matrix displays



NOTE Height and width of each rectangle is 20 % of display height and width respectively.

Figure 3 – Standard measurement positions at the centres of all rectangles p0-p24

Luminance, radiance distribution and/or tristimulus values may be measured at several specified positions on the DUT surface. To this end, the front view of the display is divided into 25 identical imaginary rectangles, according to Figure 3. Unless otherwise specified, measurements are carried out in the centre of each rectangle. Care shall be taken that the measuring spots on the display do not overlap. Positioning of the measuring spot on the thus prescribed positions in the x and y direction shall be to within 7 % of X and Y respectively (where X and Y denote the length of the active display area in the x and y direction, respectively).

While scanning the position of the measuring spot over the surface of the DUT, the polar angles shall stay fixed.

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

4.2.2 Segment displays

Standard measurement positions are the same as those prescribed for matrix displays in 4.2.1. However, for segment displays, all measurements shall be performed at the centre of a segment and the chosen segment should be as close as possible to the centre of the designated rectangle. Thus, when measurements on position p_i (i = 0 to 24) are requested, the geometrical centre of the segment closest to the centre of box p_i should be used for positioning of the detector.

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

4.3 Standard device operation conditions

The module being tested shall be physically prepared for testing. It shall be warmed up for the stable operation of liquid crystal display devices at a specified period of less than 1 h. Testing shall be conducted under nominal conditions of input voltage, current, etc. The bias setting (if any) of the module shall be specified and set to those expected under typical use.

Any deviation from the standard device operation conditions shall be added to the detail specification.

4.4 Standard ambient conditions

4.4.1 Temperature, humidity and pressure conditions

The standard measuring ambient for the liquid crystal display devices is (25 ± 2) °C for temperature, (25 to 85) % for relative humidity and (86 to 106) kPa for pressure.

4.4.2 Illumination conditions

Three possible ambient illumination variants are defined as follows:

– darkroom condition: illuminance of the measuring spot on the DUT below 1 lx; directionality unspecified;
– hemispherical diffused light condition: state of illumination of the measuring spot on the DUT where the illuminance is not quantified but Lambertian;
– room illumination condition: illuminance of the measuring spot on the DUT with an intensity between 300 lx and 1000 lx. The intensity of the incident light is equal in all directions (Lambertian illumination).

Records of the measured ambient illumination should be kept on the measuring data sheet. Any deviation from the standard ambient conditions shall be added to the detail specification.

4.5 Standard measuring process

Due to the physics of LCDs almost all optical properties of these devices vary with the direction of observation (i.e. viewing direction). Therefore, it should be understood that for the determination of several of the parameters below, good (mechanical) control and specification of the viewing direction is necessary. Also, the distance between the light measuring device and the measuring spot on the DUT shall remain constant for all viewing directions.

All light sources used for illumination of the DUT during the measurement shall be constant in intensity and spectrum, at least over the time-period of measurements that are related to each other in the evaluation (e.g. bright and dark state of a display for contrast evaluation). The luminance or illuminance of the arrangement used for illumination of the DUT shall be constant to within ±1 % over a time period of minimum 15 min and shall not exhibit short-term fluctuations (e.g. ripple, PWM modulations, etc.).

The standard measuring process consists of the following steps:

a) prepare the measurement equipment and set-up, device-under-test and ambient conditions to the specified (standard) values;
b) make records of standard condition choices and of deviations from standard conditions;

c) measure the necessary parameters in a darkroom;

d) if an external light source is used, measure the following parameters of the light source in the plane of the DUT. At p0 (Figure 3), measure and specify

1) spectrum of emission,

2) luminance L,

3) temporal stability of the luminance $L(t)$,

4) luminance distribution with viewing angle $L(\theta,\varphi)$.

When measuring window contrast ratio (5.5.3.2), chromaticity uniformity (5.9), display uniformity (5.1) or cross-talk (5.12), measure the spectrum of emission, luminance and luminance distribution with viewing angle also at the other relevant positions p1-p24 (Figure 3).

e) add a drawing or photo of the exact geometry of arrangement between light source, DUT and light measuring device to the specification.

The illumination apparatus shall be specified in detail since corrections to the standard conditions are not possible.

5 Measuring methods

5.1 Luminance and luminance uniformity

5.1.1 Purpose

This method is applied to the measurements of luminance and its lateral uniformity (i.e. in the active area) of the liquid crystal display devices with a built-in backlight system.

5.1.2 Measuring equipment

The measuring instruments shall consist of a luminance meter, a driving power supply and a driving signal generator for liquid crystal display devices.

5.1.3 Measuring method

5.1.3.1 Maximum luminance

Measurements are performed in a darkroom under standard measuring conditions and design viewing direction.

Supply the signals to the device as it would be used under normal operating conditions, e.g. maximum contrast ratio, and specify these signals, then apply the data-input signal for maximum luminance.

5.1.3.1.1 Matrix displays

Measure the luminance L_0 at position p0 (the centre of the active area of the display).

5.1.3.1.2 Segment displays

Measurement shall be carried out at the centre of a segment, where the measurement spot is smaller than the segment.

5.1.3.2 Luminance non uniformity

Measurements are performed in a darkroom under standard measuring conditions. All 25 rectangles are addressed with 100 % data-input signal-level (WHITE). Measure the luminance L_i at the rectangles *i* = 11, 15, 19, 23 or *i* = 9, 11, 13, 15, 17, 19, 21, 23 and the centre position (*i* = 0). The luminance non uniformity (LNU) is calculated from the individual luminances L_i and the average luminance L_av according to

$$LNU = \left[\max\left(\left|\frac{L_\mathrm{av} - L_\mathrm{i}}{L_\mathrm{av}}\right|\right)\right] \times 100\% \tag{1}$$

where LNU = 0 % indicates a perfectly uniform display.

5.1.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

- driving signals (waveforms, voltage and frequency);
- measuring points.

5.2 Warm-up characteristics

5.2.1 Purpose

This method is applied to the measurements of turn-on luminance transient characteristics for the transmissive type liquid crystal display devices with built-in backlight system (these effects are mostly due to warm-up).

5.2.2 Measuring equipment

The measuring instruments shall consist of a luminance meter, a driving power supply and a driving signal generator for liquid crystal display devices.

5.2.3 Measuring method

5.2.3.1 Matrix displays

The measurement shall be performed under dark-room and standard measurement conditions, unless otherwise specified.

The device under test (DUT) shall be supplied with all voltages and input data required to obtain the maximum transmittance of the LCD. The measurement of the luminance as a function of time shall be carried out at position p0 and the luminance is recorded versus time until the observed fluctuations of luminance become less than 1 % of the mean value. This mean value shall be obtained by taking at least 10 measurements over a period of typically 15 min. The mean luminance level after having settled to the stable state is called the "luminance value after stabilization, L_stab". All measuring conditions shall be kept stable over the time period of recording the luminance.

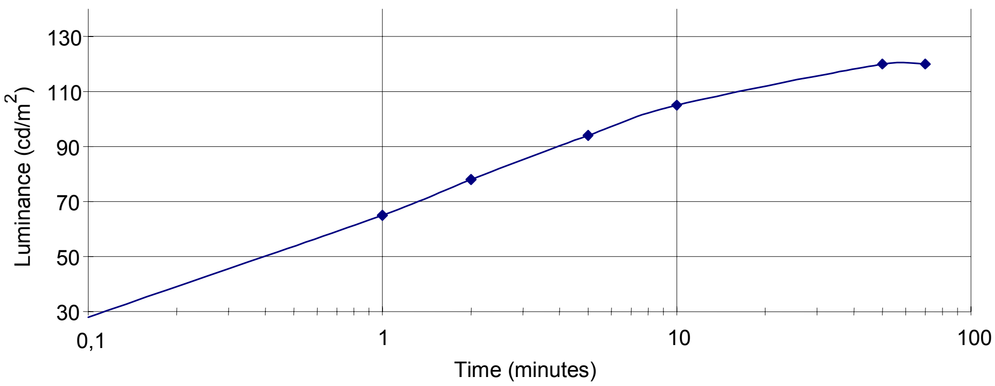


Figure 4 – Example of warm-up characteristic

Values of characteristics can be derived from the recorded luminance versus time values by computation of, say, t_{90} (time period required for the luminance to reach 90 % of L_{stab}).

When the time dependent luminance data are required for other positions, measure the luminance at these positions.

5.2.3.2 Segment displays

The same requirements as for matrix displays are applicable.

5.2.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

– driving signals (waveforms, voltage and frequency);
– timing of data acquisition (sampling frequency and integration period).

5.3 Response times (turn-on time, turn-off time, rise time and fall time)

5.3.1 Purpose

The purpose of this test is to determine the time needed to change from light to dark (dark to light) by application of the driving voltage.

By convention, the response of LCDs to an increase in driving voltage is called "turn-on" whereas the relaxation following a decrease of the driving voltage is called "turn-off". While this definition is straightforward in the case of segment and low resolution LCDs, it is significantly more complicated in the case of high resolution matrix LCD screens, due to the complex data-processing included in such a display.[1]

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[1] As a consequence, ISO 13406-2 uses the term "image formation time" (sum of turn-on and turn-off) with the distinction of positive and negative contrast polarity (the turn-on process in the case of positive contrast polarity is then the switching from "bright" to "dark" as required to generate an image on the bright background).

5.3.2 Measuring equipment

These typical times are measured using a luminance meter with sufficient frequency response, power supply, driving signal generator, trigger signal generator and recorder.

5.3.3 Measurement method

Measurements are performed in a darkroom under standard measurement conditions. The electrical signal of the detector, which is positioned under the design viewing direction at position p0 (see Figure 3), is recorded as a function of time. The display is driven by an invertible plain field signal from a signal generator. Upon inverting, the signal shall go from start level to end level without displaying any intermediate level on the display. The frequency of inversion shall be low enough to allow the display to obtain optical equilibrium in each of the two states. A trigger signal is sent to the recorder upon inversion of the video at position p0. If the trigger signal has another timing (e.g. at the beginning of the field), corrections shall be made to allow for the scanning time t_s needed for video signal inversion to arrive at position p0. The luminance meter measures the optical response. Ripples in the detected signal due to irrelevant effects (e.g. originating from the display frame frequency) shall be eliminated from the response. The luminance in the WHITE (100 % input data signal) mode is chosen as 100 % and in the BLACK (0 % input data signal) mode as 0 %.

Caution: For high resolution displays (> 320 × 240 pixels), care should be taken that the measured response times are not significantly influenced by the time needed by the display for the (line sequential) "scanning" of the measuring spot. If the display frame time is indicated by $T = 1/f_{FRM}$ (with f_{FRM} being the frame frequency), the display has N_{row} rows with a vertical pixel-pitch of V_{pitch}, leading to a display height (i.e. display dimension in the "scanning direction") of $H = N_{row} \times V_{pitch}$, and the diameter of the measuring spot in the same direction is given by S, then the measured response times t (see below) should obey

$$t \geq 5\ T\ \frac{S}{H} \tag{2}$$

5.3.4 Specification of dynamic characteristics

Thus, for all types of LCDs, the times needed for the luminance at position p0 to change from 0 % --> 90 % (t_1) and 100 % --> 10 % (t_2) are measured (see Figure 5). Also, at the same position, the times needed for the luminance to change from 10 % --> 90 % (τ_1) and 90 % --> 10 % (τ_2) are measured. The turn-on and turn-off time t_{on} and t_{off} are then defined for the normally white (normally black) DUT according to

$$t_{on} = t_2 \quad (t_1) \tag{3}$$

and

$$t_{off} = t_1 \quad (t_2) \tag{4}$$

and the rise time (t_r) and fall time (t_f) according to

$$t_r = \tau_2 \quad (\tau_1) \tag{5}$$

and

$$t_f = \tau_1 \quad (\tau_2) \tag{6}$$

Both on and off times, as well as rise and fall times, are examples of (dynamic) response times, also called “switching” times; in other words, the (dynamic) response time and switching time are general terms that are not strictly defined. The difference between turn-on and turn-off times on the one hand, and rise and fall times on the other, is called the delay time.

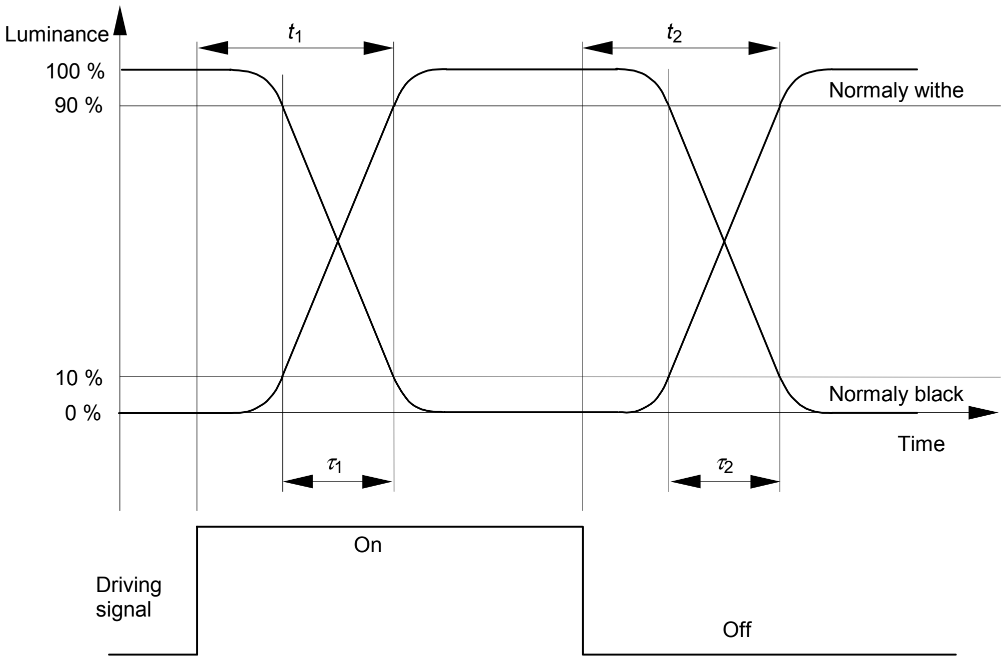

Figure 5 – Relationship between driving signal and optical response times

5.3.5 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

- driving signals (waveforms, voltage and frequency);
- filtering applied to remove frame response and refresh artifacts;
- dynamic properties of light measuring device and data sampling and recording;
- if use is made of the term switching time or (dynamic) response time, explanation of the use should be given in the detail specification, and deviations from the above prescribed nomenclature should be given when using other names for any of these times.

5.4 Flicker (multiplexed displays)

5.4.1 Purpose

This method is used for assessment of the temporal variation of display luminance for multiplexed and/or matrix displays. Although this is often called “flicker” by people active in the field, the latter name is, strictly speaking, reserved for the perceptual effects of this temporal variation. The actual flicker, i.e. the visual perception of temporal fluctuations, is a complicated matter depending amongst other things on the brightness and colour of the light source as well as the direction at which it is observed. The perceptual side will not be discussed here; instead, determination of the temporal fluctuations is considered. Only the frequency response of the human visual system is taken into account to determine this flicker. More relevant information about the technical and perceptive issues of display flicker can be found in ISO 13406-2, Annex B.

5.4.2 Measuring equipment

The measuring instruments shall consist of a power supply, a driving signal generator and a luminance meter with a cut-off frequency of at least three times the display frame frequency.

5.4.3 Measuring method

Measurements are performed under darkroom standard measuring conditions. First, the contrast ratio is adjusted to the maximum value. Next, the luminance is adjusted to 50 % of its maximum (by selecting the appropriate grey level or video input signal). Thereafter, measure the luminance at the centre of the active area or the segment of interest by the luminance meter as a function of time. In order to account for the frequency response of the human visual system, the signal from the luminance meter may be passed through an integrator with visual sensitivity characteristics (see Figure 6) before the recording of the frequency response on the frequency analyzer. (Alternatively, the frequency response of the human visual system may be taken into account by numerical multiplication of the measured power-spectrum with the response-function given in Figure 6). Next, for each thus found frequency 60 Hz > f > 0 Hz, determine the power present in the spectrum and find the component with the highest power value $P_{f\text{max}}$. The flicker level F is obtained according to

$$F = 10 \times \log\left(\frac{P_{f\,\text{max}}}{P_0}\right) \quad \text{[dB]} \tag{7}$$

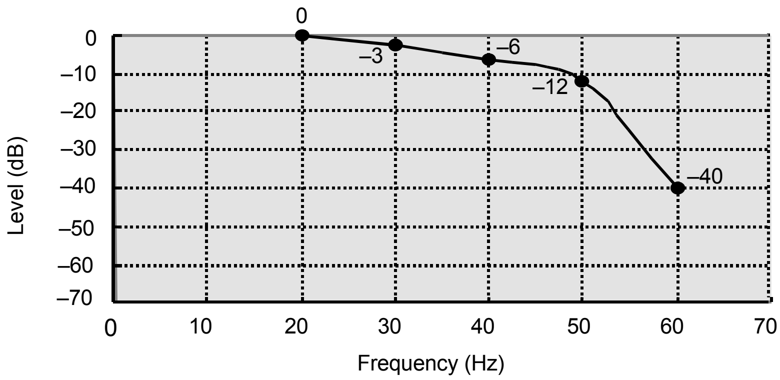

Figure 6 – Frequency characteristics of the integrator (response of human visual system)

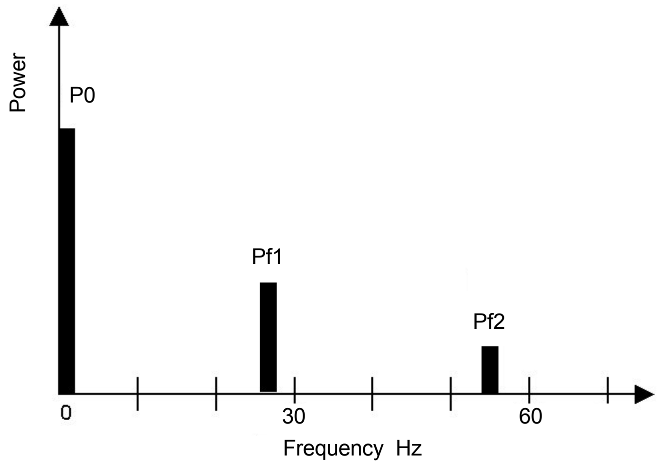

Figure 7 – Example of power spectrum

5.4.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

– driving signals (waveforms, voltage and frequency);

– the absolute value of the luminance at which the flicker measurement was performed (i.e. 50 % of the maximum value of the device).

5.5 Luminance contrast ratio

5.5.1 Purpose

The purpose of this method is to determine the luminance contrast ratio (in short "contrast ratio") of the LCD device.

5.5.2 Measuring equipment

The measurement instruments shall consist of a luminance meter, driving power supply and driving signal generator.

5.5.3 Measuring method

The contrast ratio of LCDs is not directly measurable with non-imaging detectors. It shall be evaluated as the quotient of two luminance values that are sequentially measured in the bright and the dark state of the display. It shall be assured that all conditions besides the electrical driving remain constant during the measurement of both luminance values (e.g. temperature, illumination, etc.).

Measurements are performed under darkroom and standard measurement conditions. The luminance meter is positioned under θ = 0°.

5.5.3.1 Plain field contrast ratio (high resolution display)

The module is driven by a plain field test pattern signal from a signal generator (i.e. all 25 rectangles have the same grey level). The luminance is measured at position p0 on the DUT (centre of the display area, see Figure 3) in the WHITE mode (100 % input data-signal or video level) and in the BLACK mode (0 % input data signal or video level), leading to L_{white}, and L_{black}, respectively. Care shall be taken that the reading of the luminance meter due to stray light is less than 1 % of the luminance reading [2]. The plain-field contrast ratio CR_{PF} is defined as

$$CR_{\text{PF}} = \frac{L_{\text{white}}}{L_{\text{black}}} \tag{8}$$

5.5.3.2 Window contrast ratio (high resolution display)

The module is driven by a test pattern that generates WHITE (100 % input data signal or video level) on all 25 rectangles except for rectangle p0 which is driven BLACK (0 % input data signal or video level). This leads to a (black) window of 4 % of the display area. (Alternatively, it is allowed to shrink the window homogeneously to an area of 2,77 %, i.e. a window of 1/6 x 1/6 of the total display area).

Furthermore, the background can be made BLACK and rectangle p0 driven WHITE. These situations lead to the "dark image contrast ratio on a light field", CR_{dol}, and the "light image contrast ratio on a dark field", CR_{lod}, respectively. Luminance of rectangles p3 and p7 are measured. Indicating the luminance within rectangle *i* by L_i, we define

$$CR_{\text{dol}} = \frac{L_3 + L_7}{2\,L_0} \tag{9}$$

and

$$CR_{\text{lod}} = \frac{2\,L_0}{L_3 + L_7} \tag{10}$$

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2 The contrast ratio can only be determined reliably if stray light does not constitute a significant part of the measured signal. The allowable (absolute) deviation is larger for higher luminance values.

Note that cross-talk may adversely affect the values of CR_{lod} and CR_{dol}, which is not the case in the determination of CR_{PF}. In addition, extra straylight can be generated by the DUT during the determination of the window contrast ratio. This should therefore be evaluated and controlled carefully. (See also VESA Flat Panel Display Measurement Standard, pp 72-79 304: Box pattern measurements.)

5.5.3.3 Low resolution displays

The module is driven by a plain field test pattern signal from a signal generator (i.e. all 25 rectangles have the same grey scale) or a waveform generator (passive display). The luminance is measured at position p0 on the DUT (centre of the display area, see Figure 3) in the WHITE mode (100 % video level, or on-waveform) and in the BLACK mode (0 % video level or off-waveform), leading to L_{white} and L_{black} respectively. Care shall be taken that the reading of the luminance meter due to stray-light is less than 1 % of L_{black}. The plain-field contrast ratio CR_{PF} is defined in Equation (8).

5.5.3.4 Segment displays

The same requirements as for low resolution displays are applicable.

5.5.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

driving signals (waveforms, voltage and frequency).

5.6 Peak viewing direction – Viewing angle range

5.6.1 Purpose and definition

Determination of the angles (θ,φ) at which maximum contrast is obtained (the peak viewing direction) and the viewing angle range (range of angles in both horizontal and vertical direction) at which the device shows contrast ratio larger than a limiting value CR_{va} (CR_{va} = 2, 3, 4, 5, or 10). The design viewing direction is the preferred viewing direction as specified by the manufacturer (also often called “preferred” viewing direction. See blank detail specification).

5.6.2 Measuring equipment

The measuring instruments shall consist of a luminance meter, a driving power supply, signal generator and goniometer stages (both horizontal and vertical) for either display or detector.

5.6.3 Measuring method

The measurements are performed under darkroom and standard measuring conditions. Position the display with the top in the "upward" direction and the correct side towards the detector. The viewing direction of the display is given in a polar (θ,φ) coordinate system according to Figure 2. Contrasts are measured at position p0 (see Figure 3).

The peak viewing direction $(\theta,\varphi)_{\mathrm{peak}}$ is defined by the direction for which maximum contrast ratio CR_{l} (θ,φ) is found (4.5).

The horizontal viewing direction range (or viewing angle range) is defined by

$$\theta_{\mathrm{H}} = \theta_3 + \theta_9 \tag{11}$$

and the vertical viewing direction range (or viewing angle range) by

$$\theta_V = \theta_{12} + \theta_6 \tag{12}$$

where θ_3, θ_6, θ_9 and θ_{12} are the θ-angles in the 3, 6, 9 and 12 o'clock directions respectively where the limiting value of the contrast ratio CR_{va} is found. (CR_{va} = 2, 3, 4, 5 or 10 : 1 or other; to be added to the specification).

5.6.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall further include the following information:

– driving signals (waveforms, voltage and frequency);

– contrast ratio condition CR_{va}.

5.7 Viewing angle range without grey-scale inversion

Grey-scale inversion is when the electrical input to the DUT should produce a brighter (darker) symbol/sign on the display for a specific viewing direction, but instead the optical response becomes darker (brighter).

5.7.1 Purpose

The purpose of this test is to determine the viewing angle range without grey-scale inversion.

5.7.2 Measuring equipment

The measuring instruments are the same as those needed for "viewing angle range".

5.7.3 Measuring method

During the measurement, the DUT shall be electrically driven to display a sufficient number of grey levels between the dark state and the bright state (i.e. completely dark and completely bright state of the entire active area of the display). The minimum number of grey levels for which the luminance is measured as a function of the viewing direction should be 8. Measurements shall be carried out at position p0 (see Figure 3) under darkroom and standard measuring conditions.

For each electrical input combination corresponding to one grey level, the luminance is measured versus the angle of inclination θ in the 12:00, 3:00, 6:00 and 9:00 direction. This measurement is evaluated to yield the inclination angles for which an inversion between any pair of grey levels is detected. It shall be specified between which grey levels the inversion occurs (see Figure 8).

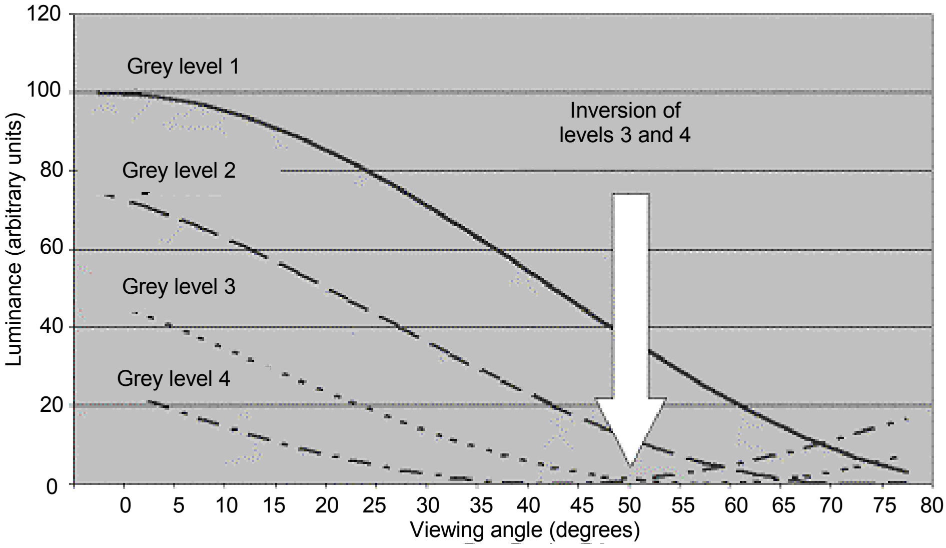


Figure 8 – Example of gray-scale inversion

The horizontal and vertical range of viewing directions without grey scale inversion is given as

$$\Theta_{GSI,H} = \theta_{3,n} + \theta_{9,n} \tag{13}$$

and

$$\Theta_{GSI,V} = \theta_{6,n} + \theta_{12,n} \tag{14}$$

5.7.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

– driving signals (field frequency, duty ratio, gray-scale signal levels, etc.);
– grey levels exhibiting inversion.

5.8 Specular reflectance from the active area surface

5.8.1 Purpose

Reflections of ambient light sources from the display surface are very disturbing for the human visual system (discomfort glare, disability glare) and they have to be avoided or at least reduced in order to avoid adversely affecting the visual performance of LCDs. In this standard, only specular reflections are considered because LCDs usually do not exhibit Lambertian diffuse reflection components. The amount of scattering from a matte surface can be characterized by two suitable specular reflectance measurements with different light source apertures.

This method is applied to the measurements of the specular surface reflectance from the active area of the display device due to the input light from the outside of the device.

5.8.2 Measuring equipment

The measuring instruments shall consist of a light source with adjustable aperture (1° and 15°), a luminance meter and a positioning mechanism.

5.8.3 Measuring method

The measurements are performed in a darkroom under standard measuring conditions at the centre of the display active area. The light source, DUT and luminance meter are positioned so that source and meter are coplanar and inclined about 15° with respect to the DUT surface normal as shown in Figure 9. The aperture angles of the light source(s) are measured from the centre of the measuring spot located on the DUT. No other light source shall be involved in the measurement (e.g. the DUT shall not be illuminated by a backlight unit; however, the specular reflectance may be evaluated in the OFF-state, the "dark" or the "bright" state of the DUT). The luminance meter shall be focused on the exit port (i.e. aperture) of the light source. If focusing is not possible due to a scattering surface of the DUT (i.e. anti-glare layer), use a microscope cover glass or a clear plastic adhesive tape to carry out the mechanical adjustment to the specular position and the focusing. In order to obtain an indication for the non-specular components in the reflectance, the reflectance of the DUT is measured under two different illumination conditions.

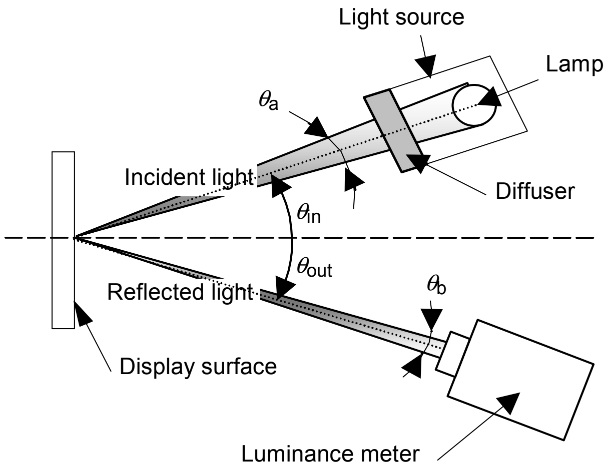


Figure 9 – Example of standard set-up for specular reflection measurements

The power and driving signal are not supplied to the device. The angle of observation by the luminance meter to the display surface should be

$$\theta_{out} = \theta_{in} \qquad (15)$$

The total aperture angle of the illuminating light should be θ_a = 1° for measurement of R_1 and θ_a = 15° for measurement of R_{15}. The total aperture angle of the luminance meter should be 0,1°< θ_b < 0,5° and be kept fixed and equal during both measurements. The distance between the surface of the DUT and the light source is l_1 (l_1 = 50 cm is a commonly used value); the distance between the surface of the DUT and the luminance meter is l_2 (also often 50 cm).

Measure the luminance from the source L_R [*i*] after reflection from the DUT at the centre position (*i =0*). The detector shall be focused at the lamp (rather than the display surface). Calibrate the light source by positioning the luminance meter directly in front of the light source at a distance of $l_1 + l_2$ and thus measure L_0.

The specular reflection factor from the centre position R [*i=0*] is given by

$$R_1[0] = \frac{L_R[0]}{L_0} \qquad (\theta_a = 1^\circ) \tag{16}$$

and

$$R_{15}[0] = \frac{L_R[0]}{L_0} \qquad (\theta_a = 15^\circ) \tag{17}$$

With increasing scattering the difference between R_1 and R_{15} increases. The perfect flat non-scattering surface does not exhibit any differences between R_1 and R_{15}.

5.8.4 Specified conditions

The light source(s) has to provide a uniform luminance across the exit aperture. The deviation of luminance shall be less than 1 %.

The light source luminance shall be stable over time. Long-term or short-term luminance fluctuations shall not exceed 1%.

In order to assure a high signal-to-noise ratio for the luminance meter, the luminance of the light source shall be sufficiently high (e.g. 5 kcd/m^2 and more).

The spectral distribution of the light source shall be specified. It is recommended to use light sources with a correlated colour temperature as close to illuminant C as possible.

The field-of-view of the luminance meter shall not exceed 0,5° in the case of the 1° source aperture and 1° in the case of the 15° source aperture. The field-of-view (i.e. measuring spot) shall be centered inside the exit aperture of the source.

The measurement is made under darkroom and standard measurement conditions and the diffusive component of the light source at the surface area of the DUT should be negligibly small.

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

– angles for the incident light (θ_{in}) and the reflected light for the luminance meter (θ_{out});
– aperture angles of the light source (θ_a) and the luminance meter;
– type of light source (spectrum and luminance);
– driving-state of the display device.

5.9 White chromaticity and its uniformity (matrix displays only)

5.9.1 Purpose

This method is applied to the measurements of white chromaticity and its uniformity for the liquid crystal display devices with a built-in backlight system. This measurement is useful for matrix displays only.

5.9.2 Measuring equipment

The measuring instruments shall consist of a colorimeter, spectroradiometer, driving power supply and a driving signal generator for liquid crystal display devices.

5.9.3 Measuring method

The measurements are performed in a darkroom under standard measuring conditions and design viewing direction. First, the plain field contrast ratio CR_{PF} is adjusted to its maximum value (see 5.5.3.1). Next, supply the input data signal leading to the full bright state of the DUT (100 % input data signal or full white) signals to the device. Then, measure the chromaticity at the specified positions in the active area. The colorimeter shall be capable of measuring the chromaticity satisfactorily for the small area in the total active area. The measurement is carried out on either one (position p0), five (positions p0, p11, p15, p19 and p23) or nine (positions p0, p9, p11, p13, p15, p17, p19, p21 and p23) points. The chromaticity corresponding to the measurement position *i* is defined by the colour coordinates x_i and y_i. Deviations from the chromaticity at position *i* from the chromaticity at the display centre are defined as

$$\Delta x_i = x_i - x_0,\ \Delta y_i = y_i - y_0 \text{ and } \Delta x\,y_i = \sqrt{((x_0 - x_i)^2 + (y_0 - y_i)^2)}.$$

For each measured position, the values of *i*, x_i, y_i and Δxy_i are tabulated.

5.9.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

– driving signals (waveforms, voltage and frequency);

– measuring points.

5.10 Reproduction of colour (matrix displays only)

5.10.1 Purpose

This method is applied to the measurements of colour gamut for the liquid crystal display devices with built-in backlight system. The measurement is useful for matrix displays only.

5.10.2 Measuring instruments

The measuring instruments shall consist of a colorimeter, spectroradiometer, driving power supply and a driving-signal generator for liquid crystal display devices.

5.10.3 Measuring method

The measurements are performed in a darkroom under standard measuring conditions and design viewing direction. Measurements are carried out at at position p0 (centre of the display). Supply the maximum value of the colour input signals of the primaries R (red), G (green) and B (blue) simultaneously to the device. Next, achieve the maximum contrast ratio at this value of the input primaries. Finally, separately supply the maximum R data input signal to the device, with data input of the complimentary primaries set to minimum or zero, and measure the red colour point (x_R, y_R). In the same way, measure the green and blue colour points (x_G, y_G) and (x_B, y_B), respectively. The colour gamut is represented by the triangle in the x-y chromaticity diagram formed by the above-measured colour points (x_R, y_R), (x_G, y_G) and (x_B, y_B) as corner points.

NOTE The colour gamut of *u'* and *v'* in the *u'*-*v'* diagram is calculated from the measured *x*-*y* gamuts by using the following formula:

$$u' = \frac{4x}{3 - 2x + 12y} \qquad (18)$$

and

$$v' = \frac{9y}{3 - 2x + 12y} \qquad (19)$$

5.10.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

driving signals (waveforms, voltage and frequency).

5.11 Display resolution (high resolution matrix displays only)

5.11.1 Purpose

This method is applied to the measurements of the pixel resolution in the display device. This parameter is useful for matrix displays only.

5.11.2 Measuring equipment

The measuring instruments shall consist of a driving power supply, a driving signal generator and a test pattern generator for liquid crystal display devices.

5.11.3 Measuring method

5.11.3.1 Display device using analogue TV signal receiver and/or multimedia function for the TV signal

The measurements are performed in a darkroom under standard measuring conditions and perpendicular viewing angle (θ = 0°). The signal corresponding to the standard TV test pattern (e.g. SMPTE pattern) is supplied to the device such that the maximum contrast ratio is achieved in the full white (transmitting) conditions. In this condition, count the number of stripes within the resolution target wedge that can be separately distinguished from each other at the centre of the test pattern. The measured data are represented as the horizontal and vertical resolution (TV line number).

5.11.3.2 Display device not using analogue TV signal receiving capability

The resolution is represented as the pixel number horizontally and vertically in the active area.

5.11.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

driving signals (waveform, voltage and field frequency, duty ratio, interlace or non-interlace, burst signal, etc.).

5.12 Cross-talk

5.12.1 Purpose

This method is applied to the measurements of the pattern-dependent cross-talk level in the display device.

5.12.2 Measuring equipment

The measuring instruments shall consist of a driving power supply, a driving signal generator and a luminance meter for liquid crystal display devices.

5.12.3 Measuring method

5.12.3.1 Grey scale matrix displays

Measurements are performed in a darkroom under standard measuring conditions.

First, the DUT is driven with a video level (GREY), which gives a luminance value as close as possible to 50 %. The luminance is then measured at locations p9, p13, p17 and p21 under normal viewing direction (= 0°). Define the measured luminance at location pi as $L_{ref}[i]$. Next, the video information within a rectangle defined by the centres of position p2, p4, p6 and p8 (i.e. width and height both 40 % of the display width and height) is changed to full black and the luminance at locations p9, p13, p17 and p21 is re-measured and denoted by L_{bl} [i]. Finally, the video information within the above-defined rectangle is changed to full white and the luminance at the aforementioned positions is re-measured and denoted by L_{wh} [i].

The horizontal white cross-talk HXT_{wh} is defined as

$$HXT_{wh}(\%) = 100 \times \max\left(\left|\frac{L_{wh}[21] - L_{ref}[21]}{L_{ref}[21]}\right| \vee \left|\frac{L_{wh}[13] - L_{ref}[13]}{L_{ref}[13]}\right|\right) \quad [\%] \qquad (20)$$

and the horizontal black cross-talk HXT_{bl} as

$$HXT_{bl}(\%) = 100 \times \max\left(\left|\frac{L_{bl}[21] - L_{ref}[21]}{L_{ref}[21]}\right| \vee \left|\frac{L_{bl}[13] - L_{ref}[13]}{L_{ref}[13]}\right|\right) \quad [\%] \qquad (21)$$

The (total) horizontal cross-talk HXT is now defined as

$$HXT = \max\left(HXT_{wh} \vee HXT_{bl}\right) \qquad (22)$$

In the same manner, the vertical white cross-talk VXT_{wh} is defined as

$$VXT_{wh}(\%) = 100 \times \max\left(\left|\frac{L_{wh}[9] - L_{ref}[9]}{L_{ref}[9]}\right| \vee \left|\frac{L_{wh}[17] - L_{ref}[17]}{L_{ref}[17]}\right|\right) \quad [\%] \qquad (23)$$

The vertical black cross-talk VXT_{bl} is defined as

$$VXT_{\mathrm{bl}}(\%) = 100 \times \max\left(\left| \frac{L_{\mathrm{bl}}[9] - L_{\mathrm{ref}}[9]}{L_{\mathrm{ref}}[9]} \right| \vee \left| \frac{L_{\mathrm{bl}}[17] - L_{\mathrm{ref}}[17]}{L_{\mathrm{ref}}[17]} \right| \right) \quad [\%] \tag{24}$$

and the (total) vertical cross-talk VXT is defined as

$$VXT = \max\left(VXT_{\mathrm{bl}} \vee VXT_{\mathrm{wh}}\right) \tag{25}$$

5.12.3.2 Black and white (two-level) matrix displays

Measurements are performed in a darkroom under standard measuring conditions.

First, the DUT is driven with the ON signal. The luminance is then measured at locations p9, p13, p17 and p21 under normal viewing direction (= 0°). Define the measured luminance at location p*i* as $L_{\mathrm{ONref}}[i]$. Next, the drive level within a rectangle defined by the centres of position p2, p4, p6 and p8 (i.e. width and height both 40 % of the display width and height) is changed to the OFF signal and the luminance at locations p9, p13, p17 and p21 is re-measured and denoted by $L_{\mathrm{OFF}}[i]$.

The OFF-of-ON cross-talk $XT_{\mathrm{OFF/ON}}$ is defined as

$$XT_{\mathrm{OFF/ON}}(\%) = 100 \times \max\left(\left| \frac{L_{\mathrm{OFF}}[i] - L_{\mathrm{ONref}}[i]}{L_{\mathrm{ONref}}[i]} \right| \quad : i = 9, 13, 17, 21 \right) \ [\%] \tag{26}$$

Next, the DUT is driven with the OFF signal. The luminance is then measured at locations p9, p13, p17 and p21 under normal viewing direction (= 0°). Define the measured luminance at location p*i* as $L_{\mathrm{OFFref}}[i]$. Next, the drive signal within a rectangle defined by the centres of position p2, p4, p6 and p8 (i.e. width and height both 40 % of the display width and height) is changed to ON signal and the luminance at locations p9, p13, p17 and p21 is re-measured and denoted by $L_{\mathrm{ON}}[i]$.

The ON-of-OFF cross-talk $XT_{\mathrm{ON/OFF}}$ is defined as

$$XT_{\mathrm{ON/OFF}}(\%) = 100 \times \max\left(\left| \frac{L_{\mathrm{ON}}[i] - L_{\mathrm{OFFref}}[i]}{L_{\mathrm{OFFref}}[i]} \right| \quad : i = 9, 13, 17, 21 \right) \ [\%] \tag{27}$$

NOTE

The result of this measurement may be considerably affected by the luminance resolution of the luminance meter. In order to increase the resolution of the measurement, the following choices are available among others:

1 change the viewing-direction in order to make the crosstalk more visible, or

2 change to operating (battery) voltage in order to make the crosstalk more visible.

Both modifications must be explicitly specified in the results.

5.12.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

driving signals.

5.13 Power consumption

5.13.1 Purpose

This method is applied to the measurements of power consumption and current for the liquid crystal display devices, which are composed of a display module, driving circuit for the module, logic circuit, and/or circuit for the accompanying backlight system.

5.13.2 Measuring equipment

The power consumption and current is measured by using a driving power supply, DC voltage meter, DC current meter and a pattern generator.

5.13.3 Measuring method

5.13.3.1 Matrix displays

5.13.3.1.1 Standard power consumption measuring method

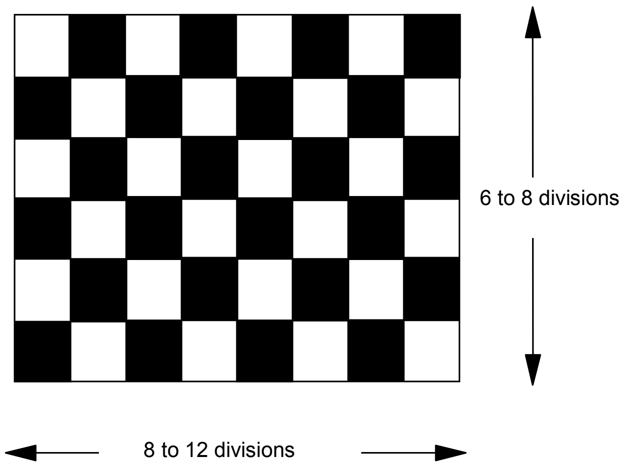


Figure 10 – Checker-flag pattern for current and power consumption measurements

The measurements are performed under standard measuring conditions. Supply the checker-flag pattern signal to the liquid crystal display device by using driving signals and special pattern generator such that the light and dark area is equally displayed as shown in Figure 10. The maximum contrast ratio is achieved in the pattern by optimizing display signals. If the module has a built-in backlight system, the standard power consumption in the backlight system is determined by measuring the power consumption in the recommended inverter circuit where the luminance is adjusted to the design maximum luminance. The voltage supplied to the circuits in the display device is set to the nominal values specified in the detail specification.

Measure the currents I_1, I_2 and I_3 flowing in the following circuits shown in Figure 11. The power consumption in each of the circuits is calculated by the following formulas:

– power consumption in the logic circuit: $P_1 = E_1 \times I_1$

– power consumption in the liquid crystal display driving circuit: $P_2 = E_2 \times I_2$
– power consumption in the backlight system circuit: $P_3 = E_3 \times I_3$
– total power consumption in the display device: $P_0 = P_1 + P_2 + P_3$

NOTE 1 When the liquid crystal display device has grey scale display capability, the measurements are carried out using the grey scales corresponding to the maximum and minimum luminance.

NOTE 2 When the standard checker flag pattern shown in Figure 10 is not used for the measurement, specify the used display pattern such as colour bar, grey scale pattern, checker pattern, etc. in the detail specification.

NOTE 3 If the circuit is not separated between logic and liquid crystal driving circuitry, measure the total voltage and current for the calculation of total current and power consumption in the liquid crystal display device.

NOTE 4 When the liquid crystal display device has no recommended inverter circuit for the backlight system, specify the current and voltage for the light bulb in the detail specification.

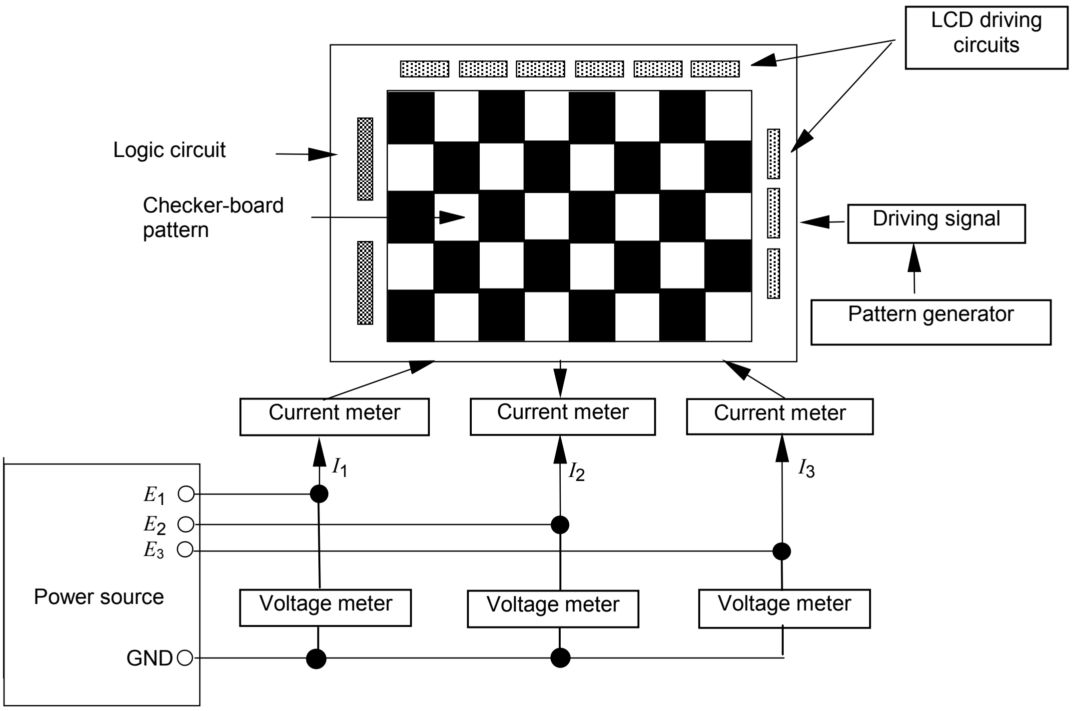


Figure 11 – Example of measuring block diagram for current and power consumption of a liquid crystal display device

5.13.3.1.2 Maximum power consumption measuring method

Adjust the conditions for liquid crystal driving, backlight operation and driving voltage given in 5.13.3.1.1 to the values specified in the detail specification for the maximum power consumption. Under these conditions, the measured individual and total power consumption is defined as the corresponding maximum power consumption.

5.13.3.2 Segment displays

5.13.3.2.1 Standard power consumption measuring method

The measurements are performed under standard measuring conditions. All display segments shall be selected and activated in a pre-defined manner, e.g. all on, all off, alternating on/off patterns, etc.

The voltages supplied to the circuits in the display device are set to the nominal values specified in the detail specification.

If the module has a built-in backlight system, the power consumption of the backlight system is determined with the luminance set to the maximum specified value.

Measure the currents of the LCD supply voltage (V_{LCD}) I_{LCD}, of the logic supply (V_{DD}) I_{DD} and of the backlight unit (V_{BL}) I_{BL} and calculate the corresponding power consumption.

5.13.3.2.2 Maximum power consumption measuring method

Adjust all driving conditions (displayed pattern, backlight, etc.) in order to obtain the maximum power consumption. Under these conditions, the measured individual and total power consumption is defined as the corresponding maximum power consumption.

5.13.4 Specified conditions

Records of the measurement shall be made in order to describe deviations from the standard measurement conditions and shall include the following information:

– design luminance;
– liquid crystal display driving signal frequency(displayed pattern signal condition);
– backlight system when the device has only a light source, specify its driving condition;
– conditions for maximum power consumption;
– standard operation voltage(s);
– logical states of the data inputs to the segments (segment displays only).

Annex A
(informative)

Standard measuring conditions

A.1 Equipment

Luminance meter: devices for measuring luminance can be realized by

– a spectro-radiometer with numerical V(λ) correction,
– a photometer with filter adaption to V(λ).

Colorimeter: Devices for measuring colour can be realized by

– spectro-radiometer with numerical evaluation,
– filter-colorimeter.

A.2 Standard lighting conditions

Display devices are mostly used in environmental lighting conditions such as office work and home utility for personal computers, word processors, audio-visual instruments, telephones, etc. Lighting conditions are considered in ISO 9241-7 and diffuse lighting conditions in a darkroom situation. In this standard, guidelines for visual display terminals are taken from NIOSH (National Institute of Safety and Health in the USA) and the Labour Ministry in Japan, and the luminance of the surface of the active area in the vertical direction is specified.

A.3 Device without built-in backlight system

The type-C light source is different in colour temperature and spectrum from normally used (incandescent or fluorescent) light source characteristics for liquid crystal display devices. At present, a more appropriate standardized light source cannot be found so the type-C light is specified in this standard.

A.4 Reference documents

ISO 9241-7:1998, *Ergonomic requirements for office work with visual display terminals (VDTs) – Part 7: Requirements for display with reflections*

Annex B
(informative)

Measuring methods for liquid crystal display devices (segment type)

B.1 General

This annex establishes measuring methods for segment type liquid crystal display devices in transmissive, reflective and transflective modes of operations.

B.2 Contrast ratios

There are two contrast ratios defined:

- diffused light contrast ratio – CR_{diff};
- direct beam contrast ratio – CR_{dir}.

a) Purpose

The purpose of this measuring method is to measure the contrast ratio of liquid crystal display devices (LCD) as a function of the viewing direction in specified optical modes of operation (transmissive, reflective, transflective) and under specified conditions.

The viewing direction at any location on the display is defined by an angle of inclination θ and by an azimuth ϕ (see Figure B.1).

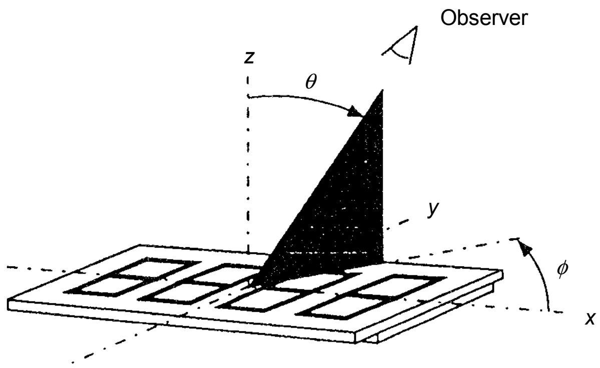


Figure B.1 – Definition of the viewing direction by the inclination θ and the azimuth ϕ

b) Diffused light contrast ratio measuring equipment and description of the procedure

This contrast ratio relates to the performance of the display under diffused illumination.

The measuring equipment shall comprise illumination, temperature control for the device under test (DUT), positioning mechanics, luminance meter and a recording unit.

In the reflective and transflective mode of operation, the measuring spot on the DUT shall be illuminated diffusely. This can be done, for example, by using an Ulbricht (half) sphere. For transmissive and transflective modes, a backlight diffusing plate shall be used if required.

The luminance meter shall be capable of being positioned relative to the LCD within a range of 0° ≤ θ ≤ 60° and 0° ≤ ϕ ≤ 360° at constant distance to the measuring spot.

An example of typical measuring equipment is shown in Figure B.2.

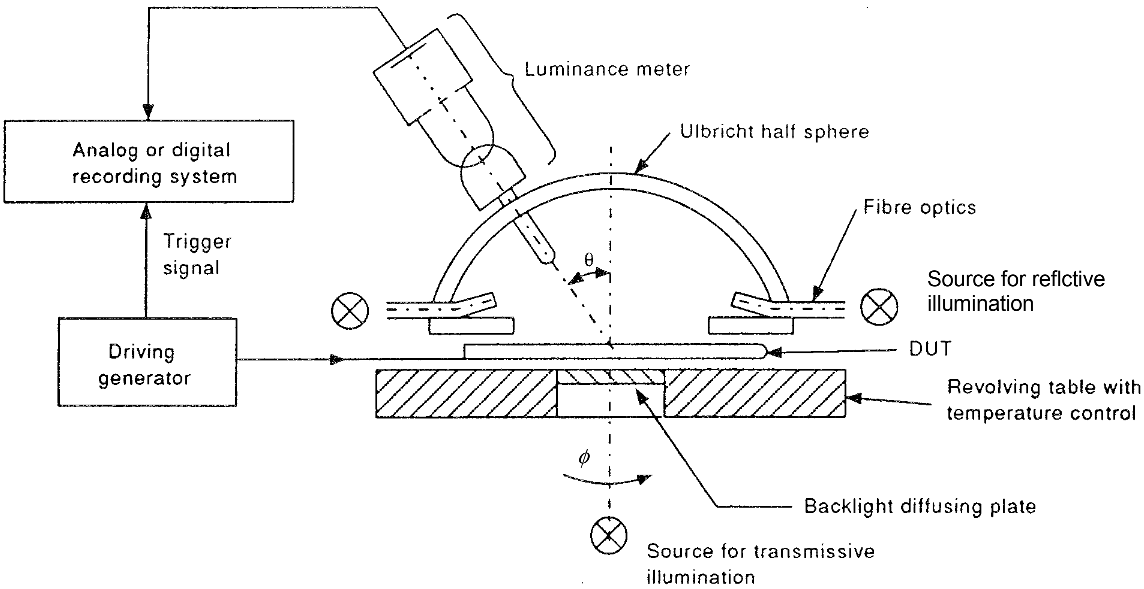


Figure B.2 – Example of system for measuring diffused light contrast ratio

The viewing direction of the luminance meter and the orientation of the illumination shall be specified.

c) Direct beam contrast ratio measuring equipment and description of the procedure

This contrast ratio relates to performance of the display under direct beam illumination.

The measuring equipment shall comprise illumination, temperature control for the DUT, positioning mechanics, luminance meter and a recording unit.

The spot on the DUT shall be illuminated by a collimated light-beam with specified spot size, collimation and uniformity both in reflective and transflective mode of operation. In the transflective and transmissive mode, a backlight diffusing plate shall be used if required.

The viewing direction of the luminance meter and the orientation of the illumination shall be specified.

An example of typical measuring equipment is shown in Figure B.3.

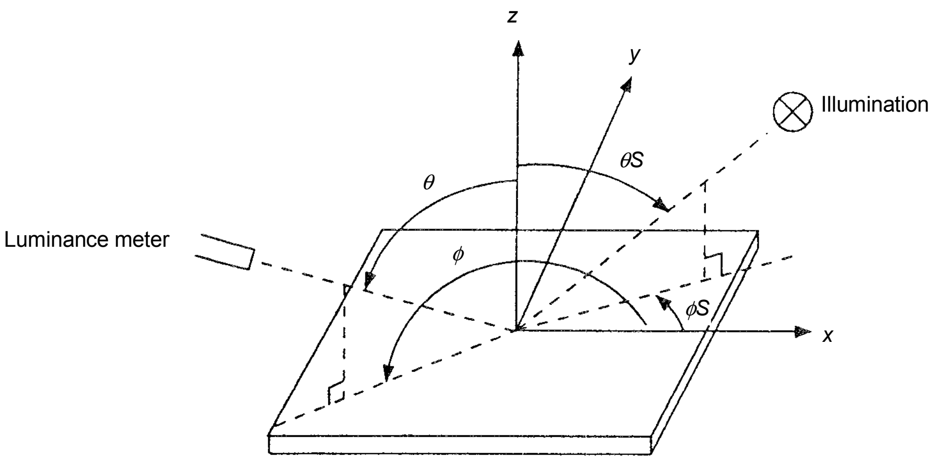


Figure B.3 – Schematic of an apparatus for direct beam contrast ratio measurement

d) Calculation of the contrast ratios

$$CR_{\text{diff}} = \frac{L_{\text{H}}(\theta,\phi)}{L_{\text{L}}(\theta,\phi)}, \text{ and}$$

$$CR_{\text{dir}} = \frac{L_{\text{H}}(\theta,\phi,\theta_{\text{s}},\phi_{\text{s}})}{L_{\text{L}}(\theta,\phi,\theta_{\text{s}},\phi_{\text{s}})}$$

where

CR_{diff} is the diffused light contrast ratio;

CR_{dir} is the direct beam contrast ratio;

L_{H} is the higher luminance value;

L_{L} is the lower luminance value;

θ, ϕ is the luminance meter orientation;

θ_{S}, ϕ_{S} is the orientation of illumination.

NOTE In calculating contrast ratio, the luminance meter orientation should be the same. For direct beam illumination, the orientation of the illumination also should be the same.

e) Precautions

1) Parasitic light shall be minimized.
2) The illumination should not affect the specified temperature of the device under test.
3) The measuring spot should be positioned in the centre of the picture element to be measured. If it is not possible, refer to the following item f).
4) The spot size of the illumination on the LCD cell has to be larger than the measuring spot size of the detector system.
5) The parallax error caused by the front glass should be considered.
6) The spectral sensitivity of the luminance meter shall conform to the CIE 1931 standard observer (IEV definition 845-03-31).
7) Polarization effects of light source and luminance meter should be avoided.
8) The aperture of the luminance meter should be compatible with required accuracy of the measurement.
9) The device under test shall be aligned in accordance with its specified reference axes.

f) Specified conditions

1) Optical mode of operation (transmissive, reflective, transflective).
2) Viewing direction.
3) Complete set of applicable electrical driving conditions, such as
   - r.m.s. value of the driving voltage,
   - driving voltage frequency,
   - waveform of driving voltage,
   - multiplexing ratio (if applicable),
   - illumination voltage (if applicable),
   - auxiliary voltage(s) (if applicable),
4) Spectral distribution of the illumination.
5) The diffuse illumination shall be specified as the function of inclination.
6) The direct beam illumination source orientation, collimation and uniformity of the beam shall be specified.
7) The aperture of the luminance meter shall be specified.
8) In the case of measurement in the transflective mode, the ratio of the luminance of transmissive and reflective illumination shall be specified.
9) It shall be specified if regular (specular) surface reflections from the device under test are included in the measurement of the luminance.
10) Temperature of the device under test at the measuring spot.
11) Position, size and shape of the measuring spot and the picture element under test shall be specified. If the picture element is smaller than the measuring spot, the ratio of activated to non-activated areas in the measuring spot shall be specified.

B.3 Switching times

a) Purpose

The purpose of this test method is to measure the electro-optical responses times of LCDs under specified conditions.

b) Measuring equipment

The measuring equipment shall comprise illumination, temperature control for the device under test, positioning mechanics, luminance meter and a recording unit.

c) Procedure

Apply a first driving signal to the DUT and allow the luminance to settle to a steady state, L_1. Change to a second driving signal and record the luminance as a function of time, until the luminance has settled to a steady state, L_2.

By convention, the difference of the luminance of the two optical steady states is taken to be 100 %.

t_{10} is the time that is noted when luminance reaches L_1 – 0,1 ($L_1 - L_2$).

t_{90} is the time that is noted when luminance reaches L_1 – 0,9 ($L_1 - L_2$).

The switching time is defined as $t_{90} - t_0$.

An alternative measure of dynamic response is $t_{90} - t_{10}$.

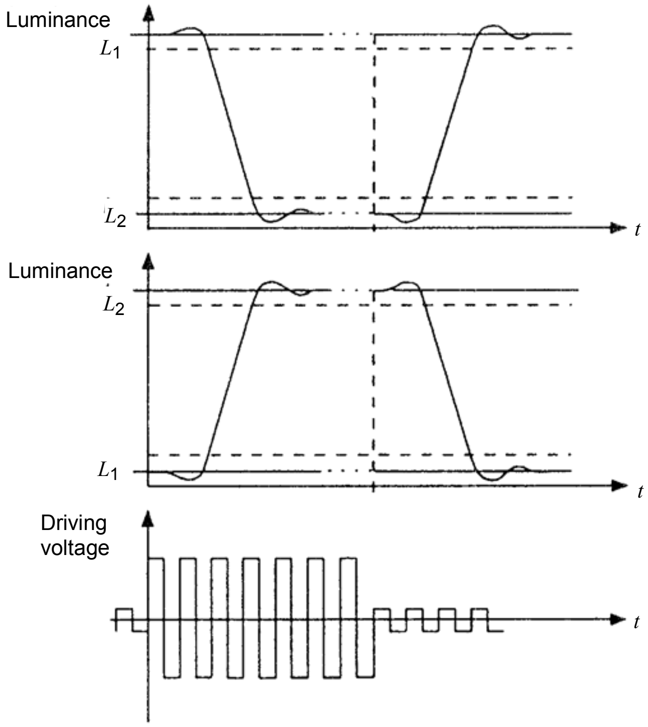


Figure B.4 – Typical examples of dynamic responses of two different LCDs

d) Precautions

Refer to item e) of Clause B.2 for the general precautions.

e) Specified conditions

Refer to item f) of Clause B.2 for the specified conditions.

Additional:

The illumination mode (diffused light or direct beam) shall be specified.

B.4 Current

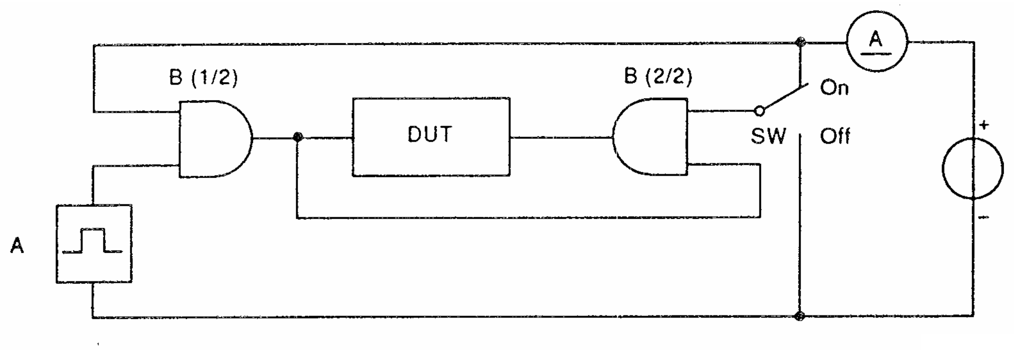
a) Purpose

The purpose of this test method is to measure the supply current(s) in an LCD device.

b) LCD cells

1) Measuring equipment

The measuring equipment shall comprise the LCD cell, an electronic driving circuit and a current meter (as shown in Figure B.5).



A = square wave generator

B (1/2), (2/2) = EXCLUSIVE OR gate

SW = switch

Figure B.5 – Schematic for the measurement of a current in an LCD cell

2) Procedure

The picture elements of interest shall be electrically connected so that the individual picture element currents are added. After application of the supply voltage the total current shall be measured with the switch SW open and closed. The supply current is then given by the difference between those two currents.

3) Precautions

The supply currents of the EXCLUSIVE OR gate should be on the order of the current to be measured.

4) Specified conditions:

i) Complete set of electrical conditions:

– amplitude of the driving voltage;

– frequency of the driving voltage.

ii) Temperature of DUT.

iii) Identification of picture elements measured.

c) LCD modules

1) Measuring equipment and description

The current in all supplies shall be measured with conventional equipment under the conditions given below in item ii).

2) Specified conditions:

i) Electrical driving conditions

ii) Logical states of the data inputs

iii) Supply voltage(s)

iv) Temperature of DUT.

B.5 Transmittance and reflectance

a) Purpose

To measure transmittance and reflectance of an LCD device under specified conditions.

b) Measuring equipment

Refer to items b) and c) of Clause B.2.

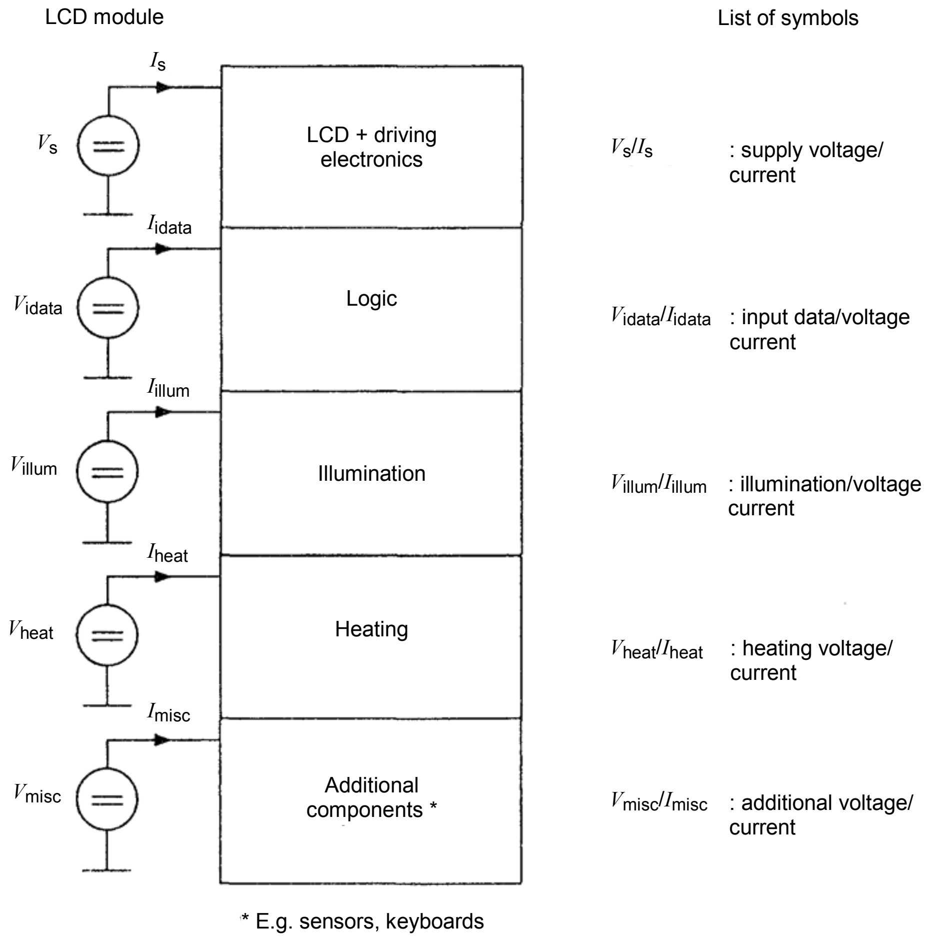


Figure B.6 – Block diagram for the measurement of the supply currents

c) Procedure

1) Transmittance

First the luminance L_s of the source for transmissive illumination shall be measured without the device under test and then, with all optical conditions kept constant, the luminance L_d of the picture element of the LCD device in a specified state of driving shall be measured. The transmittance, τ, is

$$\tau = L_d / L_s$$

2) Reflectance

First the luminance L_s of a calibrated reflectance standard with reflectance ρ_{STD} shall be measured and then, with all other conditions kept constant, the luminance L_d of the picture element of the LCD device in the specified state of driving shall be measured. The reflectance, ρ, is

$$\rho = L_d \times \rho_{STD} / L_s$$

d) Precautions

Refer to item e) of Clause B.2 for the general precautions.

e) Specified conditions

Refer to item f) of Clause B.2 for the general specified conditions.

Additional:

i) state of driving (i.e. selected or non-selected);

ii) the illumination mode (diffused light or direct beam);

iii) luminance meter viewing direction.

B.6 Threshold and saturation voltages

a) Purpose

To determine the threshold voltage V_{th} and the saturation voltage V_{sat} for an LCD cell under specified driving conditions. This characteristic is irrelevant for LCD modules.

b) Measuring equipment and description

For the optical system refer to items b) and c) of Clause B.2.

c) Procedure

For a specified viewing direction the luminance L of the device under test shall be recorded as a function of the voltage under specified driving conditions.

The voltage shall be increased from zero (0) to a specified maximum value V_{max}.

The luminance that corresponds to zero (0) V is L_1.

The luminance that corresponds to the maximum change of luminance as the voltage is increased from zero (0) to V_{max} is L_2.

The threshold voltage V_{th} is the voltage corresponding to the luminance L_1 - 0,1 (L_1 - L_2).

The saturation voltage V_{sat} is the voltage corresponding to the luminance L_1 - 0,9 (L_1 - L_2).

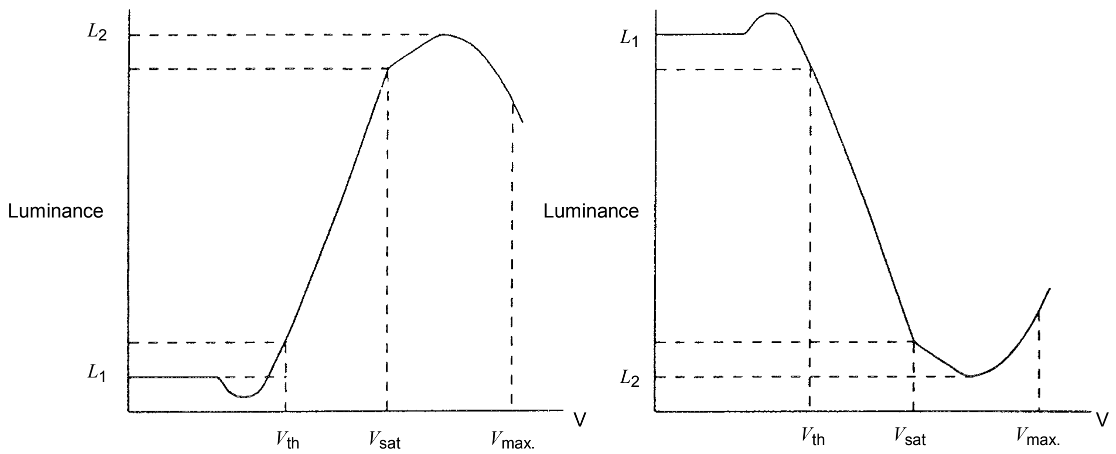


Figure B.7 – Typical examples of voltage responses of two different LCDs

d) Precautions

Refer to item e) of Clause B.2 for the general precautions.

Addition:

i) the voltage steps shall be smaller than 5 % of the difference between V_{th} and V_{sat};

ii) the maximum voltage V_{max} should be chosen high enough so that L_2 is reached;

iii) the voltage step duration should be long enough to ensure the optical steady state at the time of luminance recording;

iv) the maximum voltage V_{max} should not exceed the maximum voltage given in the detail specification.

e) Specified conditions

Refer to item f) of Clause B.2 for the general specified conditions.

Additional:

i) V_{max};

ii) voltage step size;

iii) step duration;

iv) delay time prior to luminance recording;

v) illuminating mode (diffused light or direct beam).

B.7 Reference document

IEC 60050(845):1987, *International Electrotechnical Vocabulary* (IEV) – *Part 845: Lighting*

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