

Barco LiveDots

# Viewing angle measurement on LED displays

**How to correctly measure  
viewing angles based on 50%  
brightness principle**

## Author

Bas van Heek  
Product Marketing Manager Barco  
[bas.vanheek@barco.com](mailto:bas.vanheek@barco.com)

## INTRODUCTION

In this white paper we discuss viewing angle measurement on LED displays. We will demystify how stated viewing angles in LED display specifications sometimes exceed the viewing angle specification of individual LED manufacturers, and how differences in specifications can be explained.

Our goal is to increase the understanding when reading and comparing specifications in today's over-saturated world of LED display systems. We want to provide knowledge that will help decision makers to make the right decisions and influencers to specify the right product.

We hope that after reading this white paper, you will better understand how viewing angles work and what the impact is on your application.

## STARTING ANGLE

An LED display uses an array of light-emitting diodes (LED) as a video display. By default, LED display technology is a light emitting technology. Independent of which type of LED is used (SMD<sup>1</sup> or TH RGB), light is radiated from each individual LED, whereas the intensity of light depends on where it is adopted relative to the screen. This differs between maximum (perpendicular to the LED) and zero if the angle exceeds 90° as per Fig. 1 below.

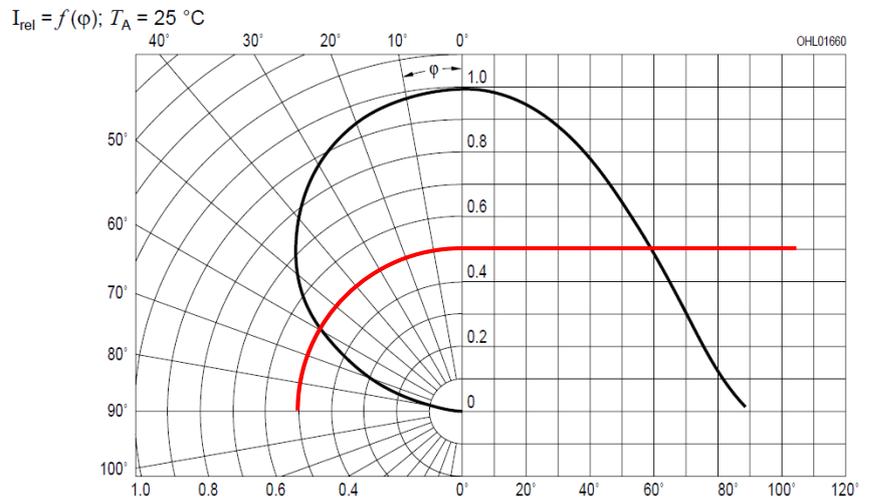


Fig. 1: Typical Radiation Characteristic of an SMD LED (by courtesy of Osram)

<sup>1</sup> SMD (Surface Mounted Device) and TH (Thru-Hole or discrete) LEDs are both type of LEDs used in display arrays. For TH each R-G-B dies are individually packed, whereas for SMD R-G-B dies are combined into one package. Both SMD and TH refer to the way the LEDs are fixed to the PCB.

In Fig. 1 the Intensity (I) is shown relative to the angle, whereas  $0^\circ$  is perpendicular to the light source or the LED. As per definition the viewing angle is defined as the angle where the measured light intensity is 50% of its maximum value, as per the red line in Fig. 1. For this LED, which is typical for other SMD LEDs as well, the viewing angle to 50% brightness is  $60^\circ$ .

Since SMD LEDs are of symmetrical lay-out, the viewing angle is  $60^\circ$  in all directions<sup>2</sup>, both horizontally and vertically. This means the actual viewing angle of the LED can be specified as  $120^\circ$  horizontally and  $120^\circ$  vertically.

So far, we have been talking LED intensity (or luminosity) of a single LED which is measured in candela (cd), while an LED display is an array of LEDs and brightness is measured in candela per square meter -  $\text{cd}/\text{m}^2$  or NIT. This is the value always mentioned in product specifications, measured perpendicular to the display surface and the LEDs.

## QUESTION

*Why do some product specifications mention  $140^\circ$  or even  $160^\circ$  viewing angle, while the physical LED characteristics does not exceed  $120^\circ$ ?*

This is all about measuring brightness relative to the display, and how the measuring is done.

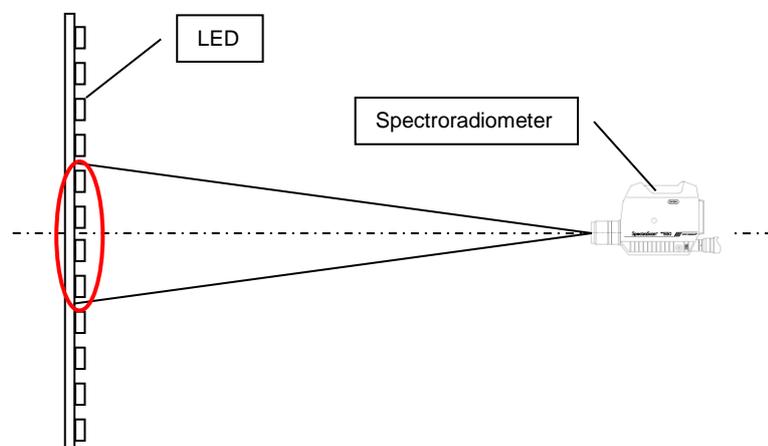


Fig. 2: Measuring LED display brightness by using spectroradiometer

In order to determine the viewing angle, we have to comply with the definition. The angle relative to the display for which the luminosity is 50% of maximum perpendicular to the display.

<sup>2</sup> For TH LEDs, this is similar with standard caps or package, but can be influenced by applying a lens. This does however have side effects.

Measuring brightness or luminosity is done by using a spectroradiometer. Spectroradiometers typically take measurements of spectral irradiance and spectral radiance, which spectral data can be used to calculate luminosity ( $\text{cd/m}^2$ ).

First the maximum brightness is measured in accordance with Fig. 2, perpendicular to the display surface. This represents 100% brightness.

Next the spectroradiometer is moved circular (or display is rotated) to allow for similar measuring relative to the display surface.

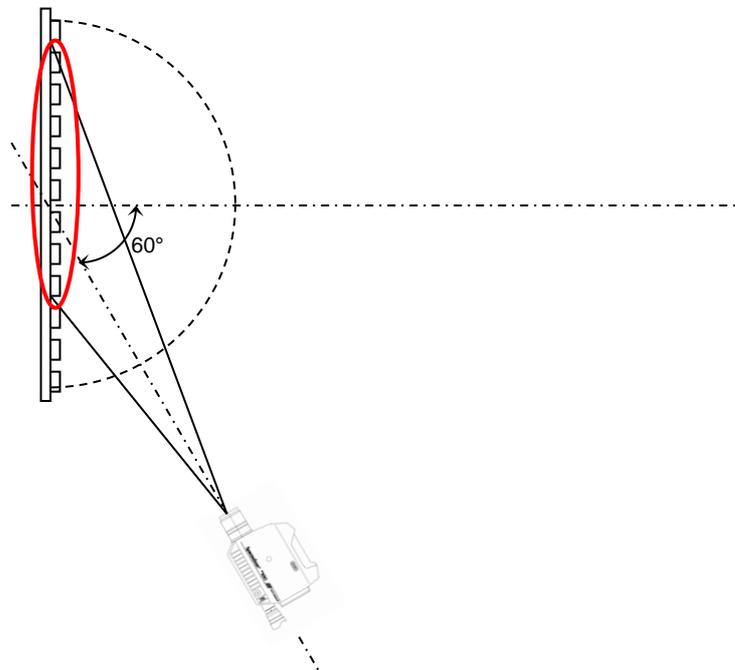


Fig. 3: Measuring display brightness under 60° angle

As per LED specification, it is expected that 50% brightness is measured at a relative angle of 60°, as per Fig. 3. Unfortunately, this is not the case. Look carefully, while in Fig. 2 only 4 LEDs are covered in the measurement, in Fig. 3 8 LEDs are covered in the measurement. This results in almost identical luminosity (8 LEDs at 50% brightness is identical to 4 LEDs at 100% brightness). The relative angle exceeds 60° and values of 70° or even 80° come within reach before the 50% brightness is reached. This is why sometimes 140° or 160° angles are specified for 50% brightness values.

This is however incorrect. Physically, you should not increase the number of LEDs (or surface) that take part in the measurement. The result should be corrected to determine the correct value relative to starting position, by  $\cos \theta$ , where  $\theta$  is the angle relative to perpendicular to the display surface. In other words, you have to rule out the side effect of the increasing display surface that is subjected to the measurement.

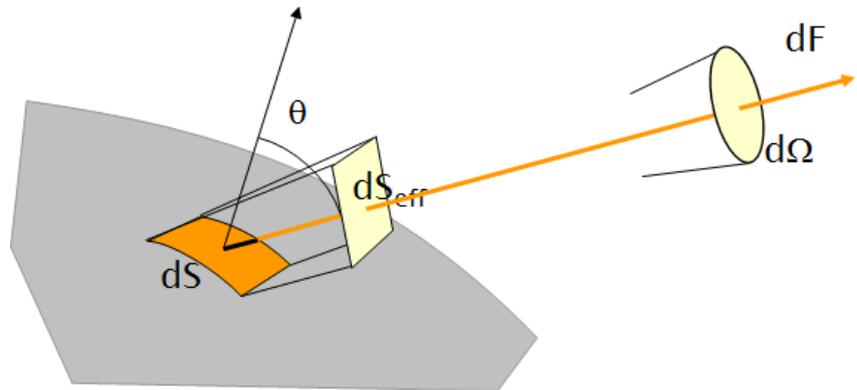


Fig. 4: Directional luminance of elementary light emitting surface (source: INTEC<sup>3</sup>)

$$L = \frac{dI}{dS_{eff}}$$

$$dS_{eff} = dS \cos \theta$$

Where:

$L$	brightness (Luminance) (cd/m <sup>2</sup> or Nit)
$dI$	Luminous intensity (cd)
$dS_{eff}$	Effective surface (m <sup>2</sup> )
$dS$	Surface (m <sup>2</sup> )
$\cos \theta$	Viewing angle (°)

Example:

For a display with maximum brightness of 2,000 Nits, the maximum brightness under 60° viewing angle is (measured on 1m<sup>2</sup> display surface):

$$L = \frac{2,000}{1 \cos 60} = 1,000 \text{ Nit}$$

The above means 50% brightness threshold on display level will never exceed individual LED specification of 60°.

<sup>3</sup> R. Baets, INTEC, Department of Information Technology, Ghent University, research group Photonics

Reflected on LED display example above:

Assume each LED emits 2cd. First measurement shows 8cd (100% of 4x2cd). Second measurement shows 8cd as well (50% of 8x2cd). The corrected brightness however should be 4cd (50% of 8x2cd x cos 60°). This corresponds with the theory above as well.

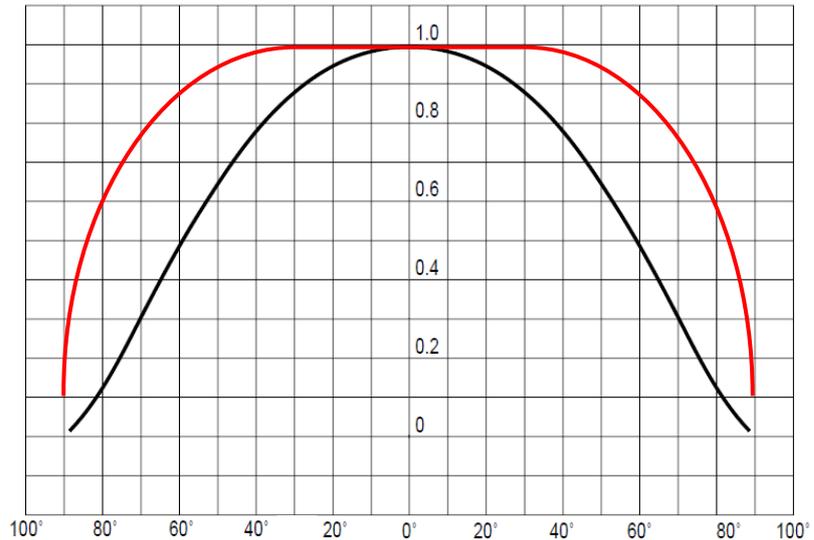


Fig. 5: Measured brightness and corrected brightness relative to angle (schematic)

Fig. 5 above shows both measured and corrected brightness under viewing angle using a spectroradiometer. In practice, between 0° and 60°, by using a spectroradiometer, brightness can even exceed the initial value if you do not apply the cos θ correction.

## OTHER ANGLE

Alternatively, to determine the 50% brightness angle, it is better to use a measurement process that rules out the side effect of the increasing display surface subjected to the measurement from the beginning.

This can be done by measuring luminance rather than luminosity. Luminance is measured in lux by using a lux meter. Although the absolute value measured has no real meaning, you can consider the value measured similar to Fig. 2 as 100%. If you then increase the angle by following again that circle until you reach 50% of the initial value, as per Fig. 3, you will find the correct angle at which brightness is degraded to 50%. This will correspond with 60° as per original LED specification. This alternative method completely rules out the surface component or cos θ in the spectroradiometer measurement.

## Impact of Louvers

All of the above is not taking into account any side effects of shaders, masks or other front surface parameters that effect viewing angle. For indoor LED displays, with no louvers influencing viewing angles, all of the above is 100% applicable.

For outdoor displays, some side notes have to be taken into account. Whilst above is true in general, vertical viewing angle is largely effected by the appearance of louvers, masks, and additional protection against water. Louvers are necessary to increase contrast, to block direct sunlight from reaching the LED, which reduces the light emitted by the LED, making the screen look completely washed out. The longer the louver, the better the contrast, but the earlier it will cut off light and the vertical viewing angle both up and downwards. Depending on the length of the louver this might affect vertical viewing angle. This will cause a sudden drop in brightness. Typically this is asymmetric, because normally louver design allows for greater downward viewing angle then upwards.

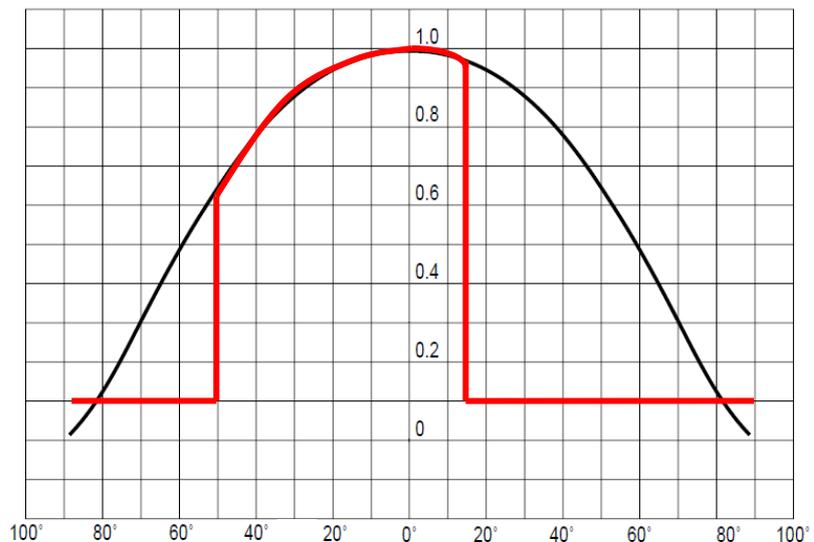


Fig. 6: Brightness relative to viewing angle (-50° / +15° louvers)

The effect of louvers, certainly for outdoor displays should be reflected in specification, even though this appears to be negative due to smaller viewing angle at first sight it is actually an advantage, when you consider the application. The 50% brightness in most cases have no real meaning at all, the gain in contrast however is of critical importance to most installs.

## COLOR SHIFT

Talking about relevance, what about color shift? We still need to meet the first advertiser or brand that prefers 50%

brightness above color shift under viewing angle, although tender documents will sometimes mention other ways, brightness might affect the punch of your advertising or brand displays under extreme viewing angles, but color shift will cause your brand color to discolor into something unrecognizable.

Discoloration happens when LEDs are (partly) blocked for various reasons. This can be louvers, shaders, masks or adjacent LEDs. Viewing angle limitations are usually wider for color shift than for 50% brightness but of greater importance for advertisers and brands.

## CONCLUSION

In conclusion, it can be stated that loss of brightness under viewing angle start with radiation characteristics of individual LEDs.

In most cases radiation characteristics of LEDs show 50% brightness level at about 60°.

Brightness of displays built from LED arrays can physically not exceed radiation characteristics of individual LEDs.

In a lot of cases manufacturers/distributors manipulate the measuring method to tweak 50% brightness viewing angles towards wider angles for commercial/marketing reasons, which is actually misleading.

Correct brightness measuring should be corrected by  $\cos \theta$  to rule out the effect of increasing surface or more LEDs that affects the measurement. Alternatively, a measuring method could be used that is not effected by an increase surface or amount of LEDs subjected to the measurement.

Barco LiveDots  
President Kennedypark 35  
B-8500 Kortrijk  
Belgium  
+32 5636 8869  
sales.livedots@barco.com