

## SEMI D71-0823

# TEST METHOD OF TONE AND COLOR REPRODUCTION FOR FLAT PANEL DISPLAYS

This Standard was technically approved by the Flat Panel Display – Metrology Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on February 1, 2023. Available at [www.semiviews.org](http://www.semiviews.org) and [www.semi.org](http://www.semi.org) in August 2023; originally published June 2014.

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### 1 Purpose

- 1.1 This Test Method describes the measurement methods of principal characteristics of flat panel display module or flat panel TV, which is related to TV standard reproduction characteristics of fidelity to original video.
- 1.2 This Standard is used to define methodologies used for measurement of flat panel displays’ native features based on average picture level (APL).

### 2 Scope

- 2.1 This Standard is applicable to display quality evaluations standard of flat panel display modules or flat panel TVs.
- 2.2 This Standard includes practical methodologies of tone and color reproduction measurements. It does not address optical performance like contrast or brightness.
- 2.3 Tone and color of display device are basic features of a general display device. For standardization of flat panel displays, high accuracy and fidelity to these standard features are necessary.
- 2.4 This Standard is only for general purpose for display methodology. Hence special languages for special features or phenomena are not included.

**NOTICE:** SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

### 3 Referenced Standards and Documents

#### 3.1 ISO® Standards<sup>1</sup>

ISO 11664:5:2009 (CIE S 014-5/E:2009) — Colorimetry – Part 5: CIE 1976 L\*u\*v\* Colour Space and u', v' Uniform Chromaticity Scale Diagram

#### 3.2 ITU® Standards<sup>2</sup>

Recommendation ITU-R BT.709-6 — Parameter Values for the HDTV Standards for Production and International Programme Exchange

#### 3.3 SID Standards<sup>3</sup>

IDMS v1.1 — Information Display Measurements Standard

<sup>1</sup> International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401-1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, Fax: +41.22.733.34.30, <http://www.iso.org>. ISO trademark is owned by International Organization for Standardization.

<sup>2</sup> International Telecommunication Union, Place des Nations 1211 Geneva 20 Switzerland, Telephone: +41.22.730.5111, Fax: +41.22.733.7256, <http://www.itu.int>. ITU trademark is owned by International Telecommunication Union.

<sup>3</sup> The Society for Information Display, 1475 S. Bascom Ave. #114, Campbell, CA 95008-4006, USA. Telephone: +1.408.879.3901, Fax: +1.408.879.3833, <http://www.sid.org>

### 3.4 SMPTE Standards<sup>4</sup>

ST 303:2002 — For Television – Color Reference Pattern

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

## 4 Terminology

4.1 The definitions of general terms follow IDMS 1, Version 1.1 and its following version.

### 4.2 Abbreviations and Acronyms

4.2.1 *APL* — average picture level

4.2.2 *CCT* — correlated color temperature

4.2.3 *OLED* — organic light emitting diode

### 4.3 Definitions

#### 4.3.1 Optical Terminology

4.3.1.1 *color* — the perceptual concept from hue and saturation of video signals including chrominance components. Generally the term color might be defined to include black, white, and gray colors that have no chrominance component, but here color is defined as output with some chrominance components.

4.3.1.2 *IRE* — an arbitrary unit used to describe a video signal. White is defined to be 100 IRE and the blanking level is defined to be 0 IRE. It stands for Institute of Radio Engineers.

4.3.1.3 *tone* — the gradation of output brightness by a display input variation. This usually means the gradation of gray, but color tone also includes the gradation of color.

#### 4.3.2 Measurement Terminology

4.3.2.1 *average picture level (APL)* — there are two kinds of APL, pre-gamma APL (Type 1 APL) for gamma corrected input signal (R, G, B) and post-gamma APL (Type 2 APL) for gamma de-corrected panel display signal (R', G', B'). APL without any notice usually indicates the post-gamma APL because APL is used for panel load processing. The post-gamma APL means the average of the total R, G and B data after gamma de-correction, not input signal (gamma corrected) values. The unit of APL is usually % and generally just APL means the post-gamma APL. The APL of input signal is greater than the post-gamma APL. The gamma de-corrected value of the input signal average is less than or equal to APL, where the equal case is only when all input data are equal or 0/100 IRE data.

4.3.2.2 *correlated color temperature (CCT)* — a term used to describe the color of a light source whose chromaticity lies close to the Planckian (black body) locus on a CIE 1960 chromaticity chart. In general, it is the temperature of a black body radiator which is the most similar to chromaticity of the evaluated light source and it is expressed in degree Kelvin. CCT is used to adjust white balance.

4.3.2.3 *gamma* — power relationship between R, G, or B input signals and their output luminance. It is applied to subdivide low level's tone resolution with limited number of bits, and expressed by form  $(V')^\gamma$  of power function and it is specially called decoding gamma ( $\gamma_D$ ). Conversely, its reciprocal is called encoding gamma ( $\gamma_E$ ) which is processed on video camera side. Normally, decoding gamma ( $\gamma_D$ ) = 2.2.

4.3.2.4 *luminance uniformity* — in IDMS v1.1, it is calculated by Minimum luminance divided by Maximum luminance among the defined screen positions and presented by %. For the measurement positions of a screen, refer to IDMS v1.1.

4.3.2.5 *primary color* — one of a set of colors that are combined to produce any desired set of intermediate colors, within a limitation called the 'gamut.' The primary colors for color television are red, green, and blue. The exact red, green, blue colors used are dependent on the television standard. Display devices do not usually use the same primary colors, resulting in minor color changes from ideal.

<sup>4</sup> Society of Motion Picture & Television Engineers, 3 Barker Ave., 5<sup>th</sup> Floor, White Plains, NY 10601, USA; Telephone: 914.761.1100, Fax: 914.761.3115, <http://www.smpete.org>

4.3.2.6 *gray balance* — adjustment or accuracy of color coordinates at all input ranges, usually from 5 to 100 IRE inputs. It is explained by all range white balance meaning.

4.3.2.7 *white balance* — adjustment or accuracy of color coordinates at a white input level, usually equal to or greater than 70% APL of full screen.

## 5 Summary of Test Method

### 5.1 Setup Conditions

5.1.1 All measurements shall be carried out in a dark room normally under 1 lux.

5.1.2 Warm up time of the display is at least an hour for all measurements, if not specified by the manufacturer of the display.

5.1.3 For tone measurement, all picture quality enhancement functions shall be bypassed to preserve the native picture qualities (luminance curve, APL, etc.). When some picture quality enhancement functions are active in the measurement, it shall be recorded in the report. When the measurement is applied to some picture mode of a display set (normal, economy, dynamic, living room, etc.), it shall also be recorded in the report. And any picture mode should be at just-scan mode without over-scan of image.

### 5.2 Measurement Setup

5.2.1 The measuring equipment shall be set as shown in Figure 1 for noncontact light measurement device (LMD). The optical axis of noncontact LMD shall be normal to the center of the display surface. The measuring point is the center of effective screen area of the display. When other point is measured, it shall be noted in the report.

5.2.2 During the measuring process, any residual level or image sticking by previous images should not exist on the display screen. The measurement order of a tone pattern shall be from lower level to higher level as preventing residual level as possible.

5.2.3 Determine the distance from LMD to center of DUT. To reduce error by stray light in the measurements, the LMD field of view should avoid containing a bright background. If this is not possible, then a frustum or stray light elimination tube shall be used (refer to IDMS v1.1 Appendix A1 to A2).

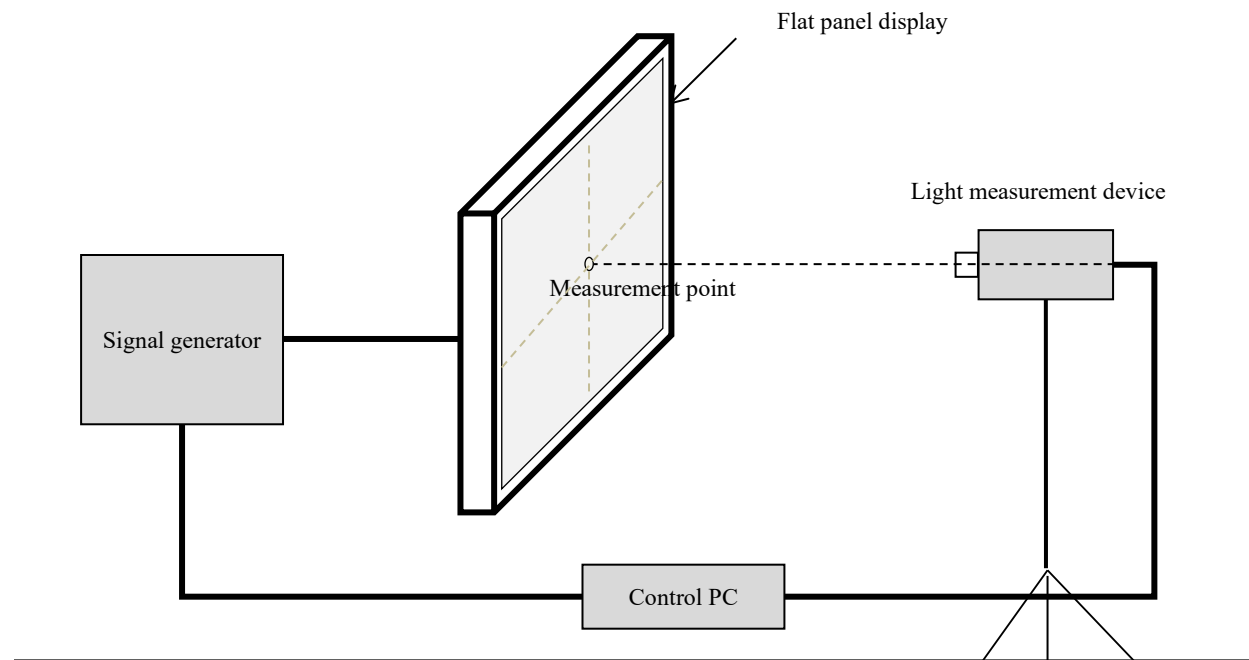


**Figure 1**  
**Measurement Set-Up**

## 6 Tone Measurement

6.1 Each test pattern to be displayed may occupy some percentage of area at over-scan screen mode, but it is not concerned whether it is at just-scan or over-scan mode. To match the results in display module and TV set, however, the just-scan mode shows the accurate results of display module and TV set.

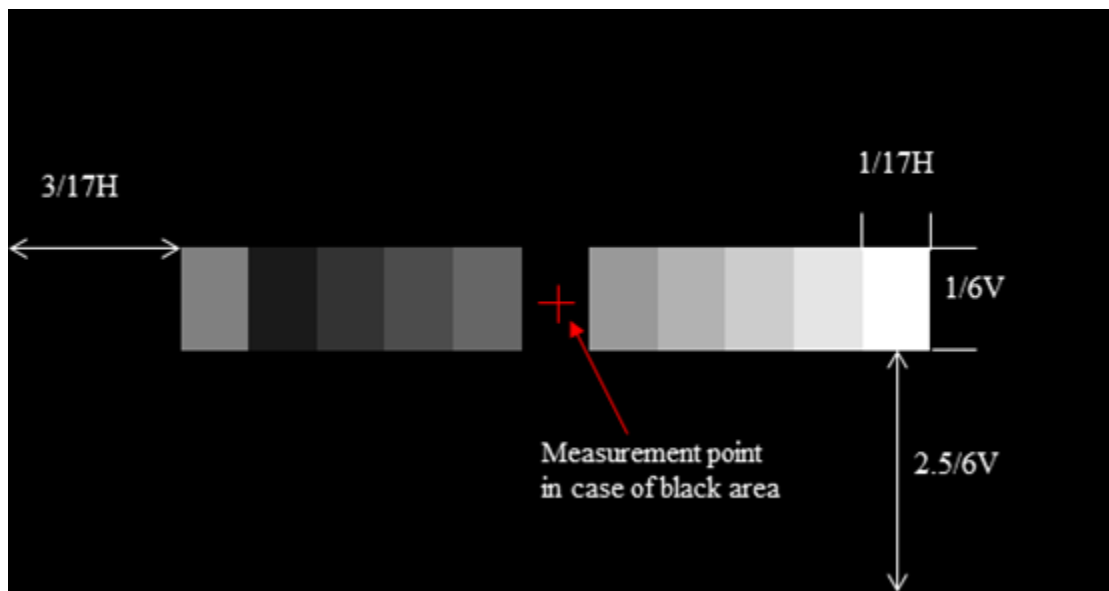
### 6.2 Constant APL Gamma

#### 6.2.1 Gray-Bar Window Gamma

6.2.1.1 Since display luminance for inputs varies by APL, the gamma values are measured at 10% to 90% APL (post-gamma APL) separately with 11 steps gray-bar pattern varying each input data step by 10%. In this Standard, just APL means the post-gamma APL.

6.2.1.2 When it is measured on a screen, the background signal level is changed for each APL while maintaining gray-bar pattern at the screen center.

6.2.1.3 For the measurement of avoiding luminance nonuniformity, each box of luminance levels is moved to center of measurement point of Figure 2 where change the positions each other in regular sequence.



#1 Example of area ratio: Each bar of gray pattern: 0.98%

#2 The whole gray-bar pattern:  $0.98\% \times 11 = 10.78\%$

#3 Background area:  $100\% - 10.78\% = 89.22\%$

**Figure 2**  
**General Pattern of Gray-Bar Window Gamma**

6.2.1.4 The APL of the pattern in Figure 2 can be calculated by display module inputted values after gamma de-correction in range 0 to 255 of 8 bits. In case of conventional 2.2 gamma (shortly 2.2 gamma),

$$APL (\%) = 10.78 \times 0.331 + 89.22 \times (Y / 255)^{2.2} \quad (1)$$

6.2.1.5 In Equation 1, 0.331 means the APL of 11 step gray-bar data. Outer background data Y is calculated using the following equation.

$$Y = 255 \times [(APL - 10.78 \times 0.331) / 89.22]^{1/2.2} \quad (2)$$

6.2.1.6 For ITU-R BT.709-6 (shortly BT.709-6) gamma, the APL and Y value are also calculated by a similar method, but it is substituted by 2.2 gamma equation because APL is just the approximate test case.

6.2.1.7 Figure 3 shows an example of a gamma measurement graph in nine kinds of output APL (post-gamma APL) for APL-dependent luminance displays such as OLED display exemplified in this Test Method.

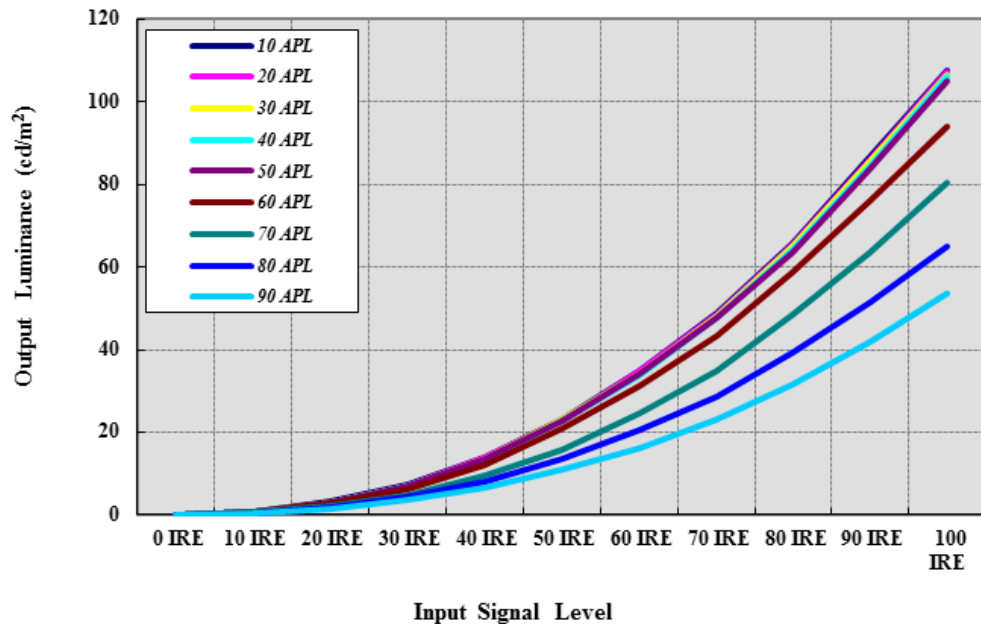


**Figure 3**  
**An Example of Input-Luminance Curve by APLs**

## 6.2.2 Single Window Gamma

6.2.2.1 Single window gamma measures white luminance according to APL change of flat panel display module in a fixed window.

6.2.2.2 In order to fix the APL, luminance of outer area would be changed down from high to low IRE while a center box is measured from 0 to 100 IRE which means 0 to 255 gray levels.

6.2.2.3 The size of the box is 1/5 horizontal and vertical pixel numbers of source video, using approximately 4% of the total screen area in a display.

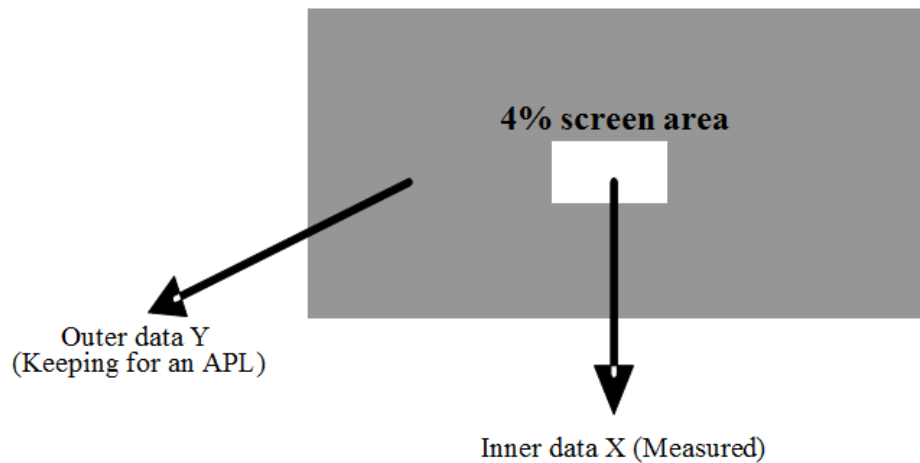


**Figure 4**  
**General Pattern of Single Window Gamma**

6.2.2.4 The APL of the pattern in Figure 4 is calculated by gamma de-correction in 8 bit. In case of conventional 2.2 gamma,

$$APL (\%) = 4 \times (X / 255)^{2.2} + 96 \times (Y / 255)^{2.2} \quad (3)$$

6.2.2.5 Outer background data Y is obtained using the following Equation 4.

$$Y = 255 \times [(APL - 4 \times (X / 255)^{2.2}) / 96]^{1/2.2} \quad (4)$$

### 6.2.3 RGB Gamma

6.2.3.1 The luminance gamma measurements in above are also used for RGB gamma measurement.

6.2.3.2 The explanation is abbreviated because it is a similar method except for APL calculation.

6.2.3.3 The inner window's APL with one color among R, G or B would be 1/3 of Gray pattern.

### 6.3 Constant Luminance APL Gamma

6.3.1 Generally, as luminance characteristics depend on the APL, the luminance curve may be approximately characterized by an exponential curve as shown in the following Equation 5 and Figure 5.

$$L_{ref} [cd / m^2] = \frac{b}{APL + a} + c \quad (5)$$

where:

$a, b, c$  = integer constants to get higher accuracy for an OLED display module. Typically,  $a$  is below 50 (about 10),  $b$  is above 5000,  $c$  is below 50.

$APL$  = average picture level in percentage, generally above 16% might be applied.

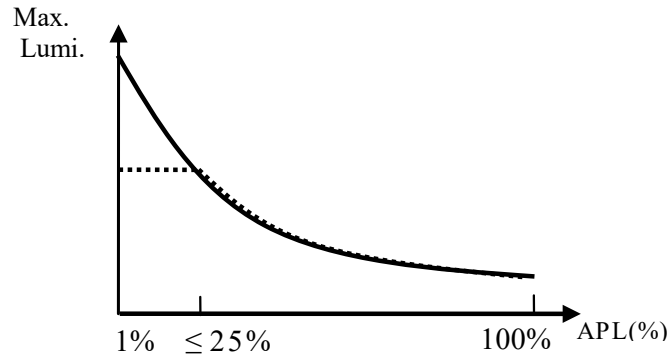


**Figure 5**  
**APL-Luminance Curve Modeling for APL-Dependent Displays**

6.3.1.1 Sometimes this approximation may be not suitable at low APL (generally under 16% APL similar to CRT), because of the optical performance limitation due to the lack of product reliability, etc.

6.3.1.2 Sometimes, as suggested by the dotted line in Figure 5, a flat region is included at low APL for maintaining constant luminance.

6.3.1.3 When a display has the APL range with constant luminance up to over 4% APL, it is measured without varying background level to maintain an APL.

6.3.1.4 This measurement is made on the center screen while a box of varying gray levels is displayed. The box of a center is fixed up with a box of 0 to 100 IRE.

6.3.1.5 The size of the box is 1/5 to 1/2 horizontal and vertical screen size of the display, using 4% to 25% of the total screen area.

6.3.1.6 The larger window means that the display has a constant luminance curve from 0 to the higher APL as large as the window size.

6.3.1.7 In the previous APL luminance equation, to evaluate and compare the shape regulation of the APL luminance curve with CRT in 16% to 100% APL range, APL luminance regulation accuracy is defined as following Equations 6, 7, and 8, and Figure 6.

$$L\_Reg_{accu.}[\%] = 100 - \frac{1}{7} \sum_{APL} |L_{APL} - L_{ref}| \quad (6)$$

where  $L_{APL}$  is maximum luminance ( $cd/m^2$ ) at each APLs (4, 9, 16, 25, 36, 49, 64, 81, 100).

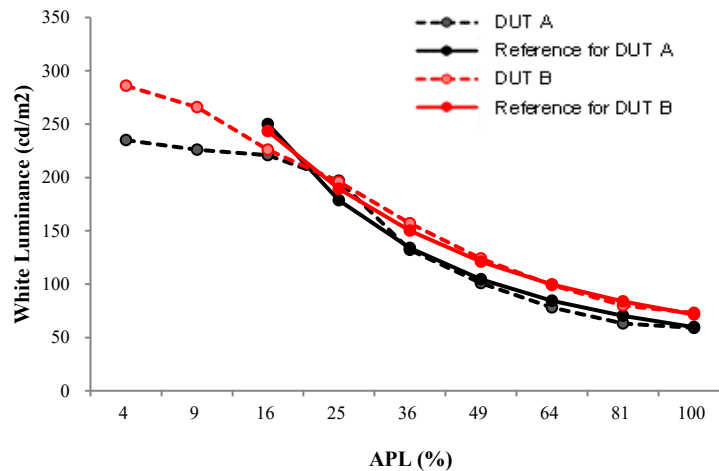


**Figure 6**  
**Examples of Maximum White Luminance Curve by APLs**

6.3.1.7.1 In these examples, for DUT A, Equation 7 is adapted to get the regulation accuracy 93.5%.

$$L_{\max}[cd/m^2] = \frac{5000}{APL + 5} + 12 \quad (7)$$

6.3.1.7.2 For DUT B, Equation 8 is used to get the regulation accuracy 96.4%.

$$L_{\max}[cd/m^2] = \frac{7000}{APL + 14} + 10 \quad (8)$$

### 6.3.2 Luminance Gamma

6.3.2.1 Luminance gamma measures the luminance of 21 gray patterns which change the gray value from white to black with the same linear steps in 4% to 25% boxes.

6.3.2.2 A level of outer area is fixed at 0 IRE and its APL is not constant. Usually, this measurement is the meaning at flat luminance range like the dotted line of above Figure 5.

6.3.2.3 All gray patterns are presented sequentially from 0 to 100 IRE in steps of 5% to 10%.