

# Achieving Uniform Front Panel Appearance using Avago Technologies' 2 Intensity Bin Select Option LED Devices



## Application Note 1031

### Introduction

Matching different displays on a front panel to have the same apparent brightness is not as simple as matching data sheet intensities. The designer must take into account the ambient light conditions, the light output and the light emitting area of the display. Avago Technologies has introduced the "2 Intensity Bin Select" option for part selection to reduce the complexity of this design problem. The 2 Intensity Bin Select parts are basic catalog devices which are presorted for luminous intensity and then selected from two predetermined adjacent categories. To ensure our customers a steady supply of product, Avago Technologies 2 Intensity Bin Select parts are normally picked from the center of our luminous intensity distribution.

This application note is written as a design guide to front panel design using Avago Technologies displays and lamps. The objective of this application note is to design a front panel where all of the displays on the front panel have the same apparent brightness. Two techniques will be presented. The first is used to match displays to a minimum acceptable level. The other is to use one display to determine an acceptable level and match the remaining displays to that level. Following either process described in this application note and using 2 Intensity Bin Select selected parts will simplify the design process and display selection.

### Sterance Matching vs. Intensity Matching

Figure 1a shows a graphical definition of intensity. Intensity,  $I_v$ , is defined as:

The measure of luminous flux per unit solid angle from a point source. The unit of luminous intensity is lumens per steradian (lm/sr). The SI and English unit for luminous intensity is the candela (cd).

Figure 1b depicts a graphical definition of luminous sterance. Luminous sterance,  $L_v$ , is defined as:

A measure of photometric brightness. It is the flux per unit solid angle per unit area emitting from a light source. The SI unit for luminous sterance is candelas per meter squared ( $\text{cd}/\text{m}^2$ ). The English unit for luminous sterance is the footlambert (fL). A footlambert is defined as  $1/\pi \text{ cd}/\text{ft}^2$ . 1 fL is equal to  $3.426 \text{ cd}/\text{m}^2$  or  $1 \text{ cd}/\text{m}^2 = 0.2919 \text{ fL}$ . For displays with uniform light emitting areas, the luminous sterance,  $L_v$ , of the segment can be approximated as the luminous intensity,  $I_v$ , of the segment divided by the light emitting area,  $A$ .

$$L_v = I_v / A \quad (1)$$

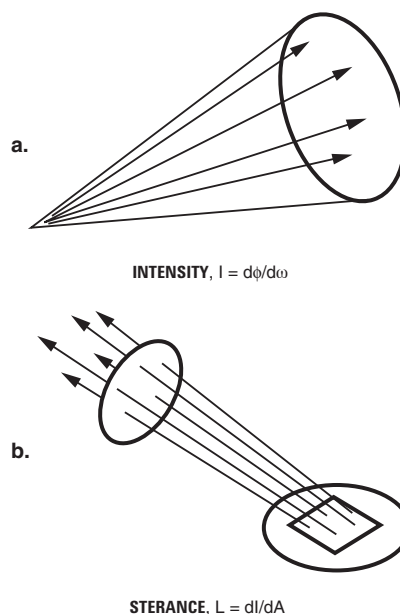


Figure 1a and 1b. Graphical Definition of Intensity,  $I_v$ , and Sterance,  $L_v$

Brightness perceived by the human eye may quantitatively be defined as luminous sterance,  $L_v$ . Sterance, unlike intensity, takes into account the area which radiates the light energy. This means that given two identical light emitting areas, the first with twice the intensity of the second, the first would appear twice as bright. Alternatively, when both parts have the same intensity, the first with half the area of the second, the first would appear twice as bright.

Luminous intensity can be used to compare the light output of two parts with the same light emitting area. However, luminous intensity should not be used to compare the apparent brightness of displays with different light emitting areas. Sterance should be used to compare the apparent brightness of two or more displays with different light emitting areas.

Luminous sterance should be used to match displays with different light emitting areas. Increasing the drive current will cause an increase in intensity and in sterance. Front panel matching is accomplished by varying the display drive current. Thus, it is possible to have the sterance of several displays with assorted sizes match by driving the displays at different currents.

**Ambient Light**

Luminous Incidence ( $E_v$ ) is the measure of flux per unit area incident to a surface. The unit of luminous incidence in lumens/m<sup>2</sup>, the SI unit is the lux. The English unit is the footcandle (fc) defined as lumens/ft<sup>2</sup>. 1 lux is equal to 0.0929 fc or 1 fc is equal to 10.76 lux.

**“2 Intensity Bin Select” Selected Parts**

Due to advances in the testing process, Avago Technologies is able to offer lamps and displays categorized by luminous intensity. The human eye can detect a difference in luminous intensity when the intensity ratio of two devices is 2:1. Bins are set up so that displays selected from the same bin will appear to have the same brightness when driven by the same test current.

Parts are shipped from available bins. For parts shipped in tubes, they will have the same luminous intensity bin within each tube, but will vary from tube to tube. The number of different bins shipped per part can be as high as 4 or 5. Keeping track of 4 or 5 bins per part number can be very costly. Even if only 2 bins are shipped they may not necessarily be adjacent to each other. To simplify the design process Avago Technologies has introduced 2 Intensity Bin Select option selected parts. These selected displays are basic catalog devices which are presorted for luminous intensity, then selected from two predetermined adjacent bins. Whenever the 2 Intensity Bin Select option is ordered, Avago Technologies will keep the individual bins separate and clearly labeled to aid in customer handling. Table 1 shows the bins,  $I_v$  range and quantity for a theoretical part. Bins B and C would be the bins used for 2 Intensity Bin Select option selection.

For optimum matching it is best to use only one of the bins for each individual panel. Mixing both 2 Intensity Bin Select bins on the same assembled panel may produce an unacceptable appearance.

**Table 1. Hypothetical Bin Limits and Quantity Available for a Theoretical Part**

Bin	$I_v$ Range (mcd)	Quantity
A	1 – 2	50
B	1.5 – 3	200
C	2.25 – 4.5	250
D	3.38 – 6.76	75

## Effects of Color and Filtering on Front Panel Design

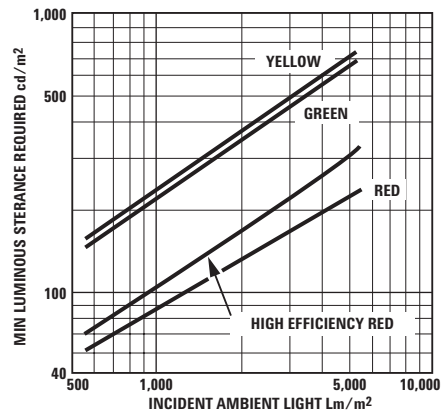
Graphs 1, 2, and 3 show the effects of color and filtering on front panel design. The graphs were created by conducting an experiment in which each participant was asked to match 12 displays to a given ambient light level and filter condition. Each color (High Efficiency Red (HER), Yellow, High Performance Green and Red) was represented by three different displays with different light emitting areas. The sizes used were the .8" numeric, .3" micro bright numeric, and the .750" X .150" light bar. Three ambient light levels and three filter conditions were used for a total of nine different combinations. Each participant's observation was converted to a sterance value. The two highest and lowest observations were discarded. Light levels used were 540 lux, 1600 lux and 5400 lux. The observations were averaged by color, ambient light level and filter conditions to create graphs 1, 2, and 3.

Graph 1 is a plot of minimum acceptable display luminous sterance versus level of incident ambient light without any filtering.

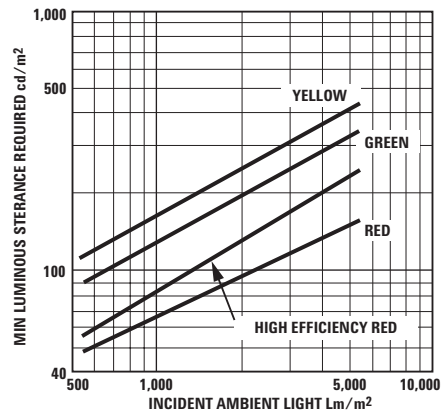
Graph 2 is a plot of minimum acceptable display luminous sterance prior to filtering with an 18% transmission neutral density gray filter versus level of incident ambient light. Graph 2 should be used as a starting point when designing with neutral density gray or bronze filters. Adjustments may be necessary when using neutral density gray filters with different transmission factors.

Graph 3 is a plot of minimum acceptable display luminous sterance prior to filtering with colored filters versus level of incident ambient light. Red is filtered with a red longpass filter with a 70% transmission at 655 nm. HER is filtered with a red longpass filter with a 50% transmission at 630 nm. Yellow is filtered with an amber semi-bandpass filter with a 27% transmission at 583 nm. High Performance Green is filtered with a green semi-bandpass filter with a 48% transmission at 565 nm. Graph 3 should be used as a starting point for filtering a single color with a colored filter. Adjustments may be necessary when using filters with different transmission factors.

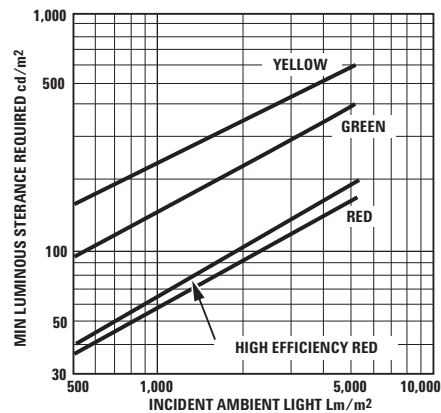
Several factors have not been included in these graphs which may have an influence on the designer's choice of minimum sterance required. Factors such as environmental effects, human factors, circuit variations and expected operating life may require higher minimum levels and should be considered by the designer.



**Graph 1. Minimum Acceptable Light Output of Unfiltered Displays vs. Level of Incident Ambient Light**



**Graph 2. Minimum Acceptable Light Output of displays Prior to Filtering with an 18% Transmission Neutral Density Gray vs. Level of Incident Ambient Light**



**Graph 3. Minimum Acceptable Light Output of Displays Prior to Filtering vs. Level of Incident Ambient Light**

Display color and filter % transmission can have a profound effect on the required sterance level. The sterance ratio between two or more colors should be maintained. Table 2 shows the ratios from graphs 1, 2 and 3.

For example, assume an unfiltered yellow display has a desired sterance value of 400 cd/m<sup>2</sup>. Sterance values for the other colors can be calculated as shown below. From Table 2, the value for the HER sterance can be calculated by dividing the Yellow sterance by 2.2. The values for the other colors can be calculated by multiplying the sterance value for HER by the appropriate value for the color. Therefore,

$$\text{HER} = (400 \text{ cd/m}^2)/2.2$$

$$\text{Red} = (182 \text{ cd/m}^2)(0.75)$$

$$\text{High Performance Green} = (182 \text{ cd/m}^2)(2.1)$$

Contrast enhancement filters will lower the minimum sterance required for a given ambient versus the minimum sterance required for an unfiltered display. For additional information on filtering see Application Note 1015.

**Table 2. Sterance Ratio of Each Color Relative to HER**

	<b>Red</b>	<b>HER</b>	<b>Yellow</b>	<b>High Performance Green</b>
Graph 1 (unfiltered)	0.75	1.0	2.2	2.1
Graph 2 (gray filter)	0.83	1.0	2.0	1.7
Graph 3 (colored filters)	0.87	1.0	3.5	2.3

## Sterance Matching Process

Figure 2 shows a flow chart on how to sterance match for minimum acceptable brightness. Figure 3 shows a flow chart on how to sterance match using one display to calibrate the other displays. A design example using each process will follow.

### Sterance Matching for Minimum Acceptable Brightness

Step 1.

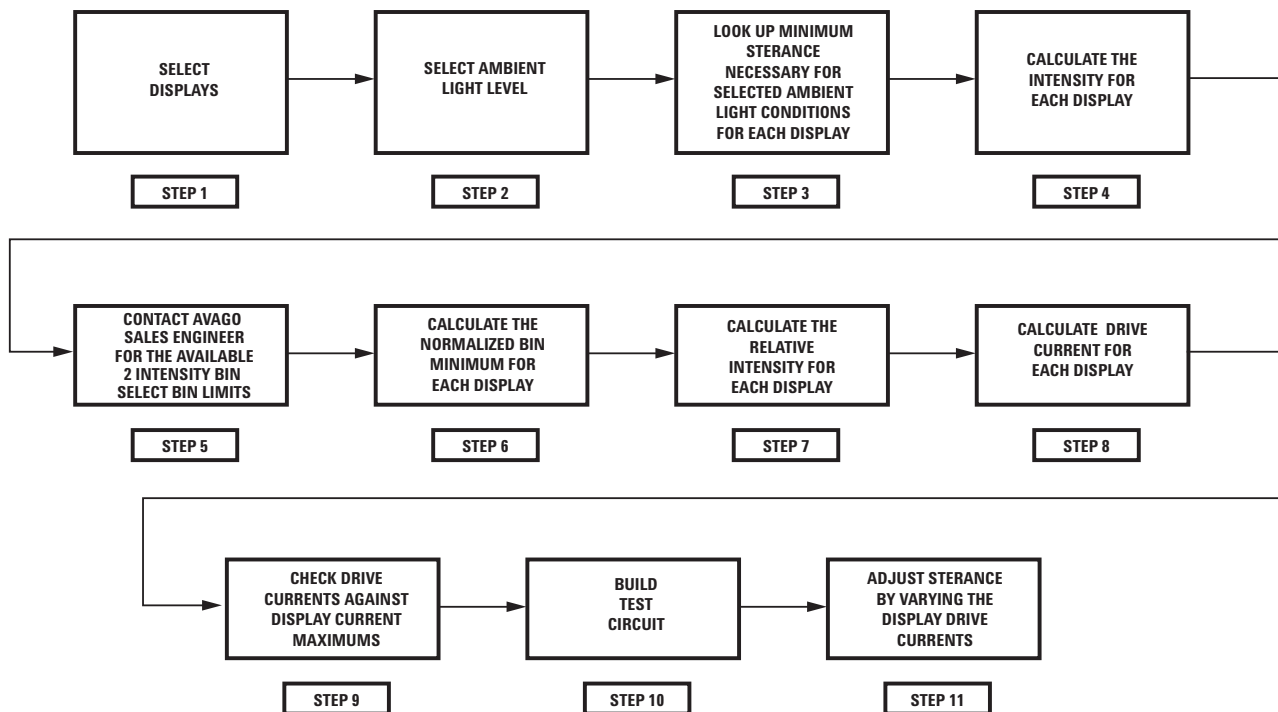
To begin the process the designer has to know which Avago Technologies LED displays and lamps are going to be used.

Step 2.

Determine the ambient lighting expected for the application. Table 3 shows the light level of various ambient lighting situations. For more specific needs, see the 1981 IES Lighting Handbook Application Volume. (Waverly Press Inc., Baltimore, MD., Second Printing, June, 1982).

**Table 3. Ambient Light Levels**

Indoor Incident Ambient Light	lux (lm/m <sup>2</sup> )	fc (lm/ft <sup>2</sup> )
General Indoors (corridors, stairways)	200 - 500	20 - 50
Desktop Level (general reading/writing)	500 - 1100	50 - 100
Moderately Bright (detailed drafting)	1100 - 2150	100 - 200
Bright Interior (fine bench/machine work)	2150 - 5400	200 - 500



**Figure 2. Flow Chart of Sterance Matching Process for Minimum Acceptable Brightness**

Step 3.

For each display determine the desired sterance ( $L_{vdes}$ ) level which corresponds with the chosen ambient level and filter conditions using graphs 1, 2 or 3.

Step 4.

Determine the light emitting areas for the devices used in the application. Appendix A lists the light emitting area of light bars, seven segment displays, lamps and bar graph arrays. The designer can calculate the minimum display luminous intensity ( $I_{vdes}$ ) needed to provide sufficient brightness for the ambient light conditions by knowing the display light-emitting area ( $A_{dis}$ ) from Appendix B and the desired sterance from Step 3.

$$I_{vdes} = (L_{vdes})(A_{dis}) \tag{2}$$

Step 5.

Contact your local Avago Technologies Sales Engineer for the current available bin limits of 2 Intensity Bin Select option displays and lamps. Use the minimum intensity value ( $I_{vbinmin}$ ).

Step 6.

Calculate the minimum Intensity value ( $I_{vnbinmin}$ ) for a 10 mA DC drive condition. Look-up the conversion factor (cf) in Table 4. For devices which are tested at currents other than 10 mA DC, the approximate luminous intensity ( $I_{vnbinmin}$ ) at 10 mA DC is equal to the minimum intensity at the test condition divided by the test conversion factor. Test conditions are listed in the Optoelectronics Designer's Catalog or in Appendix B. In case more than one test condition is given, use the one which lists a minimum luminous intensity.

$$I_{vnbinmin} = I_{vbinmin}/cf. \tag{3}$$

**Table 4. Conversion Factors to Adjust Various Test Conditions to 10 mA DC**

Test Condition/Color	HER	Yellow	Green	Red
100 mA peak 1/5 DF	3.45	4.76	–	–
20 mA DC	2.38	2.38	2.38	2.0
10 mA DC	1.0	1.0	1.0	1.0
5 mA DC	0.39	0.39	0.39	0.45

Step 7.

Calculate the relative luminous intensity,  $I_{vrel}$ . The relative luminous intensity is equal to the desired luminous intensity, from step 4, divided by the normalized bin minimum, from step 6.

$$I_{vrel} = I_{vdes}/I_{vnbinmin} \tag{4}$$

Step 8.

Calculate the drive current (in mA) needed to achieve the desired luminous intensity. Drive current (in mA) and relative luminous intensity are related to each other by equations 5 and 6. Equation 5 is used with High Efficiency Red, Yellow and High Performance Green displays. Equation 6 is used with Standard Red displays. Peak drive current is a function of duty factor (df) and relative intensity. Duty factor is the ratio of on time to the total time of one cycle. To calculate peak drive current for pulsed or multiplexed operation use equations 7, 8, 9 or 10. Equation 7 is used with HER devices. Equation 8 is used with Yellow devices. Equation 9 is used with High Performance Green devices. Equation 10 is used with Red devices. These equations have been normalized to 10 mA DC.

Equations for DC operation:

$$I_f = (10.6)(I_{vrel})^{0.747} \tag{5}$$

(use for HER, Yellow, and High Performance Green)

$$I_f = 0.747 + (8.77)(I_{vrel}) + (0.492)(I_{vrel})^2 \tag{6}$$

(use for Red)

Equations for pulsed operation:

$$I_{fpeak} = 2.31 + (7.35)(I_{vrel}/df) + (0.00652)(I_{vrel}/df)^2 \text{ (use with HER)} \quad (7)$$

$$I_{fpeak} = 2.46 + (7.33)(I_{vrel}/df) - (0.0838)(I_{vrel}/df)^2 \text{ (use with Yellow)} \quad (8)$$

$$I_{fpeak} = 2.51 + (7.37)(I_{vrel}/df) - (0.0775)(I_{vrel}/df)^2 + (0.00727)(I_{vrel}/df)^3 \text{ (use with High Performance Green)} \quad (9)$$

$$I_{fpeak} = 0.907 + (8.91)(I_{vrel}/df) + (0.0120)(I_{vrel}/df)^2 \text{ (use with Red)} \quad (10)$$

Step 9.

Check drive currents against display drive current maximums found listed in the Optoelectronics Designer's Catalog. Do not exceed the maximum ratings for any device. Please contact your Avago Technologies sales engineer with specific matching problems.

Step 10.

Build a test circuit to drive the displays with the calculated drive current.

Step 11.

Verify the perceived brightness is matched for the calculated drive currents and adjust the drive currents of any displays which are not matched.

### Design Example

Step 1:

Match an HER light bar (HLMP-2350), a Yellow light bar (HLMP-2450), a High Performance Green light bar (HLMP-2550) and a Red 0.3" micro bright numeric display (HDSP-7301).

Step 2:

Assume an ambient of 1600 lux and a neutral density gray filter with an 18% transmission factor.

Step 3:

Graph 2 shows a sterance level of 105 cd/m<sup>2</sup> is the minimum sterance necessary for HER in a 1600 lux ambient with gray filter. The minimum level for the other drive colors is:

Yellow - 210 cd/m<sup>2</sup>

High Performance Green - 160 cd/m<sup>2</sup>

Red - 82 cd/m<sup>2</sup>

Step 4:

$$\text{HLMP-2350 } I_{vrel} = (105 \text{ cd/m}^2)(72.6 \times 10^{-6} \text{ m}^2) = 7.62 \text{ mcd} \quad (2)$$

$$\text{HLMP-2450 } I_{vrel} = (210 \text{ cd/m}^2)(72.6 \times 10^{-6} \text{ m}^2) = 15.2 \text{ mcd} \quad (2)$$

$$\text{HLMP-2550 } I_{vrel} = (160 \text{ cd/m}^2)(72.6 \times 10^{-6} \text{ m}^2) = 11.6 \text{ mcd} \quad (2)$$

$$\text{HDSP-7301 } I_{vrel} = (82 \text{ cd/m}^2)(2.00 \times 10^{-6} \text{ m}^2) = 0.164 \text{ mcd/segment.} \quad (2)$$

Step 5:

HLMP-2350 2 Intensity Bin Select option bins E & F, 29.6-88.8 mcd

HLMP-2450 2 Intensity Bin Select option bins D & E, 18.0-50.0 mcd

HLMP-2550 2 Intensity Bin Select option bins E & F, 25.4-76.2 mcd

HDSP-7301 2 Intensity Bin Select option bins F & G, 0.610-1.410 mcd/segment

Obtained from your local Avago Technologies sales engineer.

HLMP-2350  $I_{vbinmin} = 29.6 \text{ mcd}$

HLMP-2450  $I_{vbinmin} = 18.0 \text{ mcd}$

HLMP-2550  $I_{vbinmin} = 25.4 \text{ mcd}$

HDSP-7301  $I_{vbinmin} = 0.610 \text{ mcd/segment}$

Step 6:

HLMP-2350 test conditions – 20 mA DC. cf = 2.38

HLMP-2450 test conditions – 20 mA DC. cf = 2.38

HLMP-2550 test conditions – 20 mA DC. cf = 2.38

HDSP-7301 test conditions – 20 mA DC. cf = 2.00

Located in Appendix B.

$$\text{HLMP-2350 } I_{\text{vbinmin}} = 29.6 \text{ mcd}/2.38 = 12.4 \text{ mcd} \quad (3)$$

$$\text{HLMP-2450 } I_{\text{vbinmin}} = 18.0 \text{ mcd}/2.38 = 7.56 \text{ mcd} \quad (3)$$

$$\text{HLMP-2550 } I_{\text{vbinmin}} = 24.5 \text{ mcd}/2.38 = 10.7 \text{ mcd} \quad (3)$$

$$\text{HDSP-7301 } I_{\text{vbinmin}} = 0.610 \text{ mcd/seg}/2 = 0.305 \text{ mcd/seg.} \quad (3)$$

Step 7:

$$\text{HLMP-2350 } I_{\text{rel}} = 7.62 \text{ mcd}/12.4 \text{ mcd} = 0.615 \quad (4)$$

$$\text{HLMP-2450 } I_{\text{rel}} = 15.2 \text{ mcd}/7.56 \text{ mcd} = 2.01 \quad (4)$$

$$\text{HLMP-2550 } I_{\text{rel}} = 11.6 \text{ mcd}/10.7 \text{ mcd} = 1.08 \quad (4)$$

$$\text{HDSP-7301 } I_{\text{rel}} = 0.164 \text{ mcd/seg.}/0.305 \text{ mcd/seg.} = 0.538 \quad (4)$$

Step 8:

$$\text{HLMP-2350 } I_f = (10.6)(0.615)^{0.747} = 7.37 \text{ mA DC} \quad (5)$$

$$\text{HLMP-2450 } I_f = (10.6)(2.01)^{0.747} = 17.9 \text{ mA DC} \quad (5)$$

$$\text{HLMP-2550 } I_f = (10.6)(1.08)^{0.747} = 11.2 \text{ mA DC} \quad (5)$$

$$\text{HLMP-7301 } I_f = 0.747 + (8.77)(0.538) + (0.492)(0.538)^2 = 5.47 \text{ mA DC} \quad (5)$$

Step 9:

Check drive currents against maximum ratings.

HLMP-2350 maximum dc current = 30 mA DC.

HLMP-2450 maximum dc current = 25 mA DC.

HLMP-2550 maximum dc current = 30 mA DC.

HDSP-7301 maximum dc current = 25 mA DC.

Calculated drive currents from step 8 are all below the maximum ratings.

Step 10:

Build test circuit.

Step 11:

Verify the perceived brightness is matched for the calculated drive currents and adjust the drive currents of any displays which are not matched.



### Sterance Matching to a Known Display

The following process, shown in Figure 3, will use one display to find an acceptable luminous sterance level for the given ambient and filter conditions. This sterance level will be used to calculate the drive currents for the other displays.

Step 1.

To begin the process the designer has to know which Avago Technologies LED displays and lamps are going to be used.

Step 2.

Build a test circuit to drive one 2 Intensity Bin Select display, such that all LEDs are driven at the same current. The best method is to use a display from the lower 2 Intensity Bin Select bin, as this will assure the sterance of the lower bin part will meet the acceptable sterance level. Adjust the drive current to produce an acceptable sterance level for the operating ambient light level and filter conditions.

Step 3.

Measure the display current through one LED.

Step 4.

Use this current to calculate the relative intensity with equations 7 and 8. Use equation 7 with HER, Yellow or High Performance Green. Use equation 8 with Standard RED.

$$I_{vrel} = (0.0943 \times I_f)^{1.34} \text{ (use with HER, Yellow or High Performance Green)} \quad (11)$$

$$I_{vrel} = -0.072 + (0.110)(I_f) - (0.000404)(I_f)^2 \text{ (use with Red)} \quad (12)$$

Step 5.

Contact your local Avago Technologies Sales Engineer for the available bin limits of the display used in the test circuit. Calculate the bin midpoint ( $I_{vbinmid}$ )

$$I_{vbinmid} = (I_{vbinmin} + I_{vbinmax})/2 \quad (13)$$

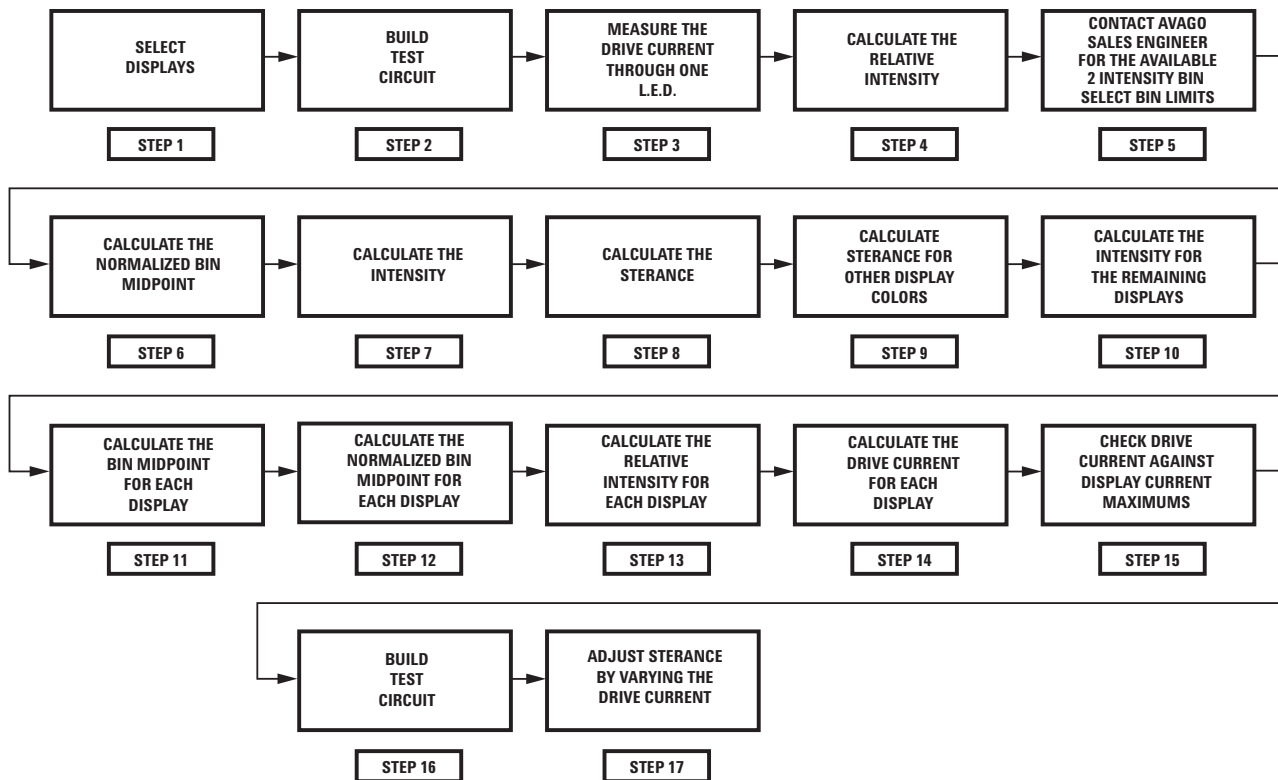


Figure 3. Flow Chart of Sterance Matching Process Using One Display to Calibrate the Other Displays

Step 6.

Calculate the midpoint luminous intensity ( $I_{vnbinmid}$ ) for a 10 mA DC drive condition. Look-up the conversion factor in Table 4. For devices which are tested at currents other than 10 mA DC, the approximate midpoint luminous intensity at 10 mA DC is equal to the bin midpoint luminous intensity at the test condition divided by the test conversion factor. Test conditions are listed on the individual data sheets or in Appendix B. In case more than one test condition is given, use the one which lists a minimum luminous intensity.

$$I_{vnbinmid} = I_{vbinmid}/cf \quad (14)$$

Step 7

Calculate the desired intensity. The desired intensity is equal to the relative intensity, from step 4, multiplied by the normalized bin midpoint, from step 6.

$$I_{vdes} = (I_{vrel})(I_{vnbinmid}) \quad (15)$$

Step 8.

Calculate the desired luminous sterance of the test device using the luminous intensity calculated in step 7 and the display light emitting area from Appendix A.

$$L_{vdes} = I_{vdes}/A_{dis} \quad (1)$$

Step 9.

Use this value of luminous sterance to calculate the desired luminous sterance of the other color displays using the ratios given in Table 2. See example at the end of Effects of Color and Filtering on Front Panel Design Section.

Use these desired luminous sterance values with the process listed in the previous section, step 4 to step 10, with the exception that the midpoint is calculated for equation 9 instead of the bin minimum determined in step 5.

Step 10.

Determine the desired luminous intensity based on the desired sterance from step 9 and the display light emitting areas given in Appendix B.

$$I_{vdes} = (L_{vdes})(A_{dis}) \quad (2)$$

Step 11.

Calculate the bin midpoint. Acceptable results can be obtained by using the minimum of the lower bin ( $I_{vbinmin}$ ) and the maximum of the higher bin ( $I_{vbinmax}$ ). However, the best method is to use the bin limits from the lower 2 Intensity Bin Select bin, as this will assure the sterance of the lower bin part will meet the acceptable sterance level.

$$I_{vbinmid} = (I_{vbinmin} + I_{vbinmax})/2$$

Step 12.

Calculate the normalized bin midpoint using the conversion factor given in Table 4.

$$I_{vnbinmid} = I_{vbinmid}/cf \quad (14)$$

Step 13. Calculate the relative intensity.

$$I_{vrel} = I_{vdes}/I_{vnbinmid} \quad (16)$$

Step 14.

Calculate the drive current (in mA) needed to achieve the desired luminous intensity.

Equations for DC operation:

$$I_f = (10.6)(I_{vrel}^{0.747}) \quad (\text{use for HER, Yellow, and High Performance Green}) \quad (5)$$

$$I_f = 0.747 + (8.77)(I_{vrel}) + (0.492)(I_{vrel})^2 \quad (\text{use for Red}) \quad (6)$$

Equations for pulsed operation:

$$I_{fpeak} = 2.31 + (7.35)(I_{vrel}/df) + (0.00652)(I_{vrel}/df)^2 \quad (\text{use with HER}) \quad (7)$$

$$I_{fpeak} = 2.46 + (7.33)(I_{vrel}/df) - (0.0838)(I_{vrel}/df)^2 \quad (\text{use with Yellow}) \quad (8)$$

$$I_{fpeak} = 2.51 + (7.37)(I_{vrel}/df) - (0.0775)(I_{vrel}/df)^2 + (0.00727)(I_{vrel}/df)^3 \quad (\text{use with High Performance Green}) \quad (9)$$

$$I_{fpeak} = 0.907 + (8.91)(I_{vrel}/df) + (0.0120)(I_{vrel}/df)^2 \quad (\text{use with Red}) \quad (10)$$

Step 15.

Check drive currents against display drive current maximums found listed in the product data sheets. Do not exceed the maximum ratings for any device. Please contact the Avago Technologies sales engineer with specific matching problems.

Step 16.

Build test circuit to test displays with calculated drive current.

Step 17.

Verify the perceived brightness is matched for the calculated drive currents and adjust any displays which are not matched.

### Design Example

Step 1:

Match an HER light bar (HLMP-2350), a Yellow light bar (HLMP-2450), a High Performance Green light bar (HLMP-2550) and 5 multiplexed ( $df = 1$  of  $5 = 1/5 = 0.2$ ) Red 0.3" micro bright numeric displays (HDSP-7301).

Steps 2 & 3:

Assume a drive current of 10 mA was measured through each LED in an 2 Intensity Bin Select selected HLMP-2450 from category D. Also assume the device has an acceptable luminous sterance in the given ambient light conditions.

Step 4:

$$\text{HLMP-2450 } I_{vrel} = (0.0943 \times 10)^{1.34} = 0.924 \quad (11)$$

Step 5:

HLMP-2450 2 Intensity Bin Select option bin D, 18.0 - 33.0 mcd at 20 mA DC

$$\text{HLMP-2450 } I_{vbinmid} = (18.0 + 33.0)/2 = 25.5 \text{ mcd} \quad (13)$$

Step 6:

HLMP-2450 test conditions - 20 mA dc.  $cf = 2.38$

$$\text{HLMP-2450 } I_{vnbinmid} = 25.5 \text{ mcd}/2.38 = 10.7 \text{ mcd} \quad (14)$$

Step 7:

$$\text{HLMP-2450 } I_{vdes} = 0.924 \times 10.7 \text{ mcd} = 9.89 \text{ mcd} \quad (15)$$

Step 8:

$$\text{HLMP-2450 Sterance} = 9.89 \text{ mcd}/72.6 \times 10^{-6} \text{ m}^2 = 136 \text{ cd/m}^2 \quad (1)$$

Step 9:

From Table 2, use the ratios for graph 2 (gray filter)

$$\text{HER Sterance level} = 136 \text{ cd/m}^2/2 = 68 \text{ cd/m}^2$$

$$\text{High Performance Green Sterance level} = 68 \text{ cd/m}^2 \times 1.7 = 116 \text{ cd/m}^2$$

$$\text{Red Sterance level} = 68 \text{ cd/m}^2 \times 0.83 = 56 \text{ cd/m}^2$$

Step 10.

$$\text{HLMP-2350 } I_{vdes} = (68 \text{ cd/m}^2)(72.6 \times 10^{-6} \text{ m}^2) = 4.94 \text{ mcd} \quad (2)$$

$$\text{HLMP-2550 } I_{vdes} = (116 \text{ cd/m}^2)(72.6 \times 10^{-6} \text{ m}^2) = 8.42 \text{ mcd} \quad (2)$$

$$\text{HDSP-7301 } I_{vdes} = (56 \text{ cd/m}^2)(2.00 \times 10^{-6} \text{ m}^2) = 0.112 \text{ mcd/seg.} \quad (2)$$

Step 11:

HLMP-2350 2 Intensity Bin Select option bin E, 29.6 - 54.2 mcd

HLMP-2550 2 Intensity Bin Select option bin E, 25.4 - 46.5 mcd

HDSP-7301 2 Intensity Bin Select option bin F, 0.610 - 1.120 mcd/seg.

Obtained from your local Avago Technologies sales engineer.

$$\text{HLMP-2350 } I_{vbinmid} = (29.6+54.2)/2 = 41.9 \text{ mcd} \quad (13)$$

$$\text{HLMP-2550 } I_{vbinmid} = (25.4+46.5)/2 = 36.0 \text{ mcd} \quad (13)$$

$$\text{HDSP-7301 } I_{vbinmid} = (0.610+1.120)/2 = 0.865 \text{ mcd/seg} \quad (13)$$

Step 12:

HLMP-2350 test conditions – 20 mA DC. cf = 2.38

HLMP-2550 test conditions – 20 mA DC. cf = 2.38

HDSP-7301 test conditions – 20 mA DC. cf = 2.00

Located in the Optoelectronics Designer's Catalog.

HLMP-2350  $I_{vbinmid} = 41.9 \text{ mcd}/2.38 = 1.76 \text{ mcd}$

(14)

HLMP-2550  $I_{vbinmid} = 36.0 \text{ mcd}/2.38 = 15.1 \text{ mcd}$

(14)

HDSP-7301  $I_{vbinmid} = 0.865 \text{ mcd/seg}/2.0 = 0.433 \text{ mcd/seg}$

(14)

Step 13:

HLMP-2350  $I_{vrel} = 4.94 \text{ mcd}/17.6 \text{ mcd} = 0.281$

(16)

HLMP-2550  $I_{vrel} = 8.42 \text{ mcd}/15.1 \text{ mcd} = 0.558$

(16)

HDSP-7301  $I_{vrel} = 0.112 \text{ mcd/seg}/0.433 \text{ mcd/seg} = 0.255$

(16)

Step 14:

HLMP-2350  $I_f = (10.6)(.281)^{0.7466} = 4.11 \text{ mA DC}$

(5)

HLMP-2550  $I_f = (10.6)(.558)^{0.7466} = 6.86 \text{ mA DC}$

(5)

HDSP-7301  $I_f = 0.907 + (8.91)(0.255/0.2) + (0.012)(.255/.2)^2 = 12.33 \text{ mA peak 1 of 5 df}$

(10)

Step 15:

Check drive currents against maximum

HLMP-2350 maximum dc current = 30 mA DC

HLMP-2450 maximum dc current = 25 mA DC

HLMP-2550 maximum dc current = 30 mA DC

HDSP-7301 maximum peak current = 150 mA

Obtained from the product data sheets. Calculated drive currents from step 14 are all below the maximum ratings.

Step 16: Build test circuit.

Step 17:

Verify the perceived brightness is matched for the calculated drive currents and adjust the drive currents of any displays which are not matched.

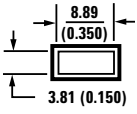
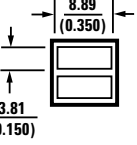
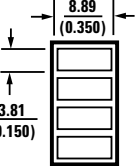
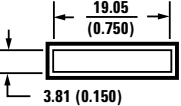
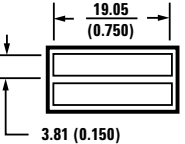
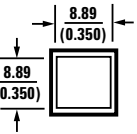
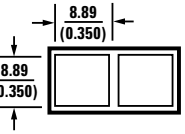
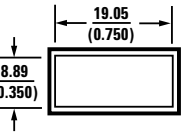
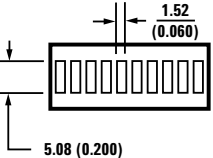
## Conclusion

Using either of the sterance matching techniques provides the designer with a process to calculate the current needed to match a wide variety of Avago Technologies displays and lamps. The 2 Intensity Bin Select option provides the designer with an easy way to design and order Avago Technologies' parts.

## Appendix A. Terms and Definitions

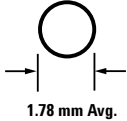
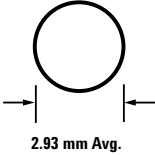
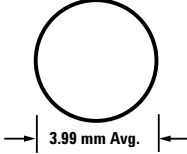
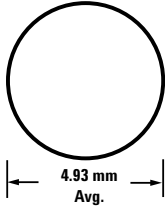
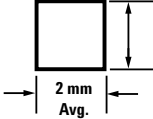
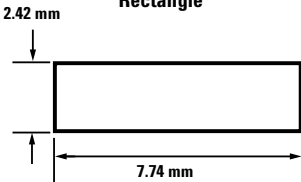
<b>Term</b>	<b>Definition</b>	<b>Location</b>	<b>Units</b>
A	Area	Eq.1	m <sup>2</sup> , ft <sup>2</sup>
A <sub>des</sub>	Display Light Emitting Area	Eq. 2	m <sup>2</sup>
cf	Conversion Factor	Eq. 3, 10	none
df	Duty Factor (on-time)	Eq. 7, 8, 9, 10	none
E <sub>v</sub>	Luminous Incidence	Table 3, Graphs 1, 2, 3	lux, fc
I <sub>f</sub>	LED Forward Current	Eq. 5, 6, 11, 12	mA
I <sub>fpeak</sub>	Peak LED Forward Current	Eq. 7, 8, 9, 10	mA
I <sub>v</sub>	Luminous Intensity	Eq. 1	mcd
I <sub>vbinmax</sub>	Bin Maximum Luminous Intensity	Eq. 13	mcd
I <sub>vbinmid</sub>	Bin Midpoint Luminous Intensity	Eq. 14, 16	mcd
I <sub>vbinmin</sub>	Bin Minimum Luminous Intensity	Eq. 3, 13	mcd
I <sub>vdes</sub>	Desired Luminous Intensity	Eq. 2, 15, 16	mcd
I <sub>vnbinmid</sub>	Bin Midpoint Luminous Intensity Normalized to 10 mA DC	Eq. 4	mcd
I <sub>vnbinmin</sub>	Bin Minimum Luminous Intensity Normalized to 10 mA DC	Eq. 14, 16	mcd
I <sub>vrel</sub>	Relative Luminous Intensity	Eq. 5, 6, 11, 12	none
L <sub>v</sub>	Luminous Sterance	Eq. 1	cd/m <sup>2</sup> , fl

Appendix B. Light Emitting Areas for 7 Segment Displays, Light Bars, Bar Graph Arrays, and Lamps

Shape	Area	Color	Part Number	Test Condition
	33.9 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2300 HLMP-2400 HLMP-2500	20 mA dc 20 mA dc 20 mA dc
	33.9 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2600 HLMP-2700 HLMP-2800	20 mA dc 20 mA dc 20 mA dc
	33.9 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2620 HLMP-2720 HLMP-2820	20 mA dc 20 mA dc 20 mA dc
	72.6 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2350 HLMP-2450 HLMP-2550	20 mA dc 20 mA dc 20 mA dc
	72.6 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2635 HLMP-2735 HLMP-2835	20 mA dc 20 mA dc 20 mA dc
	79.0 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2655 HLMP-2755 HLMP-2855	20 mA dc 20 mA dc 20 mA dc
	79.0 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2670 HLMP-2770 HLMP-2870	20 mA dc 20 mA dc 20 mA dc
	169 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	HER Yellow High Performance Green	HLMP-2685 HLMP-2785 HLMP-2885	20 mA dc 20 mA dc 20 mA dc
	7.72 x 10 <sup>-6</sup> m <sup>2</sup> Per Light Emitting Area	Red HER Yellow High Performance Green Multi Color	HDSP-4820 HDSP-4830 HDSP-4840 HDSP-4850 HDSP-4832, HDSP-4836	20 mA dc 10 mA dc 10 mA dc 10 mA dc 10 mA dc

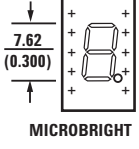
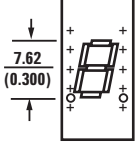
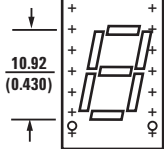
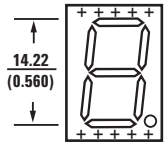
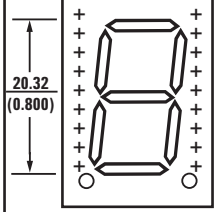
Note: All dimensions are in millimetres (inches).

Appendix B. (continued)

Shape/Lamp Style*	Area	Color	Lens	Test Condition
<p>Subminiature</p>  <p>1.78 mm Avg.</p>	<p><math>2.49 \times 10^{-6} \text{m}^2</math> Per Light Emitting Area</p>	<p>Red HER Yellow High Performance Green</p>	<p>Diffused Diffused Diffused Diffused</p>	<p>10 mA dc 10 mA dc 10 mA dc 10 mA dc</p>
<p>T - 1</p>  <p>2.93 mm Avg.</p>	<p><math>6.72 \times 10^{-6} \text{m}^2</math> Per Light Emitting Area</p>	<p>Red HER Yellow High Performance Green</p>	<p>Diffused Diffused Diffused Diffused</p>	<p>20 mA dc 10 mA dc 10 mA dc 10 mA dc</p>
<p>4 mm Flat Top</p>  <p>3.99 mm Avg.</p>	<p><math>12.5 \times 10^{-6} \text{m}^2</math> Per Light Emitting Area</p>	<p>HER Yellow High Performance Green</p>	<p>Diffused Diffused Diffused</p>	<p>20 mA dc 20 mA dc 20 mA dc</p>
<p>T - 1 3/4</p>  <p>4.93 mm Avg.</p>	<p><math>19.1 \times 10^{-6} \text{m}^2</math> Per Light Emitting Area</p>	<p>Red HER Yellow High Performance Green</p>	<p>Diffused Diffused Diffused Diffused</p>	<p>20 mA dc 10 mA dc 10 mA dc 10 mA dc</p>
<p>Square 2 mm Flat Top</p>  <p>2 mm Avg.</p>	<p><math>4.0 \times 10^{-6} \text{m}^2</math> Per Light Emitting Area</p>	<p>HER Yellow High Performance Green</p>	<p>Diffused Diffused Diffused</p>	<p>10 mA dc 10 mA dc 10 mA dc</p>
<p>Rectangle</p>  <p>2.42 mm</p> <p>7.74 mm</p>	<p><math>17.5 \times 10^{-6} \text{m}^2</math> Per Light Emitting Area</p>	<p>HER Yellow High Performance Green</p>	<p>Diffused Diffused Diffused</p>	<p>20 mA dc 20 mA dc 20 mA dc</p>

\*Table does not include Low Current, Integrated Resistor or Clear Lamps.

Appendix B. (continued)

Shape	Area	Color	Part Number	Test Condition
 <p>MICROBRIGHT</p>	2.00 x 10 <sup>-6</sup> m <sup>2</sup> Per Segment	Red HER Yellow High Performance Green	HDSP-730X HDSP-750X HDSP-74XX HDSP-78XX	20 mA dc 5 mA dc 5 mA dc 10 mA dc
	2.53 x 10 <sup>-6</sup> m <sup>2</sup> Per Segment	Red HER Yellow High Performance Green	5082-773X, 5082-774X 5082-761X HDSP-35XX 5082-762X HDSP-40XX HDSP-36XX	20 mA dc 5 mA dc 100 mA Peak 1/5 Duty Factor 5 mA dc 100 mA Peak 1/5 Duty Factor 10 mA dc
	4.38 x 10 <sup>-6</sup> m <sup>2</sup> Per Segment	Red HER Yellow High Performance Green	5082-775X, 5082-776X 5082-765X HDSP-37XX 5082-766X HDSP-41XX HDSP-46XX	20 mA dc 5 mA dc 100 mA Peak 1/5 Duty Factor 5 mA dc 100 mA Peak 1/5 Duty Factor 10 mA dc
	8.82 x 10 <sup>-6</sup> m <sup>2</sup> Per Segment	Red HER Yellow High Performance Green	HDSP-53XX HDSP-550X, HDSP-552X HDSP-553X HDSP-570X, HDSP-572X HDSP-573X HDSP-56XX	20 mA dc 10 mA dc 100 mA Peak 1/5 Duty Factor 10 mA dc 100 mA Peak 1/5 Duty Factor 10 mA dc
	14.9 x 10 <sup>-6</sup> m <sup>2</sup> Per Segment	Red HER Yellow High Performance Green	HDSP-34XX HDSP-39XX HDSP-42XX HDSP-86XX	20 mA dc 100 mA Peak 1/5 Duty Factor 100 mA Peak 1/5 Duty Factor 10 mA dc

Note: All dimensions are in millimetres (inches).

For product information and a complete list of distributors, please go to our web site: [www.avagotech.com](http://www.avagotech.com)

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5988-2012EN - July 14, 2010

