Equalizing Brightness of Standard LEDs

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Abstract: Guideline to compare optical and electrical parameters of standard light emitting diodes made by Würth Elektronik eiSos GmbH & Co. KG / Germany. LEDs of different light color need to be operated so that the emitted light intensity appears homogeneous to the human eye independent of the wavelength radiated. Individual forward current setting is required by a series resistors.

Keywords: maximum intensity, luminous intensity, millicandela, mcd, standard LED, radiation, emitted, emission, wavelength, output power, color, resistor, forward current, forward voltage, table, datasheet, equalization, damping, red, green, blue, yellow
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1 LED Types Used

The calculations conducted in this document apply to a certain set of standard LEDs only. According to the datasheets published by the manufacturer, relevant information has been extracted and pasted in the following.

The manufacturer gives the individual luminous intensity radiated at a forward current of 20mA (marked red in the following tables). By comparing these values it becomes obvious, that equalization is required. Due to the mixture of light colors emitted, the weakest LED, in this case the green one, dictates which of the remaining LEDs need to be damped down.

The maximum intensity allowed for all LEDs is defined by the maximum output of the green LED (40 mcd). See Table 2. For debugging issues and status indication on a board, intensities of 10, 20 and 40 mcd should be sufficient. See tables in 3 Summary page 8 ff.

2 How to read the diagrams?

In the diagrams below, as an example, green pointers indicate the point of operation at 40 mcd output intensity for all LEDs.

Start with the red LED, Diagram 2. The pointer is set at the 40mcd notch which yields a forward current of 4mA. Go to Diagram 1. There the pointer is set at 4mA which in turn gives a forward voltage of about 1.8V. So we have these input values for further calculations:

\[ I_f = 4\text{mA} \]
\[ V_f = 1.8\text{V} \]

On a power supply voltage \( V_{cc} \) the required series resistor equals

\[ R_s = \frac{(V_{cc} - V_f)}{I_f} \]

For a given \( V_{cc} \) of 3.3V the calculation yields:

\[ R_s = \frac{(3.3\text{V} - 1.8\text{V})}{4\text{mA}} \]
\[ R_s = 375\text{Ohms} \]

The nearest selection according to the E-24 series (3) would be 390 Ohms (See Table 7).

Repeat these steps for given parameter of 40mcd and \( V_{cc} \) with the remaining LEDs and you get the results as listed in Table 7. Table 5 and Table 6 have been calculated for luminous intensities of 10 and 20 mcd respectively.
2.1 Type 150080RS75000 (red)

Datasheet URL: [http://katalog.we-online.de/led/datasheet/150080RS75000.pdf](http://katalog.we-online.de/led/datasheet/150080RS75000.pdf)

### Electrical & Optical Properties:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Wavelength</td>
<td>20 mA</td>
<td>λ&lt;sub&gt;Peak&lt;/sub&gt;</td>
<td>630 nm</td>
</tr>
<tr>
<td>Dominant wavelength</td>
<td>20 mA</td>
<td>λ&lt;sub&gt;Dom&lt;/sub&gt;</td>
<td>625 nm</td>
</tr>
<tr>
<td>Luminous Intensity</td>
<td>20 mA</td>
<td>I&lt;sub&gt;V&lt;/sub&gt;</td>
<td>120 150 mcd</td>
</tr>
<tr>
<td>Forward Voltage</td>
<td>20 mA</td>
<td>V&lt;sub&gt;F&lt;/sub&gt;</td>
<td>2.0 2.4 V</td>
</tr>
<tr>
<td>Spectral Bandwidth</td>
<td>20 mA</td>
<td>Δλ</td>
<td>15 nm</td>
</tr>
<tr>
<td>Reverse Current</td>
<td>5 V</td>
<td>I&lt;sub&gt;Rev&lt;/sub&gt;</td>
<td>10 μA</td>
</tr>
<tr>
<td>Viewing Angle</td>
<td>20 mA</td>
<td>2θ&lt;sub&gt;50%&lt;/sub&gt;</td>
<td>140 °</td>
</tr>
</tbody>
</table>

**Table 1**

Diagram 1 Current vs. Voltage

Diagram 2 Intensity vs. Current
2.2 Type 150080VS75000 (Green)

Datasheet URL: http://katalog.we-online.de/led/datasheet/150080VS75000.pdf

D Electrical & Optical Properties:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Wavelength</td>
<td>20 mA</td>
<td>$\lambda_{\text{Peak}}$</td>
<td>572</td>
</tr>
<tr>
<td>Dominant wavelength</td>
<td>20 mA</td>
<td>$\lambda_{\text{Dom}}$</td>
<td>570</td>
</tr>
<tr>
<td>Luminous Intensity</td>
<td>20 mA</td>
<td>$I_V$</td>
<td>12</td>
</tr>
<tr>
<td>Forward Voltage</td>
<td>20 mA</td>
<td>$V_F$</td>
<td>2.0</td>
</tr>
<tr>
<td>Spectral Bandwidth</td>
<td>20 mA</td>
<td>$\Delta \lambda$</td>
<td>15</td>
</tr>
<tr>
<td>Reverse Current</td>
<td>5 V</td>
<td>$I_{\text{Rev}}$</td>
<td>10</td>
</tr>
<tr>
<td>Viewing Angle</td>
<td>20 mA</td>
<td>$2\theta_50%$</td>
<td>140</td>
</tr>
</tbody>
</table>

Table 2

Diagram 3 Current vs. Voltage

Diagram 4 Intensity vs. Current
2.3 Type 150080BS75000 (blue)

Datasheet URL: http://katalog.we-online.de/led/datasheet/150080BS75000.pdf

D Electrical & Optical Properties:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Wavelength</td>
<td>20 mA</td>
<td>$\lambda_{\text{Peak}}$</td>
<td>465 nm</td>
</tr>
<tr>
<td>Dominant wavelength</td>
<td>20 mA</td>
<td>$\lambda_{\text{DOM}}$</td>
<td>470 nm</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>20 mA</td>
<td>$I_L$</td>
<td>90 145 mcd</td>
</tr>
<tr>
<td>Forward voltage</td>
<td>20 mA</td>
<td>$V_F$</td>
<td>3.2 3.5 V</td>
</tr>
<tr>
<td>Spectral Bandwidth</td>
<td>20 mA</td>
<td>$\Delta \lambda$</td>
<td>25 nm</td>
</tr>
<tr>
<td>Reverse Current</td>
<td>5 V</td>
<td>$I_{\text{Rev}}$</td>
<td>10 $\mu$A</td>
</tr>
<tr>
<td>Viewing angle</td>
<td>20 mA</td>
<td>$2B_{50%}$</td>
<td>140 °</td>
</tr>
</tbody>
</table>

Table 3

Diagram 6 Current vs. Voltage

Diagram 5 Intensity vs. Current
2.4 Type 150080YS75000 (yellow)

Datasheet URL: http://katalog.we-online.de/led/datasheet/150080YS75000.pdf

### D Electrical & Optical Properties:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Wavelength</td>
<td>20 mA</td>
<td>$\lambda_{\text{Peak}}$</td>
<td>595</td>
</tr>
<tr>
<td>Dominant wavelength</td>
<td>20 mA</td>
<td>$\lambda_{\text{Dom}}$</td>
<td>560</td>
</tr>
<tr>
<td>Luminous Intensity</td>
<td>20 mA</td>
<td>$I_{V}$</td>
<td>120</td>
</tr>
<tr>
<td>Forward Voltage</td>
<td>20 mA</td>
<td>$V_F$</td>
<td>2.0</td>
</tr>
<tr>
<td>Spectral Bandwidth</td>
<td>20 mA</td>
<td>$\Delta \lambda$</td>
<td>15</td>
</tr>
<tr>
<td>Reverse Current</td>
<td>5 V</td>
<td>$I_{\text{Rev}}$</td>
<td>20</td>
</tr>
<tr>
<td>Viewing Angle</td>
<td>20 mA</td>
<td>2850%</td>
<td>140</td>
</tr>
</tbody>
</table>

**Table 4**

#### Diagram 8 Current vs. Voltage

#### Diagram 7 Intensity vs. Current
3 Summary

In order to keep things easy, a simple example of an LED and its series resistor is shown on the right. The LED might be driven by an IC or a transistor as well.

Table 5 through Table 7 give the value of the series resistor required to obtain a luminous intensity of around 10, 20 or 40 mcd for every light color radiated at a given operating voltage. Of course, these tables apply only to the LED types specified above.

**Note:** Mind the thermal load of the series resistor in certain cases!
<table>
<thead>
<tr>
<th>Light Color</th>
<th>R @ 3.3V [kOhms]</th>
<th>R @ 5V [kOhms]</th>
<th>R @ 12V [kOhms]</th>
<th>R @ 24V [kOhms]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>1.5</td>
<td>3.3</td>
<td>10</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>green</td>
<td>0.33</td>
<td>0.75</td>
<td>2.4</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>blue</td>
<td>0.82</td>
<td>2.5</td>
<td>10</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>yellow</td>
<td>0.91</td>
<td>2.2</td>
<td>6.8</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

*Table 5: Series Resistor Values for a homogeneous Intensity of approx. 10mcd*

<table>
<thead>
<tr>
<th>Light Color</th>
<th>R @ 3.3V [kOhms]</th>
<th>R @ 5V [kOhms]</th>
<th>R @ 12V [kOhms]</th>
<th>R @ 24V [kOhms]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>0.68</td>
<td>1.8</td>
<td>5.6</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>green</td>
<td>0.14</td>
<td>0.33</td>
<td>1.1</td>
<td>2.4</td>
<td>consider P</td>
</tr>
<tr>
<td>blue</td>
<td>0.33</td>
<td>1.2</td>
<td>4.7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>yellow</td>
<td>0.47</td>
<td>1</td>
<td>3.3</td>
<td>7.4</td>
<td></td>
</tr>
</tbody>
</table>

*Table 6: Series Resistor Values for a homogeneous Intensity of approx. 20mcd*

<table>
<thead>
<tr>
<th>Light Color</th>
<th>R @ 3.3V [kOhms]</th>
<th>R @ 5V [kOhms]</th>
<th>R @ 12V [kOhms]</th>
<th>R @ 24V [kOhms]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>0.39</td>
<td>0.82</td>
<td>2.4</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>green</td>
<td>0.075</td>
<td>0.16</td>
<td>0.56</td>
<td>1.1</td>
<td>consider P</td>
</tr>
<tr>
<td>blue</td>
<td>0.14</td>
<td>0.56</td>
<td>2.2</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>yellow</td>
<td>0.22</td>
<td>0.47</td>
<td>1.5</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

*Table 7: Series Resistor Values for a homogeneous Intensity of approx. 40mcd*
4 References

(1) Winfried Müller, “Optoelektronische Sender, Empfänger und Koppler” ; German; Militärverlag der DDR (VEB) Berlin, 1986

(2) Würth Elektronik eiSos GmbH & Co. KG / Germany, Datasheets of LEDs
   Datasheet URL: http://katalog.we-online.de/led/datasheet/150080RS75000.pdf
   Datasheet URL: http://katalog.we-online.de/led/datasheet/150080VS75000.pdf
   Datasheet URL: http://katalog.we-online.de/led/datasheet/150080BS75000.pdf
   Datasheet URL: http://katalog.we-online.de/led/datasheet/150080YS75000.pdf

(3) The E-series at http://www.logwell.com/tech/components/resistor_values.html

5 Links

- find updates of this document at www.blunk-electronic.de
- Simplify manufacturing fault detection, hardware bring-up, debugging and system tests with System M-1 the Boundary-Scan Test System at http://www.blunk-electronic.de/products.html

6 Disclaimer

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