

SnapLED / SuperFlux LED

Categories and Labels

During Lumileds' standard production process, each SuperFlux & SnapLED LED is tested before it is placed into a shipping tube. This test confirms that the luminous flux (light-output), dominant wavelength (color), forward voltage, and reverse voltage fall within the range described in Lumileds technical data sheet for each device.

This also enables Lumileds to provide matched bundles of SuperFlux LEDs to all customers. The SuperFlux & SnapLED LED Technical Data Sheets are available on-line at the following URL: <http://www.lumileds.com>

This section is dedicated to helping the customer understand the methodology behind Lumileds' categorization system. The reader should have a basic understanding of the following topics after reviewing this section: 1) category definitions, 2) typical category availability for each SuperFlux & SnapLED products, 3) location of the category code on Lumileds' labels, and 4) how category populations can change over time. A solid understanding of this topic will assist the designer in the simplification of exterior lighting system and assembly process designs.

Table of Contents

Category Definitions	3
Category Codes	3
<i>Luminous Flux Category Definitions</i>	3
<i>Color Category Definitions</i>	3
The Flux Ratio Concept	4
<i>Voltage Category Definitions</i>	4
Device Types, Option Codes and Part Numbers	6
 Packaging of SuperFlux & SnapLED LEDs	 6
Tubes of LEDs	6
Bundles of LEDs	7
Boxes of LEDs	7
 Typical Category Distributions for SuperFlux & SnapLED LEDs and Their Effect on the Lighting System and Assembly Process Design	 8
Variations in Dominant Wavelength (Color)	8
Variations in Forward Voltage	9
Variations in Luminous Flux (Light-Output)	10
<i>Samples with Data for Optical System Characterization</i>	12
<i>Requesting Flux Category Selections</i>	12

Category Definitions

Category Codes

A 3-digit category code is included on all tube and bundle labels. This category code groups the LEDs according to: luminous flux (light-output), dominant wavelength (color), and forward voltage. As shown in Figure 7.1, the first digit indicates the light-output range, the second digit indicates the color range, and the third-digit indicates the forward voltage range of the LEDs in the tube or bundle.

As a result of our production testing process, the maximum of one category is higher than the minimum of the next category. As mentioned above, Lumileds' automated test system measures three parameters of each LED to determine the category code for the device. Once the category code has been established,

the unit is placed into the shipping tube, and the test system generates the tube label, which displays this 3-digit category code. Although the automated test equipment is programmed so that each category maximum exactly matches the minimum of the next category, it is not as accurate as optical laboratory test equipment. As a result, the category minimums shown in Figure 7.1 are lower than the minimums programmed into our test equipment and the maximums are higher. This ensures that if a SuperFlux or SnapLED LED is tested using optical laboratory test equipment, the test results will fall within the ranges listed in Figure 7.1 for its assigned category code.

Luminous Flux Category Definitions

The first digit of Lumileds' category code provides information about the luminous flux, Φ_v , of the device. The table titled *Luminous Flux* in Figure 7.1 lists the minimum and maximum flux for each light-output category. The flux category minimums are conveniently coded so that each successive letter in the alphabet is one-half lumen brighter. Lumileds uses a single set of light-output category definitions for both absorbing-substrate (HPWA-series) and transparent-substrate (HPWT-series) SuperFlux and HPWS SnapLED LEDs. However, the

HPWA-series LEDs use the lower to mid-range light-output categories; the HPWT & HPWS series LEDs use the mid to higher-range categories as shown in the last two columns of this table. Because ratios, not arithmetic differences, are important when selecting an LED light source; Lumileds does not include the letters **I** or **K** in our flux category codes—the ratios of 4.5:4.0 and 5.5:5.0 are too small to justify including these half-lumen category increments. The importance of flux ratio is explained in *The Flux Ratio Concept*.

Color Category Definitions

The second digit of Lumileds' category code provides information about the dominant wavelength, λ_d , of the device. Dominant

wavelength is the parameter that defines the color of LEDs as perceived by the human eye. The table titled *Dominant Wavelength* in Figure

7.1 lists the minimum and maximum dominant wavelength for each color category. As for luminous flux, Lumileds uses a single set of color category definitions for both SuperFlux & SnapLED LEDs.

The human-eye is less sensitive to differences in color near the red-end of the color spectrum. Lumileds' measurement systems and color category widths have also been designed to be more precise in amber than in red-orange. The difference in nanometers between the bottom of category **1** and the top of category **3** is larger for red-orange LEDs (HPWx-xH00) than for amber LEDs (HPWx-xL00). However, the perceived color difference between categories **1** and **3** is similar for amber and red-orange.

Voltage Category Definitions

The third digit of Lumileds' category code provides information regarding the forward voltage, V_f , of the LEDs in the tube or bundle. The table titled *Forward Voltage* in Figure 7.1 defines these forward voltage categories. Again, Lumileds uses a single set of categories for both SnapLED & SuperFlux LEDs. However, the HPWA-series LEDs use the lower- to mid-range voltage categories; whereas, the HPWT & HPWS series LEDs use the mid- to higher-voltage categories.

The Flux Ratio Concept

In many applications, the acceptable light-output range for LED emitters is based mainly on the appearance of the final lighting system. It is important to remember that the human eye responds to light logarithmically. In other words, the perceived difference between a 1-lumen and 2-lumen light source is similar to the perceived difference between a 10-lumen and 20-lumen light source. Also, as a general rule, most people cannot easily discern differences in light-output of adjacent light sources if their ratio is less than 2:1 even under controlled, laboratory conditions. Therefore, a 1-lumen light source will appear dimmer than a 2-lumen light source; however, 10-lumen and 15-lumen light sources will have no discernible differences in brightness.

In other applications the acceptable light-output is determined by strict minimum and maximum limits as set forth by regulatory organizations. In this type of application, a designer can meet, for example, a 10 to 20-lumen lighting system requirement by using ten 1-to 2-lumen emitters, five 2- to 4-lumen emitters, or one 10- to 20-lumen emitter. This simple example demonstrates how the ratio of the maximum-to-minimum requirement is transferable from the lighting system to the individual emitters. Of course, this simplified example assumes that the lighting-system optic is perfectly efficient. Additional emitters may be required to account for inefficiencies in the optics or to provide the desired lit appearance. Please refer to Application Note AB20-5 Secondary Optic Design Considerations for SuperFlux LEDs for further information.

In both types of applications, ratios are more important than arithmetic differences in flux when selecting an LED light source.

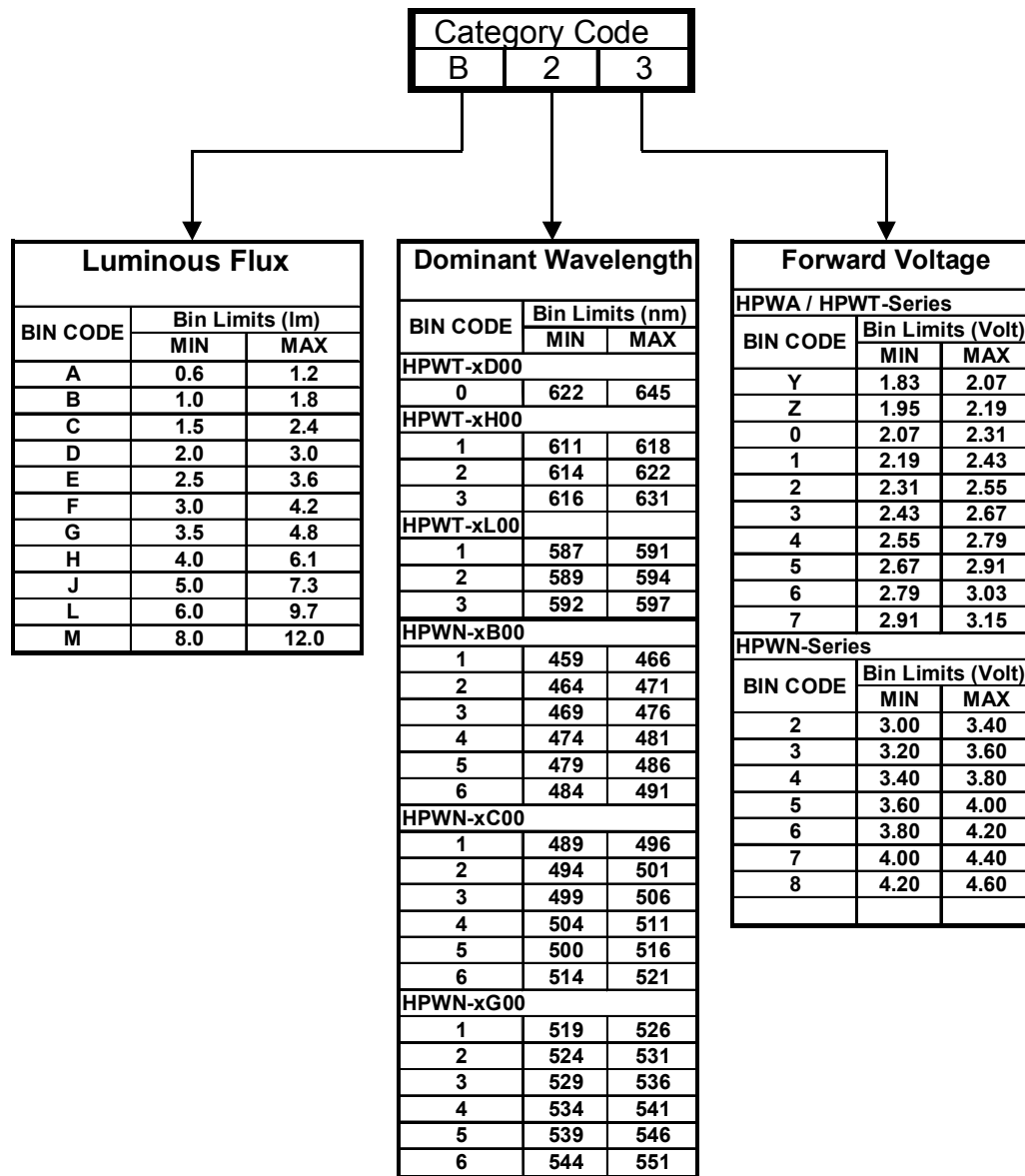


Figure 7.1
The SuperFlux LED category code system.

Notes:

1. SuperFlux categories reference $I_f = 70\text{mA}$ for HPWA/HPWT, $I_f = 50\text{mA}$ for HPWN, $T_a = 25^\circ\text{C}$, $R_{\theta(j-a)} = 200^\circ\text{C/W}$
2. Refer to Application Note AB20-4 Thermal Management Considerations for SuperFlux LEDs for discussion of $R_{\theta(j-a)}$ and T_j .

Device Types, Option Codes and Part Numbers

Lumileds uses an alphanumeric code, for example HPWT-MH00, to describe device types. The information in the Technical Data Sheet describes the characteristics and performance of each device type. When placing an order, it is important that customers use part numbers, not device types. Part numbers consist of the device type followed by a 5-digit

option code (e.g. -00000). The option code includes information about the minimum flux, flux range, color range, forward voltage range, and special requirements for the specific part number. Please contact your local Lumileds Lighting Field Sales Engineer for more information regarding available device types and option codes.

Packaging of SuperFlux LEDs

Tubes of LEDs

SuperFlux & SnapLED LEDs are packaged in tubes, each of which contains 60 LEDs. The LEDs in any individual tube come from a single category code. This means that they are all well matched for light-output, color, and forward voltage. Each tube contains a rubber stopper at each end. If the tube is held so that the lettering on the label is upright, then the label will be near the right end of the tube, and all the LEDs will be oriented so that the chamfered corner of the LED package is on the left. This chamfered corner identifies the cathode leads of the LED.

The tube label has both alphanumeric and bar code information. Figure 7.2 shows a sample label taken from a SuperFlux LED tube. Each label includes the Lumileds logo, the LED device type in alphanumeric above the corresponding bar code, a large 3-digit category code, a lot code for Lumileds' internal use, the 3-digit category code repeated in alphanumeric over the corresponding bar code, the quantity (which is always 60 pieces), and a date code. Lumileds' date code consists of the last two digits of the year followed by a two-digit

week number. Date code 0301 is the first week of 2003, or the week of January 1, 2003. Date code 0352 is the last week of 2003, or the week of December 31, 2003. Please note that tube labels include the device type and 3-digit category code, but not the specific part number used for ordering (device type plus option code).

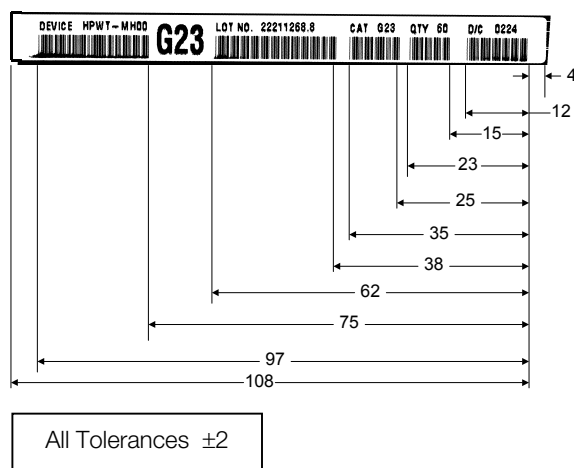


Figure 7.2

Example of SuperFlux LED tube label (dimensions in mm).

Bundles of LEDs

Individual tubes are combined into bundles of twenty for SuperFlux and ten for SnapLED. As with the individual tubes, bundles contain tubes from a single category code. Therefore all LEDs in the bundle are well matched for light-output, color, and forward voltage. All of the tubes are oriented in the same direction. Each bundle is shrink-wrapped in plastic as shown in Figure 7.3. A sample bundle label is shown in Figure 7.4. The following information is always included on the bundle label: Lumileds part number, 3-digit category code, lot code (for Lumileds' internal use), quantity (1,200 pieces per SuperFlux, 600 pieces per SnapLED), and the date code range. In addition, the following fields are provided for customer-specific information: vendor code, customer part number, customer revision level, and customer purchase order number. There are some restrictions regarding the format of each field, so please consult your Lumileds Lighting Field Sales Engineer if you require information in these customer-specific fields.



Figure 7.3
Example of SuperFlux LED bundle.

Lumileds occasionally creates special part numbers to accommodate special customer requirements. These special part numbers are similar to our standard part numbers except the 'H' at the beginning of the number is replaced by a 'Q', and the two '0's' in the second group of digits are replaced by a unique two-digit numeric code to identify the specific customer requirements (e.g. QPWT-DH99-E0000.) Bundle labels for these special parts will be labeled with the special part number. However, individual tube labels will contain only the device type and category code.

Boxes of LEDs

Each box of SuperFlux LEDs contains ten bundles, or 12,000 LEDs. The box dimensions are 510 x 255 x 115 mm (L x W x H). All of the bundles—and consequently all of the SuperFlux LEDs—are in the same orientation.

Lumileds bundles our SuperFlux LEDs in narrow categories and uses the option code portion of our part number to describe the categories used for each part. Lumileds has found that this provides a higher value to our customers than

enlarging our categories so that every box, shipment, or series of shipments includes only one category. Lumileds ships SuperFlux LEDs in 1,200 piece-matched bundles, but Lumileds does not offer a single category for a whole box, shipment, or series of shipments. The semiconductor material that generates the light emitted by SuperFlux LEDs is made in batches of wafers. These wafers are then cut into small, individual diodes, which are placed in SuperFlux LED packages. The electrical and optical

characteristics of these individual diodes vary across a wafer, between wafers, and between batches of wafers. In addition, the placement of these tiny diodes in SuperFlux LED packages can influence the electrical and optical performance of the SuperFlux LED. Therefore, each batch of SuperFlux LED's spans several categories. In addition, the exact distribution is not perfectly predictable: minute changes in source elements, other materials, or process conditions can affect the distribution of a batch of wafers or SuperFlux LEDs. Finally, growing semiconductor material and building it into SuperFlux LEDs is a lengthy process. Offering a single category or even a small number of

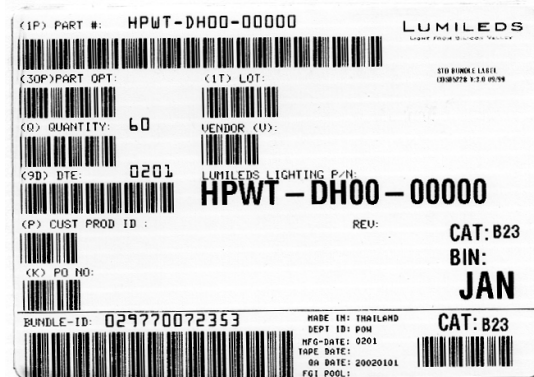


Figure 7.4
Example of SuperFlux LED bundle label.

categories for a whole box, shipment, or series of shipments would result in frequent interruptions in supply. Shifts in demand or supply distribution would result in a shortage of SuperFlux LEDs in one range and surpluses in other ranges.

Typical Category Distributions for SuperFlux & SnapLED LEDs and their Effect on the Lighting System and Assembly Process Design

All SuperFlux & SnapLED LEDs span several categories. The technical data sheet and Figure 7.1 describe the full range of categories for each product type. For example HPWT-MH00 products range from 611 to 634 nm, from 1.0 to 9.7 lm, and from 2.19 to 3.03 V. This section will briefly discuss the causes of these variations and their effect on exterior lighting system and assembly process design. The variation in

dominant wavelength is the easiest to explain and will be addressed first. This will be followed by explanations of forward voltage and luminous flux output variations. Although luminous flux output is typically the most important parameter, it will be easier to explain after variations in dominant wavelength and forward voltage are understood.

Variations in Dominant Wavelength (Color)

For most applications, the full range of color is acceptable. Lumileds splits the color ranges into categories to accommodate the differences in regional color requirements of our target markets. Due to local regulations, some applications may require parts from only

categories **1 & 2**; while applications in other regional markets may require parts from only categories **2 & 3**. For applications without strict local requirements, all color categories should be acceptable.

Offering only one or two color categories for a whole shipment, or series of shipments requires overbuilding, higher inventory levels, and a high-level of production oversight to avoid frequent interruptions in supply. Shifts in demand can result in a shortage of SuperFlux LEDs in one of the color categories and a surplus in the others. Therefore, supplying SuperFlux LEDs for applications that allow only one or two color categories significantly increases Lumileds' manufacturing cost, and will thus result in a price premium to the customer. Part numbers requiring only one or two color categories also require a longer lead-time between placing the order and receiving shipment. Customers that can accept only one or two color categories must work closely with their Lumileds representative to ensure continuity of supply.

The actual color ranges for HPWA-series and HPWT-series SuperFlux LEDs are slightly different. HPWT & HPWS-series LEDs are typically more red than HPWA-series SuperFlux LEDs. However, a single set of color category definitions is used for both series. As Lumileds gains experience with specific semiconductor materials, variation is gradually decreased. Lumileds is working to achieve this by improving our understanding of the semiconductor material, the appropriate process and material controls, and by working with regulatory bodies throughout the world to standardize color definitions. Lumileds would like to work together with our customers to influence regional regulatory bodies to move toward more favorable color ranges and color measurement techniques for LEDs.

Variations in Forward Voltage

As with color, most applications can accept the full range of forward voltage. In fact, most LED devices in the industry are not categorized according to forward voltage. Lumileds, however, has determined that categorizing our high-power LEDs according to their forward voltage can significantly increase the efficiency of our customers' lighting systems.

Resistors and other circuitry are typically required in voltage-driven circuits to ensure that all the LEDs receive the same current. It is important to control the current going through each LED to avoid thermally-induced failures—refer to Application Note AB20-4 *Thermal Management Considerations for SuperFlux LEDs* for further discussions on exceeding the maximum junction temperature of the LEDs.

However, in lighting systems that include a large number of LEDs, the drive circuitry can be a significant source of heat. If LEDs from a single forward voltage category are used, then they can be placed in parallel without sacrificing control of the current flowing through each LED. This simplifies the driving circuit design allowing it to be located in the wire harness or in another location far from the LEDs—please refer to Application Note AB20-3 *Electrical Considerations for SuperFlux LEDs* for a more in-depth discussion on voltage considerations for lighting systems.

A single drive circuit design may be used for Lumileds' whole range of voltage categories. It is only important that LEDs placed in parallel with each other all come from a single voltage

category. Lumileds marks the voltage category clearly on the side of each tube and on the outside of each bundle. Therefore, placing LEDs from different categories in parallel with each other can easily be avoided. However, in assembly processes that allow rework, it is important to consider voltage categories when replacing LEDs. Because it is difficult to effectively mistake-proof the rework process to avoid mixing voltage categories, Lumileds does not recommend removing and replacing LEDs during rework operations.

To understand variation in LED forward voltage, it is convenient to separate variation in the turn-on voltage from variation in series resistance (refer to Application Note AB20-3 *Electrical Considerations for SuperFlux LEDs* for a more detail description of these two parameters). The turn-on voltage is higher in amber devices than in red-orange devices—this is a fundamental property of the semiconductor energy band gap. In order to achieve the shorter wavelength, a higher turn-on voltage is required. Therefore,

the forward voltage of amber parts is typically about 100 mV higher than that of red-orange parts.

The series resistance of HPWT & HPWS-series AlInGaP LEDs is higher than that of HPWA-series AlInGaP LEDs. This is the result of the higher resistivity of the transparent material and of the unique process Lumileds uses to join the transparent-substrate and the light-emitting epitaxial layers. Therefore, at 70 mA the forward voltage of HPWT-series AlInGaP LEDs is typically 400 mV higher than that of HPWA-series LEDs.

This transparent-substrate process also introduces more variation in series resistance. Therefore, more categories are required for HPWT-series SuperFlux LEDs than for HPWA-series SuperFlux LEDs.

Lumileds' forward voltage process improvement efforts are focused on reducing both the variation and the magnitude of the series resistance of our LEDs.

Variations in Luminous Flux (Light-Output)

According to the table titled *Luminous Flux* in Figure 7.1, the HPWT-series LED light-output can range from 1.0 lm to 9.7 lm. This range is not ideal for most applications. First, almost ten times as many 1.0 lm LEDs as 9.7 lm LEDs would be required to meet a specific minimum light-output requirement. In addition, some applications require matching of lamps on the left and right side of the vehicle, e.g. rear combination lamps. Therefore, flux category information is important to virtually all lighting-system designs.

Currently Lumileds does not manufacture HPWT-series SuperFlux LEDs spanning this full range of light-output. Current production units do not populate the brightest categories in large amounts. However, one of Lumileds' most important goals is the improvement of LED material brightness. Nevertheless, it is important for lighting designs to accommodate several flux categories. The number of LEDs required for a specific application can be calculated based on the minimum light-output requirement for the lighting system, the minimum SuperFlux LED flux category to be used, the area to be illuminated,

and the operating conditions (voltage range, ambient temperature range, thermal resistance, etc). Once the number of LEDs required has been determined, the minimum flux category is set. There is typically no maximum category because the drive current or the optical transmittance of the cover lens can be reduced to accommodate more efficient LEDs. Please refer to Application Note AB20-3 *Electrical Considerations for SuperFlux LEDs* for further information on the effects of operating conditions and drive circuitry.

If the optical design efficiently matches the target radiation pattern (e.g. H-V does not have to be near the maximum in order to get off-axis test points above their minimums), then a single drive current can typically be used for four or more flux categories. However, as mentioned above, due to process-improvement efforts, Lumileds expects average light output to increase over time. At some point, the LEDs available from Lumileds will exceed the flux category range allowable using the initial drive current. The drive current or lens transmittance will have to be lowered to accommodate the brighter LEDs. Therefore, it is imperative that lighting system designers include information regarding the modifications required to accommodate brighter flux categories in their product and process documentation. This information should be documented so that the Engineer in charge of the product during its

second or third year of production will be able to find it and efficiently implement the change. Over-bright LEDs may be included in lighting-system risk analyses (e.g. Failure Mode and Effects Analyses, FMEA).

Optical designs that do not efficiently match the required radiation pattern or that require closely matched lamps (e.g. RCL) may not be able to accommodate four flux categories. These lighting system designs require an assembly process that can adjust driving circuitry or cover lens transmittance based on the flux category code. Again, please refer to Application Note AB20-3 *Electrical Considerations for SuperFlux LEDs* for further information on selecting drive circuitry.

Lowering the drive current prevents more efficient LEDs from exceeding the maximum light-output specification. However, if it is possible, lowering the number of LEDs required to fulfill a specific lighting requirement is usually a more cost-effective solution. In most automotive applications, the number of light sources in a lighting system cannot be changed without a complete redesign or freshening of the vehicle. In these situations, lowering the drive current or optical transmittance of the system are the only feasible solutions. However, in other applications—such as truck, bus, or aftermarket lighting—it is possible to reduce the number of emitters in response to improvements in LED efficiency.

Samples with Data for Optical System Characterization

The electrical models provided in Application Note AB20-3 *Electrical Considerations for SuperFlux LEDs* are suitable for conducting feasibility studies and for predicting ‘worst case’ scenarios. However, when designing an LED lighting system, it is important that optical prototypes be used frequently during the development process to confirm that there is sufficient light at each test point to meet photometric requirements and that the lit appearance is acceptable. Lumileds does not offer samples from the exact bottom (or top) of each category. However, Lumileds can provide

data logged samples for use in optical prototypes. In addition to labeling each tube of LEDs with the flux, color, and voltage categories of the devices; data logged samples are retested in order to record the average, minimum, and maximum luminous flux, dominant wavelength, and forward voltage for each sample set of LEDs. This data can be used to predict the brightness of a lighting system constructed with LEDs at the lower limit of the luminous flux specification. This measurement process is suitable for only a small quantity of LEDs due to the labor and testing required.

Requesting Flux Category Selections

Customers interested in obtaining a SuperFlux LED product with a minimum flux category brighter than **B**, or with a maximum flux limit, should contact their Lumileds Lighting Field Sales Engineer. Lumileds uses the option code portion of the part number to create a limited quantity of special part numbers with higher minimum flux categories and/or a restricted flux range based on our projected flux distribution.

These special products require careful management by Lumileds to ensure continuity of supply. Therefore, they are typically more expensive than standard products that accept our full-distribution. In addition, the standard lead-time for these special products may change more frequently, and dimmer options may become obsolete as typical SuperFlux LED light-output increases.

Company Information

Lumileds Future Electronics™ brings a unique relationship to the customer focused on delivering world-class products, engineering, support and services that make it easier to develop and manufacture "never before possible" Luxeon-based solutions.

By its charter, only Lumileds Future Electronics provides a comprehensive range of services designed to enable customers to develop and bring products to market more quickly and efficiently. With Engineering Resource Centers (ERC), comprehensive technical solutions support, worldwide inventory, custom product selection, 24 hour customer support, global supply chain capabilities and the Luxeon Lighting Network™, Lumileds Future Electronics is positioned to meet all your needs.

Lumileds may make process or materials changes affecting the performance or other characteristics of Luxeon. These products supplied after such change will continue to meet published specifications, but may not be identical to products supplied as samples or under prior orders.

LUMILEDS

www.luxeon.com
www.lumileds.com
www.lumiledsfuture.com

For technical assistance or the location of your nearest Lumileds Future Electronics sales office, call:

In North America:

1-888-Luxeon2 (589-3662)

In Asia:

800-LUMILEDS (586-4533)

In Europe:

+00 800 443 88873

Fax: 408-435-6855

Email us at info@lumileds.com

Lumileds Lighting, LLC
370 West Trimble Road
San Jose, CA 95131

Future Electronics
237 Hymus blvd.
Pointe-Claire, Quebec
H9R 5C7



©2005 Lumileds Lighting. All rights reserved. Lumileds Lighting is a joint venture between Agilent Technologies and Philips Lighting. Luxeon is a trademark of Lumileds Lighting, U.S. LLC. Product specifications are subject to change without notice.

Publication No. AB20-7 (08/2005)