LED Lighting

Understanding LED Performance

Rudi Hechfellner and Steve Landau explain how to make accurate performance assessments from a power LED datasheet

Understanding and comparing LED performance appears straightforward: get the datasheets, compare numbers for light output, efficacy and lumen maintenance, and make a decision. Unfortunately, any purchase and design decision based simply on the top-line numbers – the specs on the early pages – without analysis of how the LEDs will perform under real operating conditions can lead to unsatisfactory results and significant business risks. This article describes the tools contained in datasheets that can be used to show how an LED will perform under real operating conditions.

LED Lamp

Use of these tools is best illustrated by way of an example. Let us imagine that you are to design a single-LED desk lamp with the highest possible light output. The average lamp must be capable of producing light output after 50,000 hours of operation at a level that is at least 70% of output when the lamp was new. A key part of this design project will be to choose an appropriate brand of power LED as the light source.

This example compares high-performance power LEDs from four leading suppliers, identified here as MFR 1-4. It uses only publicly available datasheet information as provided by each of the manufacturers for their own LED. The example headline light output figures for each device are shown in Table 1.

This data does not allow a like-for-like comparison, as the MFR 3 part is specified at 700 mA. The brief, however, was to maximise light output consistent with the lifetime goal of 50,000 hours. By driving the LEDs at 350 mA (as per the datasheet figures),

Table 1. Example headline product specifications for minature power LEDs.

LED	Datasheet Min. Flux	Datasheet drive current	Datasheet test temp	Datasheet test time
MFR 1	91 lm	350 mA	T_A 25C	25 ms
MFR 2	107 lm	350 mA	T_J 25C	25 ms
MFR 3	130 lm	700 mA	T_A 25C	25 ms
MFR 4	100 lm	350 lm	T_{Pad} 25C	25 ms

T_A: Ambient Temperature
T_J: Junction Temperature
T_{Pad}: Solder Pad Temperature

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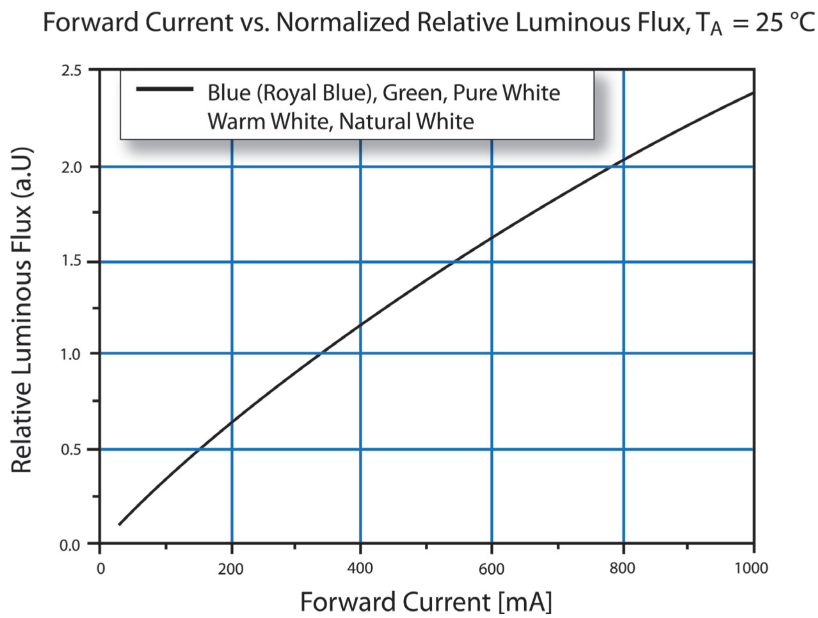

Figure 1. Example of Flux normalization graph.

we would not be maximising light output, so let us instead compare all four LEDs at the higher figure of 700 mA (see Table 2).

For three of the parts, this means applying the 'flux normalisation' graph found in each datasheet (see Figure 1 for a typical example). The graph will provide a factor to use for each specific LED to calculate the light output produced at the higher current.

As we now see in Table 2, the MFR 3 emitter is no longer the leader in light output, but the comparisons here are still some way from being like-for-like, since we are not yet comparing the LEDs' performance in actual operating temperatures.

For this we need the 'temperature derating' graph provided in every manufacturer's datasheet. First, we must specify the conditions in which our LEDs will operate: the ambient temperature, and the thermal resistance of the luminaire. Using conservative assumptions (an ambient tem-perature of 25°C and a small heat sink), the light output comparison in Table 3 has changed strikingly when compared with Table 2.

The first interesting point to note is that the MFR 3 part cannot be used at all under these conditions: the high system thermal resistance drives the temperature at the LED junction up to 141°C, 16°C above its maximum rated value. Also interest-ing is the rate at which the output from the MFR 1 part declines under these conditions.

We now have a much more realistic basis for comparing different brands of LED. But we still have not taken into account the requirement for 70% lumen maintenance after 50,000 hours.

Table 2. Raw comparison of LEDs at 700 mA drive current.

Manufacturer	Datasheet Min. Flux	**Normalize** to drive current	**Normalized** Min. Flux @ 700 mA	Datasheet test temp	Datasheet test time
MFR 1	91lm	**700 mA**	**164 lm**	T_A 25C	25 ms
MFR 2	107 lm	**700 mA**	**182 lm**	T_J 25C	25 ms
MFR 3	130 lm	700 mA	130 lm	T_A 25C	25 ms
MFR 4	100 lm	**700 mA**	**165 lm**	T_{Pad} 25C	25 ms

Table 3. Comparison of light output under real operating temperature conditions.

Manufacturer	Datasheet Minimum Flux	Actual Drive Current	**Normalized** Min. Flux @ 25 C	Datasheet T_J max.	Operating T_J (calculated) @ 25CA, Rth50K/W	Determine Flux De-rating Factor	Actual Flux
MFR 1	91 lm	**700 mA**	**164 lm**	145C	**135C**	72%	**118 lm**
MFR 2	107 lm	**700 mA**	**182 lm**	150C	**128C**	78%	**142 lm**
MFR 3	130 lm	700 mA	130 lm	125C	**141C**		
MFR 4	100 lm	**700 mA**	**165 lm**	150C	**130C**	81%	**133 lm**

Again, all datasheets provide lumen maintenance information and it is important to look carefully at the operating conditions that apply to valid data sets (see Table 4). For the MFR 4 emitter, these operating conditions are consistent with the lumen maintenance conditions: the device is able to provide 50,000 hours of use at a junction temperature of 135°C; in the desk lamp example, the LED will actually run at 130°C. So we now know that the MFR 4 LED will produce at least 133 lumens when new, and will still provide at least 70% of peak output after 50,000 hours.

Table 4 also shows the conditions under which the MFR 2 part can pro-vide 70% lumen mainte-nance at 50,000 hours: the junction temperature – the temperature at the LED itself – must be 85°C or less. But in our example, when driving LEDs at 700 mA for high light output, the MFR 2 de-vice runs at a much higher 128°C.

Simple Comparisons

The simplest way to compare the MFR 2 emitter with the others in our example while achieving a 50,000-hour lifetime is to lower the drive current to a value at which junction temperature is 85°C. To achieve this, current must be reduced to 407 mA, and at this low current the LED only produces 107 lumens, versus the 133 lumens from the MFR 4 LED at the full 700 mA. Additionally, off-the-shelf LED drivers are generally available only for 350 mA or 700 mA. Since 407 mA is not a standard value, a custom solution would likely have to be created, which could add cost to the solution.

The conditions that apply in the raw statements of performance shown in Table 1 and typical of LED datasheets are very different from those that apply in real luminaires. Only through analysis of the LED performance metrics based on the actual application and intended environment can an appropriate selection decision be made.

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Table 4. LED output consistent with 50,000-hour lifetime requirement.

Manufacturer	Calculated Lumens	Lumen Maintenance L70 Claim	Datasheet T_J max.	L70/50Kh conditions	Actual Operating T_J (calculated)	Calculated current to achieve lumen maintenance	Final Calculated Lumens
MFR 2	**142 lm**	**50,000 hours**	150C	$T_J \leq 85C$ $T_A \neq 25C$	**128C**	407 mA	107 lm
MFR 4	**133 lm**	**50,000 hours**	150C	$T_J \leq 135C$ & if ≤ 700 mA T_A N.A.	**130C**	700 mA	133 lm

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