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Technical Notes

Issue 3 January 2011

Specifying LEDs: How to read an LED datasheet

This Technical Note discusses information found on an LED datasheet and is intended to give ***engineers, system designers, and manufacturers*** assistance in reviewing LED packages and making purchasing decisions for their lighting products.

The Information contained in this article builds on previous Technical Notes. See also: http://www.lightingafrica.org/resources/briefing-notes.html

Introduction

LEDs, like all electronic components, have specifications that describe the device performance. Specifications are typically listed on a datasheet that contains enough information to allow a designer or engineer to use the component in an electronic assembly.

LED performance can vary widely and is a function of the LED chip quality, the LED package, and all of the materials and manufacturing steps used in the process of making the device. The LED datasheet is the primary way to initially identify the performance capabilities of the device.

There is no standard format for an LED datasheet, but all datasheets should contain a minimum amount of information about the device. Some information is common to all electronic components, and some is specific to LEDs and their optical and thermal performance. The metrics listed in this Briefing Note are not intended to include *all* of the information on an LED datasheet. Rather, it is suggested that a lighting manufacturer should have access to *at least* this much data for the LEDs used in their products.

Lamp manufacturers should not hesitate to ask for additional information from LED manufacturers where data appears to be inaccurate or missing from an LED datasheet.

Accuracy of Datasheet Information

The information on an LED datasheet is provided by the LED manufacturer, and may not in all cases be accurate. Light output data in particular should be treated with skepticism, as most photometric data are measured by the LED manufacturer and usually do not take into account temperature effects on light output under real world operating conditions.

LED Electrical Characteristics

Absolute Maximum Ratings – these values should never be exceeded under any circumstances:

- **Maximum Forward Current** (Continuous/Pulsed)
- **Maximum Operating Temperature**
- **Maximum LED Junction Temperature** (Tj)

Operating Characteristic - Normal operating parameters will vary from LED to LED in any production batch. Operating characteristics provide numeric ranges for these parameters.

Forward Voltage (min, max, average) at a specific drive current.

Thermal Resistance (Junction to Solder Point) This is the resistance, in °C/W, between the LED chip and the heat sink lead of the LED package.

Derating Curves – External conditions alter the current and voltage characteristics of the LED. Derating profiles show these relationships and provide limits for safe device operation.

It is *strongly* recommended that lamp manufacturers verify the performance of their products independently, and do not rely solely on the information contained in the LED datasheet. The datasheet should be used in the initial LED evaluation process, and also throughout engineering development as a guide to system design and prototyping. The datasheet claims should not, however, be used as a substitute for actual product performance tests.

A Note about Light Output

There are two ways to list the light output of an LED: luminous intensity and/or luminous flux. The preferred method for lighting products is to list the Luminous Flux, or lumen output, of the LED at its rated drive current. This is often given at a 25°C LED Junction Temperature and is measured by the LED manufacturer during the manufacturing process. Under real world conditions, however, the LED junction temperature will be higher than 25 °C, and the output of the LED will be lower than the value on the datasheet. Testing the final product is the most reliable way to determine the light output.

Lower power LEDs will often have luminous intensity listed instead of luminous flux. The intensity value is the peak intensity of the LED. This value should *not* be confused for luminous flux.

LED Optical Properties

Luminous Flux – Luminous Flux is a measure of the *total* light output of the LED and is independent of the light distribution (or focusing) of the LED.

Intensity – Peak intensity (or brightness), measured in candela (cd) or millicandela (mcd), can be given instead of luminous flux. Intensity should *not* be confused for luminous flux.

Viewing Angle – The lens on the LED determines the light distribution. An LED can have a tight beam or a wide distribution of 180° or more.

Correlated Color Temperature (CCT) /Chromaticity/ Color Rendering Index (CRI) - Color information is always provided and should include binning tolerances and CRI minimums.

Light Output vs. Temperature – Light output characteristics change when the LED die heats up during normal operation. Lumen output drops and the color can shift with increased temperature.

Lifetime - This information will often be contained in a separate document dedicated to the measurement and prediction of LED lifetime. Lifetime is a function of LED chip temperature and drive current.

The performance of individual LEDs of the same type will vary slightly from LED to LED. This is a normal result of the manufacturing process.

When they come off the assembly line, LEDs are tested one at a time and sorted into 'bins' with other similar LEDs. The bin categories are usually Forward Voltage, Luminous Flux (or Intensity) output, and Chromaticity (or Correlated Color Temperature, CCT).

Bins are used to sort LEDs into subgroups with consistent performance characteristics. Luminous flux bins are used to separate high lumen output LEDs from lower ones. These are often sold at a higher price.

Color bins are used to distinguish one LED color from another. Color values can be given as Correlated Color Temperature (CCT) ranges or, more accurately, as x,y coordinates on a color chart (such as the 1931 CIE Chromaticity Diagram).

Handling Precautions

Soldering Instructions - Temperature profiles and time limits for reflow are given to ensure no damage to the LED during soldering.

Footprint Pad Design - PCB footprint guidelines allow proper heat dissipation and mechanical solder attachment to the PCB substrate.

Moisture Sensitivity – LEDs will absorb atmospheric humidity and may be damaged during soldering without proper precautions.

Automated Equipment - Nozzle design of pick and place equipment can damage LED lens materials if not properly chosen.

Storage Temperature - Do not exceed these limits during LED or product storage.

ESD rating – Electrostatic discharge may damage LEDs during handling and PCB assembly.

LED Datasheet Examples - The following examples show some of the methods typically used to convey datasheet information. They are not particular to any one LED, and every manufacturer will use their own format and specific layout.

The numeric values used in the examples are typical of low and mid power LEDs in the ½ watt range and below. Actual LED performance, however, will vary widely according to the specific LED make and manufacturer.

LED Electrical Ratings – Typical and maximum ratings are usually the first information provided by an LED datasheet.

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Power Dissipation	P_d	100	mW
Forward Current	I_F	30	mA
Pulsed Forward Current [1]	I_P	100	mA
Reverse Voltage	V_R	5	V
Operating Temperature	T_{OP}	-40 to +85	°C
Junction Temperature	T_j	125	°C
Storage Temperature	T_{STG}	-40 to +100	°C

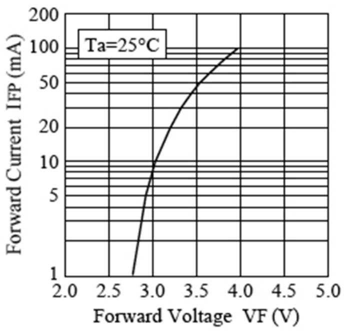
[1] I_P conditions: pulse width ≤ 10 msec. and duty cycle ≤ 1/10

Electro –Optical Characteristics

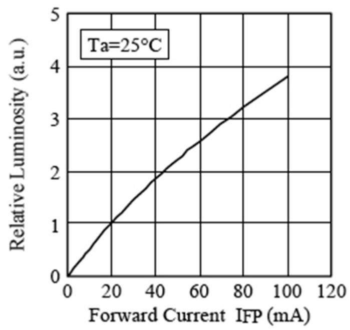
Parameter	Symbol	Condition	Min.	Typical	Max	Unit
Forward Voltage	V_F	I_F=20 mA	3.2	3.4	3.6	V
Reverse Voltage	V_R	I_R= 5 mA	-	0.9	1.2	V
Luminous Flux	Φ_V	I_F=20 mA		4		lm
Luminous Intensity		I_F=20 mA		3000		mcd
Correlated Color Temperature	CCT	I_F=20 mA		5000		K
Viewing Angle [2]	$2\Theta_{1/2}$	-		70		degrees
Color Rendering Index	Ra	I_F=20 mA	67	70	-	-
Thermal Resistance	R_{j-c}	I_F=20 mA		250		°C/W

[2] $2\Theta_{1/2}$ = FWHM = the off-axis angle where the luminous intensity is ½ the peak intensity

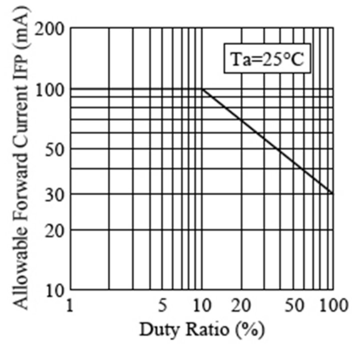
■ Forward Voltage vs. Forward Current



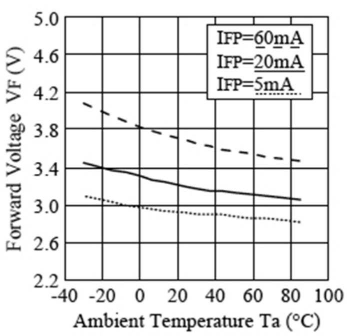
■ Forward Current vs. Relative Luminosity



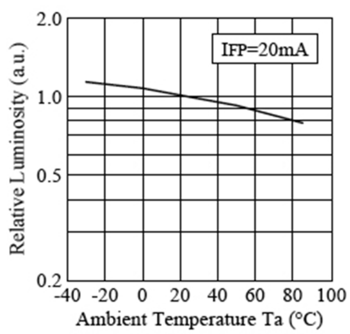
■ Duty Ratio vs. Allowable Forward Current



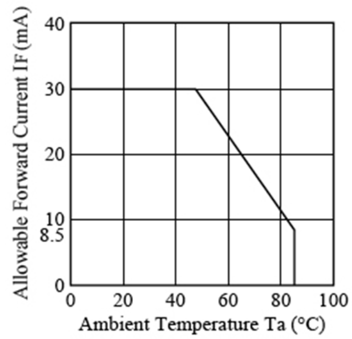
■ Ambient Temperature vs. Forward Voltage



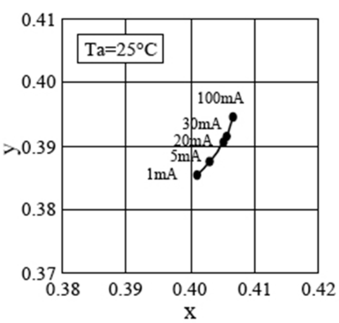
■ Ambient Temperature vs. Relative Luminosity



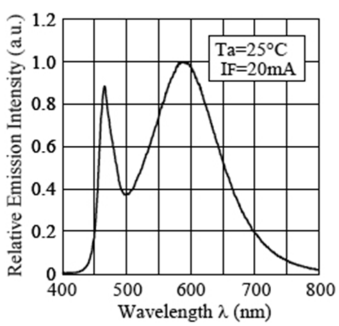
■ Ambient Temperature vs. Allowable Forward Current



■ Forward Current vs. Chromaticity Coordinate

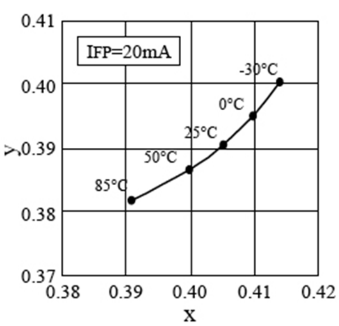


■ Spectrum

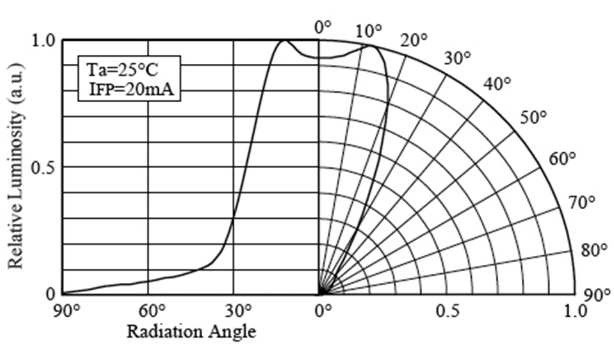


Graphs provide much of the data necessary to run the LED in a safe, reliable manner. The examples shown here should all be included *somewhere* in the datasheet, though the format and presentation may be different.

■ Ambient Temperature vs. Chromaticity Coordinate



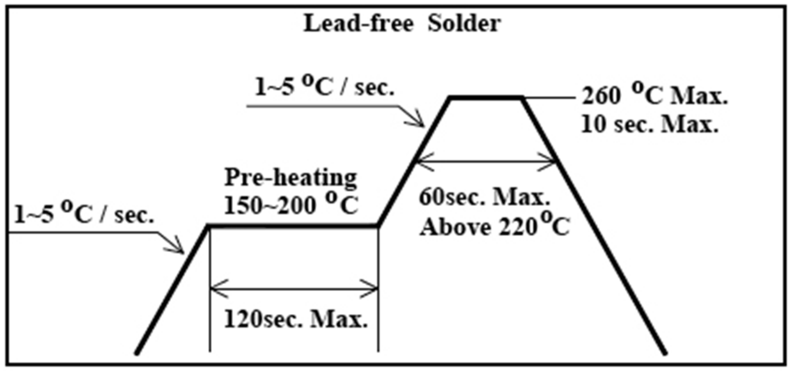
■ Directivity



Soldering - Soldering profiles should include pre-heating times, maximum temperatures, and ramp rates for all stages of the reflow process. Hand soldering guidelines should also be provided (if hand soldering is possible for the LED type)

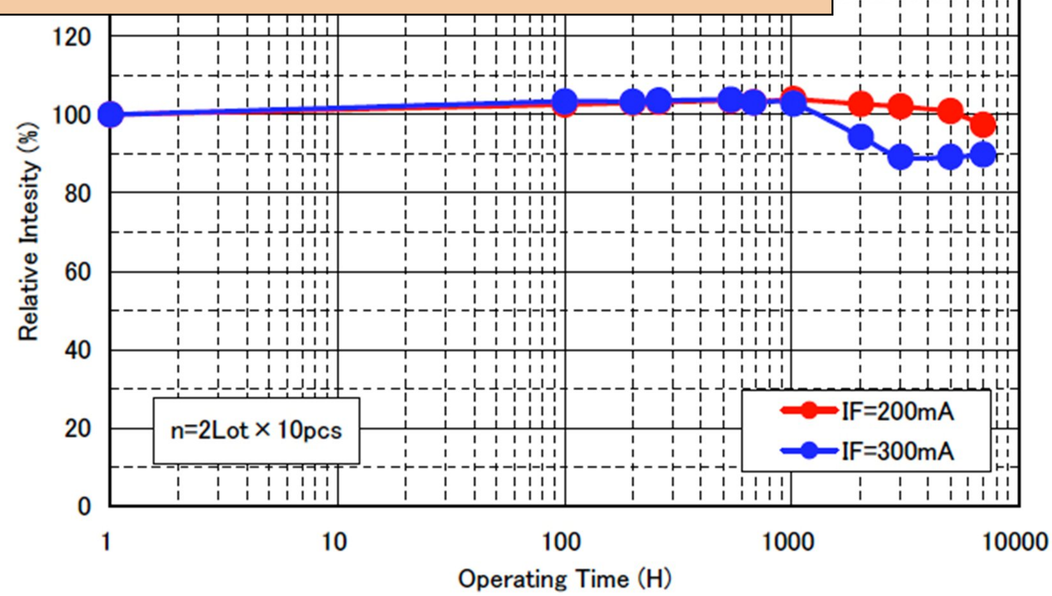
(2) Lead-Free Solder

Lead Free Solder	
Pre-heat	150~200℃
Pre-heat time	120 sec. Max.
Peak-Temperature	260℃ Max.
Soldering time Condition	10 sec. Max.



(3) Hand Soldering conditions
Do not exceed 4 seconds at maximum 315ºC under soldering iron.

Lifetime – LED lifetime information is often contained in a separate document. The data are based on standard test conditions and should cover at least 6000 hours of operation. Note that this information covers only the LED in a laboratory environment. Real world conditions for the LED in a lighting system can dramatically alter the lifetime of the LED.



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Binning – LEDs are sorted into bins by the LED manufacturer. The bin categories are luminous flux (or luminous intensity), forward voltage, and color. Color categories are usually given as x,y coordinates on the 1931 CIE Chromaticity chart.

Bin Code		
Luminous Intensity	CIE	Forward Voltage
S5	G5	Z1

Luminous Intensity (mcd) @ I_F = 100mA			Flux (lm)
Bin Code	Min.	Max.	Typ
Q5	7500	8000	25.8
R0	8000	8500	27.7
R5	8500	9000	28.7
S0	9000	9500	30.6
S5	9500	10000	33
T0	10000	10500	34
T5	10500	11000	35.6
V0	11000	11500	36

Color Rank @ I_F = 100mA
A~H

Forward Voltage (V) @ I_F = 100mA		
Bin Code	Min.	Max.
Y3	2.9	3.0
Z1	3.0	3.1
Z2	3.1	3.2
Z3	3.2	3.3
A1	3.3	3.4

CCT
5300~7000 K (CIE A,B)
3700~5300 K (CIE C,D,E)
2600~3700 K (CIE F,G,H)