Application Brief AB12

LUXEON
never before possible

Custom LUXEON®
Design Guide

Introduction

The objective of this design guide is to provide customers with the technical resources necessary to identify custom LUXEON® Power Light Sources for unique applications. A LUXEON Power Light Source is a configuration of LUXEON Light Emitting Diodes (LEDs) mounted on an aluminum-core printed circuit board (PCB). LUXEON Power Light Sources, also referred to as "Level 2" products, are customized to meet the requirements of indoor and outdoor applications. Lumileds Lighting also builds standard LUXEON Power Light Sources in a variety of configurations.[1]

Lumileds Lighting offers both standard products, as described in the product data sheets and customized LUXEON solutions to customers who require specialization. Customization requires a high volume commitment, and is therefore not suitable for low volume applications. In these cases, the standard LUXEON Star may be easily assembled by the customer. Lumileds Lighting charges for non-recurring engineering costs to develop a custom LUXEON Power Light Source.

If the standard product board sizes or configurations do not fit in your application, a custom LUXEON Power Light Source may be the solution. For information on product lines other than LUXEON, please consult your regional Lumileds sales representative.

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PHILIPS

LUMILEDS
Light From Silicon Valley

Benefits of LUXEON Technology

- Highest Flux per Light Source in the world
- Very Long Operating Life (up to100k hours)
- Superior Material Technology: Aluminum Indium Gallium Phosphide (AlInGaP) for Red, Red-Orange and Amber, and Indium Gallium Nitride (InGaN) for White, Green, Cyan, Blue, and Royal Blue
- More Energy Efficient than Incandescent and most Halogen lamps
- Low Voltage DC operated
- Cool Beam, Safe to the Touch
- Instant Light (less than 100ns)
- Virtually Maintenance-Free Operation
- Fully Dimmable
- No UV
- Superior ESD Protection

Order Process

Complete Custom Design Information Form

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Formal Quote from Lumileds

↓

Customer Approval of Quote. Commitment from Lumileds to develop the custom Luxeon product.

↓

Finalize Custom Design Information Form/Specification and bill NRE

↓

Begin Product Development

↓

Ship High Volume Order to Customer

Guidelines for Design

Although LED technology offers many benefits to various applications, semiconductor light sources behave differently than conventional incandescent or halogen light sources. To assess if LUXEON technology will meet your application demands, we use a Custom Design Information Form to summarize the detailed requirements. Please contact your local Lumileds sales representative or our website to obtain a "Custom Design Information Form"[2]. In addition to the guidance of sales engineers, this design guide will assist you in completing this three-page summary.

General Project Tracking Information

The second page of this form contains the table shown in Figure 1. The purpose of this table is to list the basics of the requested product and gage the customer's expectations.

Figure 1. Custom Design Information Form.

Start Date:	State date of project
Last Update / By:	Record maintenance
Target date for quote:	When do you expect a formal quote from Lumileds?
Customer:	Your Company Name
Customer project name:	Customer internal/external product name
Customer part number:	
Lumileds part number:	
Application:	Where will this product be used?
Product functionality description:	What is the product going to do?
Level 2 board option: · Standard · Customized Design	Is a custom product necessary or does Lumileds have product that will serve the needs of application?
Customer Expectations on quantity and timing (mark all that apply): · Prototypes (built to final specs) · Pre production (product for reliability testing by customer) · Production (full volume commitment)	Once a design is agreed upon, how many samples will be required and when?
Estimated cumulative volume over 3 years after product release:	What is the total volume required for this product?
Target price for Custom Design:	What price is the customer expecting?
Customer Contact:	Name, Phone Number, Email Address of main design engineer contact.
Lumileds contacts (Sales Engineer)	Name, Phone Number, Email Address of Lumileds Representative

Initial Light Technical Requirements

The third page of the form defines the initial light output requirements as shown in Figure 2. For customers not familiar with LED technology, this section will assist in describing the unique light output measures of LEDs. For more information on light measurement, please review the Light Measurement Handbook.[3]

Figure 2. Custom Design Information Form, Initial Light Technical Requirements.

Lifetime Conditions: · Operating hours · Ambient temperature range · Lumen maintenance expectations	What is the total on-time of the product? What is the average board temperature over this period of time? How much light loss is expected?
Optical flux or radiated power required from LED array stated in lm or mW (required for quoting): · Minimum · Typical · Maximum	What is the minimum and maximum amount of flux required for total application (photometric or radiometric)?
Dominant Wavelength (nm) or Peak Wavelength (nm) of CIE coordinate window or Color Temperature (K): · Minimum · Typical · Maximum	What is the acceptable color range?
Specify the maximum to minimum flux ratio requirement within the array. (Typical ratio is approximately 2:1)	How much can the light output vary from LED to LED on one single board?
LED radiation pattern requirement (batwing, lambertian, or other).	Lumileds offers several types of LEDs, each with a different radiation pattern.
Direct view or indirect view application?	Final application for illumination?
Are secondary optics used in this application?	Will the customer be designing optics?
Other:	

Light Output Measures

There are several different ways to describe the amount of light emitting from a light source. LED light is most commonly characterized by on-axis luminous intensity expressed in candela. Intensity describes the flux per solid angle radiated from a source of finite area (Figure 3).[4] Flux is the total amount of light or energy emitted from a source in all directions (Figure 4). It is important not to confuse or interchange the two descriptions.

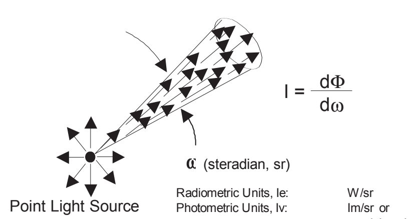


Figure 3. Definition of Intensity.

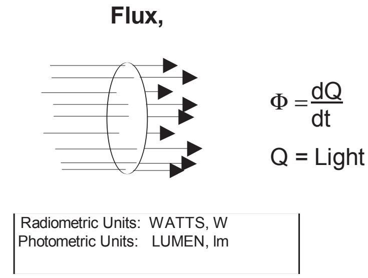


Figure 4. Definition of Flux.

Radiometric vs. Photometric Light Measures

Radiometric light is specified according to its radiant energy and power without regard for the visual effects of radiation. Photometric light is specified in terms of human visible response according to the CIE standard observer response curve (photopic luminous efficiency function). In the world of photonics and solid state physics, luminous efficacy is defined as the conversion between photometric flux, expressed in Lumens, and radiometric flux, expressed in Watts. Figure 5 plots the luminous efficacy over the InGaN wavelength range. Figure 6 shows the photometric to radiometric flux conversion for the AlInGaP spectrum.

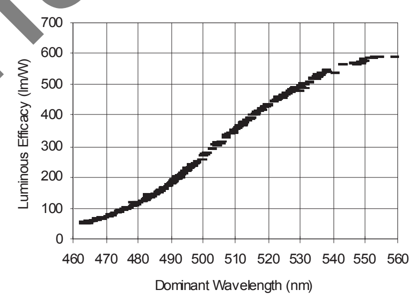


Figure 5. Luminous Efficacy vs. Dominant Wavelength for InGaN Material.

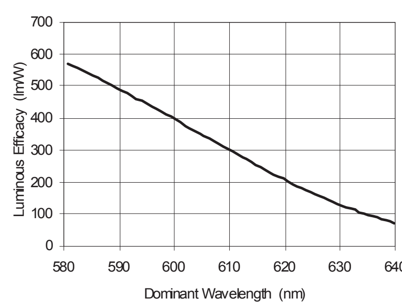


Figure 6. Luminous Efficacy vs. Dominant Wavelength for AlInGaP Material.

Typical Flux Performance

As our material performance improves, the flux values per lamp will increase. For the most current luminous flux performance values, please refer to the LUXEON Star Power Light Sources technical data sheet[1] or contact your Lumileds Authorized Distributor or sales representative. Unless otherwise specified, Lumileds builds to flux per array requirements and may decrease the number of LEDs in a given array over time.

Wavelength

LEDs color is defined by the wavelength. Wavelength can be defined as peak or dominant. Peak wavelength is the peak of the radiated spectrum. Dominant wavelength and x,y chromaticity coordinates define color as perceived by the human eye. The dominant wavelength is derived from the CIE Chromaticity Diagram and represents the perceived color of the device. Figure 7 gives the dominant and peak wavelength and spectral halfwidth values for Lumileds product. Spectral halfwidth is defined as the width of the spectral curve for the device at the ½ power point. Figure 8 gives the optical characteristics for Lumileds White LUXEON Power Light Sources.

Compared to broadband conventional light sources, color LEDs have a nearly monochromatic emission of color. This means that LEDs emit light in a narrow wavelength range and do not require the use of a filter to achieve a specific wavelength. Traditional white light sources contain every color in the visible spectrum then are filtered to get a narrow wavelength range. All the excess filtered light is wasted in addition to the wasted energy.

Figures 9 and 10 give the spectral distribution for LUXEON LEDs.

Figure 7. Dominant Wavelength.

$\lambda_{Dominant}$ Color	$\lambda_{Dominant}$ Typ.	Spectral Half-width Range	λ_{Peak} $\Delta\lambda_{1/2}$	Typ.	Units
Red	625/627	620.0-645.5	20	638	nm
Red-Orange	617	613.0-631.5	20	627	nm
Amber	590	584.0-597.5	14	592	nm
Green	530	519.5-560.5	35	522	nm
Cyan	505	489.5-520.5	30	503	nm
Blue	470	459.5-490.5	25	464	nm
Royal Blue	455	439.5-460.5	20	450	nm

Figure 8. White LED Color.

	Typical Color Temperature CCT	Color Rendering Index
White	4500 K	CRI 70

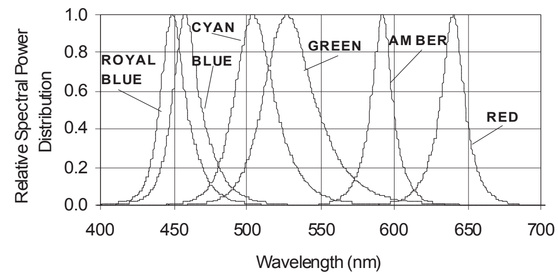


Figure 9. Relative Intensity vs. Wavelength.

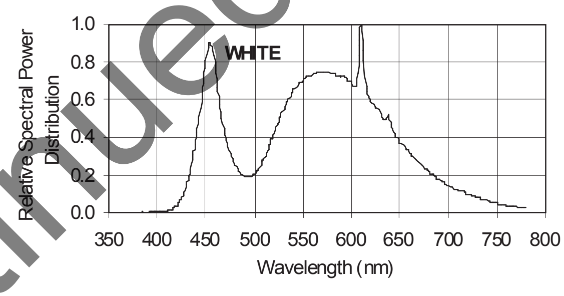


Figure 10. Relative Intensity vs. Wavelength for White.

LED color can shift with temperature. For AlInGaP product, the wavelength shifts to longer wavelengths with increased temperature. Figure 11 gives the shift values. With an increase in junction temperature, white LED correlated color temperature (CCT) also shifts to higher values (Figure 12). Figure 13 graphs the eye sensitivity to changes in wavelength. Because the human eye cannot discriminate small changes in wavelength in the red region, Lumileds does not maintain narrow color bins for the red spectrum.

Figure 11. LED Color Shift.

Color	$\frac{\Delta\lambda_{Dominant}}{\Delta T_J}$	$\frac{\Delta\lambda_{Peak}}{\Delta T_J}$	Units
Red	+0.03	+0.13	nm/ºC
Red-Orange	+0.06	+0.13	nm/ºC
Amber	+0.09	+0.13	nm/ºC
Green	+0.04	+0.05	nm/ºC
Cyan	+0.04	+0.05	nm/ºC
Blue	+0.04	+0.05	nm/ºC
Royal Blue	+0.04	+0.05	nm/ºC

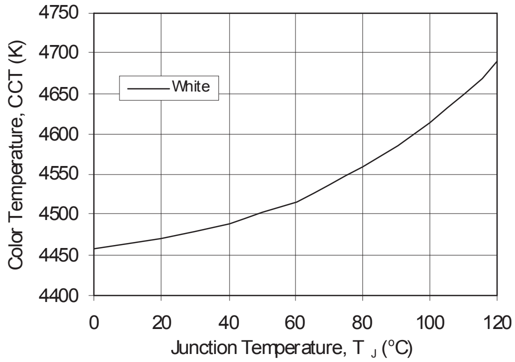


Figure 12. Color Temperature Shift.

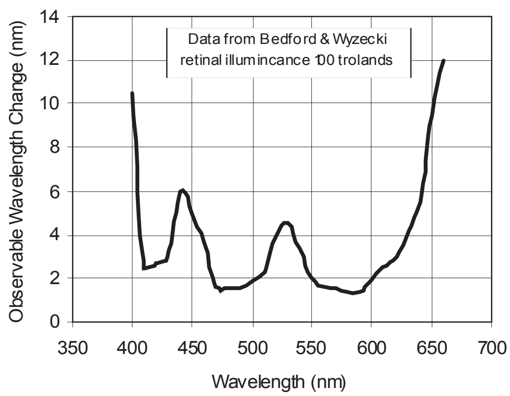


Figure 13. Hue Discrimination.

LEDs and Eye Safety

In the 1993 edition of IEC-60825-1, LEDs were included: "Throughout this part 1 light emitting diodes (LED) are included whenever the word "laser" is used." The CENELEC document EN 60825-1 contains all the technical content of the IEC standard.

The scope of the IEC standard states that "…products which are sold to other manufacturers for use as components of any system for subsequent sale are not subject to IEC 60825-1, since the final product will itself be subject to this standard." Therefore, it is important to determine the Laser Safety Class of the final product. However, it is important that employees working with LEDs are trained to use them safely. Most of the products containing LEDs will fall in either Class 1 or Class 2. A Class 1 label is optional:

CLASS 1 LED PRODUCT

If a label is not used, this description must be included in the information for the user. Class 2 products shall have affixed a laser warning label, and an explanatory label:

LED RADIATION
DO NOT STARE INTO BEAM
CLASS 2 LASER PRODUCT

Amendment 2 to IEC 60825-1 is expected to be published in January 2001. The CENELEC equivalent is expected to follow three months after the IEC publication. This document contains increased Class 1 and Class 2 limits, as well as the introduction of less restrictive Class 1M and Class 2M.

For the exact classification and further information, the IEC documents can be used:

IEC-60825-1
ISBN 2-8318-4169-0
This is available from the IEC at the following address:
IEC
3, Rue Varembé
Geneva, Switserland
www.iec.ch

LED Binning Schemes

Every LED used in LUXEON Power Light Sources is measured for flux, color, and forward voltage and placed in a bin with given tolerances. The test current for all LEDs is 350mA. The more LEDs in the array, the more options are available for mixing. Lumileds does not bin LUXEON Power Light Sources.

Light Output Degradation of LEDs

Compared to conventional light sources, LEDs have a very long mean time between failure (MTBF), over 100,000 hours. This value indicates that very few of these solid state lighting devices will catastrophically fail and emit no light. After 50k hours the expected mortality is <5%.

Over time, LED light output does degrade based on environment and drive conditions. The degradation characteristics vary by material technology and LED package. Lumileds Lighting continues to do extensive research on the degradation characteristics of LEDs for several different parameters to ensure product reliability. In Figures 14-15, the degradation data on the LEDs used in LUXEON Power Light Sources is presented. These extrapolations are based on average data of LEDs. The expected average decline in flux is 30-35%, provided the system is operated within specified conditions.

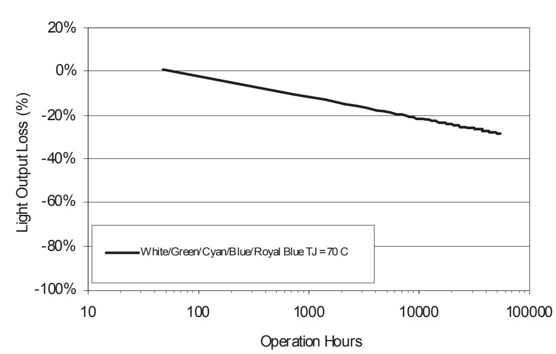


Figure 14. Light Output vs. Time for White, Green, Cyan, Blue and Royal Blue at I_F 350mA, Relative Humidity less than 25%.

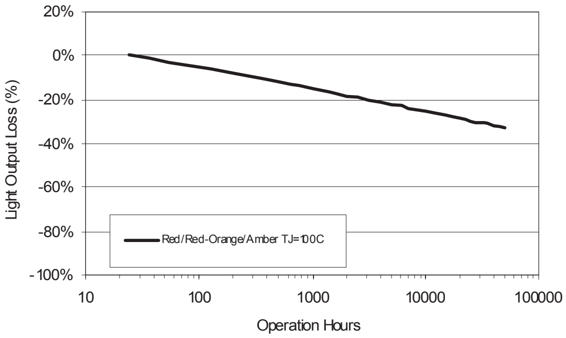


Figure 15. Light Output vs. Time for Amber, Red-Orange and Red at 385mA.

LED Performance Versus Temperature

The light output of Red, Red-Orange and Amber LUXEON, is sensitive to temperature. There is a temporary light output loss at higher temperatures and a light gain at lower temperatures. These losses are recoverable when the temperature is brought to its original value. White, Green, Cyan, Blue and Royal Blue LEDs do not lose as much light as AlInGaP LUXEON with increased temperature. Figures 16 and 17 illustrate the amount light loss to expect at a given junction temperature. This behavior varies more for AlInGaP products than for InGaN products.

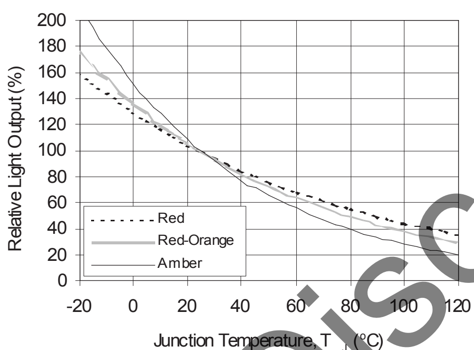


Figure 16. Temporary AlInGaP Light Output Loss (typical performance).

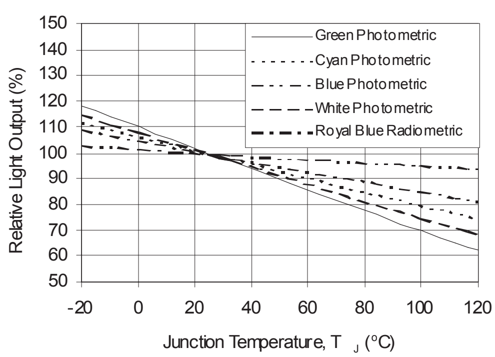


Figure 17. Temporary InGaN Light Output Loss (typical performance).

LED Radiation Patterns

There are two distinct radiation patterns in the LUXEON product family, batwing and lambertian. The batwing pattern is a wide-angle radiation pattern, with peak intensity near 40 degrees. The design provides uniform illuminance to a planer secondary optic. The lambertian devices provide a wider, flat radiation pattern. See Figures 18-20 for the relative luminous intensity versus off-axis angle data. ASAP model ray bundles for these LEDs are available upon request.

Batwing Radiation Patterns

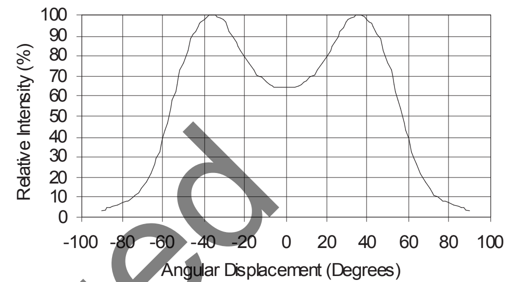


Figure 18. Representative Spatial Radiation Pattern for White.

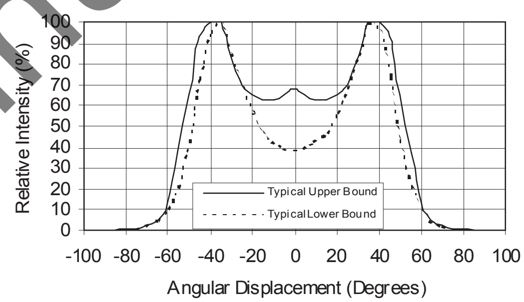


Figure 19. Representative Spatial Radiation Pattern for Red, Amber, Green, Cyan, Blue and Royal Blue.

Lambertian Radiation Pattern

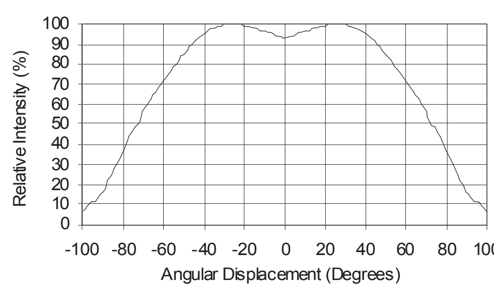


Figure 20. Representative Spatial Radiation Pattern for Red, Red-Orange and Amber.

Thermal Requirements

The fourth page of the outline also requests the thermal requirements of the applications, see Figure 21. Since certain materials used to compose LED are sensitive to temperature, it is critical that Lumileds engineers understand the entire temperature range of the product over its lifetime. It is the customer's responsibility to ensure the heat management of the total system maintains the LED array within defined temperature limits.

Figure 21. Custom Design Information Form, Thermal Requirements.

Ambient Temperature range of the application: · Maximum storage temp (no power) · Minimum storage temp (no power) · Maximum operating temp (powered) · Typical operating temp (powered) · Minimum operating temp (powered)	What is the maximum storage temperature of the product? At each possible temperature, what is the percentage on-time of the LED array?
Estimated heat sink area (calculated based on flux and operating conditions.)	Heat sink area required to stay within absolute maximum ratings.
Customer calculated predicted thermal resistance from junction to ambient (°C/W or K/W)	What is the approximate thermal resistance of the entire design?
Other:	

Good thermal system design is critical to achieve the best efficiency and reliability of LUXEON Power Light Sources. As was mentioned earlier, AlInGaP experiences a reversible loss of light output as the temperature increases. The lower the die or junction temperature is kept the better the luminous efficiency of the product. The equation shown in Figure 22 can be used to calculate the junction temperature of LUXEON device. LUXEON Power Light Sources do require additional heat sinking to the aluminum-core PCB.

Figure 22. Junction Temperature Calculation.

$$T_J = T_A + (P * R\Theta_{J-A})$$

Junction refers to the p-n junction within the semiconductor chip. This is the region of the chip where the photons are created and emitted.

T_A = Ambient temperature
P = Power dissipated
= Forward current * Forward voltage
$R\Theta_{J-A}$ = Thermal resistance junction to ambient

Maximum Thermal Ratings

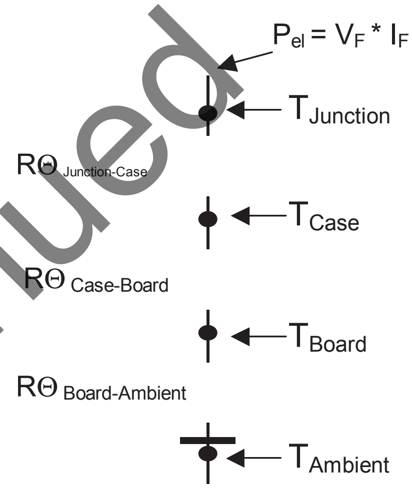
To ensure the reliability of custom LUXEON Power Light Sources, please observe the absolute maximum thermal ratings for the LEDs provided in Figure 23.

Figure 23. Thermal Maximum Ratings.

Parameter	Maximum	Units
LED Junction Temperature	120	°C
Aluminum-Core PCB Temperature	105	°C
Storage/Operating Temperature	-40 to 105	°C

Thermal Path

Heat transferred from the die follows the following thermal path: junction to case, case to board, and board to air (see Figure 24). In LUXEON Power Light Sources, the junction to board thermal path has been carefully analyzed by Lumileds to maximize the amount of heat dissipated. Due to the various applications and subsequent environments suitable for LUXEON Power Light Sources, the responsibility of thermal design, board to ambient, lies solely on engineer using the product. The designer must take into account the various ambient temperatures the LUXEON Power Light Source will experience over its lifetime and the light output requirements for the application, to successfully analyze the thermal path to maximize the light output. Please note that the ambient temperatures should include other sources of heat such as electronics or heating due to sun exposure.



$$R\Theta = \frac{ÄT}{P}$$

ÄT = Temperature difference (°C)
P = Power dissipated (W)

$$R\Theta_{J-A} = R\Theta_{J-C} + R\Theta_{C-B} + R\Theta_{B-A}$$

The thermal resistance of the LED in a Luxeon Power Light Source, junction to case is 15°C/W ($R\Theta_{J-C}$).

Figure 24. Thermal Path of LED.

Thermal Resistance

Thermal resistance, $R\Theta_{J-C}$, is a key parameter in thermal design. In order to calculate the junction temperature this parameter must be known. Thermal resistance is the opposition of heat conducted through and eventually away from the LED. This opposition or resistance causes a temperature difference between the source of the heat and the exit surface for the heat. The less heat retained by the LED the more enhanced its performance and lifetime. The complexity of thermal resistance and thermal management is increased when multiple LEDs are located on a single board. For further information please see "*Thermal Design Considerations for LUXEON Power Light Sources*"[5].

Electrical Requirements

On the fifth page, the electrical parameters of the design are highlighted, given in Figure 25. Understanding the electrical parameters or limitations of the application driver is important for insuring optimum performance of the LED array. Lumileds does not develop custom electronic drivers for custom LUXEON Power Light Sources.

Figure 25. Custom Design Information Form, Electrical Specification.

Forward voltage for the array: · Minimum · Maximum	This is the minimum and maximum LED forward voltages multiplied by the number of LEDs per string.
Current through the array: · Minimum · Maximum	This is the minimum and maximum LED current (after current regulation) multiplied by the number of LED strings.
Power consumption of array: (W)	Power consumption is the array forward voltage multiplied by the forward current through the array.
Duty factor: ($I_{average}/I_{peak}$)	What percentage of total time is the array powered on? The crest factor is the inverse of the duty factor.
Maximum initial current	This value is dependent on the driver electronics.
Maximum peak voltage:	The electrical isolator used in the aluminum-core PCB has a maximum breakdown voltage of 2000V AC and/or DC.
Other:	

Circuit Design: [6]

LEDs are current dependant devices. As such, current limiting devices are required in the drive circuitry. The most common method of current regulation is current limiting resisters placed in series with LEDs.

Calculating the resistor values necessary to achieve the desired current is clear-cut. Simply follow the equations seen in Figure 26. Bear in mind, there is a linear relationship between the forward current (I_F) and the forward voltage (V_F) of the LEDs. Specifically, as the forward current of the LEDs increases, the forward voltage also sees an increase. Figures 27 and 28 illustrate this relation with typical I_F and V_F values. Note that there exists forward voltage variation from LED to LED. These variations must be considered and accounted for in the electrical design.

For series strings, the fewer the LEDs in the string the better the current control and intensity matching. Consequently, the more uniform the current supplied to each LED, the greater the current drop across the current limiting resistor. This can unfortunately mean an increase of power consumption, and ensuing heat generation of the resistor.

DC Operation: $$R = \frac{V_{IN} - yV_F - V_D}{xI_F}$$

Pulsed Operation: $$R = \frac{V_{IN} - yV_F - V_D}{xI_{F\ PEAK}}$$

V_{IN} =	input voltage applied to the circuit
V_F =	forward voltage of LED emitter at forward current I_F
V_D =	voltage drop across optional reverse transient EMC protection diode
y =	number of series connected LED emitters
x =	number of paralleled strings

Figure 26. Current Limiting Resistor Calculations

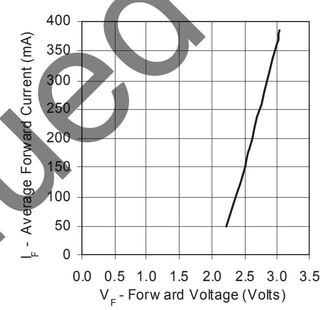


Figure 27. Forward Current vs. Forward Voltage for Red, Red-Orange and Amber.

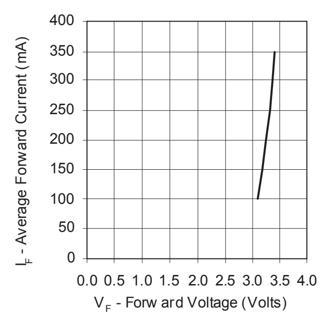


Figure 28. Forward Current vs. Forward Voltage for Green, Cyan, Blue, Royal Blue and White.

When the temperature increases, the forward voltage of the device decreases. This shift varies upon material type (see Figure 29).

Figure 29. LED Forward Voltage Shift.

Color	$\frac{\Delta V_F}{\Delta T}$	Units
Red	-2	mV/ºC
Red-Orange	-2	mV/ºC
Amber	-2	mV/ºC
Green	-2	mV/ºC
Cyan	-2	mV/ºC
Blue	-2	mV/ºC
Royal Blue	-2	mV/ºC
White	-2	mV/ºC

DC vs. Pulsed Operation

In general DC operation is the most simple and efficient way of driving LEDs. When operating an LED device under DC drive conditions, the forward current determines the light output of the LEDs as shown in Figures 30 and 31. This linear relationship between forward DC current and flux assumes a 25ºC maintained junction temperature. As the DC current is increased, the junction temperature increases. Without proper heat sinking, the efficiency of the product suffers.

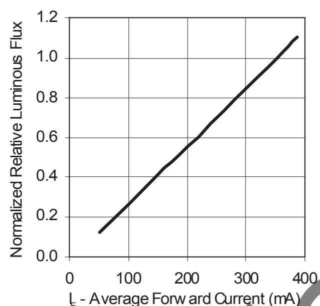


Figure 30. Relative Luminous Flux vs. Forward Current for Red, Red-Orange and Amber.

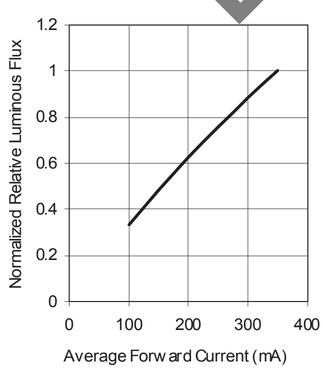


Figure 31. Relative Luminous Flux vs. Forward Current for Green, Cyan, Blue, Royal Blue, and White.

An alternative to DC operation is Pulsed Operation. This alternative is attractive when dimming is desired. Pulse width modulation is the best way to achieve dimming ratios greater than 3:1. The maximum electric ratings are given in Figure 32. These ratings should not be exceeded when pulsed operation is applied. Further, at frequencies less than 1000 Hz, the peak junction temperature is higher than the average max junction temperature. As a result, the light output and lifetime of the device could be sacrificed. At a minimum, a refresh rate of more than 100 Hz is strongly recommended. Frequencies less than 100 Hz are not fast enough to prevent observable flicker.

Driving these high power devices at currents less than the test conditions (all products tested at 350mA) will produce unpredictable results and is subject to variation in performance.

Sinusoidal waveforms are generally not recommended. The rms power will exceed that of a rectangular current waveform with the same peak current value. If a sinusoidal waveform is used, the peak current should not exceed the maximum DC current rating. Sinusoidal waveforms produce less light than an equivalent rectangular pulse.

Maximum Electrical Ratings

The two criteria that establish the operating limits are maximum drive currents and the absolute maximum LED junction temperature. The maximum drive currents per LED have been provided to ensure long operating life. The absolute maximum LED junction temperature is a device package limitation that must not be exceeded. Figure 32 gives the absolute maximum electrical ratings for the LEDs used in LUXEON Power Light Sources.

Figure 32. Electrical Maximum Ratings (per LED).

Parameter	Red Red-Orange Amber	Green/Cyan/Blue Royal Blue/ White	Units
DC Forward Current	385	350	mA
Peak Pulsed Forward Current	550 (DF≤65%)	500 (DF≤70%)	mA
Average Forward Current	350	350	mA
Reverse Voltage (I_F = 100μ A)	> 5		V

The thermal maximum ratings must not be exceeded when driving the product at the electrical maximum values. These values are limited by the thermal design of the entire system. To determine what the limits of operation are for your application, see Figures 33 and 34. Figures 33 and 34 only provide the derating curves for one LED based on different thermal resistance values, junction to ambient. Calculations must be done to set the derated limits for array applications. Staying within the safe region of these curves will ensure reliable performance.

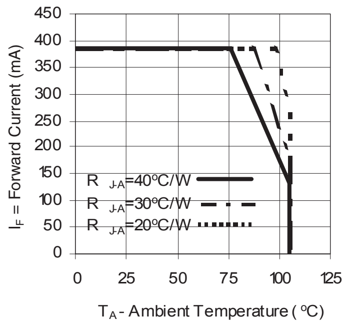


Figure 33. Maximum Forward Current vs. Ambient Temperature.
Derating based on T_{JMAX} = 120°C for Red, Red-Orange and Amber.

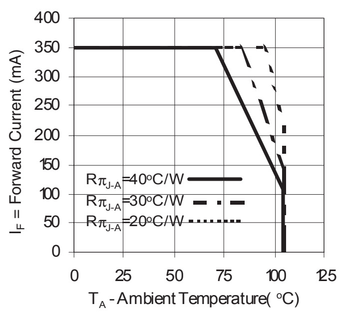


Figure 34. Maximum Forward Current vs. Ambient Temperature.
Derating based on T_{JMAX} = 120°C for Green, Cyan, Blue, Royal Blue and White (per LED).

Electrical Breakdown

EMC, electromagnetic compatibility, is a realistic problem for many LED applications. When a large transient voltage is applied to an LED or LED array, the LED shorts and catastrophically fails.

LUXEON InGaN LEDs include a transient voltage suppression chip to protect the LED from electrostatic discharge (ESD) damage. All LUXEON products are not sensitive to ESD damage (+/-16,000 Volts by the Human Body Model condition).

Testing

Figure 35 lists the possible testing for the custom LUXEON Power Light Source. Lumileds does a 100% test for flux, forward voltage, and color on the LEDs. We do not test the LUXEON Power Light Sources for those parameters. Lumileds has done extensive reliability testing on the LEDs used in LUXEON Power Light Sources. Figures 36 and 37 outline the environmental and mechanical tests completed.

Figure 35. Custom Design Testing Information.

Functionality test required: (See design guide)	Flux testing is provided on the LEDs, not the complete array. Light up testing can be done on the final assembly. No absolute light measurements on the final assembly.
Reliability tests required:	Does the product need to be qualified for additional lifetime testing?
Other:	

Figure 36. Environmental tests on LUXEON LEDs.

Test Name	MIL-STD 883 Ref	JIS C 7021 Ref.	Test Conditions	Units Tested	Units Failed
Temperature Cycle	1010	Method A-4	-40°C to +120°C, 30min. dwell, 5min. transfer, 200 cycles	465	0
Temperature Shock	HP Req.	HP Req.	-40°C to +110°C, 20min. dwell, <20 s transfer, 500 cycles	238	0
Temperature Shock	HP Req.	HP Req.	-40°C to +120°C, 5 min. dwell, <10 s transfer, 500 cycles	58	0
High Temperature Storage	1005	Method B-10	110°C for 1000 hr.	60	0
Low Temperature Storage	1005	Method B-12	-40°C for 1000 hr.	60	0
Low Temperature Storage	1005	Method B-12	-55°C for 1000 hr.	60	0
Moisture Resistance	HP Req.	Method B-11	85°C, 85% RH, for 1000 hr.	120	0
Humidity Life	HP Req.	Method B-11, Condition C	85°C, 85% RH, 280 mA for 1000 hr.	240	0
Humidity Reverse Bias	HP Req.	Method B-11, Condition C	85°C, 85% RH, -5V for 1000 hr.	120	0
Temperature Humidity Cycle	1004	Method A-5	-10°C to 65°C, 90-98% RH, 50 cycles	180	0
Corrosion Salt Atmosphere	1009	HP Req.	35°C, 48 hr.	20	0

Figure 37. Mechanical Tests on LUXEON LEDs.

Test Name	MIL-STD 883 Ref	JIS C 7021 Ref.	Test Conditions	Units Tested	Units Failed
Mechanical Shock	2002	Method A-7 Condition F	14,700 m/s2 max acceleration, 0.5 ms pulse width, 6 axes, 5 shocks each	20	0
Vibration Variable Frequency	2007	Method A-10 Condition D	10-2000-10 Hz log or linear sweep rate 20 G about 1 min., 1.5mm	20	0
Vibration Variable Frequency	2007	Method A-10 Condition D	10-55-10 Hz, ± 0.75 mm, 55-2k Hz 10 G, 3 axes	20	0
Natural Drop	HP Req.	Method A-8	on concrete from 1.2m, 3x	20	0
Random Vibration	HP Req.	HP Req.	6 G RMS from 10 to 2k Hz, 20 min/axis	20	0

Mechanical Requirements

On the sixth page of the outline, the mechanical requirement information can be found, Figure 38.

Figure 38. Custom Design Information Form, Mechanical Requirements.

Total assembly design envelope	In the final assembly, how much total area is available for the LED assembly?
AMP CT Connector or solder pads: (2 to 5 leads)	Lumileds uses these as standard connectors.
SMD resistor components?	Which other components must be on board? Fewer components gives better thermal managment.
Multiple planes in LED assembly? If yes, how many?	Does the application require a multidimensional board?
Solder mask color:	Green is our standard solder mask color, black is available at an additional charge.
Labeling or tracability requirements for the custom design	What specific labeling or barcodes need to be on the boards or panels?
Special packaging or shipping requirements.	Details of packaging. Number of boards per panel. Labels on packages.
Other:	

Aluminum-Core PCB Essentials

Aluminum-core PCB contains several layers to insure proper electrical connections as well as heat management. The board is fully insulated to protect the device from shorts or opens. The total thickness of aluminum-core PCB is 1.6mm. The LED cases are attached to the copper cladding with a heat-conducting adhesive. The leads are soldered to a copper-cladding layer that conducts current. A layer of solder resist is applied the entire top layer of the board except in the spots where the LED cases are attached to the copper cladding. White and black solder masks are also available for a price premium.

Use black solder resist to minimize the refection of sunlight off the board. The next layer is a layer of dielectric. This layer provides electrical insulation between the copper cladding and the aluminum base. However, this layer does allow heat to be transferred to the heat sink. The final and thickest layer of the aluminum-core PCB is an aluminum plate. See Figure 39 for a schematic of the aluminum-core PCB layers.

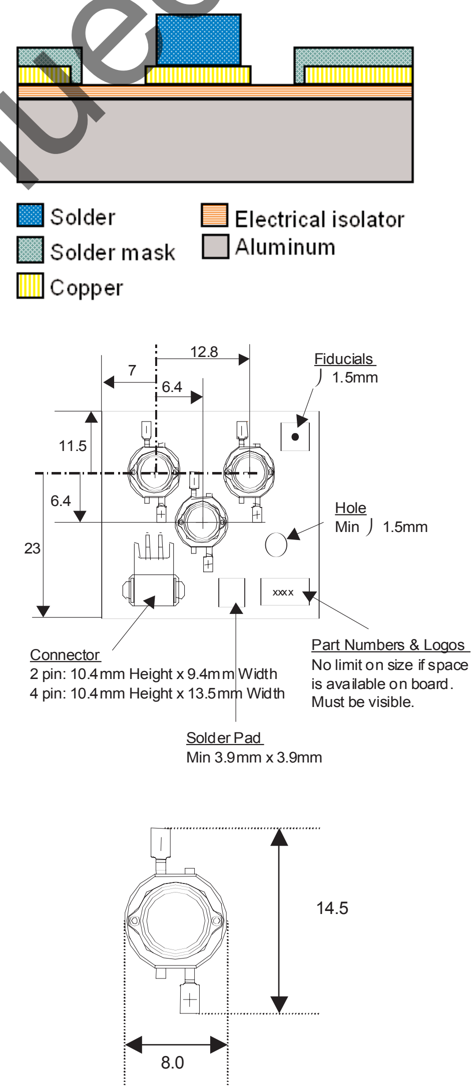


Figure 39. Details of Aluminum-Core PCB.

Board Lay-Out

There are a few things to keep in mind when designing the board layout. All LEDs should be in the same orientation and same direction with production flow. It is not possible to place components at angles less than 90 degrees with the edge of the board. Figure 40 illustrates the component placement guidelines and tolerances. Additional components can be added to the board. However, they must be surface mount devices and should not be taller than 7.2 mm +/-0.5mm. Any holes, text, bar code labels or logos can also be included in the board layout schematic. Lumileds will design the routing of the copper tracks (crossover traces available). Multilayer boards are also available. Multilayer boards with greater than two layers are very expensive.

Tolerances

LED Tolerances:	+/-0.5mm
LED Placement:	1.6mm in vertical 0.8mm in horizontal
Hole Tolerances:	If Ø </= 3mm, +/-0.05mm If Ø > 3mm, +/-0.2mm

Figure 40. Component Placement and Tolerances (all dimensions in millimeters).

Panel Lay-Out

Custom LUXEON Power Light Source boards are produced in panels that are scored for disassembly of the individual boards. There must be a clearance of 2.5mm around the panel for manufacturability. Lumileds uses an algorithm to calculate the number of boards per panel yielding the best-cost optimization. The maximum size panel for solder deposition and SMT placements by our supplier is 400 x 400 mm. The maximum size panel of multiple boards for Lumileds processing is 400 x 400 mm with a minimum size of 60 x 60 mm.

Clearance and Fiducials

There is a minimum amount of clearance that must be left on the edges of the LUXEON Power Light Source boards for manufacturability, 2.5 mm. Fiducials are also required for accurate positioning of the LEDs. Figure 41 clarifies these parameters.

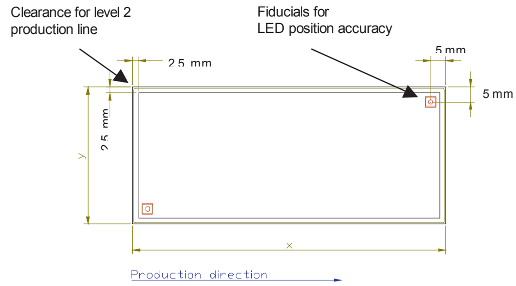


Figure 41. Board Clearance and Fiducials.

Standard Lumileds Connectors

Lumileds uses standard AMP CT SMT connectors. The type is AMP CT 2-179123-x (x is the number of pins). Non-Lumileds standard connectors and components can be placed on the aluminum-core PCB, however Lumileds must qualify the parts for thermal compatibility.

Figure 42 is a general overview of a possible LUXEON Power Light Source custom design.

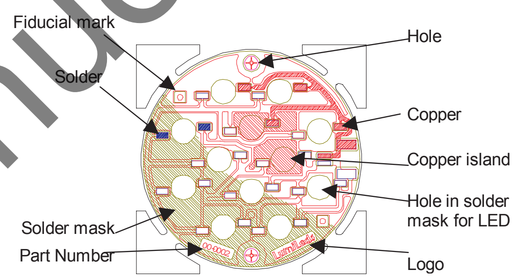


Figure 42. Board Design Example.

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6. Agilent Technologies, Application Note 1005, Operational Considerations for LED Lamps and Display Devices, (Palo Alto, CA: Agilent Technologies, Inc., 1999) 3.

Company Information

LUXEON® is developed, manufactured and marketed by Philips Lumileds Lighting Company. Philips Lumileds is a world-class supplier of Light Emitting Diodes (LEDs) producing billions of LEDs annually. Philips Lumileds is a fully integrated supplier, producing core LED material in all three base colors (Red, Green, Blue) and White. Philips Lumileds has R&D centers in San Jose, California and in The Netherlands and production capabilities in San Jose and Penang, Malaysia. Founded in 1999, Philips Lumileds is the high-flux LED technology leader and is dedicated to bridging the gap between solid-state LED technology and the lighting world. Philips Lumileds technology, LEDs and systems are enabling new applications and markets in the lighting world.

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

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