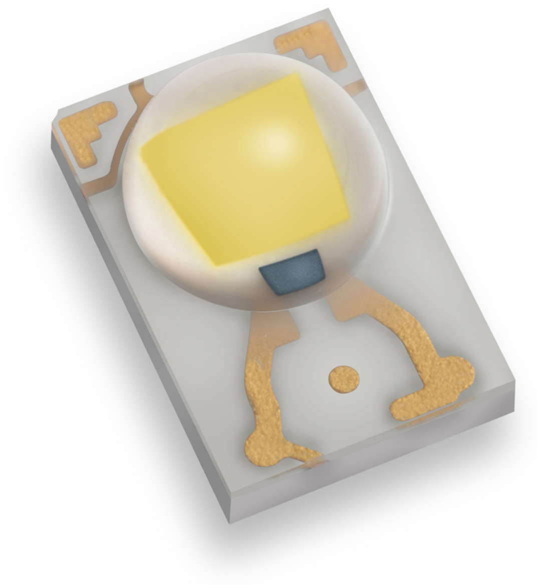

LUXEON H
Assembly and Handling
Information

Application Brief AB67

L U X E O N®
never before possible

LUXEON H

Assembly and Handling Information

Introduction

This application brief covers recommended assembly and handling procedures for LUXEON® H emitters (part number LXAC-PW27 and LXAC-PW30). LUXEON H emitters are designed to operate at high voltages, enabling space-constrained retrofit bulbs and luminaires while minimizing driver requirements.

Proper assembly, handling, and thermal management will ensure high optical output and long LED lumen maintenance.

PHILIPS
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Table of Contents

1. Component

1.1 Reference Documents

The form factor of LUXEON H is similar to the form factor of other LUXEON Rebel emitters. Therefore, all assembly and handling guidelines discussed in Application Brief AB32 also apply to LUXEON H emitters. This document only outlines assembly and/or handling guidelines which are different or specific to LUXEON H (e.g. operation with a voltage instead of a current regulated driver scheme). In addition to this document you will need to refer to:

- Application Brief AB32: LUXEON Rebel and LUXEON Rebel ES Assembly and Handling Guide
- LUXEON H Technical Datasheet, DS67

1.2 Description

The LUXEON H emitter is a revolutionary, ultra-compact, surface mount, high-voltage LED. The cross section in Figure 1 highlights the main components of the LUXEON H package. Each package contains a high brightness LED chip array on a ceramic substrate. The ceramic substrate provides mechanical support and thermally connects the LED chip array to a heat pad on the bottom of the substrate. An electrical interconnect layer connects the LED chip to a cathode and anode (not visible in this cross-section) on the bottom of the substrate. A silicone lens over the LED chip array extracts the light and shields the chip array from the environment. Every LUXEON H emitter contains a transient voltage suppressor (TVS) chip under the lens to protect the emitter against electrostatic discharge (ESD).

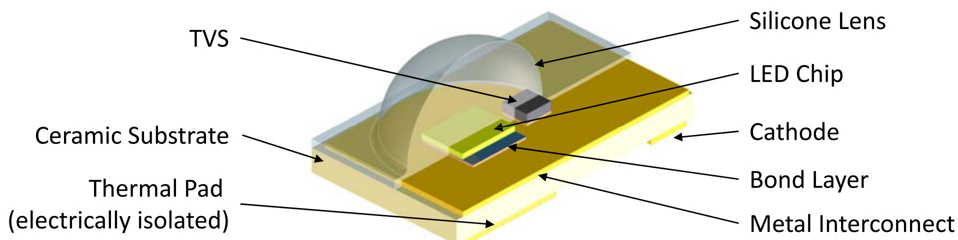

Figure 1. 3D rendering of LUXEON H emitter.

1.3 Optical Center

The LUXEON Rebel package contains three feature sets that locate the theoretical optical center. These features are the topside fiducials, backside metallization, and LED outline.

The LUXEON H package has three fiducial marks, labeled F1, F2, and F3 in Figure 2. These fiducial marks provide the most accurate methodology to locate the theoretical optical center. The theoretical optical center is located 1.450mm from the vertical and horizontal edges of fiducial marks F1 and F2. The theoretical optical center also lies 2.248mm above the center of fiducial F3, along an imaginary line drawn between the center of fiducial F3 and the midpoint between fiducials F1 and F2. The actual optical center for each LUXEON H package is within a circular diameter of 0.290mm with respect to the theoretical optical center.

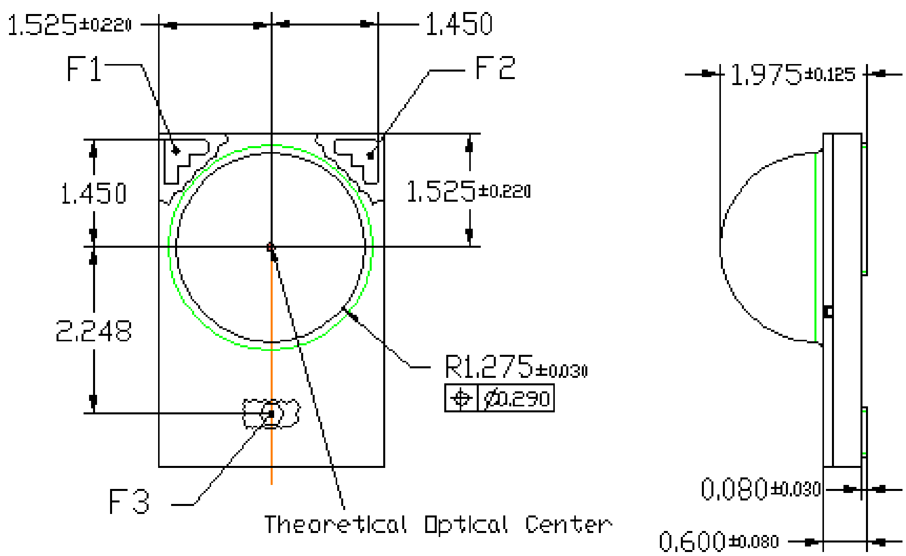

Figure 2. The most accurate method to find the theoretical optical center and the center of the dome is by using the fiducials located on the front side of the LUXEON H LED. All dimensions are in mm.

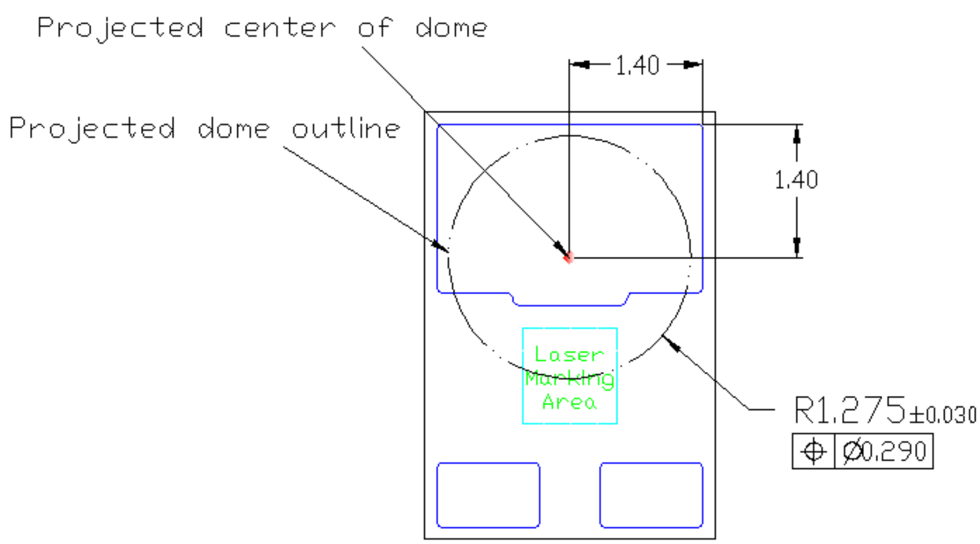

Figure 3. The theoretical optical center may be located using the edges of the thermal pad on the bottom of the ceramic substrate. The center of the silicon dome will be within a 0.35mm radius with respect to the theoretical optical center. All dimensions are in mm.

The optical center can also be located using the edges of the thermal pad on the bottom of the ceramic substrate as shown in Figure 3. The actual position of the center of the lens is within a circle with a diameter of 0.290mm with respect to the theoretical optical center found using the edges of the thermal pad as a reference. The optical center is located 1.525mm from the top and side of the LUXEON H edges (see Figure 2).

1.4 Lens Handling

See Section 1.3 of Application Brief AB32.

1.5 Cleaning

See Section 1.4 of Application Brief AB32.

1.6 Electrical Isolation

The ceramic substrate of the LUXEON H package electrically isolates the thermal pad from the LED cathode and anode (see the cross section in Figure 1). Since LUXEON H is designed to operate with RMS working voltages up to 60V, the distance between the electrodes on the bottom of the ceramic substrate has been increased compared to standard LUXEON Rebel LEDs to comply with minimum creepage distance requirements according to IEC60950, clause 2.10.4. As a reference, the minimum distance between the anode and cathode on the bottom of the ceramic substrate is 0.63mm and the distance between the electrodes and thermal pad exceeds 1.65mm (see Figure 4).

In order to avoid any electrical shocks and/or damage to the LUXEON H LED, each luminaire design needs to comply with the appropriate standards of safety and isolation distances, known as clearance and creepage distances, respectively. Compliance with appropriate standards is application and design specific. Examples of standards are IEC 60065 for audio/video equipment and IEC 60598 for general lighting applications.

1.7 Mechanical 3-D

The 3-D STP file format for LUXEON H is available from the Philips Lumileds website at www.philipslumileds.com and www.philipslumileds.cn.com.

1.8 Soldering

LUXEON H emitters are designed to be soldered onto a printed circuit board. For general board design guidelines and handling instructions for high brightness LEDs, see Sections 2 - 4 of Application Brief AB32.

1.9 Metallization Pattern / PCB Board Layout

The metallization pattern at the bottom of the ceramic substrate for LUXEON H is slightly different than the metallization pattern of LUXEON Rebel devices, see Figure 4. In particular, the distance between the anode and cathode is larger to satisfy minimum creep requirements at the higher operating voltages of LUXEON H. PCB footprints for LUXEON H are available on the Philips Lumileds website at www.philipslumileds.com and www.philipslumileds.cn.com.

Note that the standard LUXEON Rebel PCB footprint is designed for low-voltage applications, i.e. the standard LUXEON Rebel footprint may not meet all relevant creep specifications when used for LUXEON H, which operates at substantially higher voltages.

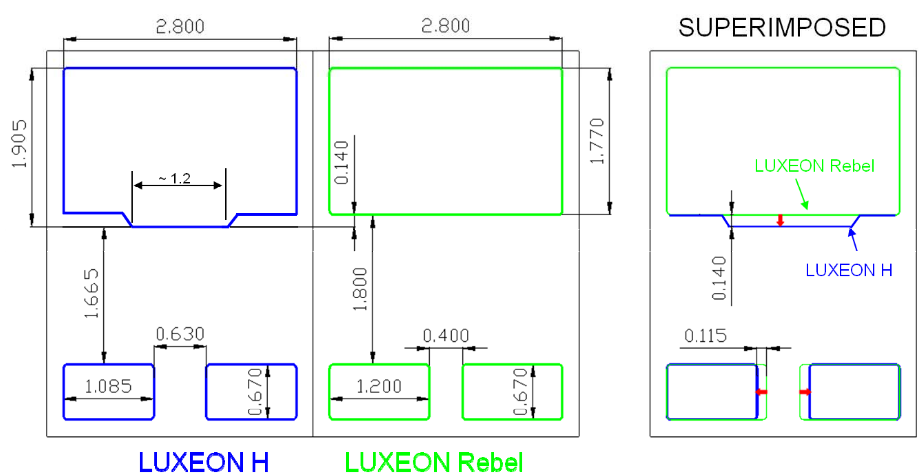

Figure 4. Metallization Pattern for LUXEON H and LUXEON Rebel emitters.

1.10 Pick-and-Place

See Section 5 of Application Brief AB32.

1.11 Chemical Compatibility

See section 7 of Application Brief AB32.

2. LUXEON H Driver Configurations

2.1 Introduction

High brightness LEDs are typically powered by a driver that regulates the current. However, fixed-current drivers are often too big for applications which require a very small form factor (e.g. candle bulbs). In those applications it is desirable to have a compact LED driver circuit which can be directly plugged into the standard AC power.

The LUXEON H emitter is designed to handle forward voltages of approximately 55V and RMS currents up to 30mA. The high operating voltage of LUXEON H emitters is ideal for space-constrained lighting applications that can only accommodate simple driver electronics which plug directly into AC power line. This section discusses various different voltage regulated driving schemes for LUXEON H that can be used with standard 120V and 230V AC power supplies.

2.2 Dimensioning guidelines for basic LUXEON H drivers

SPICE[1] models for the LUXEON H LED can be downloaded from the Philips Lumileds website. These models can be used in SPICE simulation packages to simulate the electrical performance of various driver circuits.

To help with the design-in of LUXEON H, three basic driver circuits were simulated and dimensioned in SPICE to yield RMS currents ranging from 20 mA to 30 mA. All circuits require a bridge rectifier to rectify the incoming AC voltage to prevent any reverse bias over the LUXEON H LEDs.

1. Configuration A: Resistor in series with LUXEON H LEDs (Figure 5)
   Table 1 summarizes the resistor values R1 which are needed for a specific RMS drive current through 2 LUXEON H LEDs (120V AC) and 2 – 4 LUXEON H LEDs (230V AC).
2. Configuration B: Input capacitor and 100Ω resistor in series with LUXEON H LEDs (Figure 6)
   Table 2 summarizes the capacitor values C1 that are needed for a specific RMS drive current through 2 LUXEON H LEDs (120V AC) and 2 – 4 LUXEON H LEDs (230V AC).
3. Configuration C: 10μF output capacitor in parallel and a resistor in series with LUXEON H LEDs (Figure 7)
   Table 3 summarizes the resistor values which are needed for a specific RMS drive current through 2 LUXEON H LEDs (120V AC) and 2 – 5 LUXEON H LEDs (230V AC). Note that the capacitor lifts the voltage across the LEDs close to the peak input voltage, enabling the use of up to 5 LUXEON H LEDs in 230V AC applications.

[1] SPICE (Simulation Program with Integrated Circuit Emphasis) is a general-purpose analog circuit simulation program. An LED SPICE model provides a compact description of the typical relationship between the drive current I_f and the forward voltage V_f of an LED. LED SPICE models are based on typical I_f and V_f monopulse characterization data collected for T_s = 25°C. SPICE models are unique for each LUXEON H forward voltage bin.

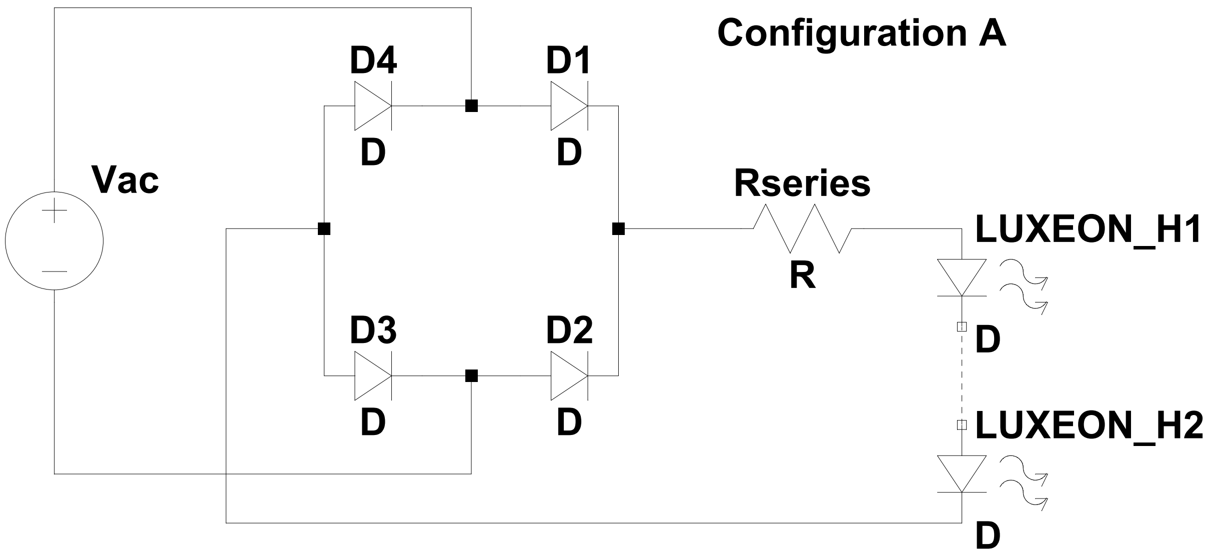

Figure 5. Configuration A, for use with Table 1.

Table 1. Simulated values for the series resistor R in driver configuration A.

# LEDs	Vin	V_f Bin	Target RMS Drive Current 20 mA	25 mA	30 mA
2	120V RMS	H	1.7kΩ	1.3kΩ	1.1kΩ
		J	1.5kΩ	1.2kΩ	1.0kΩ
		K	1.4kΩ	1.0kΩ	0.8kΩ
		L	1.3kΩ	0.9kΩ	0.7kΩ
2	230V RMS	H	7.0kΩ	5.5kΩ	4.6kΩ
		J	6.8kΩ	5.4kΩ	4.4kΩ
		K	6.6kΩ	5.2kΩ	4.3kΩ
		L	6.5kΩ	5.1kΩ	4.2kΩ
3	230V RMS	H	4.9kΩ	3.9kΩ	3.2kΩ
		J	4.7kΩ	3.7kΩ	3.0kΩ
		K	4.4kΩ	3.4kΩ	2.8kΩ
		L	4.2kΩ	3.2kΩ	2.6kΩ
4	230V RMS	H	3.0kΩ	2.3kΩ	1.9kΩ
		J	2.7kΩ	2.1kΩ	1.6kΩ
		K	2.3kΩ	1.7kΩ	1.4kΩ
		L	2.1kΩ	1.5kΩ	1.2kΩ

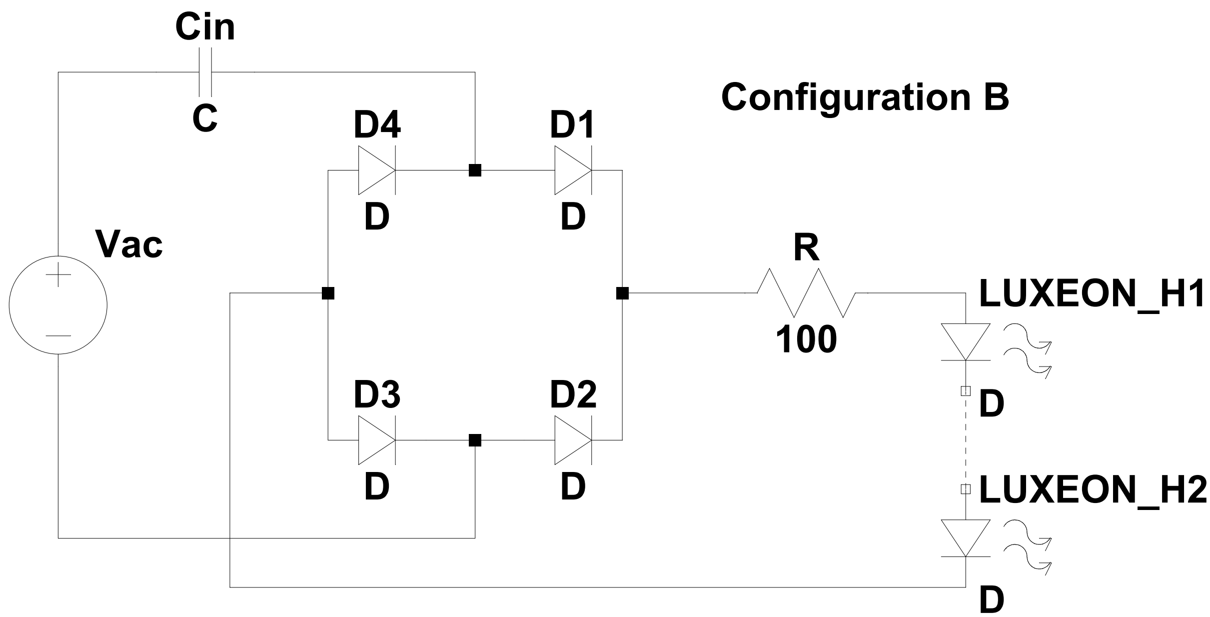

Figure 6. Configuration B, for use with Table 2.

Table 2. Simulated values for the input capacitor Cin in driver configuration B. The series resistor R is fixed at 100Ω.

			Target RMS Drive Current		
# LEDs	Vin	V_f Bin	20 mA	25 mA	30 mA
2	120V RMS	H	740nF	940nF	1150nF
		J	770nF	980nF	1210nF
		K	810nF	1050nF	1300nF
		L	840nF	1100nF	1380nF
2	230V RMS	H	320nF	410nF	490nF
		J	330nF	410nF	490nF
		K	330nF	410nF	500nF
		L	330nF	420nF	500nF
3	230V RMS	H	380nF	470nF	570nF
		J	380nF	480nF	590nF
		K	390nF	500nF	600nF
		L	400nF	510nF	620nF
4	230V RMS	H	480nF	610nF	740nF
		J	500nF	640nF	780nF
		K	530nF	690nF	850nF
		L	550nF	720nF	910nF

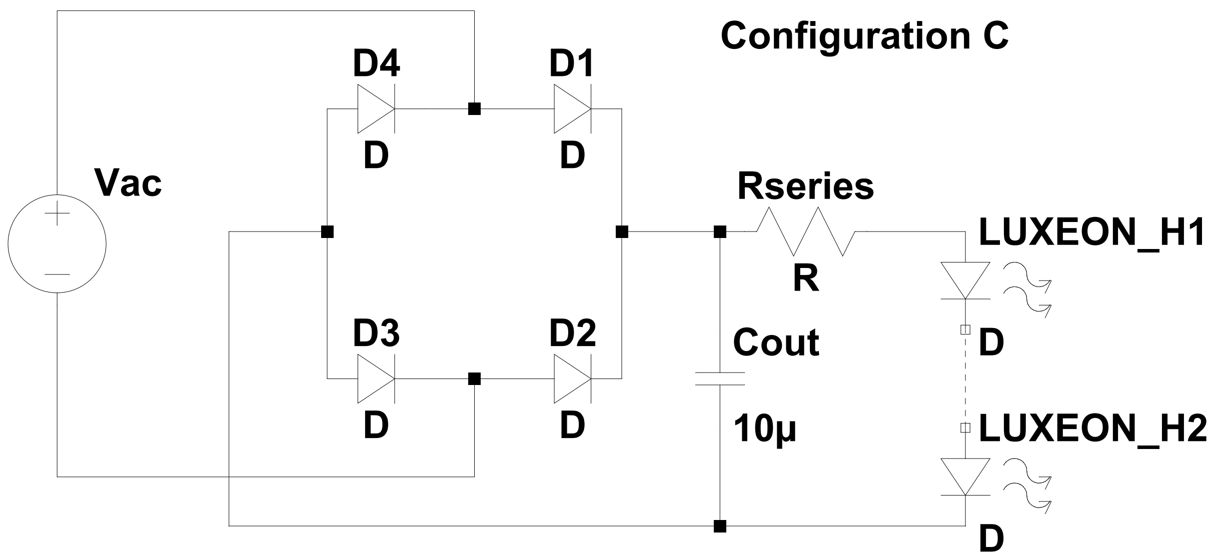

Figure 7. Configuration C, for use with table 3.

Table 3. Simulated values for the series resistor R in driver configuration C. The output capacitor Cout is fixed at 10µF.

# LEDs	Vin	V_f Bin	Target RMS Drive Current 20 mA	25 mA	30 mA
2	120V RMS	H	2.9kΩ	2.2kΩ	1.8kΩ
		J	2.7kΩ	2.0kΩ	1.6kΩ
		K	2.5kΩ	1.8kΩ	1.4kΩ
		L	2.3kΩ	1.7kΩ	1.3kΩ
2	230V RMS	H	10.6kΩ	8.3kΩ	6.9kΩ
		J	10.4kΩ	8.2kΩ	6.7kΩ
		K	10.2kΩ	8.0kΩ	6.5kΩ
		L	10.0kΩ	7.8kΩ	6.4kΩ
3	230V RMS	H	8.0kΩ	6.2kΩ	5.1kΩ
		J	7.7kΩ	6.0kΩ	4.9kΩ
		K	7.3kΩ	5.7kΩ	4.6kΩ
		L	7.1kΩ	5.5kΩ	4.4kΩ
4	230V RMS	H	5.4kΩ	4.1kΩ	3.3kΩ
		J	5.0kΩ	3.8kΩ	3.0kΩ
		K	4.5kΩ	3.4kΩ	2.7kΩ
		L	4.3kΩ	3.2kΩ	2.4kΩ
5	230V RMS	H	2.8kΩ	2.0kΩ	1.6kΩ
		J	2.3kΩ	1.6kΩ	1.2kΩ
		K	1.7kΩ	1.1kΩ	-
		L	1.4kΩ	-	-

2. 3 Test results for a single LUXEON H LED

A compact driver configuration to test a single LUXEON H LED consists of a series resistor and a bridge rectifier, see Figure 8. The bridge rectifier ensures that the LED is never subjected to a reverse bias.

In order to prevent any damage to the LUXEON H emitter, it is very important that the current through the emitter during AC voltage operation does not exceed the maximum allowable peak and RMS currents as specified in the datasheet. A properly dimensioned series resistor in the driver circuit helps to limit the peak and RMS current through the circuit.

Figure 9 shows the relationship between the nominal LUXEON H forward voltage V_f and the series resistance which is needed to achieve a fixed RMS current through a single LUXEON H emitter in this test setup. The lines in this graph correspond to experimental data which was collected for a representative set of LUXEON H emitters with the pad temperature T_s set to 25°C. (The LED junction temperature T_j can be calculated according to Application Brief AB33). All LEDs were powered by a rectified 60Hz 55V AC input voltage. Self-heating of the device was minimized by applying only a short burst (33ms) of AC power to the circuit. According to this graph, a LUXEON H emitter with a nominal forward voltage of 54.5V and a junction temperature of ~25°C requires a 500Ω resistor to achieve a 20mA RMS current through the emitter, when powered by a rectified 55V AC voltage.

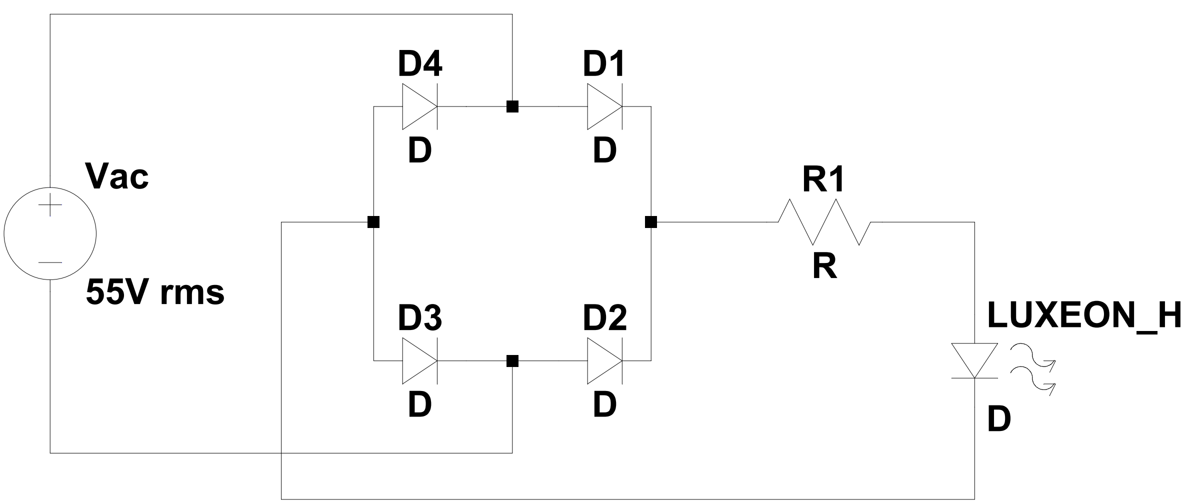

Figure 8. Experimental setup to test a single LUXEON H LED with a 55V rectified AC voltage.

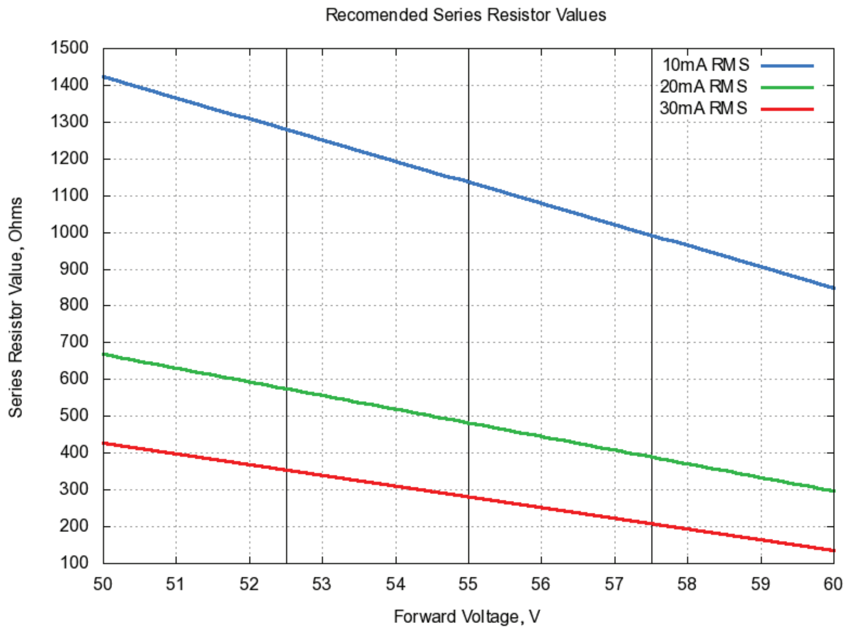

Figure 9. Series resistance vs. nominal Vf for a single LUXEON H emitter (Vin = 55V RMS, Ts=25°C). Vertical black lines correspond to the boundaries of the LUXEON H voltage bins.

During regular operation the junction temperature T_j of the LUXEON H emitter will typically be higher than 25°C. Since the forward voltage of the LUXEON H emitter decreases with increasing junction temperature $\left(\frac{dV}{dT_j} < 0\right)$, the effective resistance of the LUXEON H emitter decreases with temperature, yielding a higher RMS current through the inner loop of the circuit shown in Figure 8. As the junction temperature increases, a higher resistor value is needed to ensure the same drive current. For example, Figure 10 shows simulated series resistance values for different junction temperatures such that the total RMS current remains fixed at 20 mA for one LUXEON H emitter powered by a 55V AC input voltage.

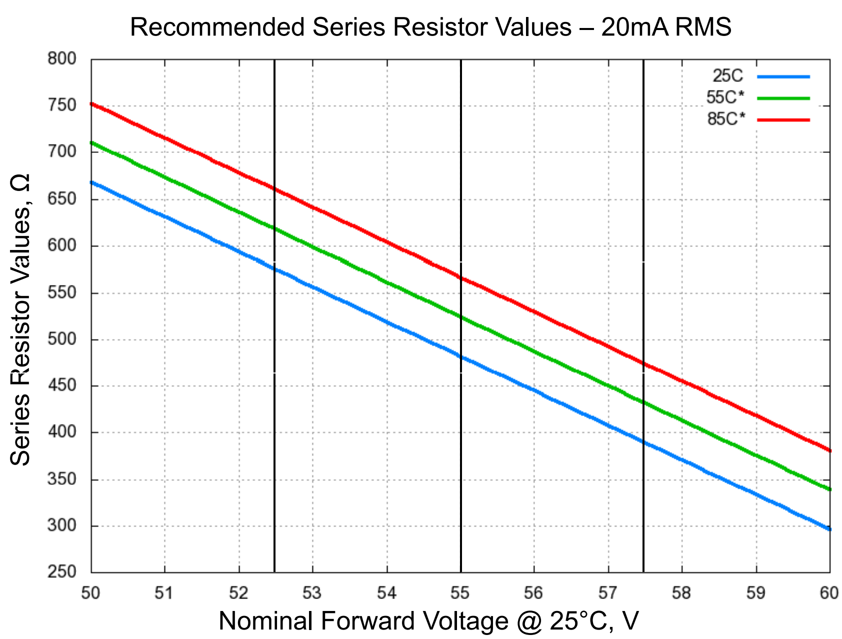

Figure 10. Series resistance vs. nominal Vf (T_s = 25°C) for a single LUXEON H emitter at various operating pad temperatures. (* Simulation results)

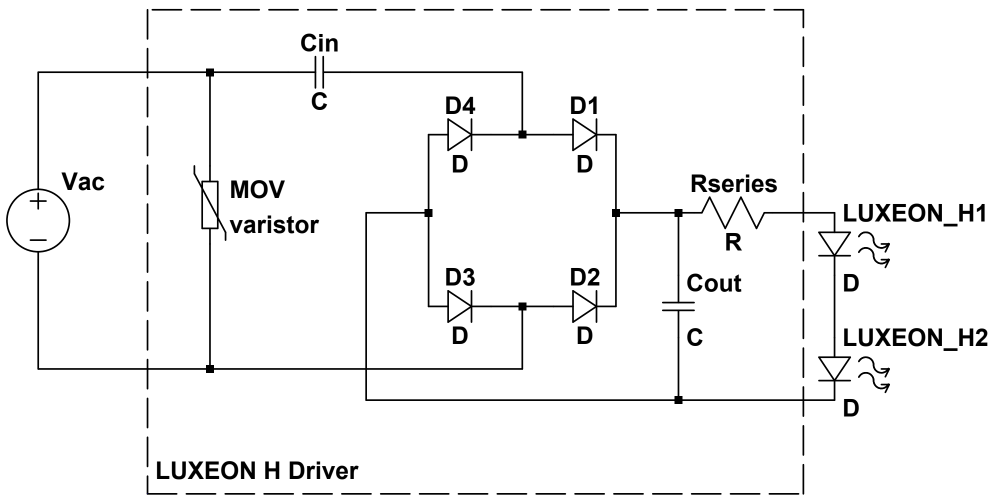

Figure 11. A compact driver circuit for LUXEON H. This circuit only contains passive components. The MOV and capacitors are optional, depending on the design constraints that have to be met.

2.4 Driver Component Selection

Designing an LED driver involves making trade-offs between various design constraints, including:

- Form-factor
- Component count and complexity
- Efficiency
- Ability to dim the LEDs
- Requirements on flicker
- Protection against voltage surges, for example, lightning strikes.

Drivers that meet all of these requirements are typically too big for the applications that LUXEON H is targeting.

A compact driver circuit for LUXEON H, which can be directly connected to an AC power line, is shown in Figure 11. This circuit contains only passive components in order to reduce circuit complexity and cost. The LEDs in this circuit configuration cycle-on and off twice with every incoming AC cycle, i.e. for a 60Hz 120V line voltage the operating frequency of the LEDs is 120Hz. A capacitor in parallel with the LEDs can help reduce any undesirable flicker.

The remainder of this section provides general guidelines on how to select and dimension the electronic components in this circuit. Note that any dimensions or ratings which are mentioned in this application brief for electronic components are for reference only. Philips Lumileds recommends that customers perform their own testing to assess proper dimensioning of all electronic components to ensure all relevant performance and safety specifications are met for the application of interest.

Metal Oxide Varistor (optional)

A Metal Oxide Varistor (MOV) can be included in the driver circuit of Figure 11 to protect against sudden surges in the input AC power due to, for example, lightning strikes. The MOV is not necessary for normal operation of the circuit and is therefore optional.

If an MOV is used, it should be dimensioned correctly in terms of its maximum voltage and energy rating. For an application that connects to a 120V AC power line, an MOV with a maximum AC voltage rating of at least 150V is recommended. The maximum energy rating of the MOV is directly related to the diameter of the MOV. Depending on how much surge protection is needed, a 10mm or 14mm diameter MOV may be suitable.

Input Capacitor (optional)

The current that flows into the circuit of Figure 8 can be limited with an input capacitor in series with the incoming AC power line. Since an input capacitor reduces the power factor of the driver, inclusion of this component is optional. The current through the LEDs can also be limited with a resistor in series with the LEDs. However, an input capacitor offers several benefits compared to a series resistor:

- improved efficiency of the overall circuit
- the current through the inner loop is less sensitive to input voltage variations

Appropriate input capacitance values range from a couple hundred nF (LEDs only after the bridge rectifier) to ~2μF if a second capacitor is used in parallel with the LEDs.

The lifetime of a capacitor is a strong function of its operating temperature, typically doubling for every 10°C the capacitor is operated below its rated temperature. Therefore, careful consideration should be given to the temperature rating and the actual operating temperature of the capacitor in the application of interest. Lifetime ratings also tend to increase with physical size (diameter).

Voltage ratings for capacitors should exceed the maximum peak voltage that may occur during high line-power occasions, i.e. a capacitor voltage rating of 200V - 250V is recommended for circuits that are operated with a 120V AC power line.

Ripple currents through the capacitor must also be kept below its rated value.

Bridge rectifier

The bridge rectifier in the circuit is required to ensure that the LEDs are never exposed to a reverse-bias. Bridge rectifiers with standard surface mount packages are readily available from different vendors. A surface mount rectifier with a maximum RMS bridge input voltage of 420V (MB6S) was successfully used by Philips to test the circuit configuration in Figure 11 with an AC power of 120V.

Output Capacitor (optional)

A parallel capacitor of 10μF reduces the current variation through the LEDs, and thus eliminates any undesirable flicker.

All the design guidelines mentioned for the input capacitor also hold for the output capacitor.

Resistor

A resistor in series with the LEDs limits the current through the LEDs. The series resistor could, in theory, be omitted if an input capacitor is used to limit the current in the circuit. Nevertheless, Philips Lumileds recommends that a small series resistor (~100Ω) is used in the circuit of Figure 11 in order to provide extra protection against voltage surges on the incoming AC power line.

The total power that is dissipated in the series resistor can be very high. For example, a 1100Ω will limit the RMS current through two LUXEON H LEDs (both from voltage bin J) to ~30 mA, assuming an input line voltage of 120V (no capacitors). At this current, the power dissipated in the resistor will be almost 1W. Therefore, it is important to select resistors that can reliably handle these loads. In some applications it may be better to put two or four surface-mount resistors (e.g. 1206-style package, rated at 0.25W) in parallel than to use a single resistor with a higher power rating.

2.5 Driver Performance Discussion

Three different instances of the driver circuit in Figure 11 were built and tested. All circuits contained 2 LUXEON H LEDs from voltage bin J and were powered with a 60Hz 120V AC power supply. Table 4 summarizes the configuration and key performance metrics for each design. Components C_{in}, C_{out}, R_{series} in this table correspond to the capacitors and resistor with the same names in Figure 11. From this summary we can conclude the following:

- Driver design #1 offers the smallest form factor and lowest cost; it only contains a bridge rectifier and a couple of resistors to limit the current through the LEDs.
- Driver design #2 offers an efficient design with a medium form factor; the small series resistor in this design is recommended to increase the robustness of this circuit against sudden voltage spikes.
- Driver design #3 offers a reasonably compact driver that eliminates undesirable flicker.
- All designs work with a trailing-edge (triac) dimmer. The response of the LED light output to the dimmer setting was not quite linear for those designs with a capacitor.
- All designs successfully passed two standard surge tests which are normally used to test the robustness of LED driver circuits against sudden spikes in the line voltage. More information about the surge tests can be found in IEEE Std C62.41.2-2002.

Table 4. Experimental test results for three LUXEON H driver configurations.

	Design #1	Design #2	Design #3
# LEDs	2 (V_f bin J)	2 (V_f bin J)	2 (V_f bin J)
C_{in}	-	680 nF	2x1μF (parallel)
C_{out}	-	-	10uF
R_{series}	2x3.3kΩ (parallel)	4x390Ω (parallel)	2x2kΩ (parallel)
MOV voltage rating and diameter	150V, 10mm	150V, 14mm	150V, 10mm
LED If RMS @Vac= 120V	19.7mA	18.4mA	22.6mA
Pin @Vac=120V	2.2W	1.3W	3.11W
Efficiency	70%	97%	80%
Power Factor	1	0.71	0.81
Dimmable (triac)	Yes	Yes	Yes
Ring wave surge test (6kV @ 100kHz)	Pass	Pass	Pass
Combi wave surge test (4k over 2Ω load)	Pass	Pass	Pass
Noticeable flicker	Yes	Yes	No
Form factor	Small	Medium	Large

3. Optical Performance in DC and AC mode

3.1 Introduction

LUXEON H LEDs will most likely be powered by a voltage regulated drive scheme such as a rectified 120V or 230V AC power line. If a rectified AC voltage is used, the drive current through the LUXEON H LED cycles with a frequency of 100Hz – 120Hz between a minimum current (typically close to or equal to 0mA) and a peak drive current of ~40 mA. The LED light output would also cycle between 0% and ~150% of the nominal light output at 20 mA. This section discusses the relative optical performance of LUXEON AC LEDs when powered with a rectified AC signal, compared to the optical performance which is reported in the technical datasheet (DS67) for constant current operation at a junction temperature of 25°C.

LED light output is routinely measured with a DC monopulse. The duration of the monopulse is typically set to 20ms to minimize any self-heating of the LED. This is the measurement method used in DS67. To enable a fair comparison of the LUXEON H light output reported in DS67 and light output in a rectified AC power line, multiple individual LUXEON H LEDs were subjected to a 33ms burst of an ideally rectified 60Hz 55V RMS AC voltage (generated by an HP 6811B EC source/analyzer). The average light output for each LED was then recorded. This setup eliminates any residual effects due to the electronics (e.g. voltage drop across bridge rectifier) and minimizes device self-heating. The RMS current through the LUXEON H LED was limited by an IET Programmable Resistance Substituter (model IET PRS) in series with the LUXEON H LED. Figure 12 shows the rectified AC input voltage and the typical current profile over time through the LUXEON H.

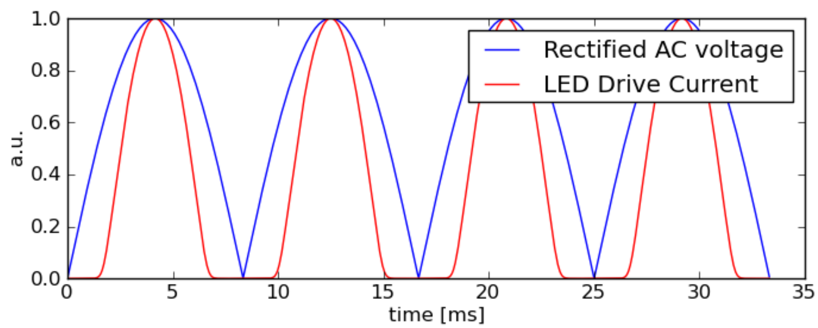

Figure 12. An ideally rectified AC voltage is applied to the LUXEON H LED to determine the relative light output compared to constant-current operation. Note that the LUXEON H LED is conducting current, and emitting light, only during part of each AC cycle.

3.2 Relative Light Output and Efficacy

The luminous flux for a representative set of LUXEON H emitters was measured both with a 20ms DC monopulse and a 33ms rectified AC voltage. The graph in Figure 13 shows the typical relative luminous flux for the LUXEON H emitter as function of the DC/AC RMS drive current. On average, the luminous flux of the LUXEON H LED when powered by the rectified AC voltage is ~65% of the luminous flux measured with the 20ms DC monopulse for the same RMS drive current.

The relative LED efficacy of the LUXEON H LED for the two driving schemes is shown in Figure 14. Despite the lower light output for the same RMS current, the efficacy of the LUXEON H LED when powered with the rectified AC voltage is only ~10% lower than the efficacy in DC mode because the LUXEON H LED is only on during part of each AC cycle (see Figure 12).

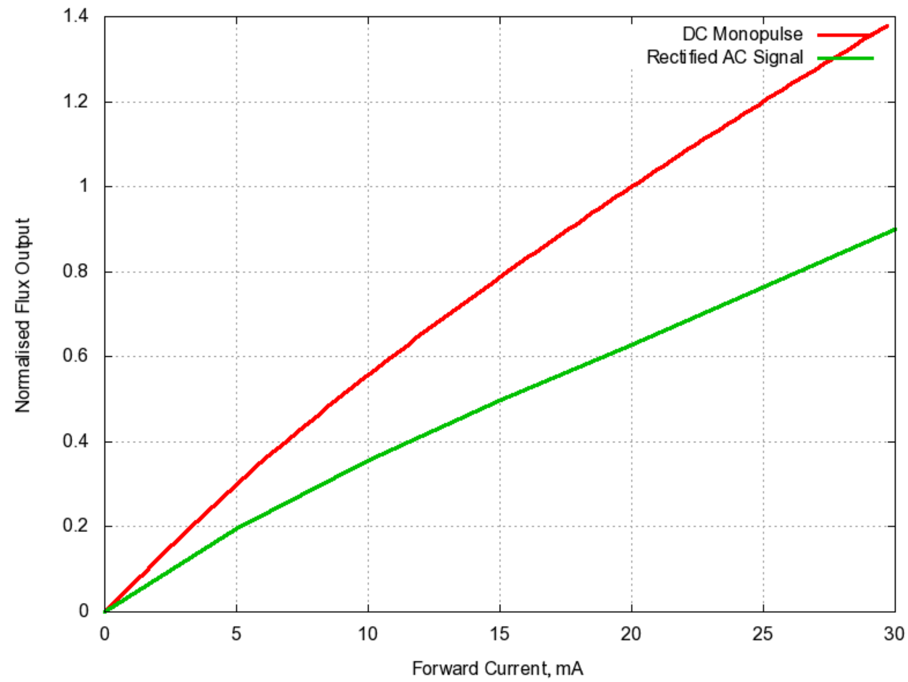

Figure 13. Typical relative luminous flux for LUXEON H with current regulated and voltage regulated drive schemes (T_s = 25°C). All results are normalized to the light output at 20 mA DC. The horizontal axis corresponds to DC current (DC operation) and RMS current (AC mode).

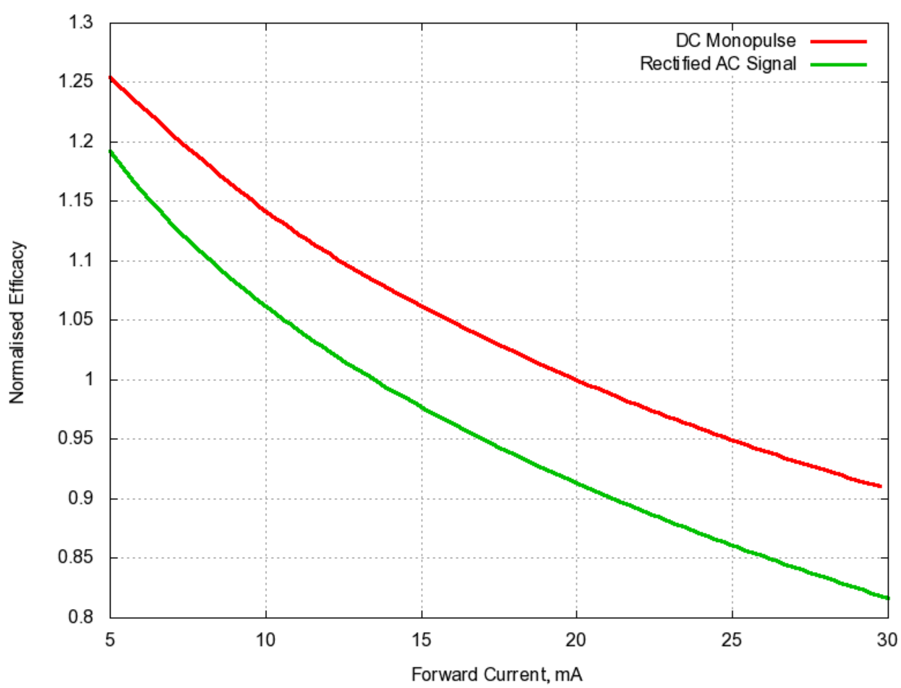

Figure 14. :Typical relative efficacy for LUXEON H with current regulated and voltage regulated drive schemes (T_s = 25°C). All results are normalized to the efficacy at 20 mA DC. The horizontal axis corresponds to DC current (DC operation) and RMS current (AC mode).

4. Safety

LUXEON H is a high-voltage device. Relevant electrical creepage and clearance distances should be observed when designing this device into an application.

The driver circuits discussed in this application brief contain high-voltage lines. All electrical lines, components, and contact pads should be shielded from the user to prevent accidental electrical shocks.

Disclaimer

Company Information

Philips Lumileds is a leading provider of power LEDs for everyday lighting applications. The company's records for light output, efficacy and thermal management are direct results of the ongoing commitment to advancing solid-state lighting technology and enabling lighting solutions that are more environmentally friendly, help reduce CO_2 emissions and reduce the need for power plant expansion. Philips Lumileds LUXEON® LEDs are enabling never before possible applications in outdoor lighting, shop lighting, home lighting, automotive lighting, display and digital imaging.

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, Singapore 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 technology and the lighting world. More information about the company's LUXEON LED products and solid-state lighting technologies can be found at www.philipslumileds.com.

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