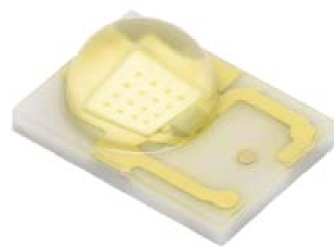
Application Brief AB33

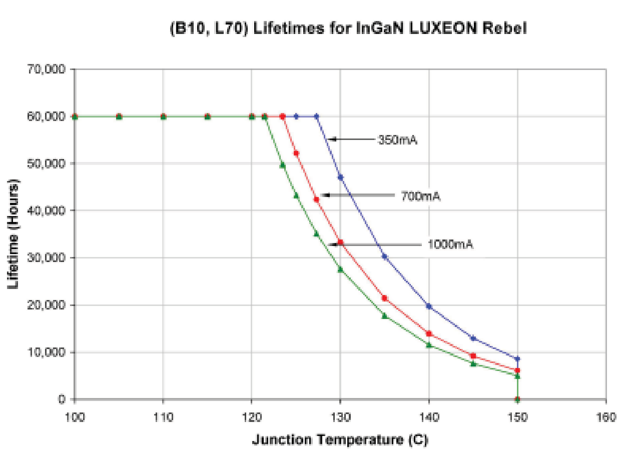
LUXEON never before possible

LUXEON® Rebel
Thermal Measurement Guidelines

Introduction



Light emitting diodes (LEDs) are among the longest-lasting light sources now available, with typical lumen maintenance measured in tens of thousands of hours. However, LEDs do experience a gradual reduction in light output during operation. This phenomenon is called “light output degradation” and may stem either from a reduction in the light-emitting efficiency of the LED chip or from a reduction in the light transmission of the optical path within the LED package. As described in Philips Lumileds document RD07 *“LUXEON® Rebel Reliability”*, increased LED drive current and junction temperature negatively affect lumen maintenance and lifetime performance. While LED drive current and forward voltage can be measured easily, LED junction temperature cannot be measured directly, but must be calculated. This application brief covers the recommended method for determining the approximate junction temperature of LUXEON Rebel.



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Scope

We recommend that customers design their LUXEON Rebel board in accordance to Philips Lumileds document AB32 *"LUXEON Rebel: Assembly and Handling Information"*. This is important because the characterization result here is based on the board being designed per the AB32 guidelines.

The result of the thermal measurement in this document covers LUXEON Rebel white and InGaN parts operating up to 1000 mA with heatsink temperature of 20°C to 70°C mounted on 0.8mm or 1.6mm FR4 board (35µm in vias/70µm top & bottom copper plating) with open plated-through-hole via design as described in Philips Lumileds AB32 document.

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1. Thermal Modeling

1.1 Basic Thermal Equation

The basic equation governing the thermal calculation is defined below.

$$R\theta_{J\text{-}Ref} = (\Delta T_{J\text{-}Ref}) / P_D \qquad (1)$$

Where:

$R\theta_{J\text{-}Ref}$ = thermal resistance (°C/W) from LED pn-junction to a reference point (which can be air, heatsink, etc)

$\Delta T_{J\text{-}Ref}$ = (T_J, junction temperature) – (T_{Ref}, reference point temperature) (°C)

P_D = power dissipation (W)

= LED forward current (If) * LED forward voltage (Vf)

Rewrite equation (1):

$$T_J = T_{Ref} + R\theta_{J\text{-}Ref} * P_D \qquad (2)$$

We can measure T_{Ref} and calculate P_D easily. If we can define what is $R\theta_{J\text{-}Ref}$, the junction temperature can then be calculated.

1.2 How Should $R\theta_{J\text{-}Ref}$ be Defined?

The best way to define $R\theta_{J\text{-}Ref}$ for a LUXEON Rebel part mounted on 0.8mm or 1.6mm FR4 board with open, plated-through-hole via is to define the thermal resistance between the LED junction and the solderability indicator pad. Let us call this the thermal characterization parameter, $\Psi_{J\text{-}S}$. The solderability indicator pad provides the lowest thermal path to the LUXEON Rebel thermal pad. This thermal pad temperature is also known as the case temperature. We can define T_{Ref} as the solderability indicator pad temperature (T_S) and place a thermocouple on any one of the two pads as shown in Figure 1.

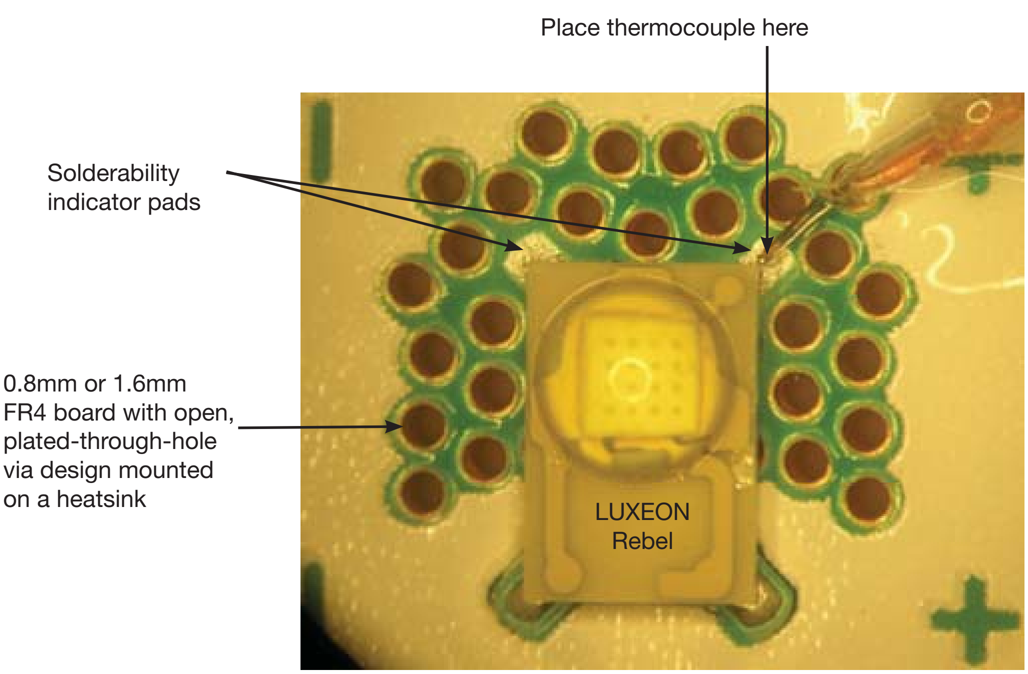

Figure 1. Solderability indicator pad and thermocouple placement.

A schematic cross section with the thermocouple is shown in Figure 2.

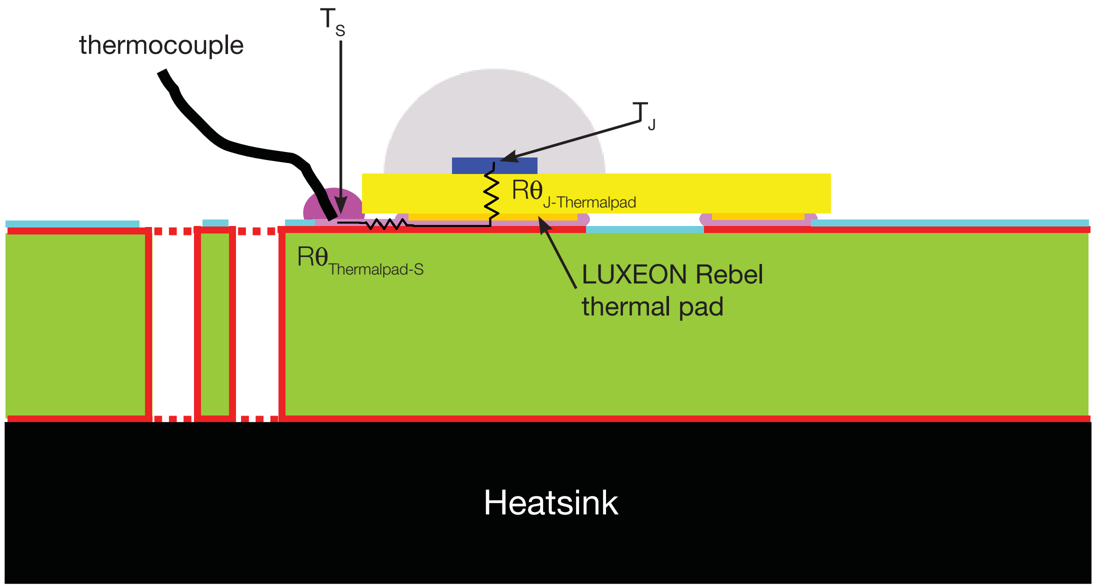

Figure 2. Cross section of LUXEON Rebel on FR4 board showing the thermal resistances from junction to solderability indicator pad.

$R\theta_{J\text{-Thermalpad}}$ is the thermal resistance from junction to LUXEON Rebel thermal pad.
$R\theta_{Thermalpad\text{-}S}$ is the thermal resistance from the LUXEON Rebel thermal pad to solderability indicator pad where the thermocouple is placed.

Note that the junction to solderability indicator pad thermal characterization parameter, $\Psi_{J\text{-}S}$ is then the sum of two thermal resistances above.

1.3 Result of Thermal Characterization Parameter, $\Psi_{J\text{-}S}$

Using thermal transient tester (MicReD T3ster) to measure T_J, a thermometer to measure T_S and knowing the total power dissipation of the LED, the $\Psi_{J\text{-}S}$ of LUXEON Rebel white and InGaN can be calculated.

Based on this study, the recommended $\Psi_{J\text{-}S}$ is 16°C/W.

From RD56 datasheet, we see that typical $R\theta_{J\text{-Thermalpad}}$ is 10°C/W. Therefore, $R\theta_{Thermalpad\text{-}S}$ contributes 6°C/W.

The above recommended value is good for operating current up to 1000 mA with heatsink temperature of 20°C to 70°C.

1.4 Determining Junction Temperature, T_J

Rewrite equation (2) as $T_J = T_S + \Psi_{J\text{-}S} * P_D$ ——————— (3)

Knowing $\Psi_{J\text{-}S}$ (16°C/W), P_D (measured) and T_S one can then calculate the typical junction temperature T_J of LUXEON Rebel without using thermal transient tester. In the next section, we describe how T_S is measured.

2. Solderability Indicator Pad, T_S Measurement

2.1 Supplies and Equipment

Below is the list of supplies and equipment used to perform T_S measurement:

- Type T precision fine wire (0.003" gauge diameter) thermocouples from Omega Engineering Inc (part number: 5SRTC-TT-T-40-36)
- Eccobond one component, low temperature curing, thermal conductive epoxy adhesive from Emerson and Cuming (part number: E 3503-1) or Arctic Alumina Thermal Adhesive compound from Arctic Sliver Inc. (part number: AATA-5G)
- Disposable 3cc barrel syringe from EFD Inc (part number: 5109LL-B)
- Disposable 0.016" inner diameter fine needle tip from EFD Inc (part number: 5122-B)
- Kapton tape
- Convection oven (for curing Eccobond epoxy)
- Thermometer
- Magnifying lamps or low power microscope (e.g. 5X to 30X)

2.2 Procedures for Eccobond Thermal Adhesive Epoxy

1. Before starting, read the manufacturer's Material Safety Data Sheet (MSDS) and preparation procedure.
2. Thaw the thermal conductive epoxy per manufacturer's recommendation.
3. Dispense sufficient epoxy into the 3cc barrel syringe with the fine needle tip. Store the balance per manufacturer's recommendation.
4. Place the thermocouple tip within the solderability indicator pad as shown in Figure 1.
5. Use a kapton tape to secure the thermocouple wire onto the LUXEON Rebel board. The thermocouple must touch the solderability indicator pad to ensure accurate reading.
6. Drop a small amount of thermal conductive epoxy just enough to cover the thermocouple tip as shown in Figure 3.
7. Cure the epoxy per manufacturer's recommendation. Make sure that the oven temperature does not exceed the maximum rated temperature of all the components on the board.
8. Let the board cool down to room temperature before starting measurement.
9. Plug in the thermocouple connector to the thermometer. We are now measuring the temperature of the solderability indicator pad, T_S.
10. Connect the board to the power supply to light up the LED at the operating current and temperature. If possible, attached all fixtures (eg. lens and cover) to simulate closely the application environment.
11. Power up and start recording the T_S until temperature stabilization is achieved. This may take a minute or more depending on the overall thermal design. See Figure 4.
12. Use equation (3) to calculate the junction temperature T_J.

2.3 Procedures for Arctic Thermal Adhesive Epoxy

1. Before starting, read the manufacturer's Material Safety Data Sheet (MSDS) and preparation procedure.
2. Place the thermocouple tip within the solderability indicator pad as shown in Figure 1.
3. Use a kapton tape to secure the thermocouple wire onto the LUXEON Rebel board. The thermocouple must touch the solderability indicator pad to ensure accurate reading.
4. Since this is a two-epoxy system and having about 3 to 4 minutes pot-life at room temperature after mixing, make sure that proper setup is done to ensure that the epoxy can be dispensed within the pot-life span. We recommend mixing small batches at a time if you have many thermocouples to work on.
5. Immediately put epoxy into the 3cc barrel syringe with the fine needle tip and dispense onto the thermocouple tip. Close to the end of the pot-life, it becomes difficult to dispense.
6. Alternatively, you can dip the fine needle tip into the epoxy mix and then "touch" the thermocouple tip to dispense the epoxy via surface tension.
7. We recommend leaving the epoxy to cure at room temperature (25°C) for at least two hours.
8. Repeat steps 9 to 12 as described above for the Eccobond epoxy.

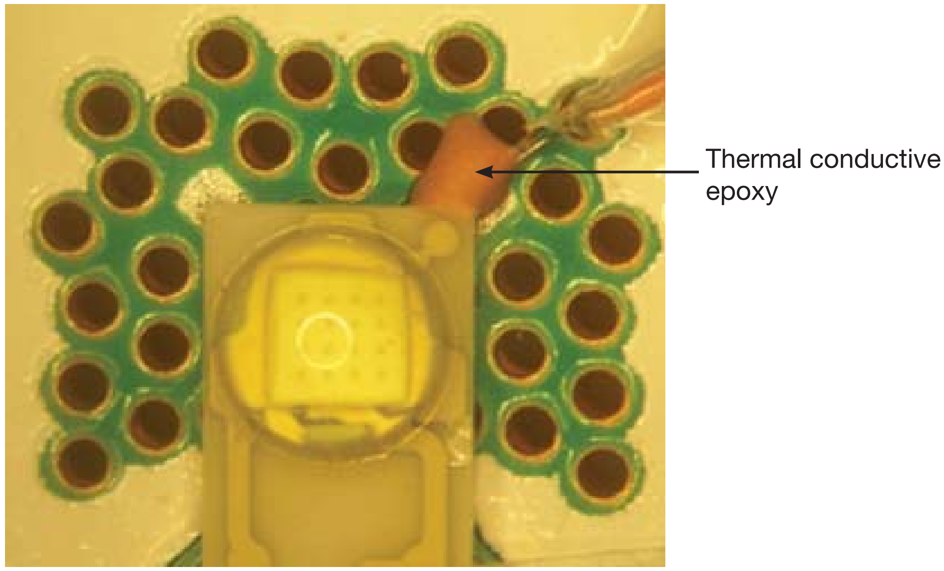

Figure 3. Thermal conductive epoxy on solderability indicator pad.

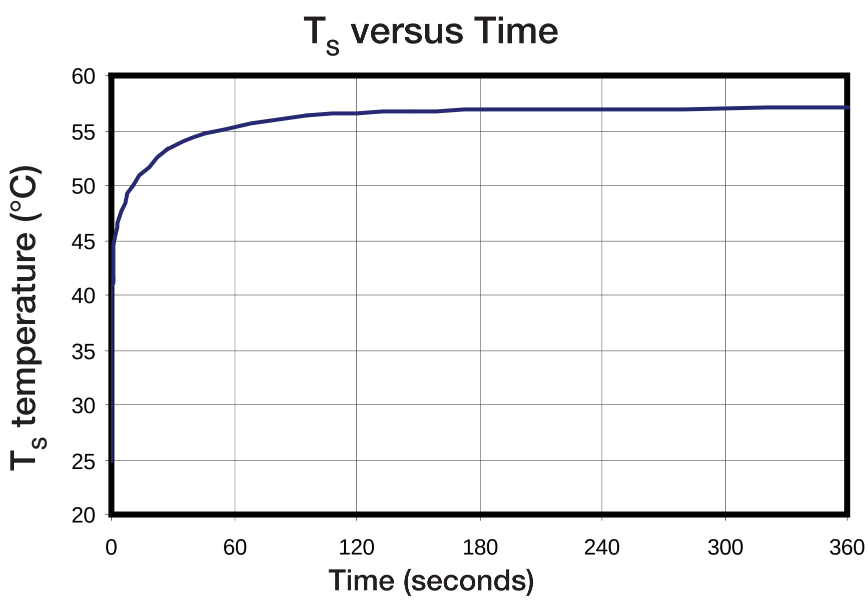

Figure 4. T_s versus time. The temperature has not changed much after 3 minutes.

2. Solderability Indicator Pad, T_S Measurement, Continued

2.4 An Example

Using the data from Figure 4, the equilibrium temperature for T_S is about 57°C.

Given that Ψ_{J-S} is 16°C/W and assuming one watt of power input, equation (3) yields T_J = 57°C + (16°C/W)*(1W) = 73°C, which is below the maximum rated junction temperature for LUXEON Rebel white or InGaN parts. It is recommended to have some safety margin in the T_J during the design phase to ensure that the maximum junction temperature is not exceeded.

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.

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