Application Brief AB32

LUXEON never before possible

LUXEON® Rebel

Assembly and Handling Information

Introduction

This application brief covers the recommended board design and assembly procedures for LUXEON® Rebel LEDs.

LUXEON Rebel is a revolutionary, ultra-compact, surface mount high power LED. LUXEON Rebel offers a compact package with high lumen output and superior thermal performance.

Proper handling, board design, and thermal management are required for high optical output, and long LED lumen maintenance times.

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LIGHT FROM SILICON VALLEY

Component

Electrically Isolated Thermal Pad

LUXEON Rebel has the benefit of an electrically isolated pad. The cross section of LUXEON Rebel is shown in Figure 1, where the LED cathode and heat pad are shown isolated by a ceramic substrate. The term pad refers to the thermal or electrical contacts on the Rebel.

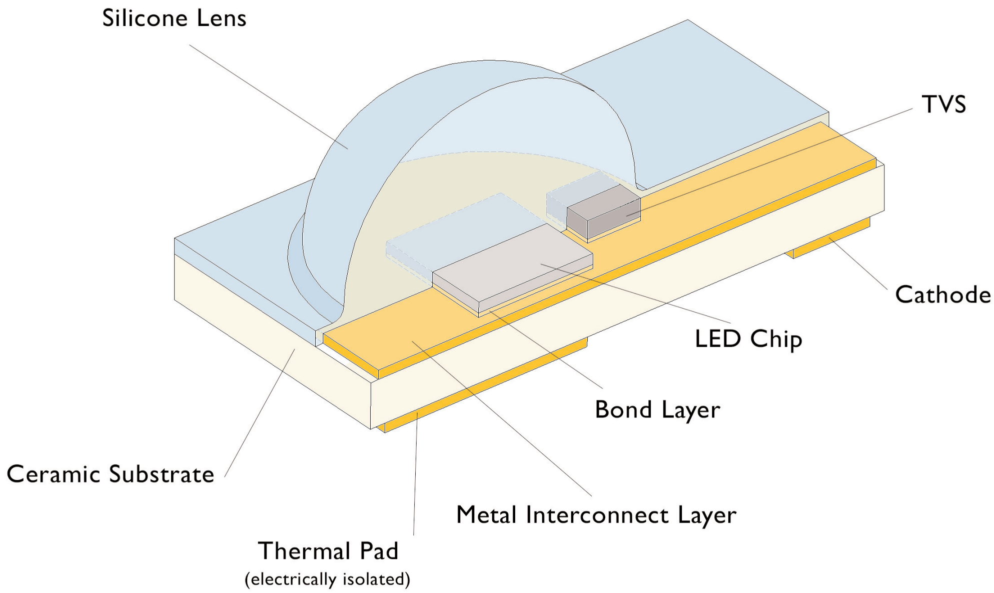

Figure 1. Cross section of LUXEON Rebel.

Optical Center

The LED has three features to locate the theoretical optical center. These features are the topside fiducials, backside metallization, and LED outline.

The fiducials on the Rebel package provide the most accurate methodology to locate the theoretical optical center, Figure 2. The optical center for LUXEON Rebel can be found by using the fiducials on the LED package as follows:

1. Draw an imaginary line between the centers of fiducials F1 and F2
2. Using fiducial F2 as the pivot point, rotate the line 19.66º counter clockwise
3. The theoretical optical center lies on this line and is 2.248mm above the center of F2

Once the theoretical optical center has been located, the center of the lens is within a circular diameter of 0.29mm with respect to that optical center.

Note that although the nominal position of fiducials is identical for the complete Rebel family, there is a difference in metallization pattern between InGaN and AlInGaP LEDs, as indicated in Figure 3.

While the fiducials provide the most accurate technique to find the optical center of the lens, one may also utilize the edges of the LED or the backside metal. The optical center is located 1.525mm from the top and side of the Rebel edge. Figure 2 also illustrates the optical center with respect to the edges of the LED. The optical center may also be located using the edges of the thermal pad, Figure 4. Using this process, the center of the lens will be within a circular diameter of 0.35mm with respect to the theoretical optical center.

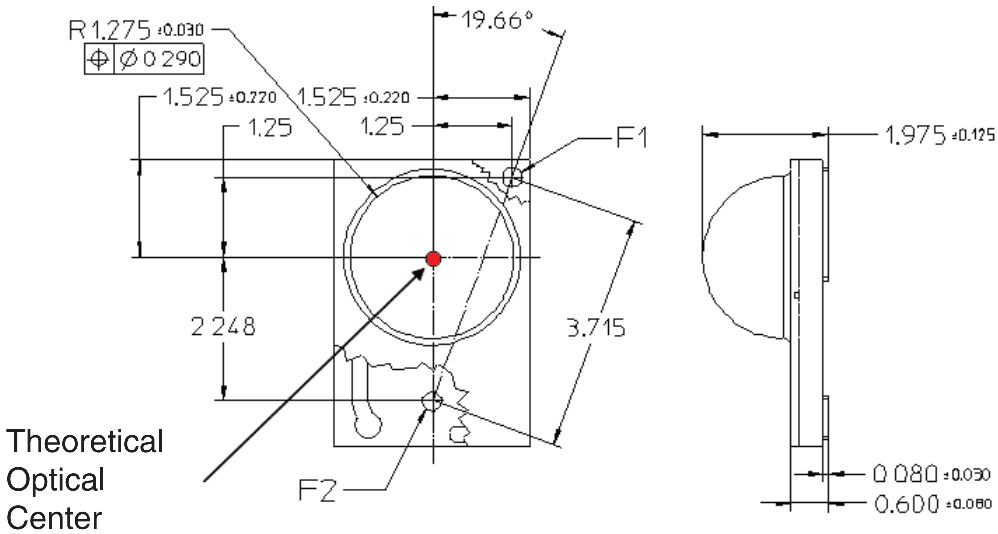

Figure 2. The most accurate method to find the theoretical optical center and the center of the dome is by using the fiducials located on the frontside of the Rebel LED.

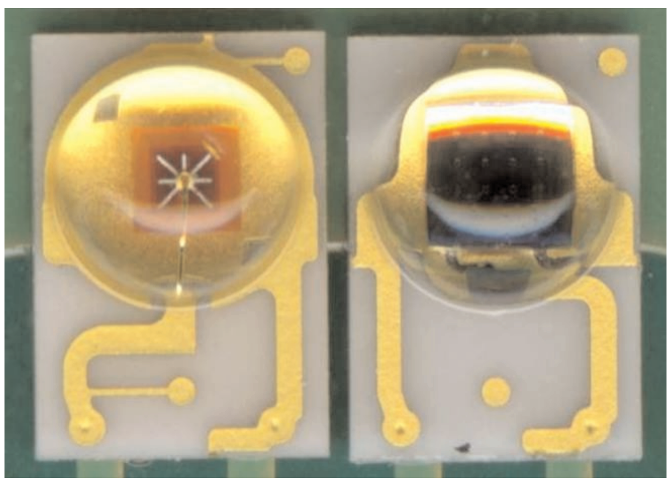

Figure 3. Picture of AlInGaP and InGaN LUXEON Rebel packages. For the AlInGaP (left) component the fiducials are connected to the metallization, while the InGaN (right) has isolated fiducials.

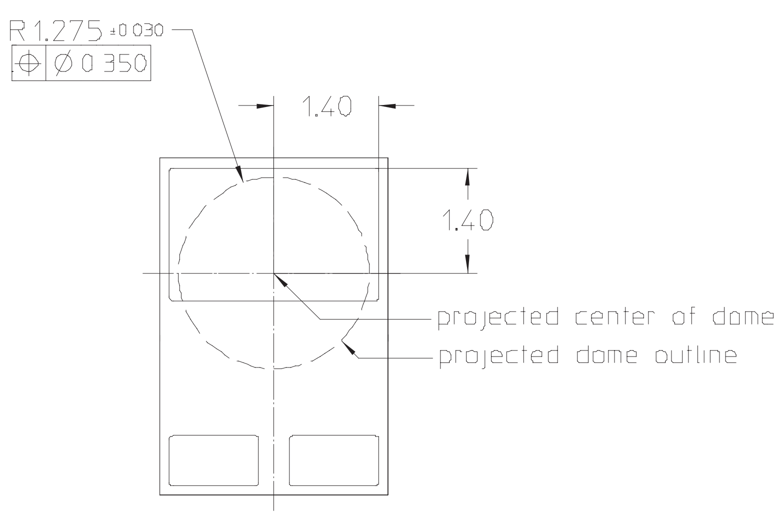

Figure 4. The optical center may be located using the edges of backside thermal pad. The center of the dome will be within a 0.35mm radius with respect to that optical center.

Component, Continued

Lens Handling

When utilizing a pick and place machine, make sure the pick and place nozzle does not place pressure onto the lens of the LED. Make sure the inner machining of the nozzle clears the lens. More information can be found in the Pick and Place section of this document.

Similar handling restrictions exist for manual handling. The LEDs should only be picked up on the sides and not on the lens. The LUXEON Rebel is a high lumen light source within a small package providing the industry's highest luminance product. The small size of the Rebel places limits on the amount of force which may be applied onto the lens.

Do not apply more than 3N of shear force (300g) directly onto the lens. Excessive force on the lens could cause mechanical damage to the part.

Figure 5. Correct handling of LUXEON emitters.

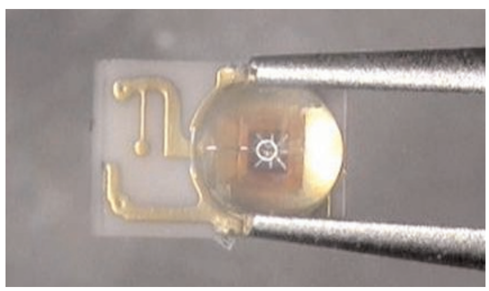

Figure 6. Incorrect handling—do not grip the lens.

Lens Cleaning

The lens of LUXEON Rebel should not be exposed to dust and debris. Excessive dust and debris may cause a drastic decrease in optical output. Steps should be taken to keep the emitter free of dust. These include keeping the LUXEON emitters in the manufacturer's package prior to assembly and storing assemblies in an enclosed area after processing.

In the event that an emitter requires cleaning, first try a gentle swabbing using a lint-free swab. If needed, the use of lint-free swab and isopropyl alcohol used gently removes dirt from the lens. Do not use other solvents as they may adversely react with the LED assembly.

Board Design Rules

PCB Requirements

This section will discuss the board design parameters for LUXEON Rebel. The LUXEON Rebel can be mounted on 2-layer FR4, multi-layer FR4 or MCPCB (Metal Core PCB). To ensure optimal operation of the LUXEON Rebel, the thermal resistance path should be as low as feasible.

A 2 layer FR4 board is the lowest cost solution. The MCPCB board provides more rigidity than FR4. By following the guidelines outlined below, one can achieve a thermal resistance for FR4 that is equivalent or lower than MCPCB.

Board Design Rules, Continued

LUXEON Rebel Footprint

Philips Lumileds has conducted an investigation for the optimal board design of the LUXEON Rebel land pattern on the PCB. The goal of the study is to create a board with low thermal resistance, high placement accuracy, low solder voids, and solder-ability indicators.

Figure 7 shows the individual layers of the suggested layout with solder-ability indicators. These layouts detail two solder masks. The green solder mask is a photolithographic mask, which offers a highly accurate alignment to the copper layer. The white mask labeled "White Text" is a printed layer consisting of a double printed layer of Tamura USI — 210WP ink (UL E38152). This white mask enhances reflectivity, but is optional.

The solder-ability indicators are the diagonally extended copper areas on the thermal and electrical land patterns. In addition to acting as solder-ability indicators, the extended area can also be electrically probed for LED analysis. Reflow placement accuracy and thermal resistance will not be affected with the removal of the solder-ability indicator in the layout. For clarity, the term land refers to the pattern on the PCB for the LED pads.

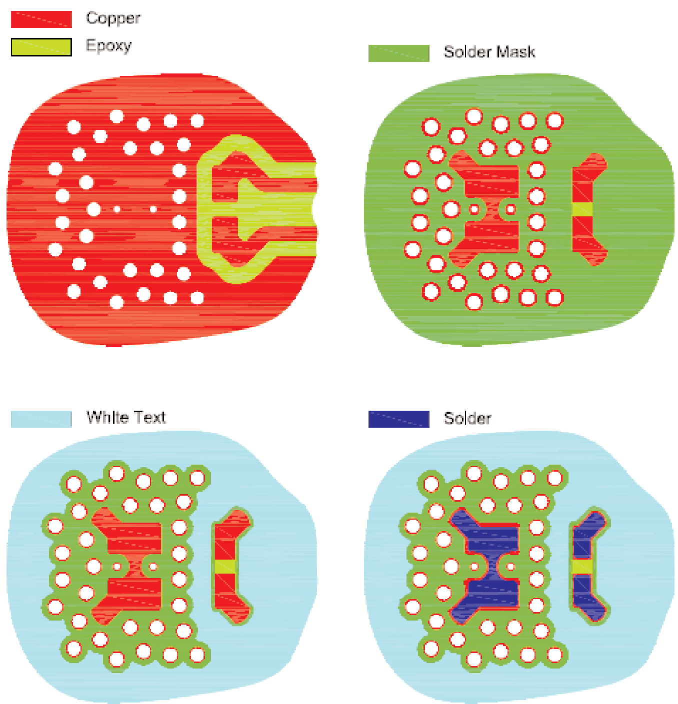

Figure 7. Configuration of the layout pattern for LUXEON Rebel.

LUXEON Rebel Close Density Spacing

Philips Lumileds recommends a minimal edge to edge spacing of 0.3mm between components. If the edge to edge spacing is less than 0.3mm, the components will drift together. Close spacing of Rebel will require the omission of the solder-ability indicators in the land pattern.

FR4 Based Boards

Material Properties

FR4 is an industry standard PCB technology. The base material is available in a range of variations. Depending on the LED application, drive condition, and the number of LEDs on the board, the choice for Tg and CTI value of the base material needs to be set. Most common material is Tg=130ºC and CT=175. For applications with many LEDs in series, thus larger voltage differences, trace clearances and CTI value must be increased accordingly. Here we refer to the appropriate standards for the application type in which the LUXEON Rebel is used. FR4 is available in a wide range of thicknesses. A thin substrate is advantageous to reduce thermal resistance and increase solder joint reliability.

FR4 Based Boards, Continued

Optimal Thermal Design

Thermal vias are the primary method of heat transportation from the PCB thermal land to the heat sink at the PCB bottom. A thermal via is a plated through hole that can be open, plugged, filled or filled and capped. A cross section of a FR4 based PCB with plated through holes is given in Figure 8. The final thermal resistance is determined by the number and density of vias, the copper plating thickness and the plated through hole (PTH) thickness. Philips Lumileds conducted a study aimed at reducing the thermal resistance. Figure 9 shows a design for a standard 2-layer board. Here the total copper plating is 0.070mm with the plated through hole plating thickness of 35 micrometer. In total, 33 vias are placed outside the thermal land. The 2 smaller thermal vias are placed such that voiding in the solder joint is minimized. The measured thermal resistance for a 0.8mm thick FR4 PCB with these design features is 7ºC/W.

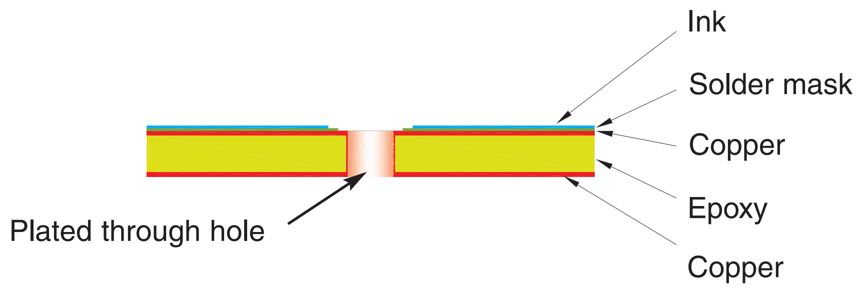

Figure 8. Cross section of FR4 based PCB with thermal vias to decrease the thermal resistance

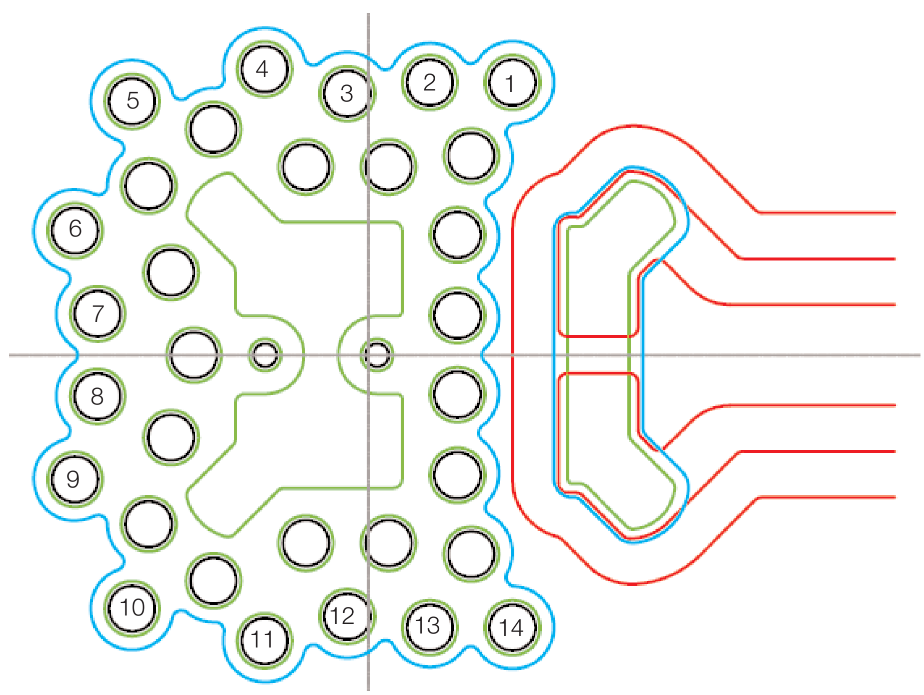

Figure 9. Outline of recommended layout pad for LUXEON Rebel with copper layer (red), photolithographic solder mask (green), white solder mask (blue, optional), drill holes (black), and solder stencil (blue hatched). Please note that there is a 0.5 mm spacing between the thermal and electrical pads.

FR4 Based Boards, Continued

Thermal Via Design

The thermal vias placed outside the land pattern have a finished hole diameter of 0.5mm. A smaller diameter will lead to an increase of thermal resistance. The recommended distance between two holes is 0.4 mm. This results in a minimal pitch of 0.9 mm between the vias. Figure 10 indicates the typical dimensions. The position of the vias may differ from the preferred layout of Figure 9, without significantly changing thermal properties.

The two smaller via's inside the thermal land have a finished diameter of 0.25mm. The drill hole for a 35 micron PTH thickness will be 0.32mm. The solder mask area around the vias is needed to avoid solder to flow through the vias to the backside. This would lead to a reduced heat sink contact of the PCB bottom surface.

Around each via an opening in the solder mask is designed. The clearance is 0.05mm minimum. The total minimal width of the solder mask around the via is 0.25 mm. Figure 11 shows the resulting solder mask design of the thermal pad.

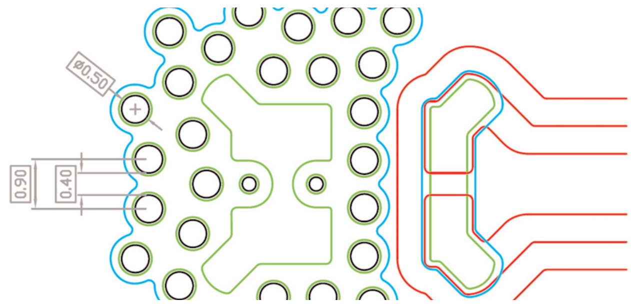

Figure 10. Finished diameter and spacing dimensions.

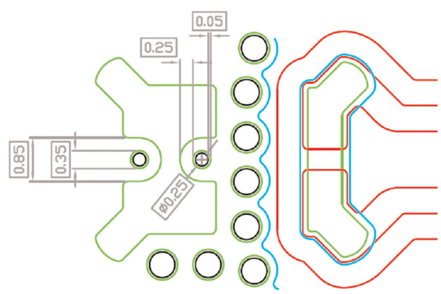

Figure 11. Solder mask design of thermal pad.

Component Spacing

With the above optimal thermal design, the minimal spacing edge to edge is 4mm, see Figure 12. Spacing below 4 mm will result in less vias in between the components than the original design.

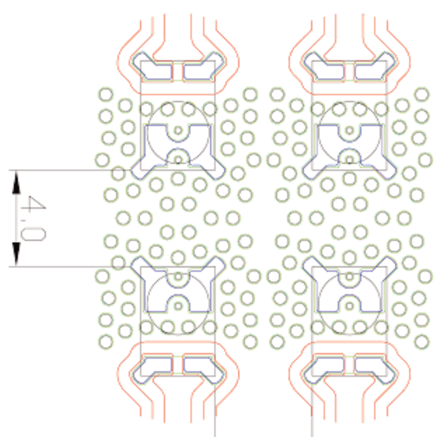

Figure 12. Illustration of edge to edge spacing. The thermal resistance will increase dramatically if the spacing is less than 2mm edge to edge.

FR4 Based Boards, Continued

Thermal Resistance

The thermal resistance between the component case (body) and the back of the board ($R\theta_{c\text{-}hs}$) of the PCB depends on: the size of Cu area around the thermal pad, the number of vias, the placement of vias, the Cu plating thicknesses, and the PCB thickness.

Figure 13 shows the simulated $R\theta_{c\text{-}hs}$ values for double layer FR4 with through hole plating of 20 µm and 35 µm and surface plating of 50 µm and 70 µm. Note that in this case the minimal spacing between the LEDs is 4mm. The total thermal resistance junction to heatsink is found by adding the $R\theta_{j\text{-}c}$ of the LUXEON Rebel (See values in the datasheet DS56).

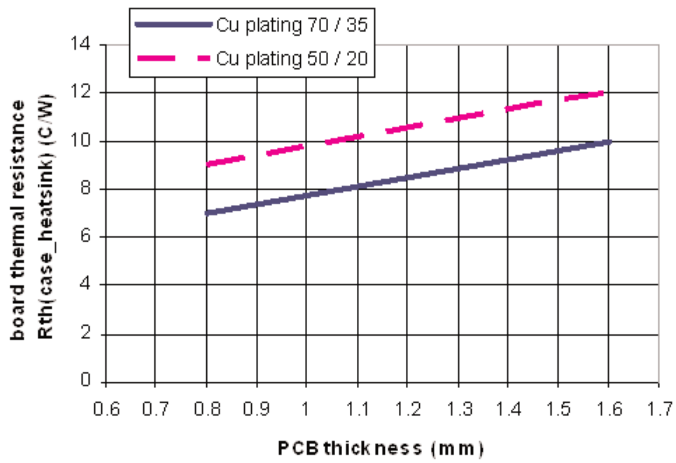

Figure 13. $R\theta_{c\text{-}hs}$ values as function of PCB thickness for 2-layer FR4 with PTH plating 20 or 35 µm and surface plating of 50 or 70 µm.

Removal of the 14 outer vias increases the thermal resistance by approximately 1K/W. The 14 outer vias are labeled in Figure 9. Eliminating the two vias in the thermal land will also increase the $R\theta_{c\text{-}hs}$ value with 1 K/W. The Copper area around the thermal land has a large contribution to the thermal spreading. The optimal copper area extends 3mm beyond the thermal pad. Any extension beyond 3mm will not significantly lower the thermal resistance. Elimination of both the outer vias and the copper area outside the thermal pad increases the thermal resistance to above 30 K/W.

Bringing the components closer together then 4mm will lead to elimination of via's and decrease the copper area around the thermal pad. If the spacing is less than 2mm, the thermal resistance will increase dramatically. Figure 14 shows the simulated thermal resistance as a function of spacing. Figure 15 shows the reduction of vias when the spacing decreases from 4mm to 2mm. The thermal resistance discussed in Figures 14 and 15 are for a 0.8mm FR4 board with 70microns of total copper plating.

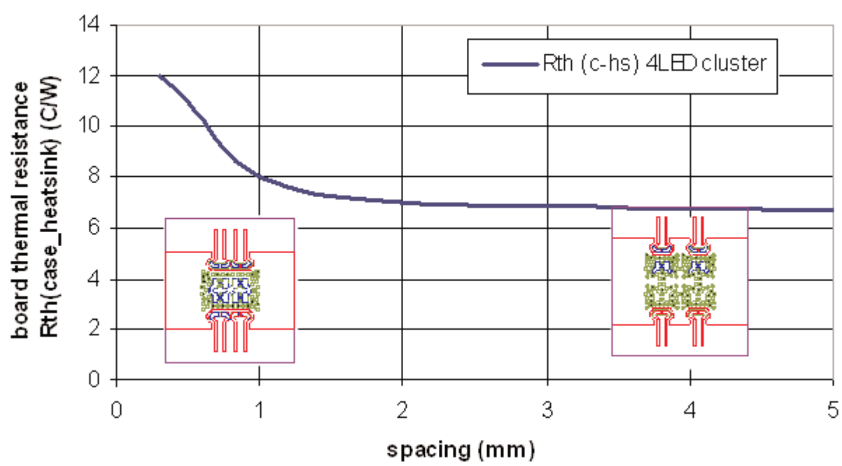

Figure 14. Simulated $R\theta_{c\text{-}hs}$ values for close spacing of LEDs for a 2-layer FR4 PCB. Board parameters are: PCB thickness 0.8mm (finished board), 35mu Cu plating via, 70 mu Cu plating layer.

FR4 Based Boards, Continued

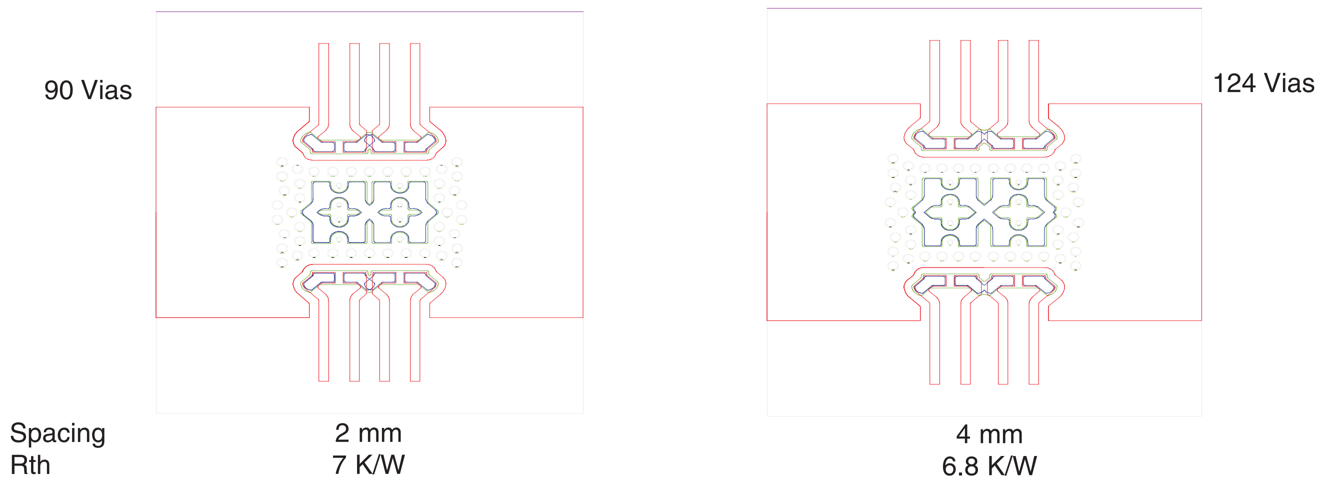

Figure 15. When the edge to edge spacing is reduced from 4 to 2mm, the number of vias decreases from 124 to 90. Thermal resistance values are simulated.

Surface Finishing

The surface finishing for the FR4 board is high temperature organic solder-ability preservatives (OSP) on copper.

MCPCB Board Design

The layout for the MCPCB design is similar to the FR4 design, but without the vias.

Two sets of design parameters are shown in Table 1. Using standard MCPCB design rules produces a board with 10ºC/W thermal resistance. This number is lowered considerably by increasing the copper thickness and using a thinner dielectric with higher thermal conductivity.

Table 1. MCPCB Design Parameters.

Dielectric	Typical epoxy	High conductivity epoxy
Dielectric thermal conductivity [W/mK]	0.8	4
Al thickness [mm]	1.5	1.5
Copper thickness [µm]	30	70
Dielectric thickness [µm]	100	85
Total MCPCB thermal resistance for low density design [degC/W]	10	5

The difference between the coefficients of thermal expansion (CTE) for Rebel mounted on MCPCB is greater than the difference for Rebel mounted on FR4 PCB. Therefore, there is greater solder joint stress for Rebel on MCPCB. Despite the greater joint stress, Philips Lumileds has successfully completed 1000 thermal shock cycles from -40ºC to 110ºC.

Assembly Process Recommendations and Parameters

Stencil Design

The recommended solder stencil thickness is 125 µm. The area coverage of the solder paste is greater than 90%. This yields a solder joint thickness of approximately 50 microns, using the leadfree solder mentioned in this guide.

Figure 16 shows the recommended stencil design for the footprint with two small thermal vias and solder-ability indicators.

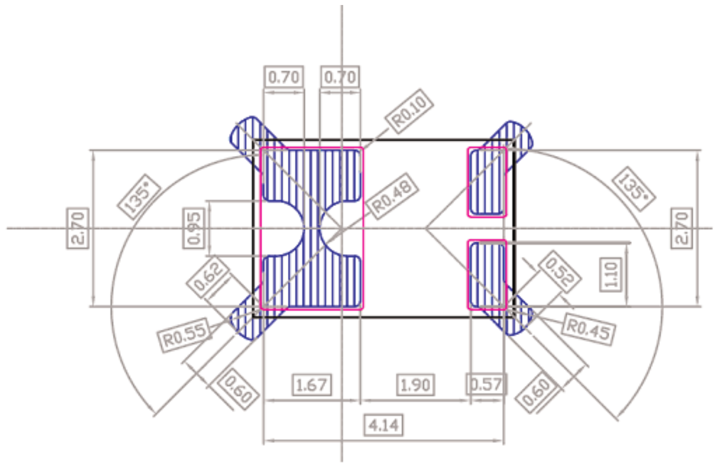

Figure 16. Solder stencil for footprint with two thermal vias and four solder ability indicators.

Solderpaste

Philips Lumileds recommends leadfree solder for the LUXEON Rebel. Philips Lumileds has successfully tested the following SAC 305 solder pastes: Alpha Metals OM338 grade 3; and OM 325 grade 4.

Pick And Place Nozzle

Automated pick-and-place equipment provides the best placement of LUXEON Rebel emitters. Philips Lumileds has evaluated 2 pick and place nozzles, a generic nozzle for 0603 components with a pick up area of 0.95mm x 1.75mm, and a Philips Lumileds specific nozzle for LUXEON Rebel. Neither nozzle places any contact onto the Rebel lens.

Figure 17a shows the pick up area on Rebel for a 0603 pick up nozzle. Make sure that the exterior of the nozzle does not touch the dome. The position of the nozzle during pick up is manually taught. For guidance the bottom fiducial can be used as shown in the figure.

Assembly Process Recommendations and Parameters, Continued

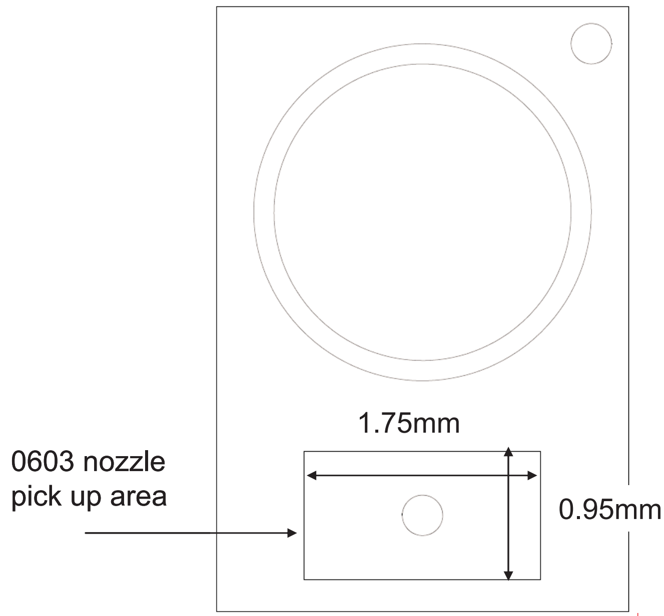

Figure 17a. Pick up area on the Rebel for a 0603 nozzle.

This section will specify the mechanical parameters for the Philips Lumileds specific nozzle. The nozzles are customer specific and machined to fit each equipment type. Figure 17b illustrates the mechanical dimensions of this nozzle design (units in mm). Philips Lumileds also uses a mold release spray to prevent the LED from sticking to the nozzle after placement. Philips Lumileds uses the mold release spray SR3-500B from Solent Maintenance.

Philips Lumileds has utilized the following company to make the dedicated nozzles for the LUXEON Rebel.

- Micro-Mechanics, Malaysia
- Email: mmmalaysia@micro-mechanics.com
- Telephone number: +604-6434648

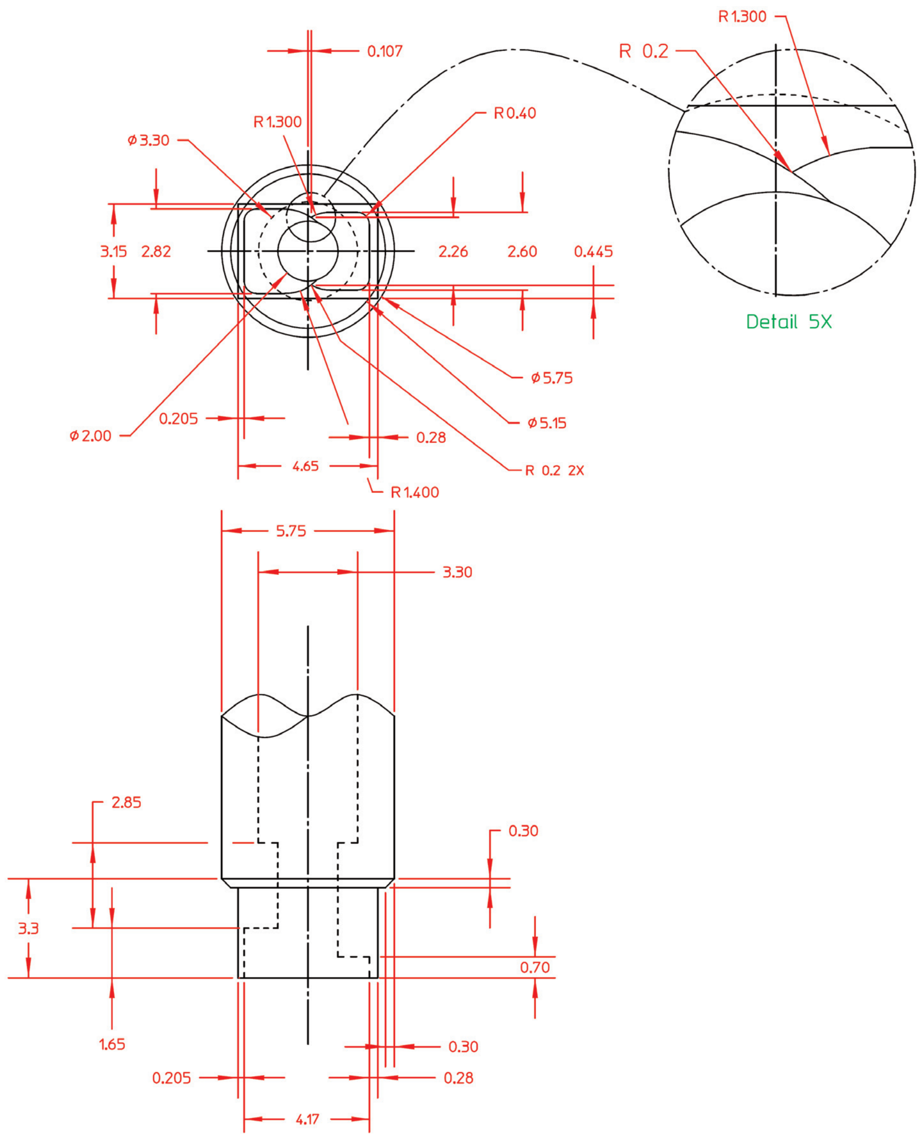

Figure 17b. Dedicated LUXEON Rebel nozzle design (units mm). The nozzle tolerance must account for the tolerances of the LED dimensions.

Pick and Place Parameters

The pick and place parameters for Philips Lumileds nozzle is summarized in Table 2 below.

Table 2. Pick and Place Parameters.

Pick up location referenced to top of the reel, see Figure 18	-0.2
Vacuum	-20kPa
Stencil thickness [micrometer]	125
Placement into solder [micrometer]	25
Over travel spring force during placement [N]	2
Material	Black anodized aluminum

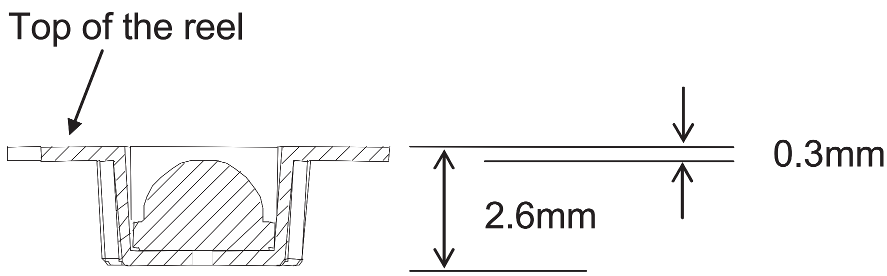

Figure 18. Referencing the top of the reel as 0mm, the nozzle will over-travel by 0.2mm into the reel's pocket.

Placing Accuracy

Achieve the highest placement accuracy by using an automatic pick and place equipment with a vision system to recognize the bottom metallization (3 pads). If available use the SOT32 profile from the component library, and modify the lead dimensions and pitch, see Figure 19 for dimensions. Recognition tolerance can be set at 30%. A lower percentage improves placement accuracy but may reduce recognition yield.

For high density placement, such as spacing between components below 0.5 mm, Philips Lumileds recommends recognition of the outline dimensions of the LED (see Figure 19). Reduce the tolerance on the outline dimensions to 5% to eliminate the risk of staggering of components.

Philips Lumileds recommends to have a minimal spacing of 0.3 mm between LUXEON Rebel packages. This avoids the risk of neighboring components touching each other after reflow.

For manual placement, the fiducials on the top side assist in locating the optical center. Figure 2 serves as a guideline to find the optical center on the top side.

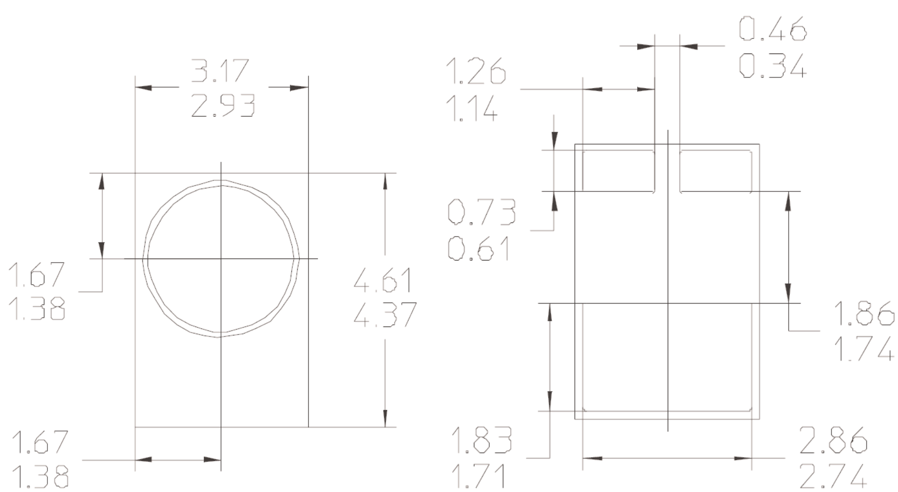

Figure 19. Mechanical dimensions of LUXEON Rebel package.

JEDEC Moisture Sensitivity Level

LUXEON Rebel LEDs have a JEDEC moisture sensitivity level of 1. This is the highest level offered in the industry and highest level within the JEDEC standard.

This provides the customer with ease of assembly. The customer no longer needs to be concerned about bake out times and floor life. No bake out time is required for a moisture sensitivity level of 1.

Moisture sensitivity level 1 requires the device be reflowed three times under the specifications listed in Figure 20 and Table 3 without performance degradation after removal from a 85ºC/85%RH temperature/humidity chamber, see Table 4.

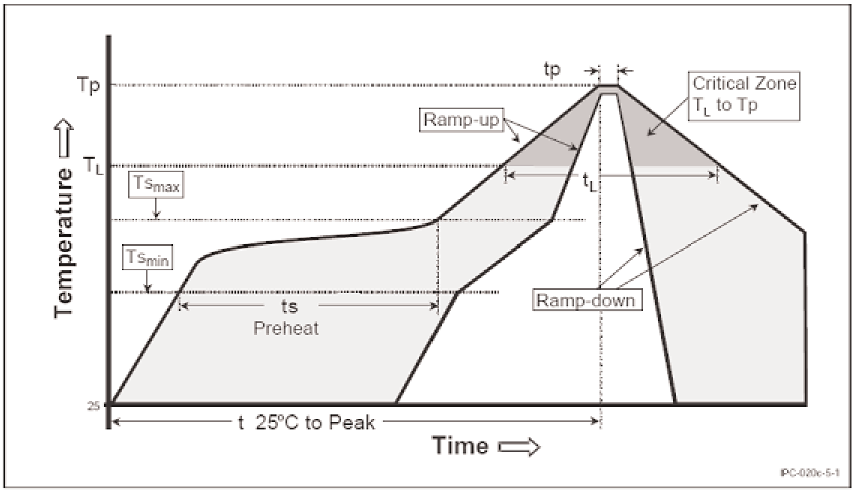

Figure 20. JEDEC 020c reflow solder profile for MSL classification.

Table 3. JEDEC 020c profile feature points.

Profile Feature	Lead Free Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)	3°C / second max
Preheat Temperature Min (Ts_{min})	150°C
Preheat Temperature Max (Ts_{max})	200°C
Preheat Time (ts_{min} to ts_{max})	60 - 180 seconds
Time Maintained Above Temperature (T_L)	217°C
Time Maintained Above Time (t_L)	60 - 150 seconds
Peak / Classification Temperature (T_P)	260°C
Time Within 5°C of Actual Peak Temperature (tp)	20 - 40 seconds
Ramp-Down Rate	6°C / seconds max
Time 25°C to Peak Temperature	8 minutes max

JEDEC Moisture Sensitivity Level, Continued

JEDEC has defined eight levels for moisture sensitivity, as shown in Table 4.

Table 4. JEDEC moisture sensitivity levels.

			SOAK REQUIREMENTS			
Level	Floor Life		Standard		Accelerated Equivalent [1]	
	Time	Conditions	Time (hours)	Conditions	Time (hours)	Conditions
1	Unlimited	≤ 30°C / 85% RH	168 +5/-0	85°C 85% RH		
2	1 year	≤ 30°C / 60% RH	168 +5/-0	85°C 60% RH		
2a	4 weeks	≤ 30°C / 60% RH	696[2] +5/-0	30°C / 60% RH	120 +1/-0	60°C / 60% RH
3	168 hours	≤ 30°C / 60% RH	192[2] +5/-0	30°C / 60% RH	40 +1/-0	60°C / 60% RH
4	72 hours	≤ 30°C / 60% RH	96[2] +2/-0	30°C / 60% RH	20 +0.5/-0	60°C / 60% RH
5	48 hours	≤ 30°C / 60% RH	72[2] +2/-0	30°C / 60% RH	15 +0.5/-0	60°C / 60% RH
5a	24 hours	≤ 30°C / 60% RH	48[2] +2/-0	30°C / 60% RH	10 +0.5/-0	60°C / 60% RH
6	Time on Label (TOL)	≤ 30°C / 60% RH	TOL	30°C / 60% RH		

Reflow Profile

LUXEON Rebel emitters are compatible with surface mount technology and lead-free reflow. This greatly simplifies the manufacturing process by eliminating the need for adhesives and epoxies, which for instance are needed for LUXEON I packages

The following is an excerpt from Philips Semiconductor, now NXP, applicationn note AN10365.

"The most important step in reflow soldering is reflow itself, when the solder paste deposits melt and soldered joints are formed. This is achieved by passing the boards through an oven, and exposing them to a temperature profile that varies in time. A temperature profile essentially consists of three phases:

1. Preheat: the board is warmed up to a temperature that is lower than the melting point of the solder alloy

2. Reflow: the board is heated to a peak temperature that is well above the melting point of the solder, but below the temperature at which the components and boards are damaged

3. Cooling down: the board is cooled down rapidly, so that soldered joints freeze before the board exits the oven

The peak temperature during reflow has an upper and a lower limit:

1. Lower limit of peak temperature; the minimum peak temperature must be at least high enough for the solder to make reliable solder joints; this is determined by solder paste characteristics; contact your paste supplier for details

2. Upper limit of peak temperature; the maximum peak temperature must be lower than:

    a. The test temperature used for MSL assessment; see section on "JEDEC Moisture Sensitivity Level".

    b. The temperature at which the boards are damaged; this is a board characteristic; contact your board supplier for details."

Reflow Profile, Continued

As a point of reference, the melting temperature for SAC 305 is 217°C, and the minimum peak reflow temperature is 235°C.

Philips Lumileds utilizes the following reflow profile for Rebel on PCB, Figure 21.

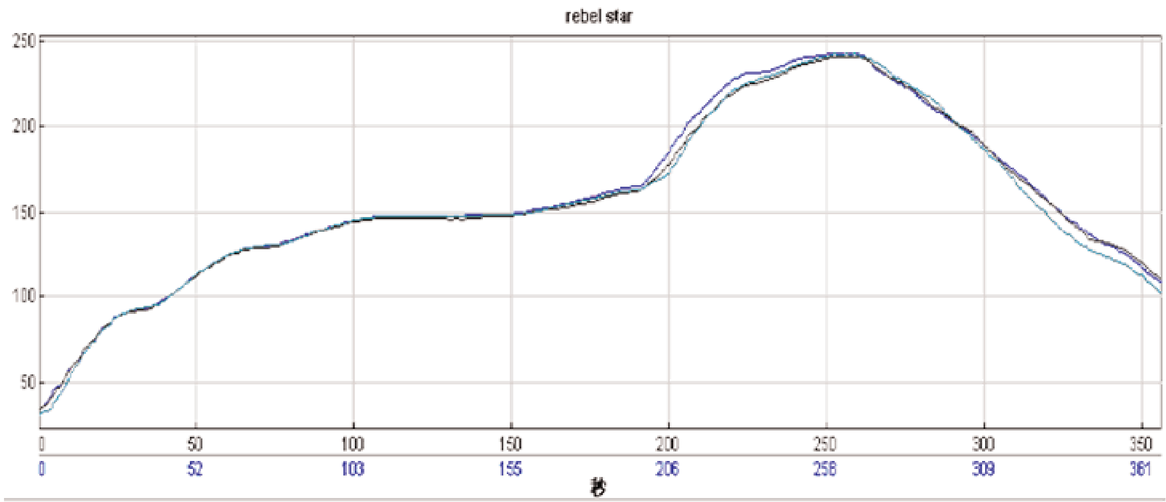

Figure 21. Reflow profile of LUXEON Rebel using SAC-305 solder paste.

Reflow Accuracy

Calculate the reflow accuracy between the centers of the component to the nominal board position by using global fiducials on the PCB board, as shown in Figure 22. The section titled "Optical Center" defines how to calculate the theoretical center of the Rebel. Philips Lumileds has determined the placement accuracy after reflow to be well within 90 m in the x and y directions for the footprint of Figure 9. The placement accuracy is determined as follows: The PCB onto which the LUXEON Rebel is assembled must have fiducials to determine the origin. The position of the LUXEON Rebel is determined using the component fiducials. The difference between this measured value and the nominal placement position is the placement accuracy.

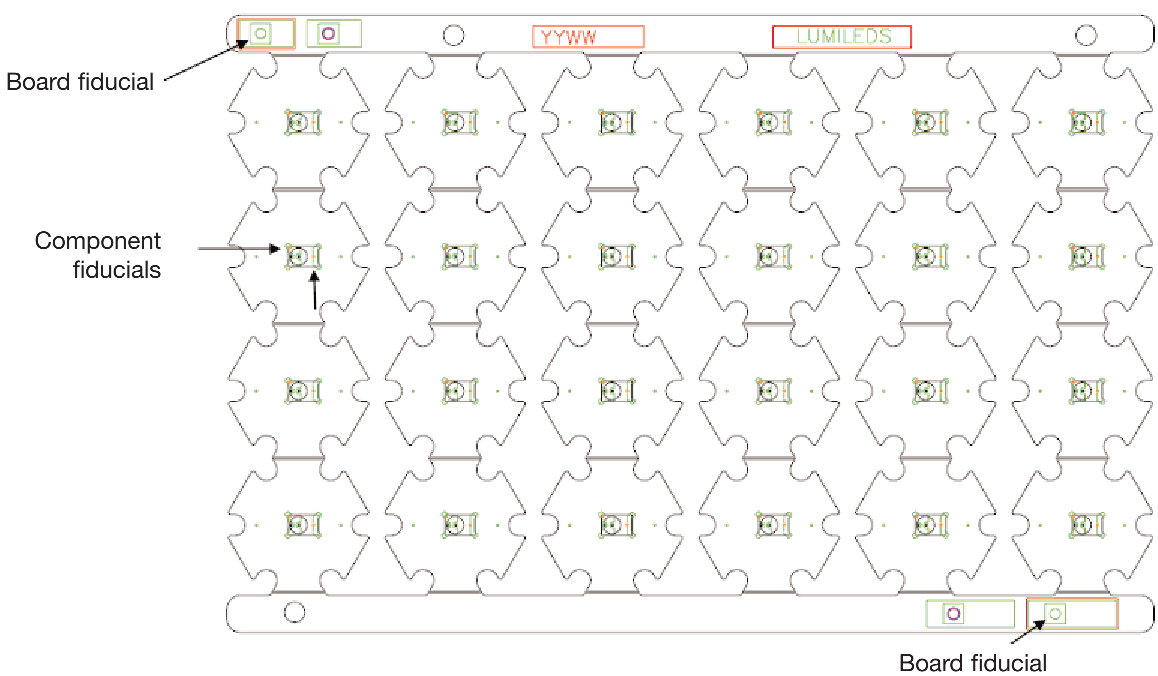

Figure 22. The board fiducials provide the origin of the board. The fiducials on Rebel determine the optical center of the LED. The difference between the measured coordinates of the optical centre and the nominal position is the placement accuracy.

Reflow Profile, Continued

Void Inspection and Solder-ability Indicators

An in-line X-Ray machine can inspect for voids after reflow. Philips Lumileds has determined that the two small thermal vias in the thermal pad footprint minimizes voiding by serving as an air vent during reflow.

A large percentage of voids in the thermal pad will increase of the thermal resistance. Figure 23 shows the impact of solder voiding on board thermal resistance ($R\theta_{c\text{-}hs}$).

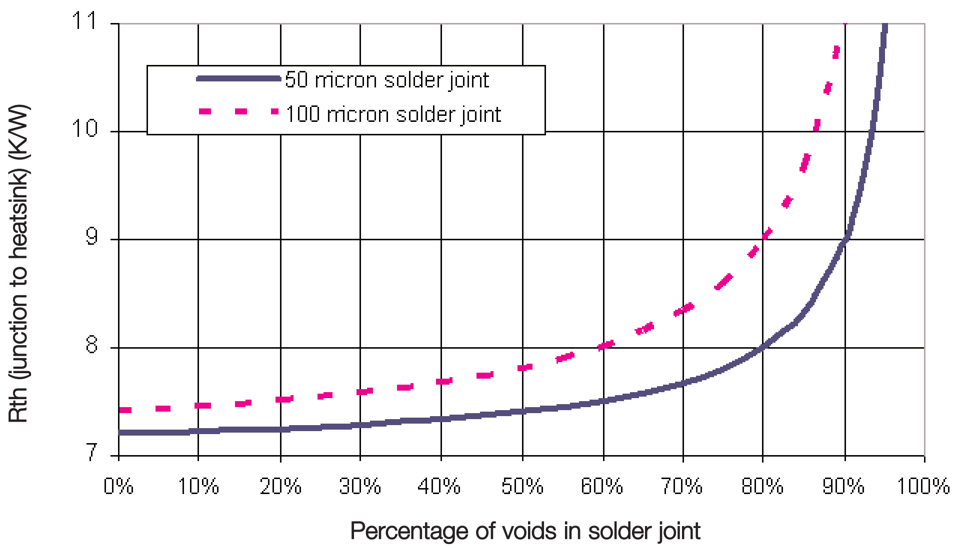

Figure 23. Impact of voiding in thermal land on thermal resistance.

For visual inspection of solder wetting, solder-ability indicators have been design in the footprint, see Figure 24.

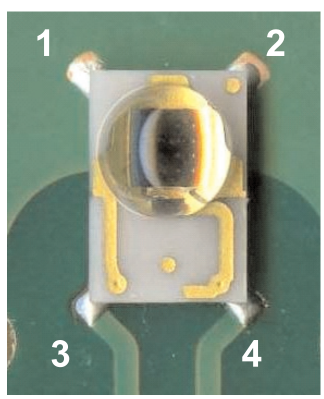

Figure 24. LUXEON Rebel reflowed into PCB with four solder-ability indicators.

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Company Information

Philips Lumileds Lighting Company is a world class supplier of Light Emitting Diodes (LEDs) and produces 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 as well as production capabilities in San Jose, Penang Malaysia and Singapore. 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 technologies, LEDs and systems are enabling new applications and markets in the lighting world.

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