**LUXEON Versat 3030**

Assembly and Handling Information

**Introduction**

This application brief addresses the recommended assembly and handling procedures for LUXEON Versat 3030 emitters. LUXEON Versat 3030 emitters are designed to deliver high luminous flux and efficacy in automotive exterior lighting applications. Due to the small size and construction, they require special assembly and handling precautions.

Proper assembly, handling and thermal management, as outlined in this application brief, ensures high optical output, long term lumen maintenance and high reliability of LUXEON Versat 3030 emitters in automotive applications.

**Scope**

The assembly and handling guidelines in this application brief apply to the following products:

<table>
<thead>
<tr>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUXEON Versat 3030 Red 700</td>
</tr>
<tr>
<td>LUXEON Versat 3030 Red 200</td>
</tr>
<tr>
<td>LUXEON Versat 3030 CW 150</td>
</tr>
<tr>
<td>LUXEON Versat 3030 PCA 150</td>
</tr>
<tr>
<td>LUXEON Versat 3030 CW 350</td>
</tr>
<tr>
<td>LUXEON Versat 3030 PCA 350</td>
</tr>
</tbody>
</table>

Any assembly or handling requirements that are specific to a subset of LUXEON Versat 3030 products are clearly marked. In the remainder of this document, the term LUXEON Versat refers to any product in the LUXEON Versat product family.
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1. Component

1.1 Reference Documents
The LUXEON Versat 3030 product datasheets are available upon request. Please contact your local sales representative.

1.2 Description
The LUXEON Versat emitter consists of a single LED chip covered by silicone material. For Cool White (CW) and Phosphor Converted Amber (PCA) products, the silicone is combined with a phosphor material to converted emitted light. For red products, the LED chip emits the light directly. These are placed on a carrier substrate made of metal lead frame. Underneath the carrier substrate are the electrical pads. The outside of the package is a cup shape made of silicone mold compound (SMC) to shield the chip from the environment. The LUXEON Versat emitter for CW and PCA includes a separate transient voltage suppressor (TVS) chip on the carrier substrate and covered by the silicone material in the cup. The TVS protects the emitter against electrostatic discharges (ESD). See Figure 1 for top and bottom view.

![Figure 1. Top view (left) and bottom view (right) of the LUXEON Versat 3030 CW emitter.](image)
Table 1. Design features by LUXEON Versat part number.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PART NUMBER</th>
<th>NOMINAL DRIVE CURRENT</th>
<th>DIE SIZE</th>
<th>LIGHT EMITTING AREA</th>
<th>PACKAGE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUXEON Versat 3030 RO* 700</td>
<td>A1VA-O612C10</td>
<td>700mA</td>
<td>1.1mm²</td>
<td>Ø 2.4mm</td>
<td>3mm x 3mm</td>
</tr>
<tr>
<td>LUXEON Versat 3030 CW 150</td>
<td>A1VA-5850A010</td>
<td>150mA</td>
<td>0.48mm²</td>
<td>Ø 2.4mm</td>
<td>3mm x 3mm</td>
</tr>
<tr>
<td>LUXEON Versat 3030 PCA 150</td>
<td>A1VA-P591A010</td>
<td>150mA</td>
<td>0.48mm²</td>
<td>Ø 2.4mm</td>
<td>3mm x 3mm</td>
</tr>
<tr>
<td>LUXEON Versat 3030 CW 350</td>
<td>A1VA-5850B010</td>
<td>350mA</td>
<td>0.82mm²</td>
<td>Ø 2.4mm</td>
<td>3mm x 3mm</td>
</tr>
<tr>
<td>LUXEON Versat 3030 PCA 350</td>
<td>A1VA-P591B010</td>
<td>350mA</td>
<td>0.82mm²</td>
<td>Ø 2.4mm</td>
<td>3mm x 3mm</td>
</tr>
<tr>
<td>LUXEON Versat 3030 RO* 200</td>
<td>A1VA-O612A10</td>
<td>200mA</td>
<td>0.23mm²</td>
<td>Ø 2.4mm</td>
<td>3mm x 3mm</td>
</tr>
</tbody>
</table>

*See datasheet for other Red product colors (RO=Red Orange).

1.3 Form Factor

The dimensional design for LUXEON Versat 3030 is outlined below in Figure 2. See the latest LUXEON Versat 3030 product datasheets for detailed dimensions and applicable tolerances.

![Figure 2. Outline dimensions for LUXEON Versat 3030 family.](image)
1.4 Optical Center

The LUXEON Versat has no lens (primary optics). The optical center is at the center of the circle shaped cup, as indicated by the red dot in Figure 3. See datasheet for latest information on distances and tolerances. Optical rayset data of each LUXEON Versat emitter is available upon request.

![Optical Center](image)

Figure 3. Optical center for LUXEON Versat 3030.

1.5 Mechanical Files

Mechanical drawings for LUXEON Versat 3030 (2D and 3D) are available upon request. For details, please contact your local sales representative.

2. Handling Precautions

Like all electrical components, there are handling precautions that need to be taken into account when setting up assembly procedures. The precautions for LUXEON Versat 3030 emitters are noted in this section.

2.1 Electrostatic Discharge (ESD) Protection

Electrostatic discharge, rapid transfer of charges between two bodies due to an electrical potential difference between those bodies, can cause damage to electronic components. In LED devices, ESD events can result in a slow degradation of light output and/or early catastrophic failures. In order to prevent ESD from causing any damage, Lumileds devices include a protection diode that is in parallel to the chip. This transient voltage suppressor (TVS) diode provides a current path for transient voltages (see Figure 4 and Figure 5).

![Electrical Schematic](image)

Figure 4. Electrical schematic of a Lumileds LED with bidirectional TVS.
Common causes of ESD include the direct transfer of charges from the human body or from a charged conductive object to the LED component. In order to test the susceptibility of LEDs to these common causes of ESDs, three different models are typically used:

- Human Body Model (HBM)
- Machine Model (MM)
- Charged Device Model (CDM)

LUXEON Versat emitters have been independently verified to successfully pass ESD tests under HBM, MM and CDM conditions. For the respective test voltages of these tests, please refer to the latest LUXEON Versat datasheets. Nevertheless, Lumileds strongly recommends that customers adopt handling precautions for LEDs similar to those which are commonly used for other electronic surface mount components which are susceptible to ESD events. Additional external ESD protection for the LED may be needed if the LED is used in non-ESD-protected environments and/or exposed to higher ESD voltages and discharge energies, for example, as described in ISO 10605 or IEC 61000-4-2 (severity level IV). For details please contact your local sales representative.

2.2 Component Handling

Minimize all mechanical forces exerted onto the silicone package of LUXEON Versat. The package consists of a fragile white silicone material and should not be handled with tweezers that can lead to damage of the package, especially not with metallic tweezers. Any force above 2.0N may damage the silicone side coat and change the optical performance. A vacuum pen can be used instead of tweezers.

The suction tip should be made of a soft material, such as rubber, to minimize the mechanical force exerted onto the top surface of the LED and on the silicone side coat layer. Avoid contaminating the top side surface of the LED with the soft material. Do not stick any tape on top of the light emitting surface, such as capton- or UV-tape. A contamination of glue or its invisible constituent parts may change the LED performance.

Electrical testing before assembly should be avoided. Probe tips may scratch or dent the pad surface and damage the LED. Avoid contact with the LED other than what is required for placement.

Do not touch the top surface with fingers or apply any pressure to it when handling finished boards containing LUXEON Versat emitters. Do not stack finished boards because the LED can be damaged by the other board outlines. In addition, do not put finished boards with LUXEON Versat emitters top side down on any surface. The surface of a workstation may be rough or contaminated and may damage the LED. These warnings are shown in Figure 6 and Figure 7.
Mishandling will lead to damages of package and encapsulant material as shown in Figure 8 below. Please see section 5.9, “Packing of Assembled LED Module,” for proper handling of finished products.

### 2.3 Cleaning

The surface of the LUXEON Versat emitter should not be exposed to dust and debris. Excessive dust and debris on the LED surface may cause a decrease in light output and optical behavior. It is best to keep LUXEON Versat emitters in their original shipping reel until actual use.

In the event that the surface requires cleaning, a compressed gas duster or an air gun with 1.4 bar (at the nozzle tip), a distance of 15cm will be sufficient to remove the dust and debris. Make sure the parts are secured first, taking above handling precautions into account.

One can also rinse with isopropyl alcohol (IPA). Do not use solvents listed in Table 8, as they may adversely react with the LED assembly. Extra care should be taken not to damage the housing around the LED chips. Lumileds does not recommend ultrasonic supported cleaning for LUXEON Versat 3030 emitters.
3. Printed Circuit Board

3.1 PCB Requirements

The LUXEON Versat can be mounted on multi-layer FR4 printed circuit boards (PCB) or insulated metal substrates (IMS).

To ensure optimal operation of the LUXEON Versat emitters, the thermal path between the LED package and the heat sink should be optimized according to the application requirements. Please ensure that the PCB assembly complies to the applicable IPC standards listed below.

**General PCB standards:**

- IPC A-600J: Acceptability of Printed Boards
- IPC A-610G: Acceptability of Electronic Assemblies
- IPC 2221B: General Standard on Printed Board Design
- IPC 7093: Design and Assembly Process Implementation for Bottom Termination Components

**Filled and capped via boards:**

- IPC 4761: Design Guide for Protection of Printed Board Via Structures
- IPC 2315: Design Guide for High Density Interconnects and Micro Vias
- IPC 2226A: Design Standard for High Density Interconnect Printed Boards

3.2 Footprint and Land Pattern

Lumileds recommends using solder mask defined land pattern for LUXEON Versat, as shown in Figure 9. Due to this, the copper area can be extended as far as possible for better heat spreading, which results in lower thermal resistance. However, a solder mask defined pad requires good mask quality and tight registration tolerances during PCB manufacturing (see section 6, “PCB Quality and Supplier,” for more details).

For the solder mask defined land pattern, the self-alignment of the component during reflow soldering can be controlled well by solder mask geometry in X- and Y-direction.

![Figure 9. Solder mask defined land pattern for LUXEON Versat 3030.](image)
3.3 Surface Finishing
Lumileds recommends using ENIG (Electroless Nickel Immersion Gold) plating according to IPC-4552A. Other surface finishes are possible but have not been tested by Lumileds. Surface finish Hot-Air-Solder-Leveling (HASL) may lead to inhomogenous pad height. Unsymmetrical solder thickness may have an influence on LED height and soldering tolerances. The actual quality of HASL finish should be checked in each single case.

3.4 Solder Mask
A flat solder mask thickness on top of metal layer is desired. Mask and PCB vendors have to be evaluated for proper quality. Systems with a photo lithographic structuring process are known to deliver better tolerances than screen printed materials. Due to the small footprint of the LUXEON Versat emitters, this requirement is important in order to achieve good assembly quality. Detailed specifications and information regarding solder mask requirements are contained in IPC-6012D and IPC-SM-840E.

3.5 Silk Screen or Ink Printing
Silk screen markings within and around the LUXEON Versat 3030 outline should be avoided because the height of the ink may interfere with the LUXEON Versat 3030 emitter and the solder stencil printing process. This can cause rotation, tilt and increased risk of solder bridging (short circuit). If needed, the ink printing should be at least 2mm away from the LUXEON Versat 3030 outline.

3.6 PCB Quality and Supplier
Select only PCB suppliers that are capable of delivering the required level of quality. Leastwise, the PCBs must comply with IPC standard IPC-A-600J, 2016 (“Acceptability of Printed Boards”).

A maximum mask registration tolerance of 50µm between the copper trace pattern and solder mask is desirable to achieve optimum solder joint contact area using the recommended solder mask defined footprint as shown in Figure 9. If the offset between the solder mask and the copper land pattern is large, one side of electrode pads will have less solder joint contact area. This may affect package centering, tilting, and thermal performance and may increase risk of solder bridging (short circuit) and solder balling if the stencil is not properly aligned to the solder mask during printing.

Figure 10 below shows an example of the solder pad size for three different registration offset levels between the copper trace pattern and the solder mask for LUXEON Versat using the recommended footprint in Figure 9. Large misalignment between solder mask opening and copper trace will cause one of the two electrode copper land patterns to be smaller than the other. Depending on the PCB manufacturer capability, PCB cost consideration and customer position tolerance needs, it may be necessary to extend the area of the solder mask opening.

Figure 10. Solder mask registration offset to copper trace.
4. Thermal Management

4.1 Thermal Resistance

The thermal resistance between the junction of the LED and the bottom side of the PCB depends on the following key design parameters of a PCB:

- PCB dielectric materials
- Cu plating thickness
- Solder pad pattern and solder thickness

Lumileds conducted simulations to evaluate the thermal performance of LUXEON Versat 3030 on different PCB design concepts. Details of the simulation model are given in Figure 11 below. The model geometry comprises the LUXEON Versat 3030 on a board (metal-core printed circuit board or FR4 board) that is mounted on a plate Al heatsink. A thermal interface material (TIM) is assumed to be present between board and heatsink. The thermal resistances junction-to-board bottom (\(R_{\text{th,j-b,el}}\) - thermal resistance based on electrical input power) are calculated as \(R_{\text{th,j-b,el}} = \frac{R_{\text{th,j-b,real}}}{1-WPE}\), where WPE denotes the wall plug efficiency. The WPE is not constant and depends on drive condition and flux binning class. The thermal resistance \(R_{\text{th,j-b,real}}\) is based on thermal power and is obtained by \(R_{\text{th,j-b,real}} = \frac{(T_j-T_b)}{P_{\text{th}}}\), where \(T_j\) is the average junction temperature, \(T_b\) the maximum temperature at the bottom side of the board obtained from the simulations, and \(P_{\text{in}}\) the thermal input power.

Simulation Details

Simulation Model

- LUXEON Versat on board and plate heatsink with TIM
- Simulation of heat conduction and radiation
- Bottom of heatsink is assumed to be ideally heat-sunk to ambient

Heatsink and TIM Parameters

- Heatsink size: 50mm x 50mm x 10mm
- Heatsink material: Al – 200 W/(mK)
- TIM thickness: 200µm
- TIM th. cond.: 2 W/(mK)

Board Parameters

- Board area: 20mm x 20mm
- Board thickness: 1.5mm
- Al metal core th. cond.: 200 W/(mK)
- Cu layer thickness: 35µm
- Cu layer th. cond.: 380 W/(mK)
- IMS diel. thickness: 75µm or 38µm
- IMS dielectric th. cond.: 2.2 W/(mK) or 3 W/(mK)
- FR4 epoxy th. cond.: 0.35 W/(mK) or 0.50 W/(mK)
- Vias plating th. cond.: 380 W/(mK)

Board Thermal Conductivities

- Cu: 380 W/(mK)
- IMS dielectric: 2.2 W/(mK) or 3 W/(mK)
• FR4 epoxy: 0.35 W/(mK)
• Vias plating (Cu): 380 W/(mK)

Solder Parameters
• Thickness (BLT): 55µm
• Th. conductivity: 56 W/(mK)

Figure 11. Model geometry and board parameters used for the simulation.
Table 2 lists the simulated thermal resistances $R_{th,j-b,real}$ and the thermal resistances $R_{th,j-b,el}$ for LUXEON Versat 3030 CW, LUXEON Versat 3030 PCA, and LUXEON Versat 3030 Red. To calculate $R_{th,j-b,el}$, a wall-plug efficiency of 0.41, 0.27, and 0.28 has been used for LUXEON Versat 3030 CW, LUXEON Versat 3030 PCA, and LUXEON Versat 3030 Red, respectively.

Table 2. Simulated LED-junction-to-board-bottom thermal resistances $R_{th,j-b,real}$ (based on thermal power) and $R_{th,j-b,el}$ (based on electrical power) for different board types. The thermal resistances $R_{th,j-b,el}$ have been calculated assuming a WPE of 0.41 for the cool white products, a WPE of 0.27 for the PCA products and a WPE of 0.28 for the Red product.

<table>
<thead>
<tr>
<th>BOARD MATERIAL/DIELECTRIC</th>
<th>LUXEON VERSAT 3030 150 CW</th>
<th>LUXEON VERSAT 3030 150 PCA</th>
<th>LUXEON VERSAT 3030 350 CW</th>
<th>LUXEON VERSAT 3030 350 PCA</th>
<th>LUXEON VERSAT 3030 350 PCA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R_{th,j-b,real}$ (K/W)</td>
<td>$R_{th,j-b,real}$ (K/W)</td>
<td>$R_{th,j-b,real}$ (K/W)</td>
<td>$R_{th,j-b,real}$ (K/W)</td>
<td>$R_{th,j-b,real}$ (K/W)</td>
</tr>
<tr>
<td>1.5mm Al-IMS, dielectric</td>
<td>28</td>
<td>19</td>
<td>20</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>3 W/(mK) – 38µm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 W/(mK) – 75µm</td>
<td>31</td>
<td>18</td>
<td>31</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>1.5mm FR4 with open vias,</td>
<td>52</td>
<td>31</td>
<td>52</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>0.35 W/(mK) epoxy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>56</td>
<td>95</td>
<td>95</td>
<td>69</td>
<td>83</td>
</tr>
<tr>
<td>1.5mm FR4 with 0.50 W/(mK)</td>
<td>95</td>
<td>56</td>
<td>95</td>
<td>69</td>
<td>83</td>
</tr>
<tr>
<td>epoxy material</td>
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<td></td>
<td></td>
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<tr>
<td>118</td>
<td>70</td>
<td>118</td>
<td>86</td>
<td>103</td>
<td>61</td>
</tr>
<tr>
<td>1.5mm FR4 with 0.35 W/(mK)</td>
<td></td>
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<td></td>
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<tr>
<td>epoxy material</td>
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<tr>
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<td>70</td>
<td>118</td>
<td>86</td>
<td>103</td>
<td>75</td>
</tr>
</tbody>
</table>

4.2 Thermal Measurement Instructions

The use of a temperature probe may be desirable to verify the overall system design model and expected thermal performance. Different methods exist to determine the LED temperature in terms of case temperature ($T_c$) or junction temperature ($T_j$).

Table 3 lists two methods along with the expected measurement accuracy. The more accurate a measurement is, the closer $T_c$ and $T_j$ can be designed to their maximum allowable values as specified in the LUXEON Versat datasheet.

Table 3. Temperature measurement methods for LUXEON Versat.

<table>
<thead>
<tr>
<th>METHOD</th>
<th>ACCURACY [°C]</th>
<th>EFFORT</th>
<th>EQUIPMENT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermo sensor (e.g. thin wire thermocouple)</td>
<td>±2.0 to ±5.0(1)</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Forward voltage measurement</td>
<td>±0.5</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Notes for Table 3:
1. See section “Temperature Probing by Thermo Sensor” for parameters determining the measurement accuracy.

Temperature Probing by Thermo Sensor

Figure 12 schematically shows the LED soldered to a PCB, including the relevant temperatures as defined for specific positions in the setup. Since the LED is directly soldered to the board, the case temperature is equal to the temperature of the solder material ($T_{solder}$). A practical way to verify the case temperature ($T_c$) is to measure the temperature ($T_{sensor}$) at a measurement point close to the case of the LED. Lumileds recommends attaching the sensor to the solder-joint inspection pad at the long edge of the anode as indicated in Figure 12. In this case, the case temperature can be directly measured, since it holds $T_c = T_{sensor}$. 
Temperature Probing by Forward Voltage Measurement

The forward voltage measurement uses the temperature dependence of the LED's forward voltage ($V_f$). The forward voltage, after switching off the thermally stabilized system, is measured and analyzed, yielding information on the LED junction temperature. By using a thermal model of LUXEON Versat 3030 or the LED junction-to-case thermal resistance as indicated in the datasheet, the case temperature ($T_c$) can be estimated. To ensure high accuracy, a precise and fast voltage measurement system is needed. In addition, the relationship between forward voltage and temperature needs to be properly characterized for each individual LED. Please contact your local sales representative for further support on this topic.

5. Assembly Process Recommendations and Parameters

5.1 Solder Paste

For reflow soldering, a standard lead free SAC solder paste (SnAgCu) with no clean flux can be used. The majority of the Lumileds internal testing has been conducted with the Indium 8.9HF SAC305 solder paste, which showed reasonable reflow and voiding performance for the given settings. Solder paste with powder type 3 is recommended for required stencil thickness and aperture size.

5.2 Stencil Design

For solder mask defined land pattern, the appropriate stencil aperture is given in Figure 13. The corner radius of stencil aperture should be selected according to paste particle size to improve paste release. For type 3 paste, a thickness of 150µm (6 mil) is recommended. Lumileds internal testing has been conducted with a stencil aperture of 58% (Anode pad) and 54% (Cathode pad) of the LED footprint area.
5.3 Pick and Place Nozzle

The LUXEON Versat is packed in a tape and reel with the light emitting surface facing upward. Automated pick and place equipment provides the best handling and placement accuracy for LUXEON emitters.

Lumileds recommends taking the following general pick and place guidelines into account:

1. The pick-up area is defined in Figure 14.
2. The nozzle tip should be clean and free of any particles since this may interact with the top surface coating of the LUXEON Versat during pick and place.
3. During setup and the first initial production run, it is good practice to inspect the top surface of LUXEON Versat emitters under a microscope to ensure that the emitters are not accidentally damaged by the pick and place nozzle.
4. To avoid any mechanical overstress, it is a good choice to use soft material for pickup. Rubber nozzles are available from various suppliers.
5. Ceramic nozzle can be used as low mass nozzles.
6. Lower Z-axis velocity at the point of board contact to avoid LED damage.

Since LUXEON Versat has no primary optics or lens, which can act as a mechanical enclosure protection for the LED chip, the pick-up and placement force applied to the top of the package should be minimized and kept well controlled.
Picking the component out of the carrier tape should be performed from a defined height position and should not apply forces to the component and carrier tape, as this may damage the component. The LUXEON Versat is packed in a recess of the carrier tape, and the nozzle geometry must be selected accordingly to not get in contact with carrier tape (see Figure 15).

![Figure 15. Pick-up from carrier tape.](image)

Figure 16 shows the standard pick and place nozzles from different SMT machine vendors, which can be used to handle the LUXEON Versat emitters.

![Figure 16. Nozzle recommendation for LUXEON Versat 3030.](image)

Nozzles for specific equipment platforms are under analysis. Please contact your local Lumileds sales representative if you need support regarding pick and place nozzle selection.

### 5.4 Placement Force

In order to avoid any damage of the LED and minimize squeeze-out of solder paste, placement process needs to be tightly controlled. Lumileds recommends using low placement forces or a Z-height controlled placement during the pick and place process. The force during pick and place should not exceed 2.0N. An additional large dynamic peak force occurs if the LED is placed with high Z-axis velocity at the point of touching the board and if the nozzle mass is high. Under worst case conditions, the phosphor LED coating can be damaged if, for example, large particles are underneath or if, due to a placement offset, the side coat touches the board surface (see Figure 17). Lower the Z-axis velocity if needed.

![Figure 17. LED touching the board during pick and place can (worst case) damage the LED.](image)
5.5 Feed System

Pick and place machines are typically equipped with special pneumatic or electric feeders to advance the tape containing the LEDs. The indexing step in the pick and place process may cause some LEDs to accidentally jump out of the pocket tape or may cause some LEDs to get misaligned inside the pocket tape, resulting in pick-up errors. Depending on the feeder design, minor modifications to the feeder can substantially improve the overall pick and place performance of the machine and reduce/eliminate the likelihood of scratch or damage to the LEDs. An optimum situation will be given when the pickup position is right after cover tape peel off. Do not leave index positions uncovered between peel off and pick position. This will prevent the LEDs from tilting over or jumping out when indexing. Furthermore, the cover tape peeling angle, relative to the tape, should be small to reduce the vertical pulling force during indexing (see Figure 18).

![Figure 18. Pick position and cover tape peeling.](image)

5.6 Reflow Profile

The LUXEON Versat is compatible with standard surface-mount and lead-free reflow technologies. This greatly simplifies the manufacturing process by eliminating the need for adhesives and epoxies. The reflow step itself is the most critical step in the reflow soldering process and occurs when the boards move through the oven and the solder paste melts, forming the solder joints. To form good solder joints, the time and temperature profile throughout the reflow process must be well maintained.

A temperature profile consists of three primary phases:

1. **Preheat**: the board enters the reflow oven and is warmed up to a temperature lower than the melting point of the solder alloy.
2. **Reflow**: the board is heated to a peak temperature above the melting point of the solder, but below the temperature that would damage the components or the board.
3. **Cool down**: the board is cooled down rapidly, allowing the solder to freeze, before the board exits the oven.

As a point of reference, the melting temperature for SAC 305 is 217°C, and the minimum peak reflow temperature is 235°C. Lumileds successfully utilized the reflow profile in Figure 19 and Table 4 for LUXEON Versat on FR4 and MCPCB.
Table 4. Temperature measurement methods for LUXEON Versat.

<table>
<thead>
<tr>
<th>PROFILE FEATURE</th>
<th>MINIMUM VALUE</th>
<th>TYPICAL VALUE FOR SAC</th>
<th>MAXIMUM VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheat Minimum Temperature ($T_{\text{min}}$)</td>
<td>150°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preheat Maximum Temperature ($T_{\text{max}}$)</td>
<td>200°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preheat Time ($T_{\text{min}}$ to $T_{\text{max}}$)</td>
<td>100 seconds</td>
<td>120 seconds</td>
<td></td>
</tr>
<tr>
<td>Ramp-Up Rate ($T_{\text{max}}$ to $T_p$)</td>
<td>2°C/second avg.</td>
<td>3°/second</td>
<td></td>
</tr>
<tr>
<td>Liquidus Temperature ($T_L$)</td>
<td>217°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Maintained Above Temperature $T_L$ ($t_L$)</td>
<td>60 seconds</td>
<td>120 seconds</td>
<td></td>
</tr>
<tr>
<td>Peak / Classification Temperature ($T_p$)</td>
<td>240°C</td>
<td></td>
<td>260°C</td>
</tr>
<tr>
<td>Time Within 5°C of Actual Peak Temperature ($t_p$)</td>
<td>10 seconds</td>
<td>20 seconds</td>
<td></td>
</tr>
<tr>
<td>Time Within 5°C of Maximum Peak Temperature ($t_p$)</td>
<td></td>
<td></td>
<td>30 seconds</td>
</tr>
<tr>
<td>Maximum Ramp-Down Rate ($T_p$ to $T_L$)</td>
<td>2.5°C/sec. avg.</td>
<td>6°C/second</td>
<td></td>
</tr>
<tr>
<td>Time 25°C to Peak Temperature</td>
<td>240 seconds</td>
<td>310 seconds</td>
<td>480 seconds</td>
</tr>
<tr>
<td>Nitrogen Atmosphere (O2)</td>
<td>&lt;1000 ppm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: All temperatures refer to the application Printed Circuit Board (PCB), measured on the surface adjacent to the package body.

Things to watch for after reflow should include:

1. Solder voids: perform x-ray inspection
2. Solder bridge between anode and cathode
3. Solder balling
4. Any visible damage, tilt or misplacement of LED
5. Any contamination on light emitting area; this may impact the light output extraction or cause color shift
6. Functional test (open/short)
7. Current test, e.g. $V_f$ at 1mA $\geq$ 2.0V
5.7 Reflow Accuracy
For solder mask defined designs, Lumileds facilitated internal tests with shown position accuracy after reflow (see Figure 20 and Table 5). Results may vary based on printed circuit board quality and used assembly process.

![L1 and L2 tolerance definition.](image)

**Figure 20. L1 and L2 tolerance definition.**

**Table 5. Dimension and placement tolerances for LUXEON Versat.**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>MAXIMUM VALUE (5σ)</th>
<th>TYPICAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>L1: Package outline X/Y</td>
<td>±100µm</td>
<td>—</td>
</tr>
<tr>
<td>B</td>
<td>L1: Total thickness Z</td>
<td>±100µm</td>
<td>—</td>
</tr>
<tr>
<td>C</td>
<td>L2: Optical center to L2 fiducial, X/Y</td>
<td>—</td>
<td>±100µm</td>
</tr>
</tbody>
</table>

Note: Typical values given are derived from sample based assembly tests performed at Lumileds and calculated for 5 Sigma.

5.8 Board Handling and Bending
The LED package handling precaution, as described in section 2.2, “Component Handling”, must also be applied when handling completed boards. Even though this product has a small form factor and is unlikely to cause any problems, forces on the package should be kept to a minimum. Bending of a PCB is a common handling problem typically seen on large boards. A printed circuit board may warp after reflow when layers with different CTE (coefficient of thermal expansion) are applied to the top and bottom of the boards. If the PCB is subsequently secured to a flat surface, a vertical force is applied to the LED package (see Figure 21).

Any deformation by mounting the board and screwing it onto a heatsink or by de-paneling, like punching-off or breaking-off, should be kept to minimum. As a general guideline, it should be at most 2mm of vertical deflection for every 90mm of FR4 PCB length. The guideline should be maintained to prevent the sapphire chip, used in the LED, from cracking and causing device failure. Reference AEC-Q200-005 for board bending test preparation.

This guideline does not apply to solder joint reliability, as the ability of the solder joint to withstand this stress (elongation) depends on the footprint layout, solder joint thickness, solder voiding and the type of solder paste used.

![Maximum PCB bending guideline to prevent damage to the LUXEON Versat 3030 package.](image)

**Figure 21. Maximum PCB bending guideline to prevent damage to the LUXEON Versat 3030 package.**
5.9 Packing of Assembled LED Module

Finished boards must be protected against damage during transport. It is recommended using a customized tray package, which is designed to hold the PCBs during transport (see Figure 22).

Here are some general rules of best practice tray design:

1. Design the tray to avoid accidently touching the LED by manually taking assemblies out or putting into tray. Ideally, the tray only allows one way to hold the assembly. If there are several ways to put assemblies into the tray or take them out, a strict operator discipline and clear instruction on how to safely handle the assemblies is needed.

2. It must be designed in a way that force from the tray or packing material is not applied to the LED.

3. In a stack of multiple trays, the PCB should also be secured from the top. This can be done by bottom structures of the next tray which is put on top of the stack.

4. The tray should also protect the LED against movement and shaking/vibrations during transport.

![Figure 22. Schematic of a good tray design. The LEDs are protected against movement and no force is applied to the LEDs.](image)

6. Interconnect Reliability

The reliability of board interconnect under thermal cycling and thermal shock condition is mainly determined by thermal expansion of used materials. The LUXEON Versat package is based on a copper lead frame which has a CTE of ~16 ppm (coefficient of thermal expansion). The CTE mismatch between LED package and printed circuit board will lead to mechanical stress and cause solder fatigue or solder cracking. To achieve highest possible reliability, the CTE of the board material should be as similar to the LED package as possible. Table 6 shows commonly used materials and their CTE.

Table 6. CTE of common board substrate materials for LUXEON Versat.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>COEFFICIENT OF THERMAL EXPANSION (CTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapphire (LED chip)</td>
<td>5-6 ppm</td>
</tr>
<tr>
<td>Solder SAC305</td>
<td>19-22 ppm</td>
</tr>
<tr>
<td>Copper</td>
<td>16.5 ppm</td>
</tr>
<tr>
<td>FR4</td>
<td>12-17 ppm*</td>
</tr>
<tr>
<td>Aluminium</td>
<td>23.1 ppm</td>
</tr>
<tr>
<td>AlN</td>
<td>4 ppm</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>6-8 ppm</td>
</tr>
</tbody>
</table>

* Depending on laminate vendor, pre-preg type and fiber orientation.
Also, the mechanical properties of solder material and solder thickness have an impact on interconnect reliability. Using a ductile material and increasing the bond line thickness will increase solder joint reliability.

Lumileds performed measurements at corner cases of LUXEON Versat. Cross-sections of solder joint and x-rays for voiding and solder balling behavior were taken. The test results after conditioning by air to air thermo-mechanical shock (AA-TMSK) from -40 to +125°C for 1000, 2000, and 3000 cycles are shown in Figure 23.

![Figure 23. X-section and x-ray of LUXEON Versat after AA-TMSK testing.](image)

### 7. JEDEC Moisture Sensitivity Level

The LUXEON Versat has a JEDEC moisture sensitivity level of 1. This is the highest level offered in the industry and the highest level within the JEDEC J-STD-020D.1 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 allows the device to be reflowed three times under the specifications as described in the respective LUXEON Versat datasheets. JEDEC has defined eight levels for moisture sensitivity, as shown in Table 7.

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>FLOOR LIFE</th>
<th>TIME</th>
<th>CONDITIONS</th>
<th>SOAK REQUIREMENTS</th>
<th>TIME (HOURS)</th>
<th>CONDITIONS</th>
<th>ACCELERATED EQUIVALENT</th>
<th>TIME (HOURS)</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unlimited</td>
<td>Unlimited</td>
<td>≤30°C/85% RH</td>
<td>168 Hours</td>
<td>+5/-0</td>
<td>85°C/85% RH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 Year</td>
<td>≤30°C/60% RH</td>
<td>168 Hours</td>
<td>+5/-0</td>
<td>85°C/60% RH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a</td>
<td>4 Weeks</td>
<td>≤30°C/60% RH</td>
<td>696 Hours</td>
<td>+5/-0</td>
<td>30°C/60% RH</td>
<td>120 Hours</td>
<td>+1/-0</td>
<td>60°C/60% RH</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>168 Hours</td>
<td>≤30°C/60% RH</td>
<td>192 Hours</td>
<td>+5/-0</td>
<td>30°C/60% RH</td>
<td>40 Hours</td>
<td>+1/-0</td>
<td>60°C/60% RH</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>72 Hours</td>
<td>≤30°C/60% RH</td>
<td>96 Hours</td>
<td>+2/-0</td>
<td>30°C/60% RH</td>
<td>20 Hours</td>
<td>+5/-0</td>
<td>60°C/60% RH</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>48 Hours</td>
<td>≤30°C/60% RH</td>
<td>72 Hours</td>
<td>+2/-0</td>
<td>30°C/60% RH</td>
<td>15 Hours</td>
<td>+5/-0</td>
<td>60°C/60% RH</td>
<td></td>
</tr>
<tr>
<td>5a</td>
<td>24 Hours</td>
<td>≤30°C/60% RH</td>
<td>48 Hours</td>
<td>+2/-0</td>
<td>30°C/60% RH</td>
<td>10 Hours</td>
<td>+5/-0</td>
<td>60°C/60% RH</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Time on Label (TOL)</td>
<td>≤30°C/60% RH</td>
<td>TOL</td>
<td></td>
<td></td>
<td>30°C/60% RH</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. Packaging Considerations—Chemical Compatibility

The LUXEON Versat package contains a silicone encapsulant to protect the LED chip and extract the maximum amount of light. As with most silicones used in LED optics, care must be taken to prevent any incompatible chemicals from directly or indirectly reacting with the silicone.

The silicone encapsulant in LUXEON Versat is gas permeable. Consequently, oxygen and volatile organic compound (VOC) gas molecules can diffuse into the silicone overcoat. VOCs may originate from adhesives, solder fluxes, conformal coating materials, potting materials and even some of the inks that are used to print the PCBs. Some VOCs and chemicals react with silicone and produce discoloration and surface damage. Other VOCs do not chemically react with the silicone material directly, but diffuse into the silicone and oxidize during the presence of heat or light. Regardless of the physical mechanism, both cases may affect the total LED light output. Since silicone permeability increases with temperature, more VOCs may diffuse into and/or evaporate out from the silicone.

Careful consideration must be given to whether LUXEON Versat emitters are enclosed in an “air tight” environment or not. In an “air tight” environment, some VOCs that were introduced during assembly may permeate and remain in the silicone overcoat. Under heat and “blue” light, the VOCs inside the silicone overcoat may partially oxidize and create a silicone discoloration, particularly on the surface of the LED where the flux energy is the highest. In an air rich or “open” air environment, VOCs have a chance to leave the area (driven by the normal air flow). Transferring the devices, which were discolored in the enclosed environment back to “open” air, may allow the oxidized VOCs to diffuse out of the silicone overcoat and may restore the original optical properties of the LED.

Determining suitable threshold limits for the presence of VOCs is very difficult since these limits depend on the type of enclosure used to house the LEDs and the operating temperatures. Also, some VOCs can photo-degrade over time. Table 8 provides a list of commonly used chemicals that should be avoided as they may react with the silicone material. Note that Lumileds does not warrant that this list is exhaustive since it is impossible to determine all chemicals that may affect LED performance.

The chemicals in Table 8 are typically not directly used in the final products that are built around LUXEON Versat LEDs. However, some of these chemicals may be used in intermediate manufacturing steps (e.g. cleaning agents). Consequently, trace amounts of these chemicals may remain on sub-components, such as heatsinks. Lumileds, therefore, recommends the following precautions when designing your application:

1. When designing secondary lenses to be used over an LED, provide a sufficiently large air-pocket and allow for “ventilation” of this air away from the immediate vicinity of the LED.

2. Use mechanical means of attaching lenses and circuit boards as much as possible. When using adhesives, potting compounds and coatings, carefully analyze its material composition and do thorough testing of the entire fixture under High Temperature Over Life (HTOL) conditions.
Table 8. List of commonly used chemicals that may damage the silicone encapsulant of LUXEON Versat 3030.

<table>
<thead>
<tr>
<th>CHEMICAL NAME</th>
<th>TYPICAL USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric Acid</td>
<td>Acid</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Acid</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>Acid</td>
</tr>
<tr>
<td>Acetic Acid</td>
<td>Acid</td>
</tr>
<tr>
<td>Sodium Hydroxide</td>
<td>Alkali</td>
</tr>
<tr>
<td>Potassium Hydroxide</td>
<td>Alkali</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Alkali</td>
</tr>
<tr>
<td>MEK (Methyl Ethyl Ketone)</td>
<td>Solvent</td>
</tr>
<tr>
<td>MIBK (Methyl Isobutyl Ketone)</td>
<td>Solvent</td>
</tr>
<tr>
<td>Toluene</td>
<td>Solvent</td>
</tr>
<tr>
<td>Xylene</td>
<td>Solvent</td>
</tr>
<tr>
<td>Benzene</td>
<td>Solvent</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Solvent</td>
</tr>
<tr>
<td>Mineral spirits</td>
<td>Solvent</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>Solvent</td>
</tr>
<tr>
<td>Tetrachloromethane</td>
<td>Solvent</td>
</tr>
<tr>
<td>Castor Oil</td>
<td>Oil</td>
</tr>
<tr>
<td>Lard</td>
<td>Oil</td>
</tr>
<tr>
<td>Linseed Oil</td>
<td>Oil</td>
</tr>
<tr>
<td>Petroleum</td>
<td>Oil</td>
</tr>
<tr>
<td>Silicone Oil</td>
<td>Oil</td>
</tr>
<tr>
<td>Halogenated Hydrocarbons (containing F, Cl, Br elements)</td>
<td>Misc.</td>
</tr>
<tr>
<td>Rosin Flux</td>
<td>Solder Flux</td>
</tr>
<tr>
<td>Acrylic Tape</td>
<td>Adhesive</td>
</tr>
</tbody>
</table>

Note: Avoid using any of these chemicals in the housing that contains the LED package.
About Lumileds

Companies developing automotive, mobile, IoT and illumination lighting applications need a partner who can collaborate with them to push the boundaries of light. With over 100 years of inventions and industry firsts, Lumileds is a global lighting solutions company that helps customers around the world deliver differentiated solutions to gain and maintain a competitive edge. As the inventor of Xenon technology, a pioneer in halogen lighting and the leader in high performance LEDs, Lumileds builds innovation, quality and reliability into its technology, products and every customer engagement. Together with its customers, Lumileds is making the world better, safer, more beautiful—with light.

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