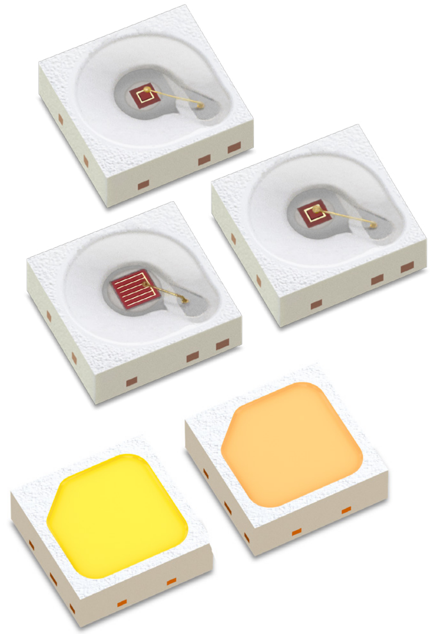
LUMILEDS

AUTOMOTIVE

LUXEON Versat 2020

Assembly and Handling Information



Introduction

This application brief addresses the recommended assembly and handling procedures for the LUXEON Versat 2020. As a matter of principle, LEDs 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 Versat 2020 in automotive applications.

Scope

The assemblyand handling guidelines in this application brief apply to the products:

- LUXEON Versat 2020 20 Red-Orange / Red / Long-Red / Super-Red
- LUXEON Versat 2020 50 Amber / Red-Orange / Red / Long-Red/ Super-Red
- LUXEON Versat 2020 140 Amber / Red-Orange / Red / Long-Red/ Super-Red
- LUXEON Versat 2020 150 CoolWhite / PC Amber

Any assembly or handling requirements that are specific to a subset of LUXEON Versat 2020 products is clearly marked. In the remainder of this document, the term Versat 2020 refers to any product in the LUXEON Versat 2020 product family unless specifically noted otherwise.

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1. Component

1.1 Reference Documents

The LUXEON Versat 2020 datasheets are available upon request. Please contact your sales representative.

1.2 Description

The Versat LED consists of a single chip, directly emitting red lor blue light and covered by silicone material. In case of phosphor converted products (Versat 2020 CoolWhite and Versat 2020 PC Amber) a phosphor material is added to the silicone to partly convert the blue light in yellow or amber.

The metal lead frame forms the electrical pads on its bottom side and the chip is placed on the top of the lead frame. The Versat Red-Orange LEDs do not include a separate transient voltage suppressor (TVS) chip, to protect the emitter against electrostatic discharges (ESD). For all red orange LEDs this protection is given by the intrinsic semiconductor. The phosphor converted (PC Amber and CoolWhite) Versat 2020 product include a TVS chip for protection against ESD up to 8kV (HBM model).

See in Figure 1 the enclosure of the Versat 2020, that is made of epoxy mold compound (EMC).

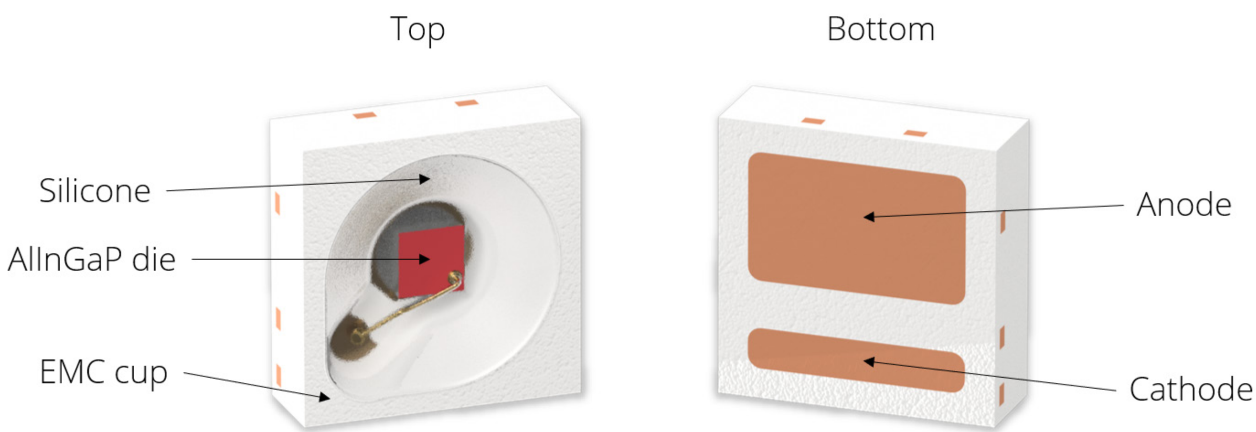


Figure 1a. Top view (left) and bottom view (right) of the LUXEON Versat 2020 Amber / Red-Orange / Red / Long-Red/ Super-Red

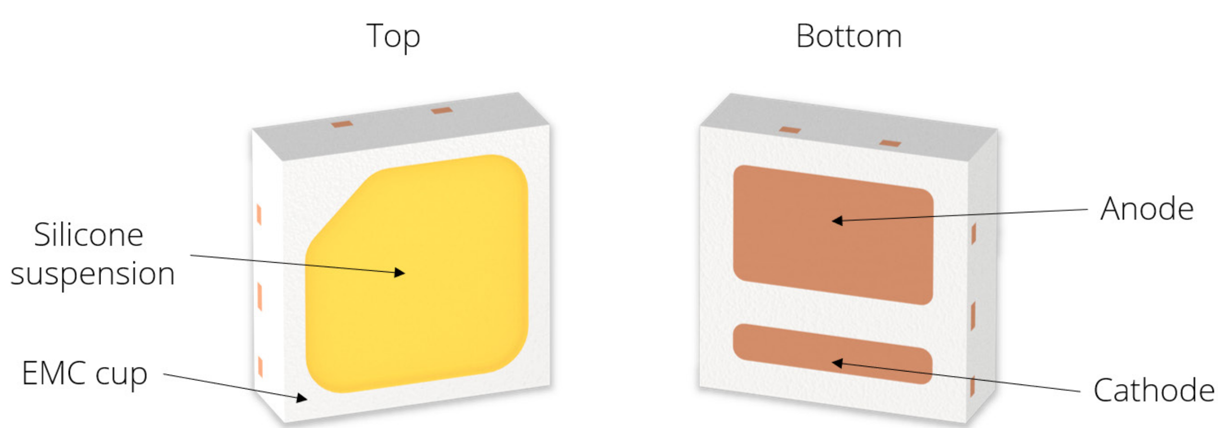


Figure 1b. Top view (left) and bottom view (right) of the LUXEON Versat 2020 Cool White / PC Amber

Table 1. Design features by LUXEON Versat part number

PART NUMBER	COLOR	TEST CURRENT
A1VB-O612A	Red Orange	20
A1VB-R620A	Red	20
A1VB-S627A	Long Red	20
A1VB-S632A	Super Red	20
A1VB-A584B	Amber	50
A1VB-A588B	Amber	50
A1VB-O612B	Red Orange	50
A1VB-R620B	Red	50
A1VB-S627B	Long Red	50
A1VB-S632B	Super Red	50
A1VB-A584C	Amber	140
A1VB-A588C	Amber	140
A1VB-O612C	Red Orange	140
A1VB-R620C	Red	140
A1VB-S627C	Long Red	140
A1VB-S632C	Super Red	140
A1VB-P591A01000xx0	PC Amber	150
A1VB-5850A01000xx0	Cool White	150

1.3 Form Factor

See in Figure 2 the LED package. Refer to the latest datasheet for detailed dimensions and applicable tolerances.

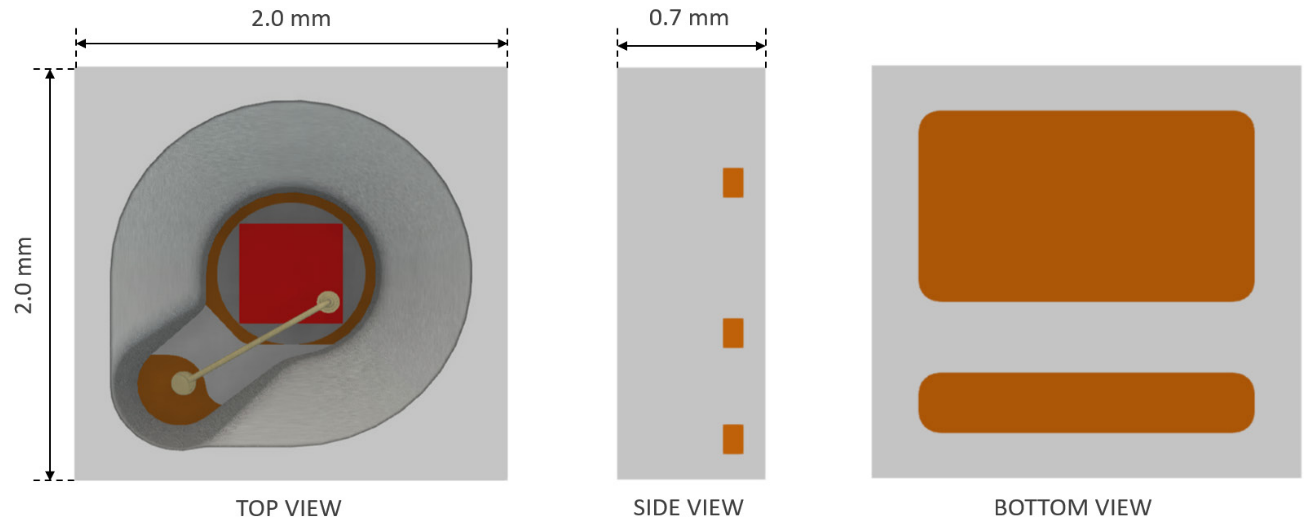


Figure 2a. Outline dimensions for LUXEON Versat 2020 Amber / Red-Orange / Red / Long-Red/ Super-Red

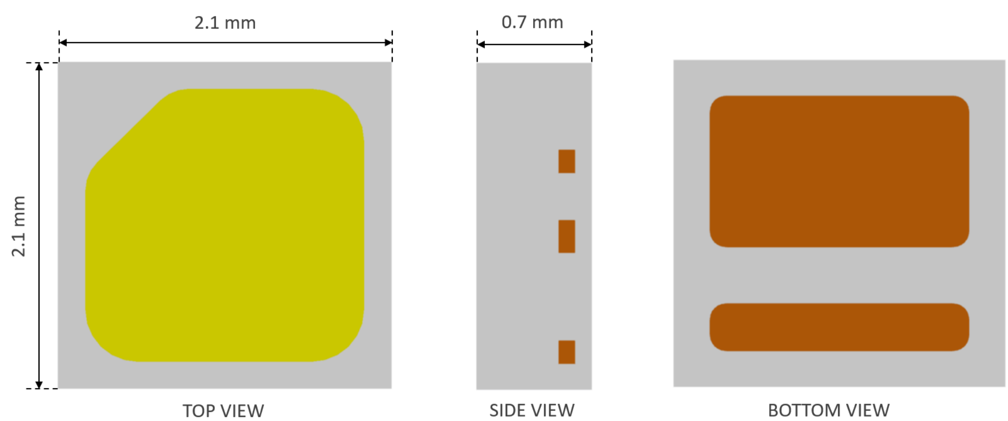


Figure 2b. Outline dimensions for LUXEON Versat 2020 Cool White / PC Amber

1.4 Optical Center

The Versat family 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 is available upon request.

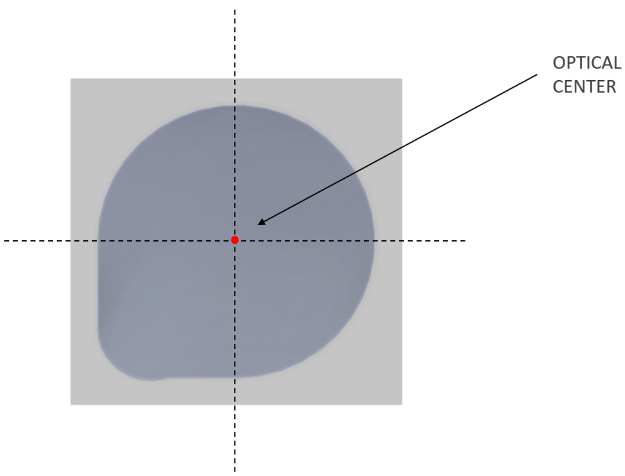


Figure 3a. Optical center for LUXEON Versat 2020 Amber / Red-Orange / Red / Long-Red/ Super-Red

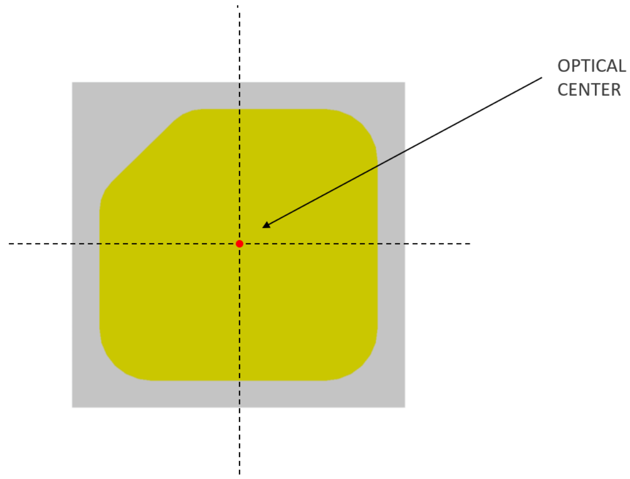


Figure 3b. Optical center for LUXEON Versat 2020 Cool White / PC Amber

1.5 Mechanical Files

Mechanical drawings and CAD-files for the Versat 2020 are available upon request. For details, please contact your sales representative.

2. Handling Precautions

2.1 Electrostatic Discharge (ESD) Protection

As indicated in paragraph 1.2, the Versat is ESD protected. LEDs with an intrinsic chip have an electrical conductivity, that has a positive electrical effect to protect the LEDs against ESD. LEDs without intrinsic chips, must protected by an additional TVS device. This transient voltage suppressor (TVS) diode provides a current path for transient voltages.

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 Modell (CDM)

The Versat has 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 LED datasheets. Additional external ESD protection for the LED may be needed if the LED is used in non ESD-protected environments or exposed to higher ESD voltages and discharge energies, e.g. as described in ISO 10605 or IEC 61000-4-2 (severity level IV). For details please contact your sales representative.

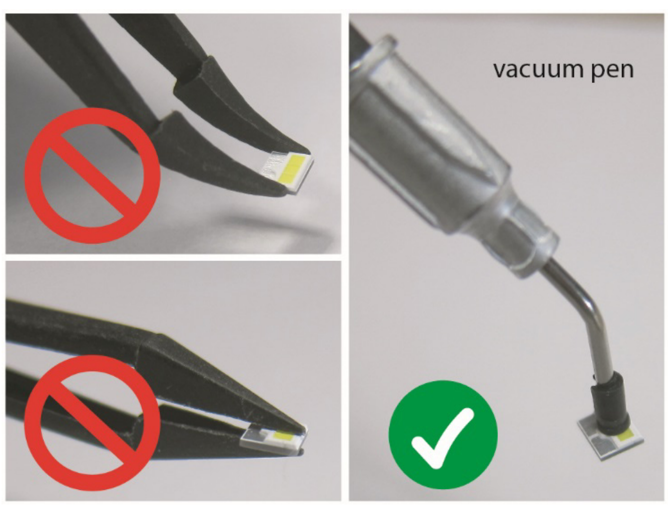
2.2 Component Handling

Minimize all mechanical forces exerted onto the LED package. It should not be handled with tweezers that can lead to damage of the package, especially not with metallic tweezers. Any force above 2.0 N may damage the LED and change optical performance. A vacuum pen can be used instead of tweezers (see Figure 4).

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. Avoid contaminating the top side surface of the LED. Do not stick any tape on top of the light emitting surface, such as Kapton™- or UV-tape. A contamination with 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, which may lead to solder issues, and damage the LED. Avoid any contact with the LED other than what is required for placement.

Figure 4. LED Handling



Do not touch the top surface with fingers or apply any pressure to it when handling finished boards containing LEDs. Do not stack finished boards because the LED can be damaged by the other board outlines. In addition, do not put finished boards with LEDs top side down on any surface. The surface of a workstation may be rough or contaminated and may damage the LEDs. These warnings are shown in Figure 5.

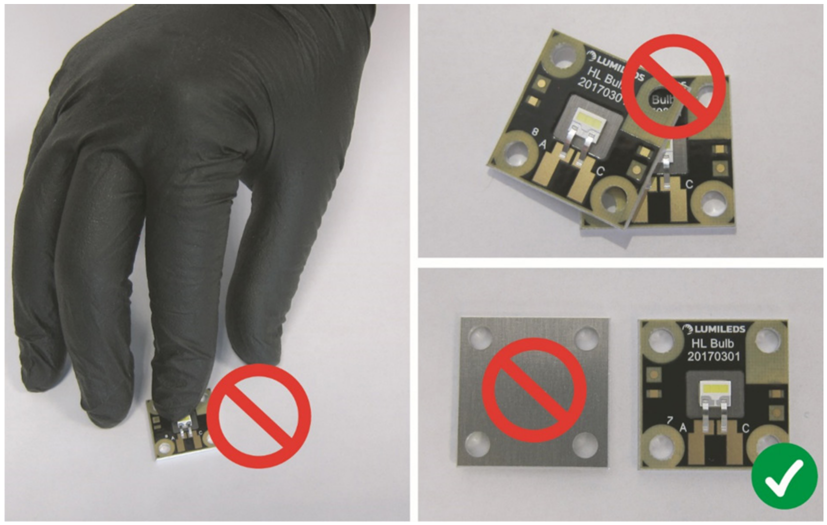


Figure 5. Board handling

2.3 Cleaning

The surface of the LED 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 the LED 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 15 cm 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 10, 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 LEDs.

3. Printed Circuit Board

3.1 PCB Requirements

The LED can be mounted on multi-layer FR4 printed circuit boards (PCB) or insulated metal substrates (IMS). To ensure optimal operation of the LED, 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-600K: Acceptability of Printed Boards
- IPC-A-610H: Acceptability of Electronic Assemblies
- IPC 2221B: Generic Standard on Printed Board Design
- IPC 7093A: Design and Assembly Process Implementation for Bottom Termination Components (BTCs)

3.2 Footprint and Land Pattern

Lumileds recommends using solder mask defined land pattern for Versat 2020, as shown in Figure 6. 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 Chapter "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.

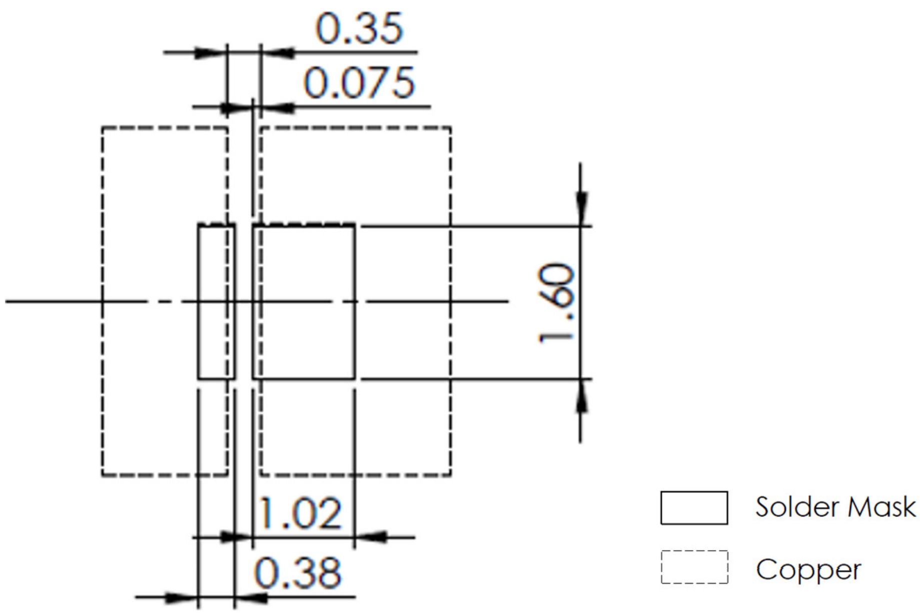


Figure 6. Solder mask defined land pattern for Versat 2020

3.3 Surface Finishing

Lumileds recommends using ENIG (Electroless Nickel Immersion Gold) plating according to IPC-4552. Other surface finishes are possible, but have not been tested by Lumileds. Surface finishing by Hot-Air-Solder-Leveling (HASL) may lead to inhomogenious pad height and is not recommended. Unsymmetrical solder thickness may have an influence on LED height and soldering tolerances. The actual quality of HASL finish shall be checked in each single case.

3.4 Solder Mask

A flat solder mask thickness on top of the metal layer is desired. Solder mask thickness variation and offset tolerances have impact on solder quality and post-solder position accuracy. Mask and PCB vendors have to be evaluated for proper quality. Detailed specifications and information regarding solder mask requirements are contained in IPC-6012 and IPC-SM-840. (see Chapter "PCB Quality and Supplier", Figure 7 for more details).

3.5 Silk Screen or Ink Printing

Silk screen markings within and around the LED outline should be avoided because the height of the ink may interfere with the solder stencil printing process.

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 50 µm between the copper trace pattern and the solder mask is desirable to achieve the optimum solder joint contact area using the recommended solder mask defined footprint, as shown in Figure 6 . 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 the risk of solder bridging (short circuit) and solder balling if the stencil is not properly aligned to the solder mask during printing.

Figure 7 shows an example of the solder pad size for the nominal position and maximum offset level between the copper trace pattern and the solder mask for this LED, using the recommended footprint in Figure 6. 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.

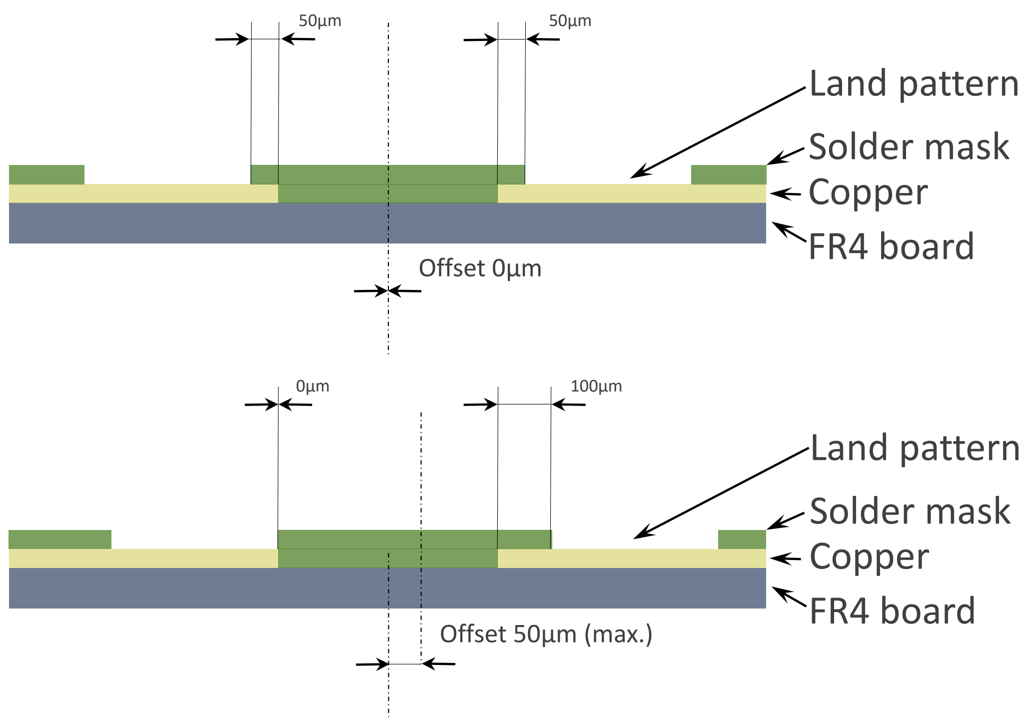


Figure 7. Solder mask registration offset to copper trace

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 dielectic materials
- Cu plating thickness and CU pattern
- Solder pad pattern and solder thickness
- Distance to neighboring heat source (LED spacing)

Lumileds conducted thermal simulations to evaluate the thermal performance of LUXEON Versat 2020 on different PCB design concepts. Details of the simulation model are given in Figure 8. The model geometry comprises the LUXEON Versat 2020 LED on a board (Al-IMS board or FR4 board open vias) that is mounted on a plate Al heatsink (dimension of 50 mm x 50 mm x 10 mm). A thermal interface material (TIM) is assumed between board and heat sink. In the simulations, a constant temperature boundary condition (T = T0 = 25 °C) is imposed at the bottom of the heat sink. More details on the simulation setup and the used material parameters can be found in Table 2.

Table 2. Layer thickness and thermal conductivities used in the simulations

COMPONENT/MATERIAL	THICKNESS	THERMAL CONDUCTIVITY
Al heat sink	10 mm	150 W/(mK)
TIM	100 mm	2 W/(mK)
Board Al core	1.0 mm	200 W/(mK)
Board FR4	1.5 mm	0.35 W/(mK)
IMS dielectric	38 µm	3 W/(mK)
Top Cu layer	70 µm	390 W/(mK)
Bottom Cu layer (FR4 board)	70 µm	390 W/(mK)
Solder mask	20 µm	0.2 W/(mK)
Vias plating	n.a.	390 W/(mK)
Solder	50 µm	56 W/(mK)

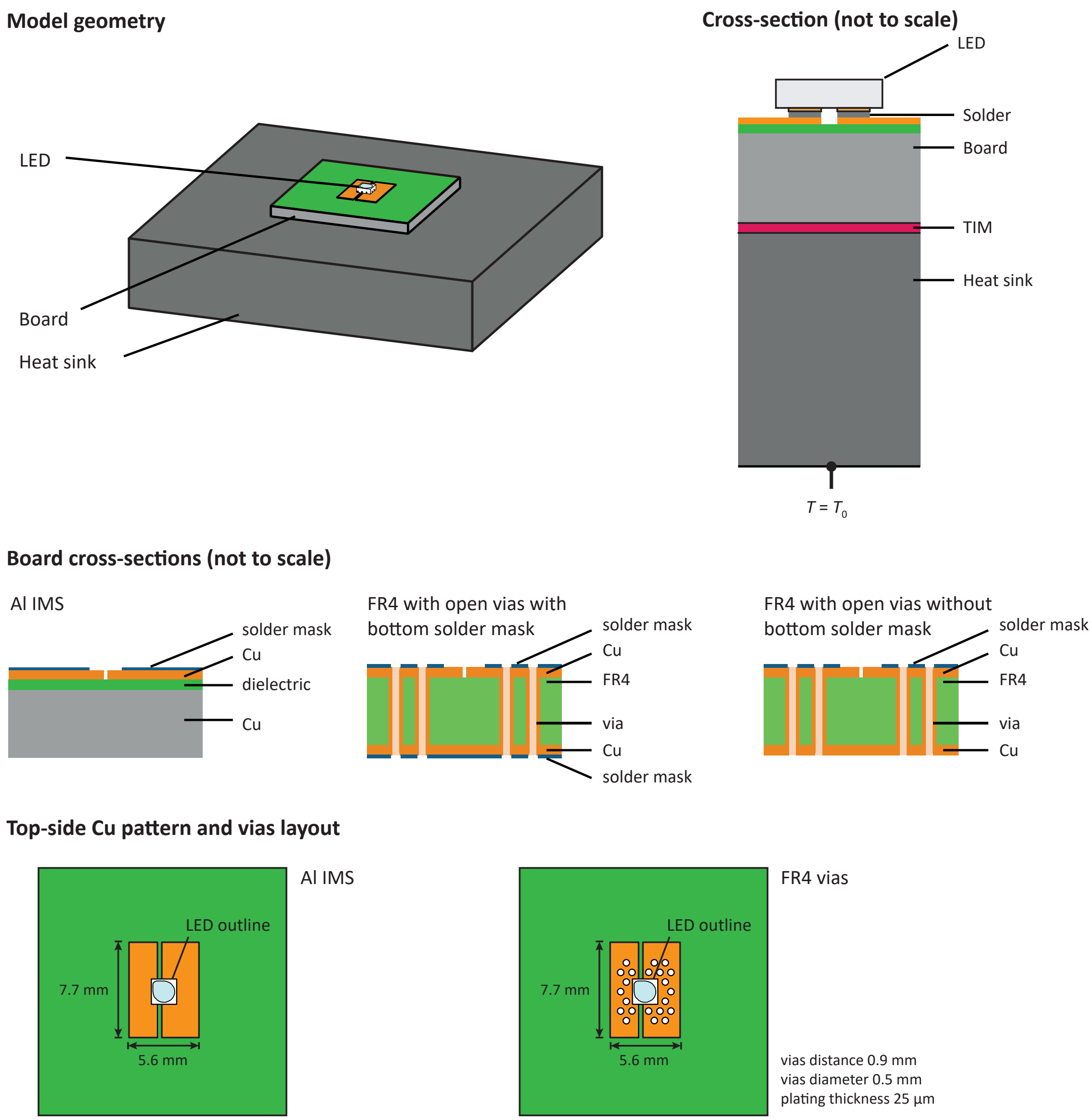


Figure 8. Geometry and board parameters used in the simulation

The thermal resistance junction-to-board bottom based on eletrical input power Rth,j-b,el (thermal resistance based on electrical input power) can be calculated as Rth,j-b,el = Rth,j-b,real*(1–WPE), where Rth,j-b,real denotes the thermal resistance based on thermal power and WPE denotes the wall plug efficiency. The WPE is not constant and depends on drive condition and flux binning class. The thermal resistance Rth,j-b,real is obtained by Rth,j-b,real = (Tj-Tb)/Pth. Here, Tj and Tb denote the junction temperature and the maximum temperature at the bottom side of the board, respectively, obtained from the simulations, and Pth is the thermal input power.

lists the simulated thermal resistances Rth,j-b,real and the thermal resistances Rth,j-b,el for LUXEON Versat 2020 on different board types. To calculate Rth,j-b,el, a wall-plug efficiency of 0.29 has been used for the Amber / Red-Orange / Red / Super-Red / Long-Red LEDs, a wall-plug efficiency of 0.28 for PC Amber and a wall plug efiiciency of 0.41 for Cool-White. Lumileds' recommendation to optimize the thermal performance of the system is to use metal-core boards with a thermally well performing dielectric.

Table 3. Simulated LED-junction-to-board-bottom thermal resistances Rth,j-b,real and Rth,j-b,el for different board types. The thermal resistances Rth,j-b,el have been calculated assuming a WPE of 0.29 for the Amber / Red-Orange / Red / Super-Red / Long-Red LEDs, a wall-plug efficiency of 0.28 for PC Amber and a wall plug efiiciency of 0.41 for Cool-White.

	AMBER / RED-ORANGE / RED / SUPER-RED / LONG-RED		PC AMBER		COOL-WHITE	
BOARD-MATERIAL AND DIELECTRIC	$R_{th,j-b,real}$ (K/W)	$R_{th,j-b,el}$ (K/W)	$R_{th,j-b,real}$ (K/W)	$R_{th,j-b,el}$ (K/W)	$R_{th,j-b,real}$ (K/W)	$R_{th,j-b,el}$ (K/W)
1.5 mm Al-IMS, 3 W/(mK) – 38 µm dielectric	34	24	30	22	30	18
1.5 mm FR4 with open vias, no bottom solder mask	46	33	42	30	42	25
1.5 mm FR4 with open vias bottom solder mask	49	35	45	32	45	27

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 (Tc), junction temperature (Tj), or surface temperature. Table 4 lists three methods along with the expected measurement accuracy. The more accurate the measurement is, the closer Tc and Tj can be designed to their maximum allowable values as specified in the LUXEON Versat 2020 datasheet.

Table 4. Temperature measurement methods for LUXEON Versat

METHOD	ACCURACY [°C]	EFFORT	EQUIPMENT COST
Thermo sensor (e.g. thin wire thermocouple)	± 2.0 – ± 5.0[1]	Low	Low
Forward voltage measurement	±0.5	High	High
Infrared thermal imaging	± 2.0 – ± 10.0[2]	Medium	High

Notes for Table 3:
1. See section "Temperature Probing by Thermo Sensor" for parameters determining the measurement accuracy.
2. See section "Temperature Probing by IR Thermal Imaging" for parameters determining the measurement accuracy.

Temperature Probing by Thermo Sensor

Figure 9 schematically shows the LED soldered to a PCB, including the relevant temperatures as defined for specific positions in the setup. A practical way to verify the case temperature is to measure the temperature Tsensor on a predefined sensor pad thermally close to the case by means of a thermocouple or a thermistor, as shown in Figure 9. The solder mask must be removed to ensure good thermal contact of the thermocouple to the board and to obtain accurate readings. To get a large signal, it is recommended to use the highest possible drive current for the application.

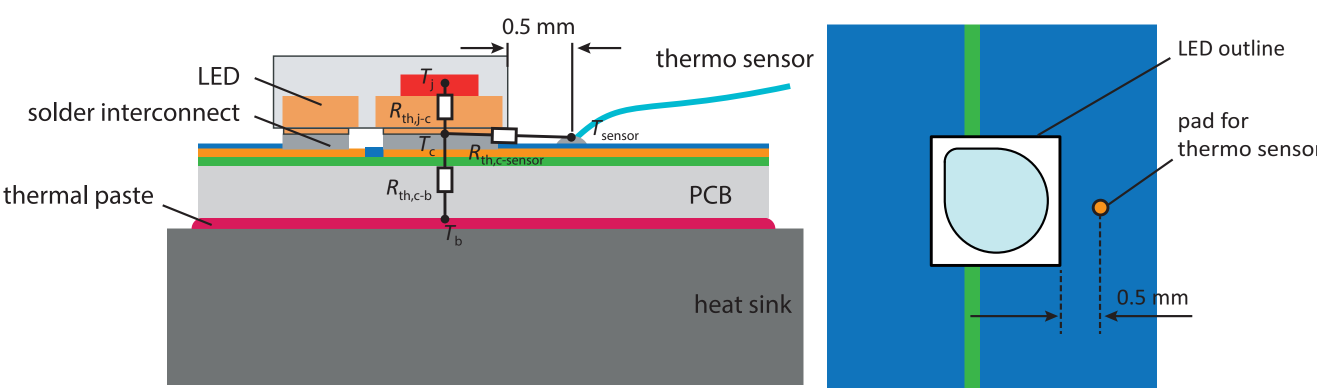


Figure 9. Temperature probing by thermo sensor (schematically)

The case temperature Tc can be calculated according to the following equations:

$$T_c = T_{sensor} + R_{th,c\text{-}sensor,el} \cdot P_{el},$$

$$T_c = T_{sensor} + R_{th,c\text{-}sensor,real} \cdot P_{th}.$$

In these equations, T_{sensor} is the sensor temperature at the predefined location and P_{el} is the electrical power of the LUXEON Versat 2020, $P_{th} = P_{el} \cdot (1 - WPE)$ the thermal power of the LUXEON Versat 2020, $R_{th,c\text{-}sensor,el}$ the thermal resistance between case and sensor point based on the electrical power, and $R_{th,c\text{-}sensor,real}$ the thermal resistance between case and sensor point based on the thermal power. The thermal resistances $R_{th,c\text{-}sensor,el}$ and $R_{th,c\text{-}sensor,real}$ are application specific and can be determined with help of thermal simulations and measurements. Lumileds has determined the typical $R_{th,c\text{-}sensor,el}$ and $R_{th,c\text{-}sensor,real}$ for LUXEON Versat 2020 on different board types (see Table 5). Please refer to section 4.1 for more detailed information regarding the board design parameters. The sensor has been mounted at a distance of 0.5 mm from the edge of the package. The accuracy of the measurement depends on the board type, the measurement accuracy of the thermocouple and the mounting position. The temperature signal at the thermocouple measurement point is larger for boards with large heat spreading in the top Cu layer (typically boards with low-conductivity dielectric). LED boards with different configuration, design, or material from the ones given in Table 4 may require additional thermal modeling or measurements to determine the right case-to-sensor thermal resistances.

Table 5. Typical $R_{th,c\text{-}sensor,real}$ and $R_{th,c\text{-}sensor,el}$ values of different board concepts. The thermal resistances $R_{th,c\text{-}sensor,el}$ have been calculated from $R_{th,c\text{-}sensor,real}$ assuming a WPE of 0.29.

BOARD TYPE	$R_{th,c\text{-}sensor,real}$ (K/W)	$R_{th,c\text{-}sensor,el}$ (K/W)
IMS with dielectric of 3 W/(mK) and 38 μm thickness, 70 μm Cu	7	5
FR4 open vias, 70 μm Cu	11	8

Temperature Probing by Forward Voltage Measurement

The forward voltage measurement uses the temperature dependence of the LED's forward voltage Vf. 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 2020 or the LED junction-to-case thermal resistances as indicated in the datasheet, the case temperature Tc can be estimated. To ensure high accuracy, a precise and fast voltage measurement system is needed. In addition, the relation between forward voltage and temperature needs to be properly characterized for each individual LED. Please contact your sales representatives for further support in this topic.

Temperature Probing by Infrared Thermal Imaging

Infrared (IR) thermal imaging can be used to measure the surface temperature of the LED or the board temperature. Lumileds does not recommend to use IR measurements to estimate the LED junction or case temperature.

For an accurate determination of the absolute temperature via IR thermography, the determination of the exact emissivity value is crucial. The emissivity generally depends on material, surface properties, and temperature. It can be determined by heating up the unbiased device to a defined temperature that can be, for example, measured with a thermocouple. Then, an IR measurement can be taken of this setup, and the emissivity setting of the material of interest (typcially the LED surface or the board surface) can be adjusted to match the thermocouple reading. The obtained emissivity value can be used to evaluate the IR image of the device in operation to determine the temperature of interest. The temperature at which the emissivity value is determined should be similar to the temperature in operation that is to be measured. During IR imaging, make sure that the recorded image is not disturbed by unwanted background reflections. Due to the small dimensions of the LUXEON Versat 2020, an imaging system with high magnification should be used in order to get a sufficient resolution of the LED in the IR image.

5. Assembly Process Recommendations and Parameters

5.1 Solder Paste

For reflow soldering, a standard lead free SAC solder paste (SnAgCu) 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. An Innolot based solder paste can improve thermal cycling reliability performance under certain conditions. Vacuum soldering equipment can be used to achieve a lower void level. 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 10. The corner radius of the stencil aperture should be selected according to paste particle size to improve paste release. For Versat 2020, a stencil thickness of 100 µm (4 mil) with a type 3 paste is recommended. Lumileds internal testing has been conducted with a stencil aperture of 60 % (Anode pad) and 80% (Cathode pad) of the LED footprint area.

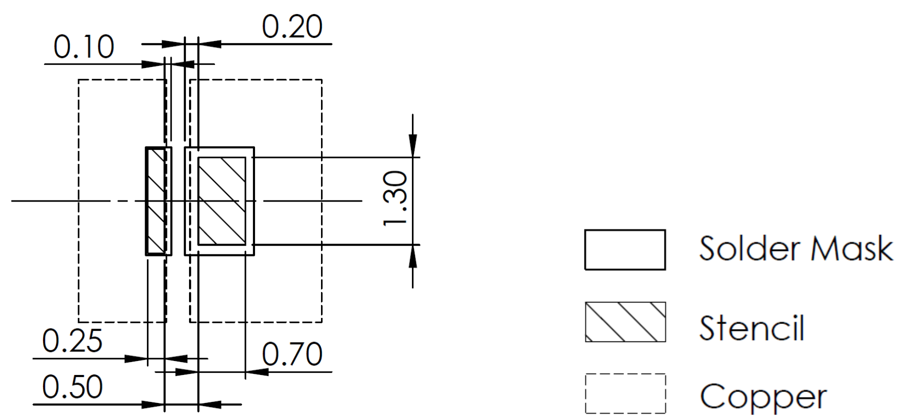


Figure 10. Versat 2020 stencil aperture for solder mask defined design

5.3 Pick and Place Nozzle

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

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

1. The pick-up area is defined in Figure 16.
2. The nozzle tip should be clean and free of any particles since this may interact with the top surface coating of the LED during pick and place.
3. During setup and the first initial production run, it is good practice to inspect the top surface of the LED 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.

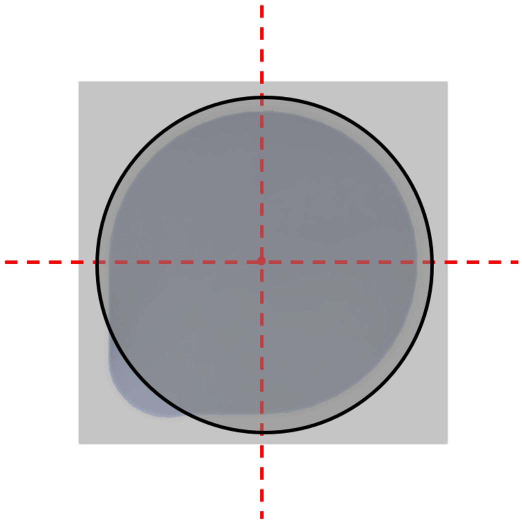


Figure 11a. Pick up position and nozzle scheme for LUXEON Versat 2020 Amber / Red-Orange / Red / Long-Red/ Super-Red

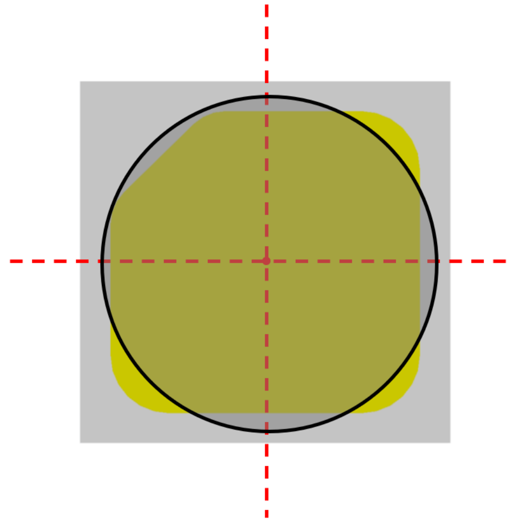


Figure 11b. Pick up position and nozzle scheme for LUXEON Versat 2020 Cool White / PC Amber

Since the LED 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 LED 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 12).

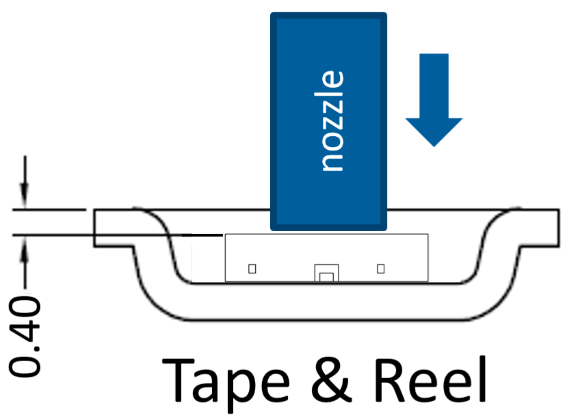
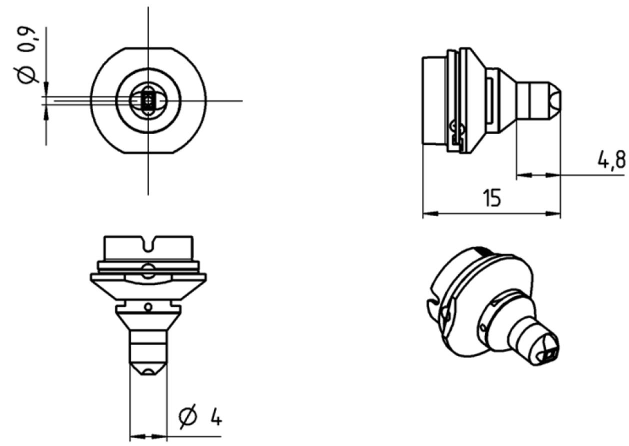


Figure 12. Pick-up from carrier tape

Figure 13 shows an available nozzle for ASM Siplace with a square rubber tip which is somewhat smaller than the package (courtesy provided by ASM).



Standard nozzle (order code)	033203323-01
Supplier	ASM Siplace
Nozzle from	Rectangular
Material: Housing / Tip	Vectra A230/TPU ESD able
P&P Head	2032
Name	Nozzle Special Type 2053 / Pipette SOKO Typ 2053
Measurements [mm]	A=2.0x1.5, a=1.4x0.9, L=15.0

Figure 13. Nozzle recommendation for theVersat 2020

5.4 Placement Force / Height Control

In order to avoid any damage of the LED and to minimize squeeze-out of solder paste, the 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 2.0 N. 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 LED can be damaged. For example, if large particles are underneath the LED (see Figure 14). Lower the Z-axis velocity if needed.

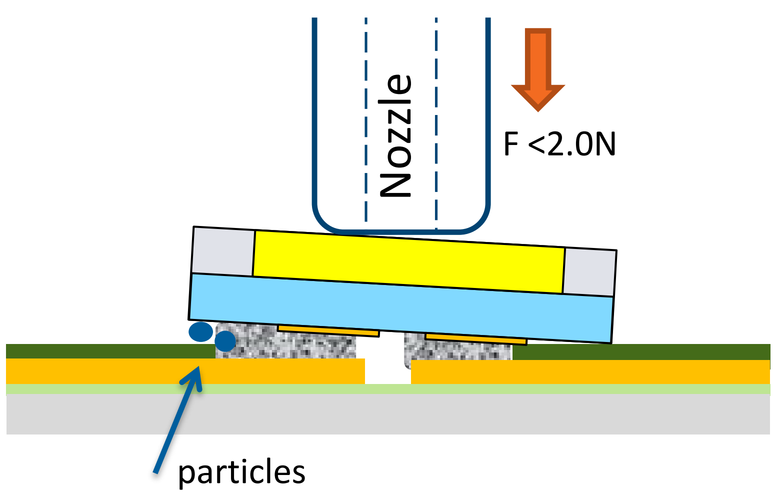


Figure 14. LED touching the board during pick and place can in worst case damage the LED

5.5 Feed System

Pick and place machines are typically equipped with special pneumatic or electric feeders to advance the tape, that contains 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. The pick-up position should be right after the 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. The cover tape peeling angle, relative to the tape, should be small to reduce the vertical pulling force during indexing (see Figure 15).

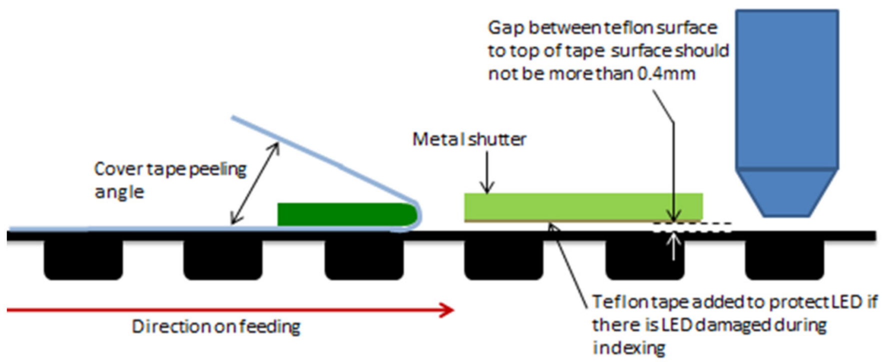


Figure 15. Pick position and cover tape peeling

5.6 Reflow Profile

The Versat LED 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 controlled.

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 16 and Table 6 for Versat LEDs on FR4 and MCPCB.

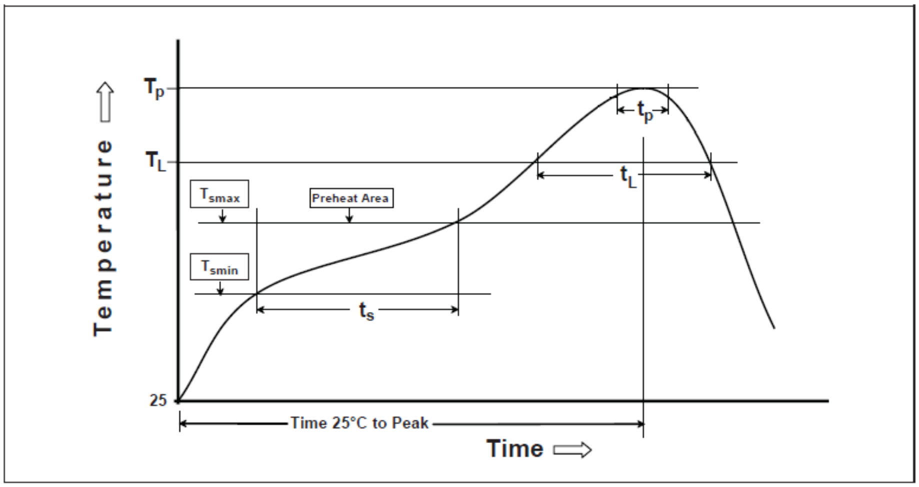


Figure 16. Reflow profile definition according to JEDEC J-STD-020E

Table 6. Temperature measurement methods

PROFILE FEATURE	TYPICAL VALUE	MAXIMUM ACC. JEDEC J-STD-020E
Preheat Minimum Temperature (T_{smin})	150 °C	150 °C
Preheat Maximum Temperature (T_{smax})	200 °C	200 °C
Preheat Time (T_{smin} to T_{smax})	100 seconds	60 to 120 seconds
Ramp-Up Rate (T_{smax} to T_p)	2 °C/second average	3 °C/second
Liquidus Temperature (T_L)	217 °C	217 °C
Time Maintained Above Temperature T_L (t_L)	60 seconds	120 to 150 seconds
Peak / Classification Temperature (T_p)	240 °C	260 °C
Time Within 5°C of Actual Peak Temperature (t_p)	20 seconds	30 to 50 seconds
Maximum Ramp-Down Rate (T_p to T_L)	2.5 °C/second	6 °C/second
Time 25°C to Peak Temperature	310 seconds	480 seconds
Nitrogen Atmosphere (O^2)	< 1000 ppm	

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)

5.7 Reflow Accuracy

For solder mask defined designs, Lumileds performed tests for position accuracy after reflow (see Figure 17 and Table 7). Results may vary based on printed circuit board quality and used assembly process.

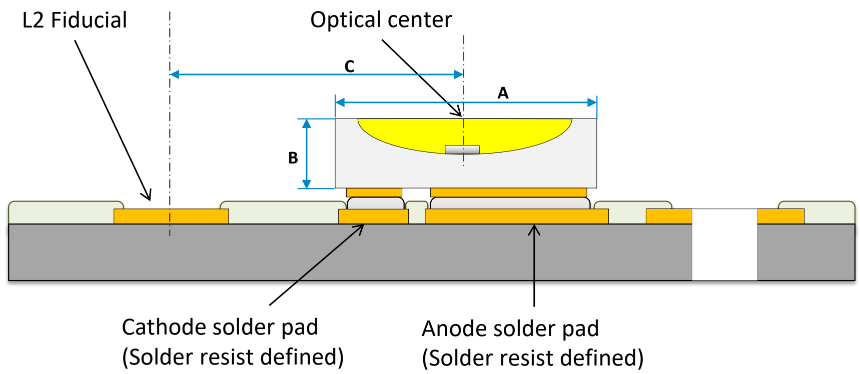


Figure 17. L1 and L2 tolerance definition

Table 7. Dimension and placement tolerances for LUXEON Versat

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

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 LED assemblies. For example, 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 17).

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 2 mm of vertical deflection for every 90mm of FR4 PCB length. This 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 board bending test 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.

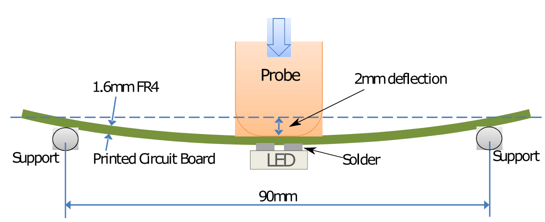


Figure 18. Graphic indicating arrangement of LED board bending test

5.9 Packing of Assembled LED Module

Finished boards must be protected against damage during transport. It is recommended to use a customized tray package, which is designed to hold the PCBs during transport (see Figure 19).

Here are some general rules of best practice tray design:

1. Design the tray to avoid accidently touching the LED by manual handling. 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 no force from the tray or packing material is 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.

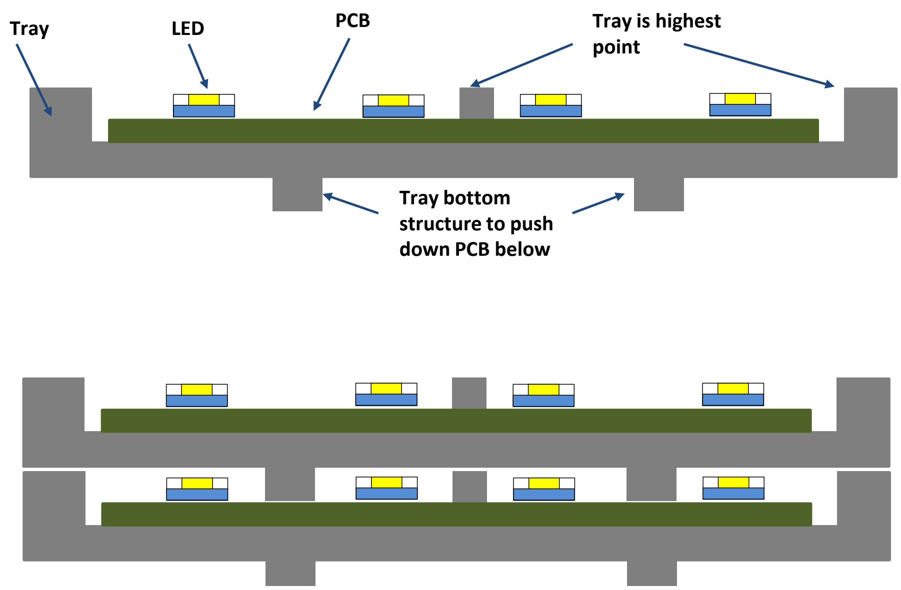


Figure 19. Schematic of a good tray design. The LEDs are protected against movement and no forces are applied to the LEDs

6. Interconnect Reliability

The reliability of the board interconnect under thermal cycling and thermal shock condition is mainly determined by the thermal expansion of used materials. The 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 8 shows commonly used materials and their CTE.

Table 8. CTE of common board substrate materials

MATERIAL	COEFFICIENT OF THERMAL EXPANSION (CTE)
Sapphire (LED chip)	5-6 ppm
Solder SAC305	19-22 ppm
Copper	16.5 ppm
FR4	12-17 ppm*
Aluminium	23.1 ppm
AlN	4 ppm
Al_20_3	6-8 ppm

* Depending on laminate vendor, pre-preg type and fiber orientation.

The mechanical properties of solder material and solder thickness have an impact on interconnect reliability also. Using a ductile material and increasing the bond line thickness will increase solder joint reliability.

Lumileds performed solder joint reliability testing of the Versat 2020 on FR4 and Al-IMS board materials. 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 / 3000 cycles are shown in Figure 20. The solder joint is still in a proper condition, without cracks or delamination.

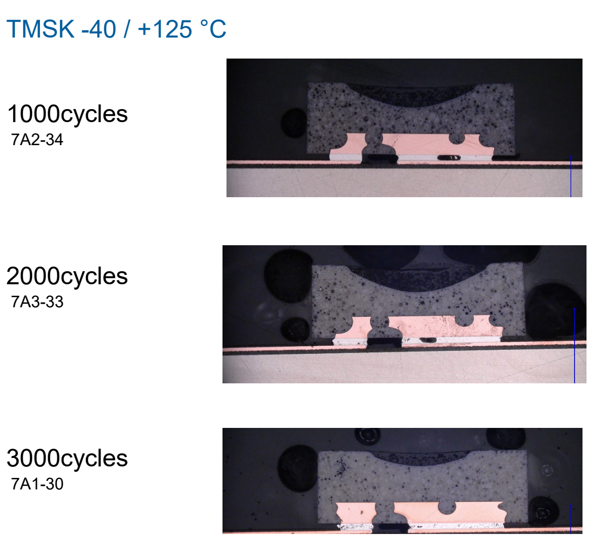


Figure 20. X-section and x-ray of Versat 2020 after AA-TMSK testing

7. JEDEC Moisture Sensitivity Level

JEDEC has defined eight levels for moisture sensitivity (MSL). MSL is a rating indicating a component's susceptibility to damage due to absorbed moisture when subjected to reflow soldering. as shown in Table 9.

Joint Industry Standard:

- JEDEC has defined eight levels for moisture sensitivity, as shown in Table 9.

Table 9. JEDEC moisture sensitivity levels

LEVEL	FLOOR LIFE		SOAK REQUIREMENTS			
			STANDARD		ACCELERATED EQUIVALENT1	
	TIME	CONDITIONS	TIME (HOURS)	CONDITIONS	TIME (HOURS)	CONDITIONS
1	Unlimited	≤30°C/85% RH	168 Hours +5/-0	85°C/85% RH		
2	1 Year	≤30°C/60% RH	168 Hours +5/-0	85°C/60% RH		
2a	4 Weeks	≤30°C/60% RH	696 Hours +5/-0	30°C/60% RH	120 Hours +1/-0	60°C/60% RH
3	168 Hours	≤30°C/60% RH	192 Hours +5/-0	30°C/60% RH	40 Hours +1/-0	60°C/60% RH
4	72 Hours	≤30°C/60% RH	96 Hours +2/-0	30°C/60% RH	20 Hours +5/-0	60°C/60% RH
5	48 Hours	≤30°C/60% RH	72 Hours +2/-0	30°C/60% RH	15 Hours +5/-0	60°C/60% RH
5a	24 Hours	≤30°C/60% RH	48 Hours +2/-0	30°C/60% RH	10 Hours +5/-0	60°C/60% RH
6	Time on Label (TOL)	≤30°C/60% RH	TOL	30°C/60% RH		

Versat LEDs have a JEDEC moisture sensitivity level of 2 with a floor life of 1 year at ≤30°C / 60% RH.

8. Packaging Considerations—Chemical Compatibility

The package contains a silicone overcoat to protect the LED chips 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 overcoat 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 the LEDs 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 output 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 10 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 10 are typically not directly used in the final products that are built around the 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:

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. 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 10. List of commonly used chemicals that may damage the silicone encapsulant ofLUXEON Versat

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

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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