ILLUMINATION

LUXEON HL1Z

Assembly and Handling Information

Introduction

LUXEON HL1Z LEDs offer high flux density performance in a compact footprint, enabling elegant and superior luminaire designs. A wide range of CCTs in 80 and 90CRI options make them ideal for high performance indoor lighting applications, designed into tunable and white color mixing solutions. Best-in-class Color over Angle, and top emission only light output, provides designers with leading Quality of Light performance for dramatic lighting designs and small fixtures. The compact package size and high punch allows design flexibility, beam steering, and white tuning versus traditional LED light sources.

Scope

The assembly and handling guidelines in this application brief apply to the following products with the part number designation as described below.

L1HZ–xxyy1zzzzzzzz		
Where:		
L 1		designates L1 packaging in Tape and Reel
x x	–	designates any alphanumeric character that designates nominal ANSI CCT (For example, 27=2700K, 30=3000K, 35=3500K, 40=4000K, 50=5000K, 57 = 5700K, 65=6500K)
y y	–	designates any alphanumeric character that designates CRI (80=80CRI, 90=90CRI)
1	–	designates 1.0mm^2 die size
zzzz zzzz	–	any alphanumeric character that designates option codes for customization/ bin selections/etc designates die size of CSP (10=1mm^2).

In the remainder of this document the term LUXEON emitter, LUXEON CSP or LED emitter refers to any LUXEON CSP HL1Z product.

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1. Component

1.1 Description

The top of LUXEON HL1Z consists of the light emitting area (Figure 1) which is composed of silicone and phosphor materials. The solder pads on the bottom are finished with gold. The polarity identification is provided on the bottom electrode pads (Figure 1). Both the electrode pads provide thermal and electrical connection.

LUXEON HL1Z is not designed to be attached with silver epoxy material. There is no transient voltage suppressor (TVS) in the package, hence ESD safe handling is required.

LUXEON HL1Z is designed to be reflowed onto a printed circuit board (PCB) using a standard surface mount technology (SMT) process.

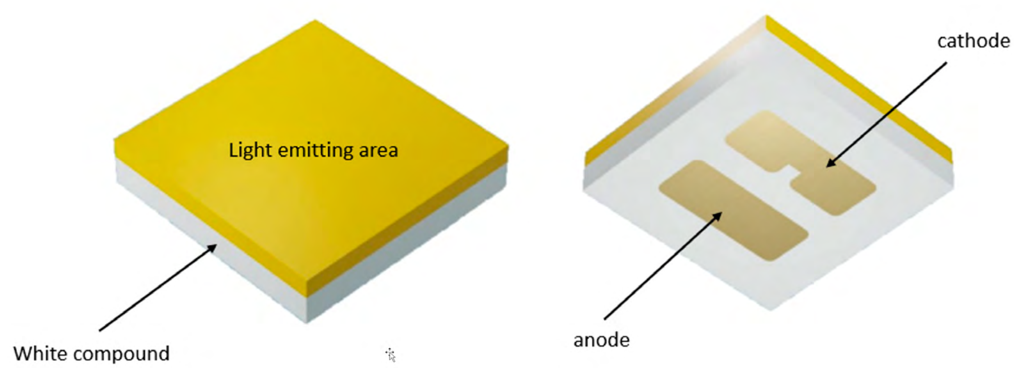

Figure 1. Top and bottom view of LUXEON HL1Z.

1.2 Optical Center

The theoretical optical center is shown in Figure 2. The nominal area of the light emitting area is 1.40mm x 1.40mm. Optical ray set downloads are available at lumileds.com.

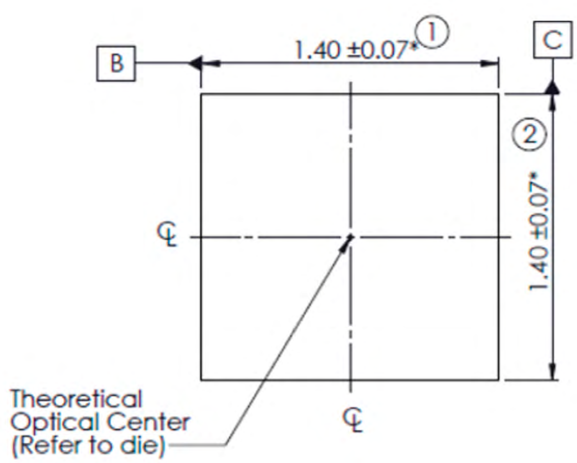

Figure 2. Theoretical optical center is located within the center of the light emitting area. Dimensions in mm.

2. Handling Precautions

ESD safe handling is required during when handling LUXEON HL1Z. See Section 4.5.

Prevent any particles and debris from falling on the package as this may cause a decrease in light output.

For manual handling, use ESD safe vacuum pen with rubber tip. Handling this LED emitter with tweezer may cause damage to the side wall of the white compound or the light emitting area.

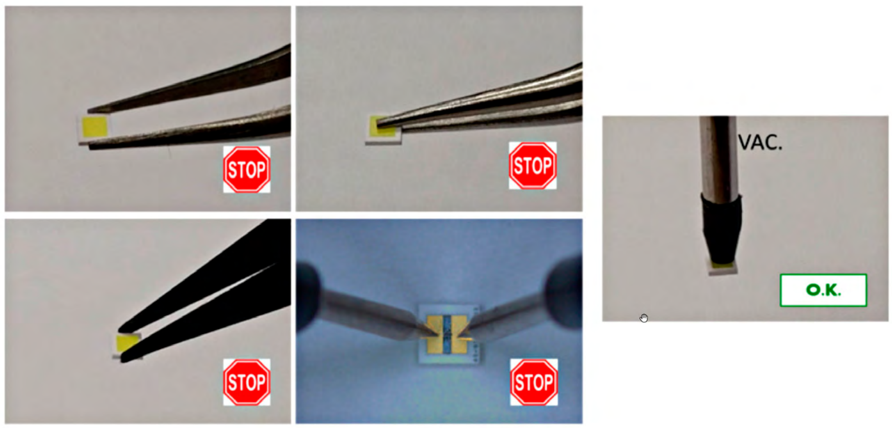

Figure 3. Illustration of correct and incorrect handling of a representative LED package.

Assembled boards must not be stacked up on top of each other or placed upside down as shown in Figure 4.

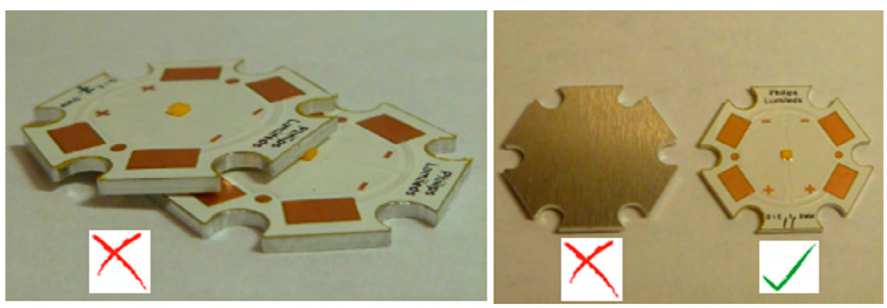

Figure 4. Do not stack assembled LED on PCBs on top of each other (left).
Do not place assembled PCBs with the top side down on any surface (right).

3. Printed Circuit Board Design

LUXEON HL1Z is engineered to be surface mounted onto a ceramic or metal-core PCB (MCPCB) substrate.

3.1 Footprint and Land Pattern

LUXEON HL1Z has two equal pads (anode and cathode) that need to be soldered onto corresponding land patterns on the PCB.

Figure 5 shows the recommended PCB footprint. Lumileds recommends a channel spacing of 0.18mm between the anode and cathode traces on the PCB to prevent possible shorting during reflow.

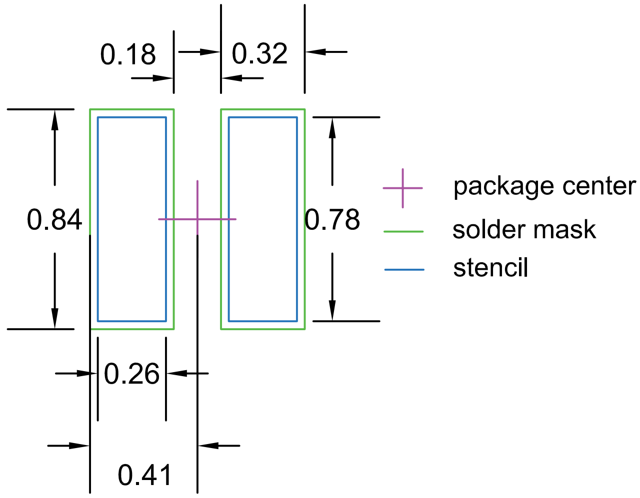

Figure 5. Recommended bottom pad drawing of LUXEON HL1Z. All dimensions in mm.

3.2 PCB Substrate Selection and Design

Table 1 provides a summary of various relevant performance characteristics of common PCB substrates to aid material selection.

Table 1. General PCB substrate characteristics for consideration when designing a PCB for LUXEON HL1Z.

	MCPCB	CERAMIC PCB
Cost	Medium	High
PCB thermal conductivity performance	Medium to excellent	High to excellent
Coefficient of thermal expansion (CTE)	Moderate CTE matching to LUXEON emitter	Good CTE matching to LUXEON emitter
LED assembly packing density (thermal resistance consideration)	Suitable for medium density applications with a moderate spacing between LEDs. If high density packing is required, operating current must be reduced to ensure max T_j not exceeded.	Suitable for high density applications with a minimal spacing between LEDs and high current operation
Mechanical assembly and handling	Easy, as board does not easily break	Extra precaution to prevent ceramic breakage (hard and brittle)

Specific PCB design considerations for each substrate material are summarized below.

Metal Core PCB

The most common MCPCB construction consists of the following layers (Figure 6):

- *A metal substrate, typically aluminum*. In some applications, a copper substrate may be more appropriate due to its higher thermal conductivity than aluminum (401 $Wm^{-1}K^{-1}$ versus 237 $Wm^{-1}K^{-1}$).
- *Epoxy dielectric layer*. This is the most important layer in the MCPCB construction as it affects the thermal performance, electrical breakdown strength, and, in some cases, the solder joint performance of the MCPCB system. The typical thermal conductivity of the dielectric layer on a MCPCB is around 2-3 $Wm^{-1}K^{-1}$. A higher value is better for good thermal performance. A thinner dielectric layer is better for thermal performance as well but can negatively impact the ability of the MCPCB to withstand a Hi-Pot (high potential) test to meet minimum electrical safety standards as required in certain lighting markets. The typical dielectric thickness layer is about 100μm. In critical applications, which need to meet strict solder joint reliability requirements, it is desirable to work with PCB manufacturers to design and engineer a low stress dielectric layer. The low stress dielectric layer can then absorb the stress generated when there is a moderate CTE mismatch between LUXEON HL1Z and the PCB substrate.

- *Top copper layer*. A thicker copper layer improves heat spreading into the PCB but may pose challenges for PCB manufacturers when fabricating narrow traces or spaces. Thicknesses of 1oz (35μm) or 2oz (70μm) are common. For optimum thermal performance on both 1oz and 2oz copper designs, the copper area should extend at least 3mm from the package outline.
- *Solder mask*. See requirement in section 3.5.

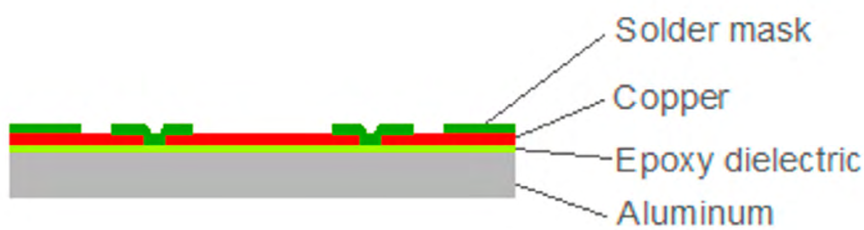

Figure 6. MCPCB typical cross section of the three-pad openings with aluminum substrate.

Ceramic PCB

Ceramic PCB construction consists of the following layers (Figure 7):

- *Ceramic substrate*. Commonly used materials are alumina (Al_2O_3) or aluminum nitride (AlN). The thermal conductivity of Alumina ranges from 20 to 30 $Wm^{-1}K^{-1}$, depending on the content of the alumina material in the substrate. The thermal conductivity of aluminum nitride ranges from 170 to 230 $Wm^{-1}K^{-1}$ depending on the additives added during the ceramic manufacturing process.
- *Top copper layer*.
- *Solder mask*. A white reflective solder mask is desirable to maximize light output extraction.

Since ceramic has an excellent thermal conductivity and is a very good electrical insulator. Therefore, there is no need to include any epoxy dielectric layer, allowing LUXEON HL1Z to be directly attached to the ceramic via copper and solder material. This enables very tight packing of multiple LUXEON HL1Z.

However, ceramic can be brittle, and may require extra handling precautions during assembly and handling.

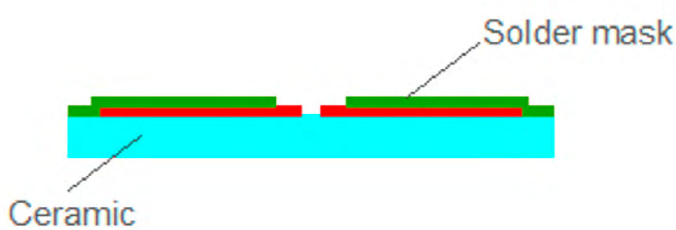

Figure 7. Cross section of ceramic based PCB. Note that there is no dielectric epoxy layer between copper (red) layer and the ceramic substrate which make ceramic PCB an excellent solution for high current operation with high density packing.

3.3 Component Spacing

Using the footprint as illustrated in shown in Figure 5, pick and place machine with placement capability of less than ±20μm and Lumileds SMT processes conditions, it is possible to achieve package to package spacing of 150μm.

3.4 Top Copper Layer Pattern Design

For Al-MCPCB, for best thermal performance always extend the top copper area as much as possible around the LUXEON emitter pads. Extends a minimum of 2mm of top copper area around the LED package as shown in Figure 8 as indicated by the red dotted square.

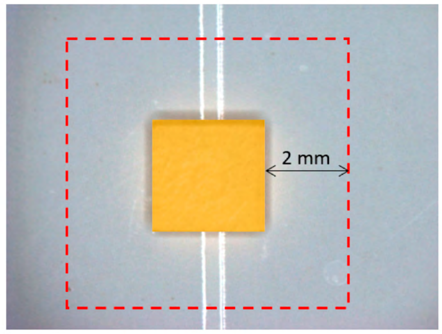

Figure 8. LED package mounted on Al-MCPCB with top white solder mask. The red dotted square shows the minimum top copper area that surrounds the LED package.

3.5 Surface Finishing on Copper

For small pad dimensions and pitch, Lumileds recommends using electroless nickel immersion gold (ENIG) or high temperature organic solderability preservative (OSP) on the exposed copper pads. Hot air solder leveling (HASL) should not be used because it yields poor co-planarity (leveling) and is, therefore, not suitable for fine pitch assembly. In addition, HASL may yield poor solder joints, potentially resulting in open failures.

3.6 Solder Mask

A stable white solder mask finish (typically a polymer compound with inert reflective filler) with high reflectivity in the visible spectrum will typically meet most application needs. The white finish should not discolor over time (change of reflectance properties) when exposed to elevated operating temperatures, back-scattered light or pollution (photo-thermal-chemical degradation of polymers). Customers are encouraged to work with their PCB suppliers to determine the most suitable solder mask options which can meet their application needs.

Lumileds has positive testing result of the performance of Taiyo PSR-4000 LEW3 solder mask.

3.7 Silk Screen or Ink Printing

Ink markings within and around the LUXEON HL1Z outline should be avoided because the height of the ink may interfere with the LED emitter self-alignment during reflow and solder stencil printing process. If needed, the ink printing should be at least 2mm away from the package outline.

3.8 PCB Quality and Supplier

Select PCB suppliers that are capable of delivering the required level of quality. At a minimum the PCBs must comply with IPC standard (IPC-A-600H, 2010 *"Acceptability of Printed Boards"*).

A maximum of 50µm masking mis-registration tolerance (Figure 9) between the copper trace pattern and solder mask is preferred to achieve optimum solder joint contact area using the recommended footprint as shown in Figure 5. Large misalignment between solder mask opening and copper trace will cause one of the two copper land patterns to be smaller than the other.

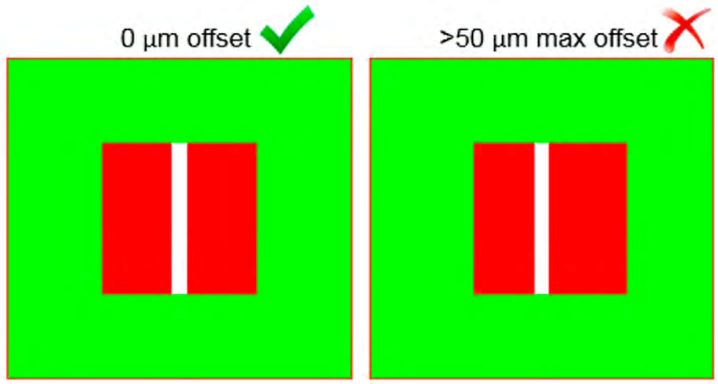

Figure 9. A maximum of 50µm mis-registration between solder mask (green) and copper pattern (red) is preferred.

Depending on the PCB manufacturer and SMT assembly process capability, it may be necessary to increase the area of the solder mask opening at the expense of possible reduction in the LED placement accuracy from LED self-alignment during reflow.

4. Assembly Process Guidelines

LUXEON HL1Z is designed to be compatible with traditional SMT processes. A SMT process typically consists SMT components (LED emitters), PCB, solder paste, die attach or pick and place machine, solder heat reflow and optional flux cleaning system. If the SMT components are ESD sensitive such as LUXEON HL1Z, ESD precautions are required (section 4.5).

4.1 Solder Paste

Lumileds successfully mounted LUXEON HL1Z LEDs on PCBs with Lumet P39, Maxrel™ solder paste of type 4 from MacDermid Alphas Assembly Division. Given the large variety of solder pastes and varying application use conditions/ requirements, customers should always perform their own solder paste evaluation in order to determine if a solder paste will meet the application requirements in terms of solderability, solder joint reliability and overall long-term optical performance.

4.2 Stencil Printing

The recommended stencil thickness for LUXEON HL1Z is 3mils. It may be necessary to make some adjustments to the stencil thickness and size opening to optimize quality of the solder joint under customer’s own assembly process. There are several important factors for consideration in obtaining good quality stencil printing (Figure 10). They are:

1. The aperture (stencil opening) wall should be smooth, free of debris, dirt, and/or burrs, and have a uniform thickness throughout the stencil plate. Nano-coat the aperture walls can aid smooth release of solder paste..
2. Positional tolerance between the stencil plate and the PCB substrate must be small enough to ensure that the solder paste is not printed outside the footprint area. Hence both the stencil plate and the PCB must be secured properly.
3. During solder paste dispense, the stencil plate must be flush with the top of the solder mask. Large particles between the stencil plate and PCB may prevent a good contact.
4. The PCB substrate must be mechanically supported from the bottom to prevent flexing of the PCB during solder paste dispenses.

Using an automatic stencil printing machine with proper fiducials or guiding feature on the PCB and the stencil plate will yield the best accuracy and repeatability for the solder paste deposition process. A manual stencil printing process is not recommended for the small pad features of LUXEON HL1Z.

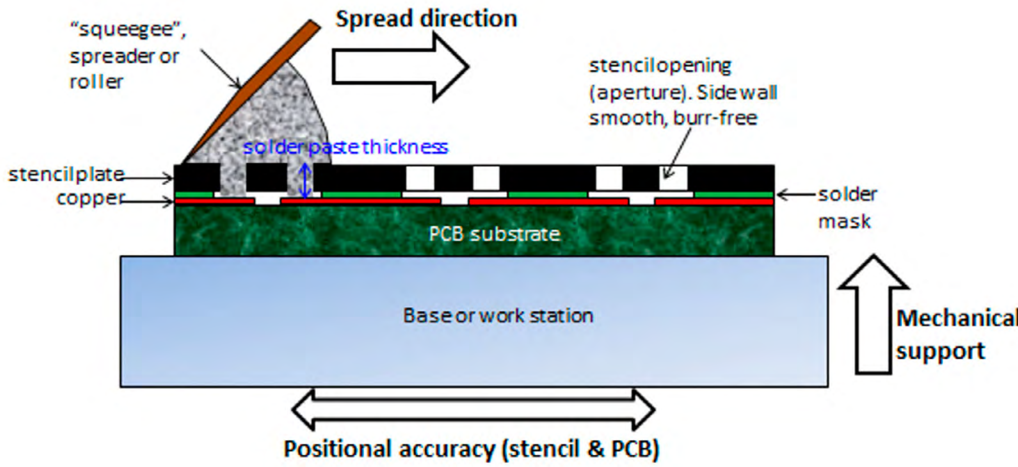

Figure 10. Stencil printing process.

Figure 11 shows some examples of a good and bad solder paste dispense process. A good reference to acceptable solder paste printing criteria can be found in IPC-7527 ***"Requirements for Solder Paste Printing"*** document. If the solder paste dispense process is in control, the dimensions of the solder paste on the PCB after dispense will match the size of the stencil opening. Stencil printing direction must follow the long side of the pads to ensure that the stencil opening is being completely filled with solder paste (Figure 12).

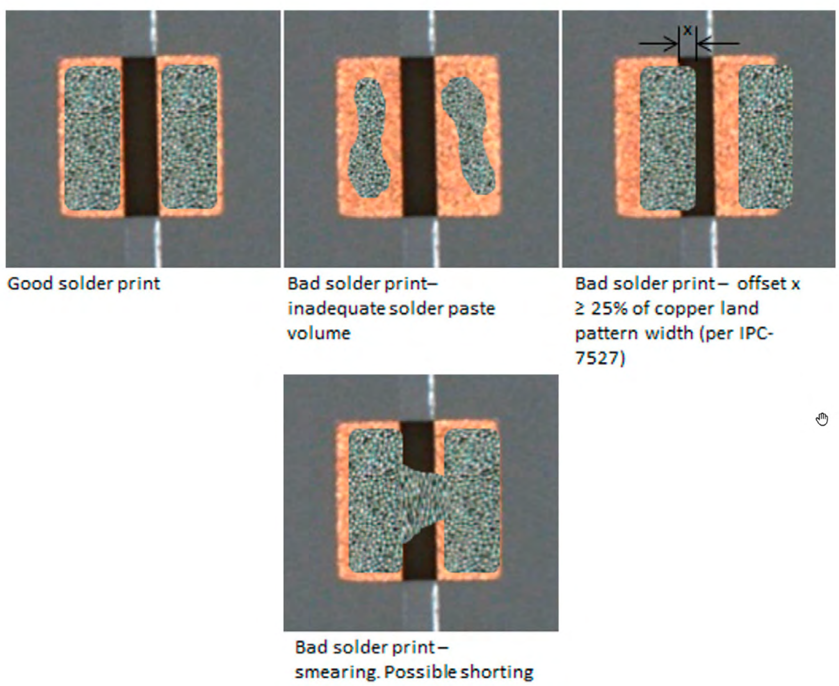

Figure 11. Examples of good and bad solder print.

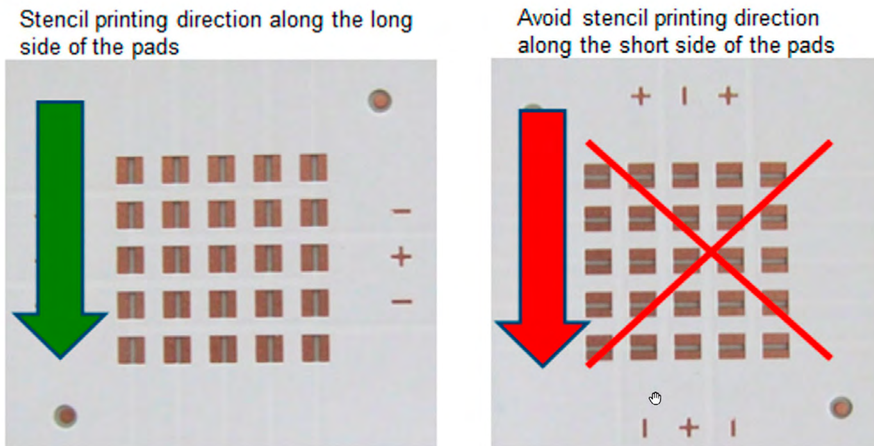

Figure 12. Orientate the PCB such that the stencil printing direction is along the long side of the pads.

4.3 Pick and Place from Tape and Reel

Automated pick and place equipment provide the best placement accuracy for LUXEON HL1Z. Note that pick and place nozzles are customer specific and are typically machined to fit specific pick and place tools. Based on these pick and place experiments Lumileds advises customers to take the following general pick and place guidelines into account when handling LUXEON HL1Z:

- The nozzle tip should be clean and free of any particles since this may interact with the silicone surface of LUXEON emitter during pick and place.
- During setup and the first initial production runs, it is a good practice to inspect the top surface of LUXEON emitter under a microscope to ensure that emitters are not accidentally damaged by the pick and place nozzle.
- Observe for emitters sticking to the nozzle or emitters coming out from the pocket tape during the initial run.
- Check that the emitter orientation is correctly placed onto the PCB board.

Nozzle Material

The nozzle material should be selected to achieve the desirable number of pick and place cycles and to prevent LUXEON HL1Z from sticking to the nozzle tip. Lumileds has successfully evaluated nozzles made out of the following materials:

- metal
- zirconia

Feeder System

Pick and place machines are typically equipped with special pneumatic or electric feeders to advance the tape containing the LEDs. In pneumatic feeders, air pressure is used to actuate an air cylinder which then turns the sprocket wheel to index the pocket tape; electric feeders, in contrast, use electric motors to turn the sprocket wheel (see Figure 13). Electric feeders often also contain a panel which allows an operator to control the electric feeder manually.

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. One such example is to cover the bottom of the metal shutter with Teflon tape such as Nitoflon from Nitto Denko if there is LED damaged during indexing (Figure 14). Also the cover tape peeling angle (Figure 14), relative to the tape should be adjusted to minimum to reduce the vertical component of the pulling force during indexing. In addition, the gap between the surfaces of the Teflon to the top of the tape should not be more than 0.4mm (Figure 15). This will prevent the LEDs from tilting over when indexing.

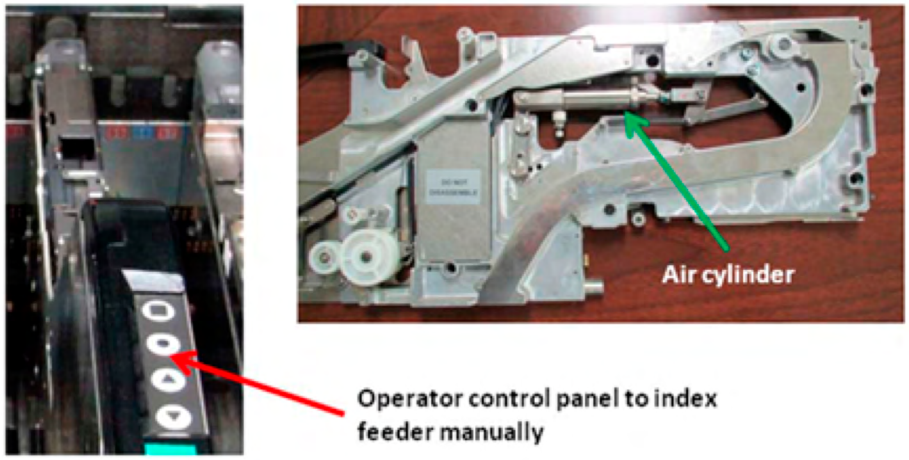

Figure 13. Examples of an electric feeder (left) and a pneumatic feeder (right) which are typically used in pick and place machines to advance the tape with LEDs.

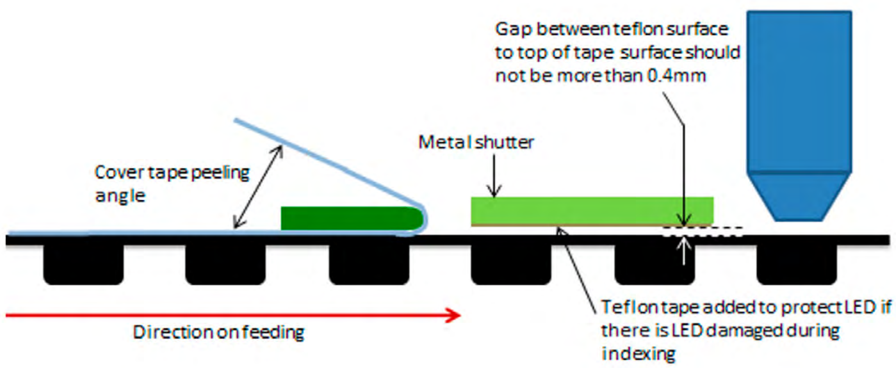

Figure 14. Simplified schematic of a feeder section where the cover tape is peeled off, metal shutter to guide LEDs from falling out or tilt over and nozzle pick up location.

Examples of the Samsung SM421 feeder system with pneumatic controller is shown in Figure 15.

Figure 15. Samsung SM421 feeder.

Another possible consideration is to evaluate putting a smaller pitch (for e.g. 2mm versus 4 mm pitch) for pneumatic based feeder (Figure 16).

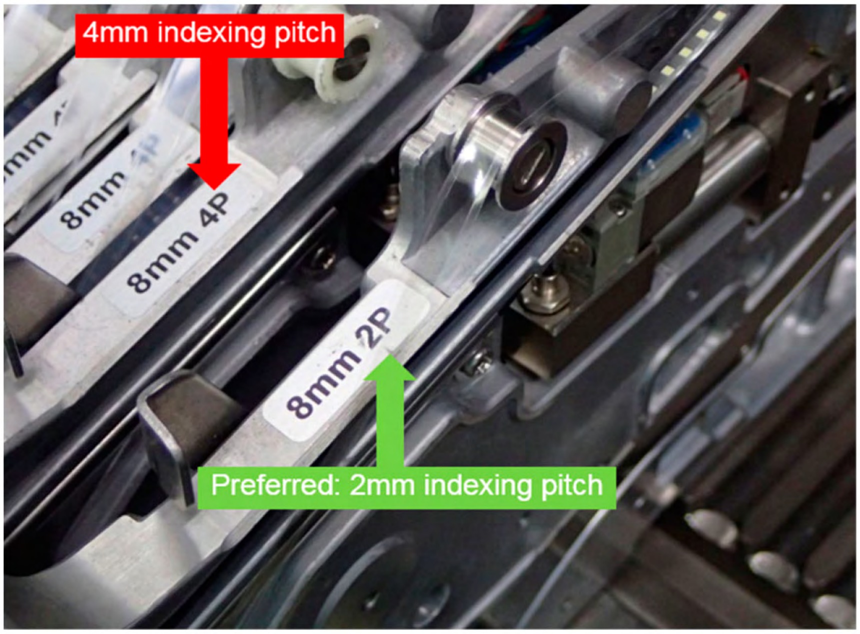

Figure 16. An example of Samsung SM421 feeder with 2mm and 4mm indexing pitches. Smaller indexing pitch creates smoother feeder motion.

To further minimize the jerking of components in pneumatic feeders during indexing, it may be necessary to install an air pressure control valve. In some pneumatic feeder designs, such a control valve is already integrated by the machine supplier; in others an external control valve may have to be installed (see Figure 17).

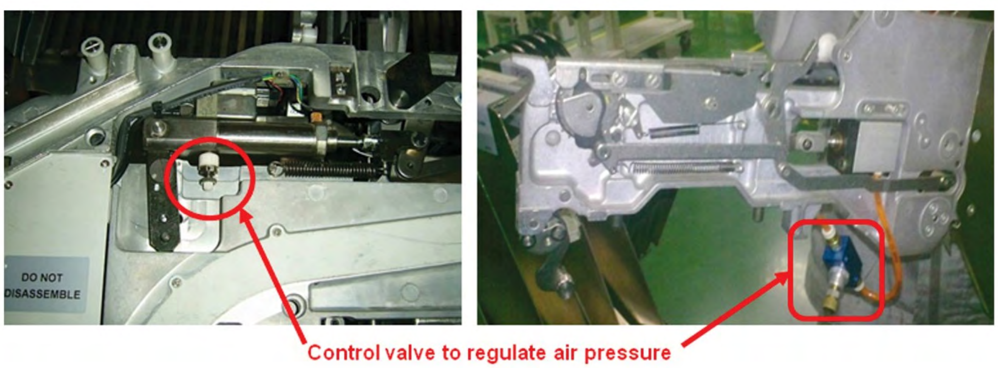

Figure 17. Pneumatic feeder with integrated air pressure control valve (left) and pneumatic feeder with air pressure control valve installed afterwards (right).

General pick and place machine optimization for LUXEON HL1Z

As there are numerous pick and place machines in the market, below is a pick and place general setup guideline to achieve good release of LUXEON HL1Z.

a. Vacuum – generally set to minimum level. For pick and place machine without the vacuum control and if the vacuum is too strong, check if there is a slight purge (blow) function during package release onto PCB. Note purging can blow away parts so extra care should be taken when using this option.

b. Pick-up transfer speed from reel to PCB – the shorter the better as less time for the LUXEON HL1Z to be under vacuum hold.

c. Z-height placement – as shown in Figure 18, the z-height starting point should be 1/3rd of the solder paste thickness. When the LUXEON HL1Z is in contact with the solder paste, it creates a certain pull force (surface tension) between the pads (solid) and the solder paste (liquid) interface. This will aid the release of LUXEON emitter from the tip of the nozzle. In some instances, one can also evaluate releasing the LUXEON HL1Z just above the solder paste. LUXEON HL1Z is light and easily self-aligns during reflow.

d. For machines with nozzle head unit assembly that accommodates multiple nozzle tips, consider reducing the number of nozzles during troubleshooting.

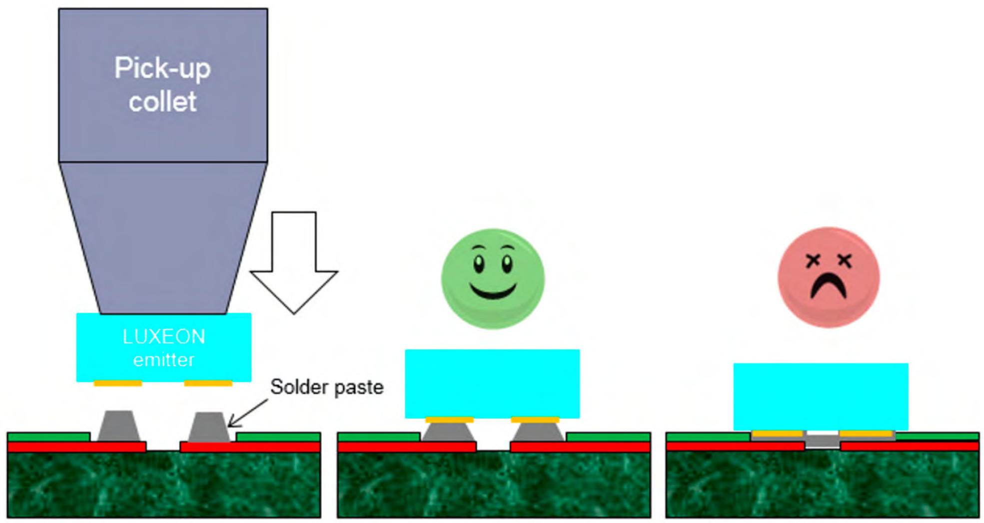

Figure 18. A proper starting point for the mounting z-height of LUXEON HL1Z is 1/3rd of the stencil thickness with reference to the top of the stencil paste, i.e. the collet should be in an under-travel position. Center picture shows the optimum result for the collet height setting. Right picture shows over-travel position and may result in bridging of the solder paste on adjacent pads prior to reflow, increasing the likelihood of electrical shorts.

Lumileds evaluated the following pick and place machines: Samsung SM421, Juki KE-2080L and Panasonic CM402. The standard off-the-shelf nozzles and machine settings are shown in the figures below.

Figure 19. Standard off-the-shelf nozzle "CN065" (inner diameter 0.65mm, outer diameter 1.2mm) with Zirconia tip for Samsung SM421 machine.

Table 2. Pick and place machine setting for Samsung SM421 machine.

PICK AND MOUNT INFORMATION	
Pick Height	-0.2 mm
Mount Height	0.0 mm
Delay – Pick Up	30 ms
Delay – Place	30 ms
Delay - Vacuum Off	0
Delay – Blow On	0
Speed – XY	1
Speed – Z Pick Down	1
Speed – Z Pick Up	1
Speed – R	1
Speed – Z Place Down	1
Speed – Z Place Up	1
Z Align Speed	1
Soft Touch	Not used

VISION INFORMATION	
Camera No	Fly Cam4
Side	15
Outer	7

4.4 Reflow

A standard SMT lead-free reflow profile can be used to reflow LUXEON HL1Z on a PCB.

Things to watch for after reflow include:

1. Solder voids – perform x-ray inspection. Keep solder void to less than 25% coverage (Figure 20)
2. Solder balling.
3. LED package tilting to PCB surface.
4. Any visible damage, tilt or misplacement of LUXEON emitter.
5. Change in color and/or reflectivity (i.e. dull appearance) of the solder mask. This may impact the light output extraction or cause color shift.
6. Functional test (open/short)

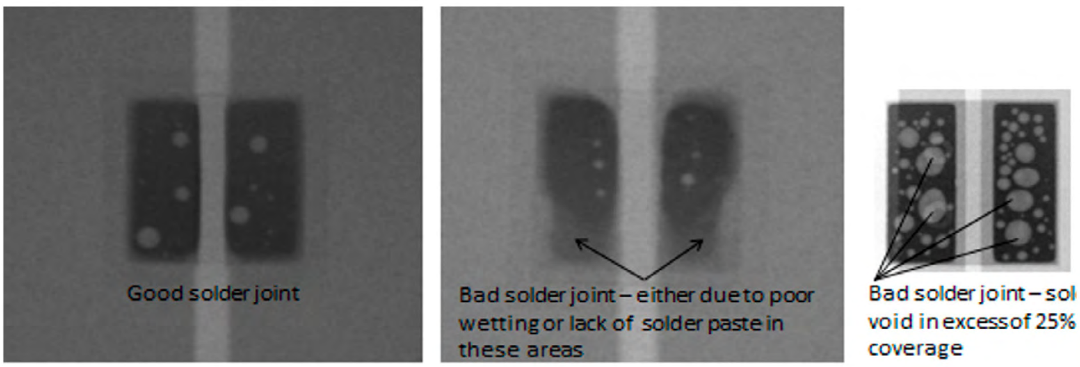

Figure 20. Example of good and bad x-ray result of a representative LED package.

4.5 Electrostatic Discharge Protection

LUXEON HL1Z does not include any transient voltage suppressor (TVS) chip to protect against ESD. A LUXEON HL1Z which is damaged by ESD may not light up at low currents and/or may exhibit abnormal performance characteristics such as a high reverse leakage current, and a low forward voltage. Latent ESD damage (no immediate failure symptom but partially damage and may degrade over time) is difficult to detect, hence safe ESD practices must always be adopted during the complete handling and assembly process.

Lumileds recommends that the workplace setup and training of those operators, who handle LUXEON HL1Z meet the ESD classification of that device per the recommendations given in JEDEC standard document JESD625B ***"Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices"*** or IEC 61340-5-1,2 and 3 documents. Some common ESD guidelines for handling LUXEON HL1Z include:

- Any handling or assembly of boards containing unprotected (no TVS) chips must be done in the designated ESD protected areas and workstations as described in JESD625B.
- Always wear a conductive wrist strap that is continuously monitored when working or handling assembled boards containing unprotected chips.
- Use an ion blower to neutralize the static discharge that may build up on the surface of the LUXEON HL1Z during storage and handling.
- Always keep unused LUXEON HL1Z in its original packaging.

Besides adding a TVS protection diode in parallel to the LED, an alternative method of ESD protection during assembly is having the LUXEON HL1Z anode and cathode temporarily at the same electrical potential by shorting both contacts. When doing this, it is important that LUXEON HL1Z has no residual charges in it (static build-up), otherwise shorting could damage the chips. By practicing safe ESD process during all stages of handling will minimize static build up.

Figure 21 shows three different electrical schematics to protect the LUXEON HL1Z from ESD damage. The middle option employs a permanent TVS diode while the left and right options are temporary solutions via shorting the LUXEON HL1Z electrodes. The shorted path must later be removed while still maintaining safe ESD practice during assembly and handling of LUXEON HL1Z.

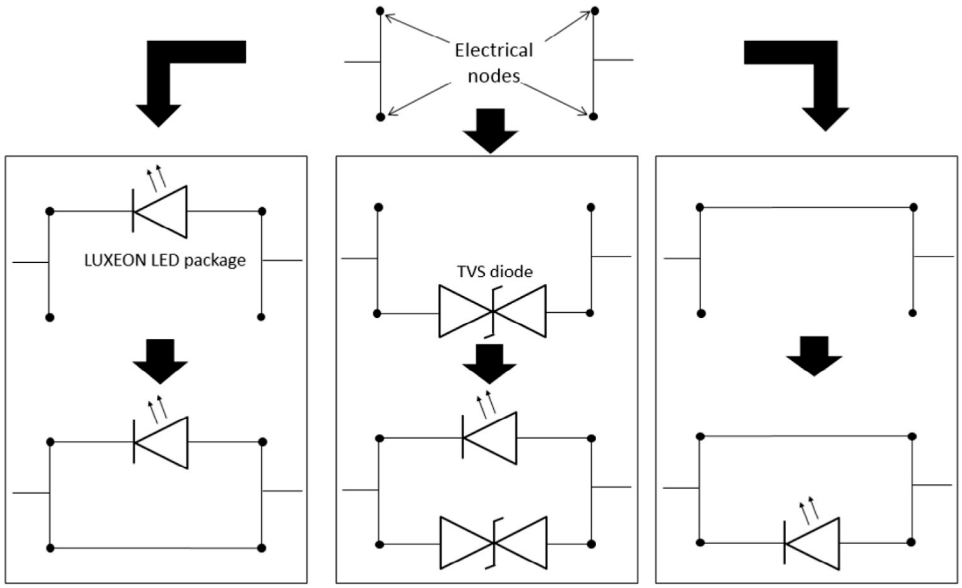

Figure 21. Electrical schematics showing three different methods of ESD protection. The middle picture provides permanent ESD protection while the left and right pictures are temporary solutions. It is important that device shorting should only be done if you know that static build up is not present by practicing safe ESD handling at all times.

4.6 Flux Cleaning

As described in section 4.1, given the large variety of solder pastes and varying application use conditions/requirements, customers should always perform their own solder paste evaluation in order to determine if a solder paste will meet the application requirements in terms of solderability, solder joint reliability and overall long-term optical performance.

4.7 Board Handling and Bending

The LED package handling precaution as described in section 2 must also be applied when handling completed board.

Bending of PCB is another common handling problem typically seen on large boards. Unlike FR-4 or CEM-3 material, MCPCB and ceramic based PCB should not be bent due to the property of metal and ceramic substrate. For example, when a MCPCB is bent, it is difficult to return to its original flatness and would create problem when used with thermal interface material for good thermal contact.

4.8 Rework

Since rework of PCB typically involves manual processes such as heating up a section of a PCB for repair/component replacement, manual cleaning of PCB pads, manual dispensing of solder paste and manual placement of replacement component, all these can create uncontrollable processes which may yield unpredictable long term performance result. Lumileds currently does not provide any guideline on how to rework LUXEON HL1Z.

5. Thermal Measurement Guidelines

5.1 Thermal Basics

This section provides general guidelines on how to determine the junction temperature of a LUXEON HL1Z in a 1-up configuration in order to verify that the junction temperature in the actual application during regular operation does not exceed the maximum allowable temperature specified in the datasheet.

The typical thermal resistance ($R\theta_{j\text{-thermal pad}}$) between the junction and the thermal pad for LUXEON HL1Z is specified in the LUXEON HL1Z product datasheet. In LUXEON HL1Z, both the anode and cathode pads act as a thermal pad which is the primary heat flow path. With this information, the junction temperature T_j can be determined according to the following equation:

$$T_j = T_{\text{thermal pad}} + R\theta_{j\text{-thermal pad}} \cdot P_{\text{electrical}}$$

In this equation, $P_{\text{electrical}}$ is the electrical power going into the LUXEON HL1Z emitter and $T_{\text{thermal pad}}$ is the temperature at the bottom of the LUXEON HL1Z thermal pad.

5.2 Temperature Sensor Pad (T_s) and Thermocouple (Tc) Attachment

In typical applications it may be difficult to measure the thermal pad temperature $T_{\text{thermal pad}}$ directly. Therefore, a practical way to determine the LED junction temperature is by measuring the temperature T_s of a predetermined sensor pad on the PCB right next to the LED package with a thermocouple (TC). The junction temperature can then be calculated as follows:

$$T_j = T_s + R\theta_{j\text{-}s} \cdot P_{\text{electrical}}$$

In the above equation. $P_{\text{electrical}}$ is the combined electrical power going into the LED package. The thermal resistance from junction to the T_s point, $R\theta_{j\text{-}s}$,depends on several factors such as the PCB type and construction (e.g. MCPCB dielectric layer thickness and its thermal conductivity), the location of the T_s point, type and volume of the adhesive used to attach the TC wire, and the LED emitter packing density.

To ensure accurate readings, the TC must make direct contact with the copper of the PCB onto which the LED package pad is soldered, i.e. any solder mask or other masking layer must first be removed before mounting the TC onto the PCB. The TC must be attached as close as possible to the primary heat flow path of the LED emitter pad which can be the cathode of LUXEON HL1Z. Figure 22 (left image) shows the thermal gradient of the Al-MCPCB. The temperature drops off quickly when the T_s points moves further away from the LED package, hence making the T_s point less sensitive in estimating the junction temperature.

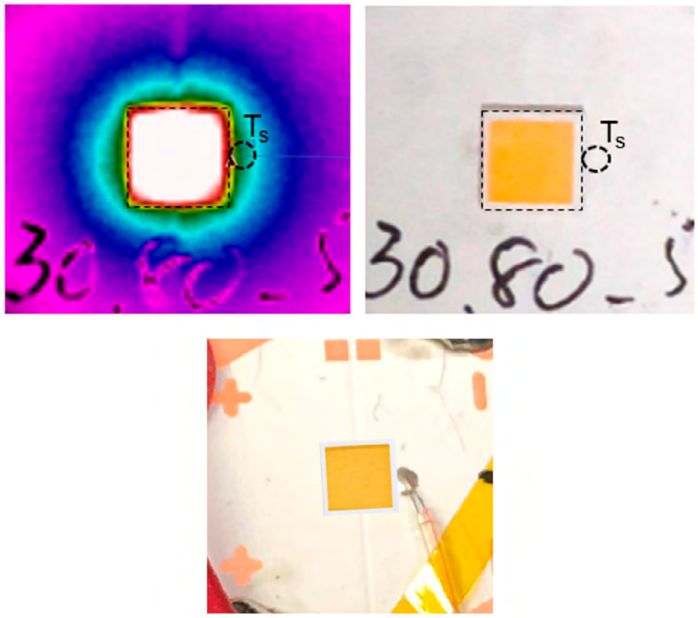

Figure 22. Shown here is a representative LED package. The T_s location should be placed close to the package as shown. The $R\theta_{j\text{-}s}$ is characterized based on this placement position. The further away the T_s point is, the calculated junction temperature will then be under-stated.

Lumileds has successfully used a two-part Artic Silver™ thermal adhesive in combination with a TC wire gauge of AWG 40 or 36. Excessive dispense of thermal adhesive may impact the accuracy of the T_s temperature reading since this may increase the thermal time constant of the setup (increase in heat capacity of the thermal adhesive). The use of non-conductive thermal epoxy is not recommended since there may be a possibility of getting some epoxy residue underneath the TC wire tip and the exposed PCB copper trace which will affect the $R\theta_{j\text{-}s}$ measurement.

5.3 Thermal Measurement Result

A 1mm thick Al-MCPCB star board with 1 oz copper foil, dielectric (NanYa NPRCA) thickness of 0.1mm with thermal conductivity of $3W{\cdot}m^{-1}{\cdot}K^{-1}$ was used in the characterization of the T_s point thermal resistance ($R\theta_{j\text{-}s}$). The average value of $R\theta_{j\text{-}s}$ for LUXEON HL1Z and the overall MCPCB thermal resistance from LED junction to heat sink is shown in Table 3. Use the equation below to estimate the junction temperature.

$$T_j = T_s + R\theta_{j\text{-}s} \cdot P_{electrical}$$

For other PCB designs and materials, an experiment or thermal simulation may be needed to determine proper $R\theta_{j\text{-}s}$. values.

Table 3. Thermal measurement result.

	TYPICAL R_{th} (JUNCTION TO T_s), $R\theta(_{j\text{-}s})$
LUXEON HL1Z	8.2 K/W_{elec}

5.4 Thermal Performance on Close Packing Assembly

The $R\theta_{j\text{-}s}$ value as shown in Table 3 cannot be used to determine the device junction temperature for close packing (high density) assembly of LUXEON emitters. In such scenario, the hottest LED emitters are usually in the center of the LED clusters surrounded by outer LED emitters. The coldest LED emitters are usually at the outer perimeter of the LED clusters where surrounding adjacent LED emitters are at minimum. Thus the limiting factor of the LED clusters depend on the hottest LEDs. Proper layout of the underlying PCB copper trace pattern and the type of PCB substrate (ceramic vs MCPCB) need to be considered when designing close packing of LED emitters.

Figure 23 shows temperature distribution taken via thermal imaging camera of two arbitrary close packing designs. Notice that where the hottest and coldest LED emitters are located (see the false rainbow color legend of each image).

Determining the junction temperature of the hottest LEDs in close packing assembly design involves either thermal simulation or the use of thermal imaging camera.

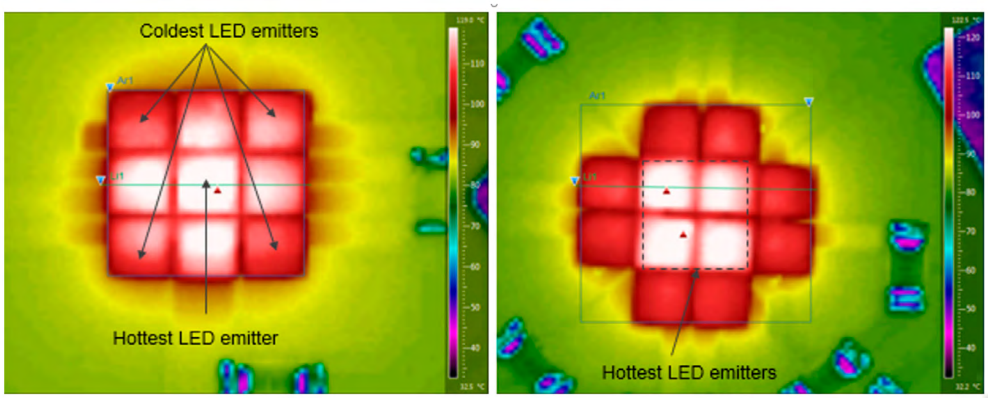

Figure 23. Thermal imaging camera results for LED clusters (150um spacing) with close packing on Al-MCPCB (1oz copper, 3W/(m.K) 100µm dielectric).

6. Packaging Considerations—Chemical Compatibility

The LUXEON HL1Z package contains a silicone material 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 in LUXEON HL1Z 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 reacct during the presence of heat or light (photo-thermal reaction). 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 HL1Z 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. Under heat and blue light, the VOCs inside the silicone coating may partially oxidize and create an appearance of 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 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 LEDs, flux density (blue photons) and the operating temperatures.

Table 4 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 4 are typically not directly used in the final products that are built around LUXEON HL1Z. 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 heat sinks or on PCBs. 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 4. List of commonly used chemicals that will damage the silicone of LUXEON HL1Z. Avoid using any of these chemicals in the housing that contains the LED package.

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 [1]
Acrylic Tape	Adhesive

Note for Table 4:

1. Other than the use of no-clean solder paste qualified by customer. See section 4.1 for more details. Avoid secondary solder flux, for example when manually soldering wires close to LUXEON emitter, solder flux should not spit onto the LUXEON emitter surface or leaving excessive secondary solder flux residue onto the PCB when operating LEDs in an air tight enclosure or poorly ventilated enclosure.

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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AB386 LUXEON HL1Z
Application Brief 20220803