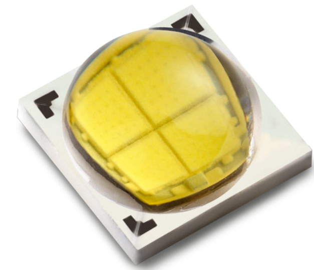
LUXEON M

Assembly and handling information



Introduction

This application brief addresses the recommended assembly and handling procedures for LUXEON M emitters. LUXEON M emitters are designed to deliver high luminous flux and efficacy from a compact optical source in order to enable a wide range of outdoor and industrial lighting applications. Proper assembly, handling, and thermal management, as outlined in this application brief, ensure high optical output and long lumen maintenance for LUXEON M emitters.

Scope

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

LXRA-BCDE-FGHJ	
Where	
a –	designates minimum CRI (7 = 70, 8 = 80, 9 = 90, 0 = Royal Blue)
b –	Four LED chips electrical configuration (S = all four chips are electrically connected in series, resulting in less than 12V, R = two by two chips in series-parallel with less than 6V, Q = all four chips in parallel with voltage less than 3V)
c –	designates color designation (W = White, R = Royal Blue)
de –	designates nominal CCT (27 = 2700K, 30 = 3000K, etc and 00 = Royal Blue)
fghj –	minimum flux (optional)

In the remainder of this document the term LUXEON emitter refers to any product in the two LUXEON product series listed above. Any handling requirements that are specific to a subset of LUXEON emitters will be clearly marked.

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1. Component

1.1 Description

The LUXEON M emitter consists of a 2x2 LED chip array mounted onto a ceramic substrate. This substrate provides mechanical support and thermally connects the LED chips to a thermal pad on the bottom of the substrate. An electrical interconnect layer connects the LED chips to a cathode and anode on the bottom of the ceramic substrate. The ceramic substrate is surrounded by a larger ceramic frame and is overmolded with a silicone dome to enhance light extraction and to shield the chip array from the environment. Each LUXEON M emitter includes a transient voltage suppressor (TVS) chip under the silicone dome to protect the emitter against electrostatic discharges (ESD).

The bottom of the LUXEON M emitter (Figure 1) contains four metallization pads, a large thermal pad in the center, an anode, a cathode, and a small pad with a laser engraved LED serial number. The pad with the serial number is not designed to be soldered onto a PCB.

Each LUXEON M emitter contains three staircase-style fiducials on the ceramic frame outside the dome (see the top view of LUXEON M in Figure 1). In order to identify the anode and cathode, rotate the LUXEON M emitter so that the three fiducials are on the top left, bottom left, and top right corner of the ceramic substrate when viewed from above as shown in Figure 1. The left side, marked by the two fiducials in the top and bottom corner, then corresponds to the cathode side of the LUXEON M emitter. The anode side only contains one fiducial in the top corner, when viewed from above.

1.2 Optical Center

The LUXEON M emitter contains three feature sets to locate the theoretical optical center (see Figure 2):

1. Topside fiducials — The fiducial marks on the ceramic frame of the LUXEON M emitter provide the most accurate methodology to locate the theoretical optical center. The theoretical optical center is located 3.14mm from the vertical and horizontal edges of each fiducial mark.
2. Backside metallization — The optical center can be located using the edges of the thermal pad on the bottom of the ceramic substrate. The theoretical optical center is 1.08mm and 1.75mm from the long and short edge, respectively, of the thermal pad.
3. LED outline — The theoretical optical center is located 3.50mm from the edge of the LUXEON M emitter.

Optical rayset data for LUXEON M is available upon request.

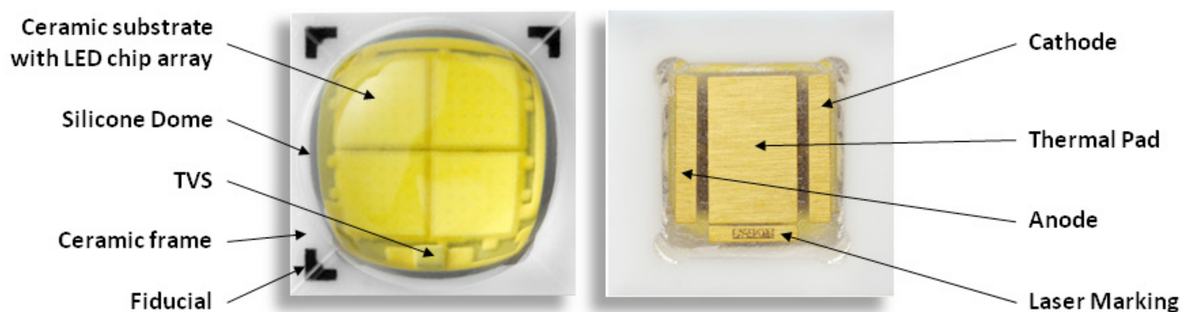

Figure 1. Top view (left) and bottom view (right) of LUXEON M emitter. The pad with the laser marking should not be soldered onto a PCB.

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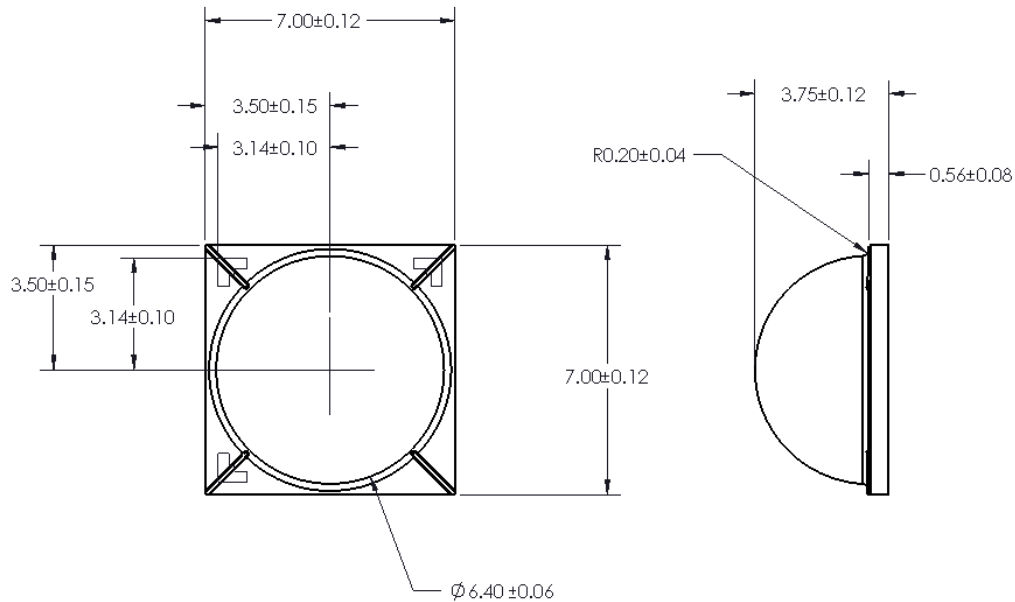

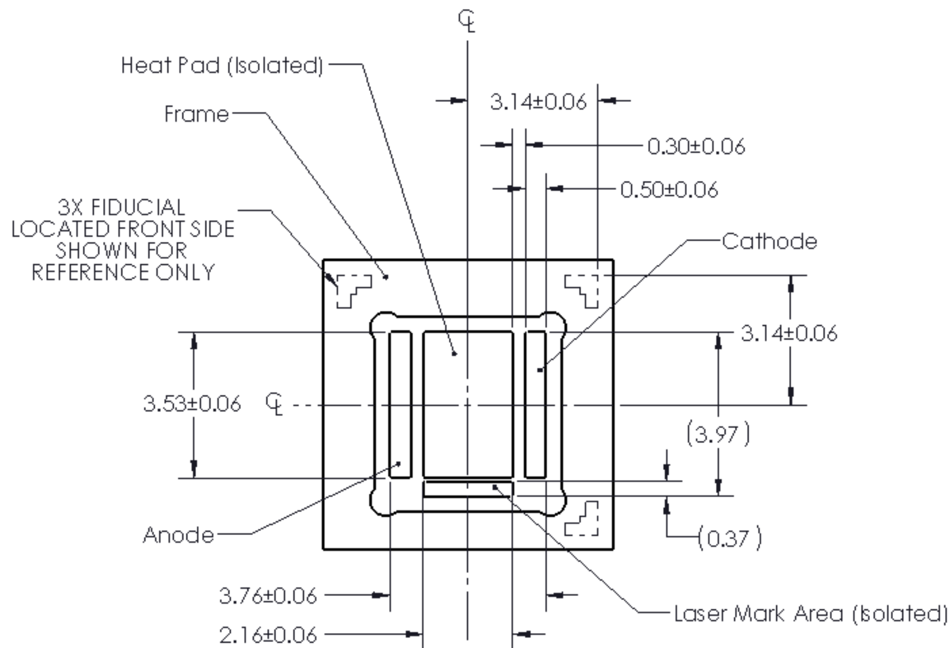

Figure 2. Fiducial marks on the top of the LUXEON M emitter provide the most accurate method to locate the theoretical optical center.

1.3 Handling Precautions

LUXEON M is designed to maximize light output and reliability. However, improper handling of the device may damage the silicone dome and affect the overall performance and reliability. In order to minimize the risk of damage to the silicone dome during handling, LUXEON M emitters should only be picked up from the side of the ceramic frame as shown in Figure 3.

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Figure 3. Incorrect handling (left and middle) and correct handling (right) of LUXEON M emitters.

1.4 Cleaning

LUXEON M should not be exposed to dust and debris. Excessive dust and debris may cause a drastic decrease in optical output. In the event that a LUXEON M emitter requires cleaning, first try a gentle swabbing using a lint-free swab. If needed, a lint-free swab and isopropyl alcohol (IPA) can be used to gently remove dirt from the lens. Do not use other solvents as they may adversely react with the LED assembly. For more information regarding chemical compatibility, see Section 6.

1.5 Electrical Isolation

The thermal pad of the LUXEON M is electrically isolated from its cathode and anode. Consequently, a high voltage difference between electrical and thermal metallization may occur in applications where multiple LUXEON M emitters are connected in series. As a reference, the nominal distance between the electrical metallization and the thermal metallization of the LUXEON M emitter is 0.3mm.

In order to avoid any electrical shocks and/or damage to the LUXEON M emitter, each design needs to comply with the appropriate standards of safety and isolation distances, known as clearance and creepage distances, respectively (e.g. IEC60950, clause 2.10.4).

1.6 Mechanical Files

Mechanical drawings for LUXEON M (2D and 3D) are available upon request.

1.7 Soldering

LUXEON M emitters are designed to be soldered onto a Printed Circuit Board (PCB). For detailed assembly instructions, see Section 2.

2. LUXEON M Printed Circuit Board Design Rules

The LUXEON M emitter is designed to be soldered onto a Metal Core PCB (MCPCB) or a multi-layer FR4 PCB. To ensure optimal operation of the LUXEON M emitter, the PCB should be designed to minimize the overall thermal resistance between the LED package and the heat sink.

2.1 LUXEON Z Footprint and Land Pattern

The LUXEON M emitter has three pads that need to be soldered onto corresponding pads on the PCB to ensure proper thermal and electrical operation. The pad with the laser engraved serial number is not designed to be soldered onto the PCB. Figure 4 shows the recommended footprint design for the solder mask and the copper layout on a Metal Core PCB. Lumileds recommends extending the thermal pad and electrodes at least 10mm from the center of the LUXEON M LED to maximize heat spreading into the PCB.

The recommended footprint design includes special fiducials near the corners of the LUXEON M to facilitate visual inspection of the placement accuracy of the LUXEON M emitter on the PCB board.

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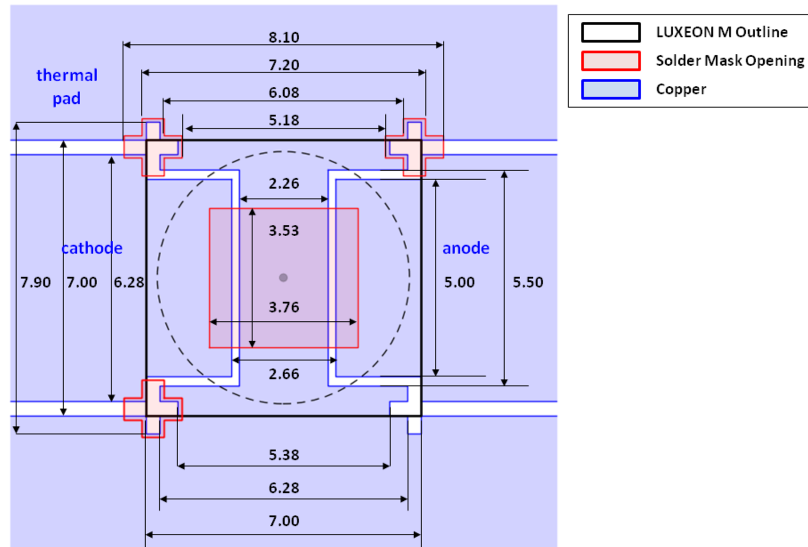

Figure 4. Recommended LUXEON M footprint design for Metal Core PCB. All dimensions in mm.

2.2 Surface Finishing

Lumileds recommends using a high temperature organic solderability preservative (OSP) or electroless nickel immersion gold (ENIG) plating on the exposed copper pads.

2.3 Minimum Spacing

Lumileds recommends a minimum edge to edge spacing between LUXEON M emitters of 13mm. Placing multiple LUXEON M emitters too close to each other may adversely impact the ability of the PCB to dissipate the heat from the emitters. Also, the light output for each LED may drop due to optical absorption by adjacent LED packages.

3. Thermal Management

The overall thermal resistance between the LUXEON M emitter and the heat sink is strongly affected by the design and material of the PCB on which the LUXEON M emitter is soldered. Metal Core PCBs have been historically used in the LED industry for their low thermal resistance and rigidity. However, MCPCBs may not always offer the most economical solution.

Multi-layer epoxy FR4 PCBs are commonly used in the electronics industry and can in certain LED applications yield a lower cost solution. Given the poor thermal conductivity of the epoxy in FR4 PCBs, it is important to include special thermal vias in the PCB design to aid the transport of heat from the LED to the heat sink on which the PCB is mounted. A thermal via is a plated through hole that can be open, plugged, filled or filled and capped. Open vias are typically placed outside the pads on which the LEDs are soldered to prevent any solder from reaching the other side during reflow. A filled-and-capped via, in contrast, can be placed directly underneath the thermal pad of the LED, improving the thermal performance of the PCB.

Lumileds conducted a simulation study to determine the typical thermal resistance for various LUXEON M PCB designs. In addition, several PCB designs were manufactured and the thermal resistance was experimentally determined. The remainder of this section discusses the different PCB designs which were considered and compares the merits of each PCB design in terms of its overall thermal resistance between the LUXEON M emitter and the heat sink.

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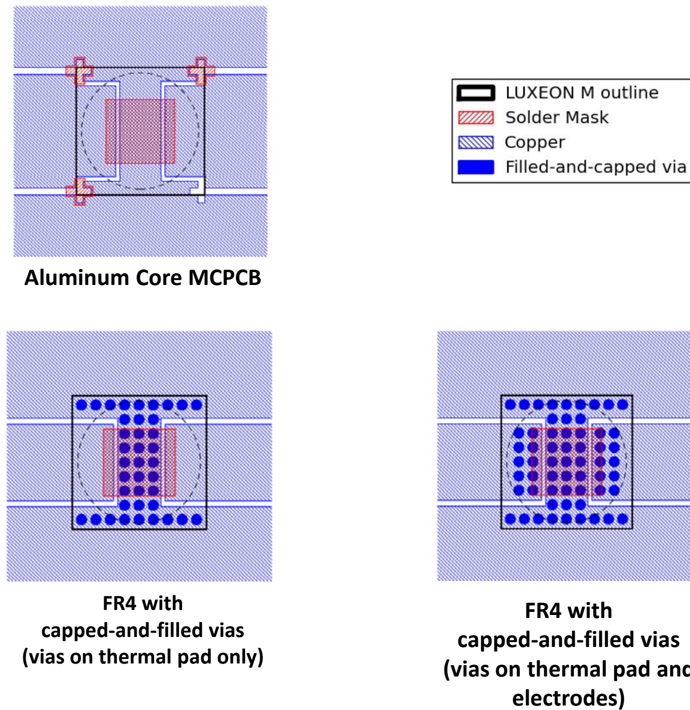

Figure 5. Several LUXEON M PCB designs were simulated and/or experimentally measured to determine the typical thermal resistance between the thermal pad and the heat sink.

3.1 PCB designs for LUXEON M

The thermal resistance study for LUXEON M focused on several different PCB designs requiring different PCB manufacturing technologies (see Figure 5):

Metal Core PCB

The thermal simulation study focused on an MCPCB design with a 100µm dielectric layer and a 70µm (2oz) copper foil. The thermal conductivity of the dielectric material in the simulation study is assumed to be $1Wm^{-1}K^{-1}$. In addition, several MCPBCs were manufactured. Each MCPCB contained an 80µm thick dielectric layer with a thermal conductivity of $2.7Wm^{-1}K^{-1}$ and a copper foil thickness of 35µm (1oz) or 70µm (2oz). In order to assess the impact of the metal substrate on the overall thermal resistance, both aluminum core and copper core MCPCB designs were evaluated.

FR4 PCB with filled-and-capped vias

The thermal simulation study included two FR4 PCB designs with filled-and-capped vias. The FR4 epoxy board in each design is assumed to be 0.8mm thick and has a glass fiber content of 25%. Copper foils with a thickness of 70µm (2oz) copper foils are attached to both sides. The metallization patterns on top and bottom of the PCBs are assumed to be identical. The filled-and-capped vias have a diameter of 0.5mm, are plated with 25µm copper, and are filled with epoxy afterwards. The pitch between the filled-and-capped vias is 0.75mm. The first design in this category contains filled-and-capped vias in the thermal pad only. The second design has additional filled-and-capped vias on the electrodes as well.

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Table 1. Rθ values between LUXEON M thermal pad and heat sink for various PCB designs.

PCB TECHNOLOGY	DETAILS	CU-FOIL	Rθ PAD-HEAT SINK [K/W]
Al-core MCPCB	80µm dielectric (2.7$Wm^{-1}K^{-1}$)	70µm (2oz)	1.8
Al-core MCPCB	80µm dielectric (2.7$Wm^{-1}K^{-1}$)	35µm (1oz)	2.9
Al-core MCPCB	100µm dielectric (1.0$Wm^{-1}K^{-1}$)	70µm (2oz)	3.3
Cu-core MCPCB	80µm dielectric (2.7$Wm^{-1}K^{-1}$)	35µm (1oz)	2.3
Cu-core MCPCB	100µm dielectric (1.0$Wm^{-1}K^{-1}$)	70µm (2oz)	3.2
FR4 (filled-and-capped vias)	Vias on thermal pad only	70µm (2oz)	5.3
FR4 (filled-and-capped vias)	Vias on thermal pad and electrodes	70µm (2oz)	3.7

The filled-and-capped vias in these FR4 designs create an electrical path between the top and bottom metallization layers of the PCB. Therefore, an additional Thermal Interface Material (TIM) is required between the FR4 PCB and heat sink to ensure sufficient electrical shielding between the traces on the FR4 PCB and the heat sink. In order to provide a fair comparison between the different board designs in this study, a 0.1mm TIM layer with a thermal conductivity 1$Wm^{-1}K^{-1}$ is included in all thermal simulations of the filled-and-capped FR4 designs.

3.2 Thermal Resistance Results

Table 1 summarizes the thermal resistance values between the heat sink and the LUXEON M thermal pad for the various PCB designs considered in this study. These results suggest that the typical thermal resistance of a properly designed MCPCB is somewhere between 2.0K/W and 3.5K/W, depending on the quality and thickness of the materials used. In contrast, an FR4 PCB with filled-and-capped thermal vias yields a thermal resistance between 3.5K/W and 5.5K/W.

For completeness, several FR4 PCB designs with open vias were also considered in this study. However, both experimental and simulation results indicate that the typical thermal resistance for these designs is above 6.5K/W.

Simulation and experimental results indicate that the thermal resistance of an MCPCB can be reduced to well below 2K/W if the dielectric material between the LUXEON M thermal pad and the core of the MCPCB is eliminated. This approach can be particularly useful in certain high-density applications where multiple LUXEON M LEDs are placed in close proximity to each other.

3.3 Other Thermal Assembly and Design Considerations

Thermal Interface Materials (TIM) Selection

Once the suitable PCB board material and design has been made, the choice of TIM material selection should be made with the following considerations:

- Pump out. Some TIMs will move out of the thermal path during extreme temperature excursions and create voids in the thermal path. These materials should not be used.
- TIM thickness. Excessive thickness of some TIMs will present an unacceptable thermal resistance even though the thermal conductivity of the material may be high.
- Surface roughness. In order to fill the air gaps between adjacent surfaces, choose the appropriate TIM that minimizes the interfacial contact resistance.
- Operating temperature. Some TIMs perform poorly at elevated temperatures. Care should be exercised to select a TIM that will perform well under the anticipated operating conditions.
- Out-gassing. Out-gassing of some TIMs at design temperatures may produce undesirable optical or appearance qualities (e.g. fogging) in a sealed system. Special consideration must be given to limit this effect.
- Clamping force. TIMs such as thermal tape or pads perform better when the right pressure is applied.

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LED Component Spacing (Density)

As more LEDs are packed closely together, thermal crowding effect becomes more important and will affect the ability of the PCB to dissipate heat.

Electrical Power Distribution

PCB electrical (copper) trace width and length (routing) can affect thermal performance. If the copper trace is too narrow and long, there is more voltage drop across the copper trace (power dissipation = current x voltage) and more heat is generated. In LED array configuration, the PCB area where the trace is generating more heat will lead to increase operating junction temperature of the neighboring LEDs. This will cause poor light output uniformity.

As a general rule of thumb, layout the copper trace first such that the most optimum thermal performance can be achieved and then figure out how to route the electrical traces. In some network topology, it may be necessary to make the LUXEON M thermal pad electrically active. Figure 6 and Figure 7 illustrate the impact of copper trace length and width on overall system thermal performance.

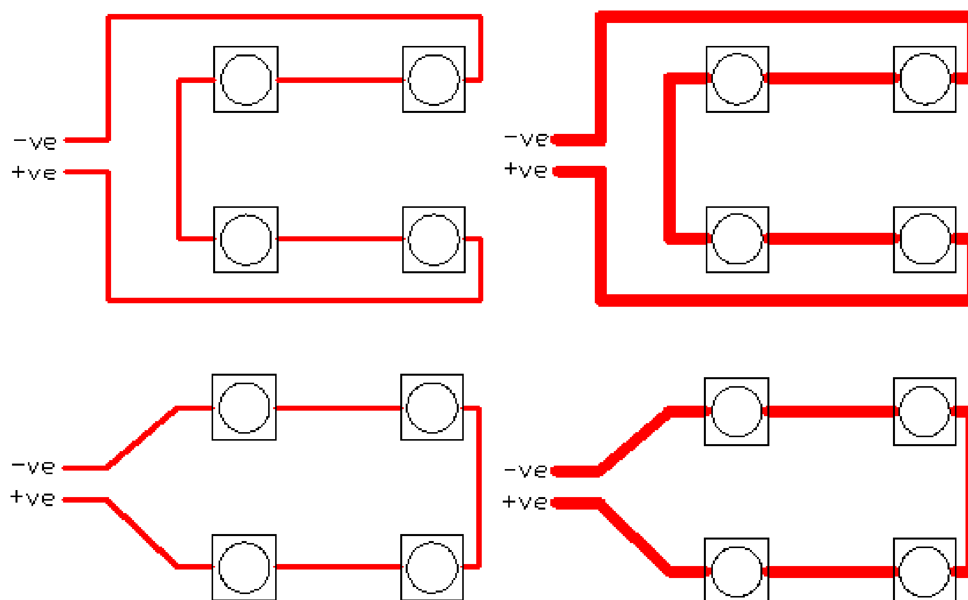

Figure 6. Top left shows long copper trace length (red lines) with narrower trace width. Top right shows the same layout as the left drawing but with wider trace width. The latter minimizes heat generated in the copper trace. Bottom left and right shows optimize trace route (shortest). Depending on the operating drive current of the LED system and the electrical layout of the LEDs (parallel-series), the copper trace width may need to be adjusted depending on the amount of current flowing through each section of the trace. See Figure 7 for this example.

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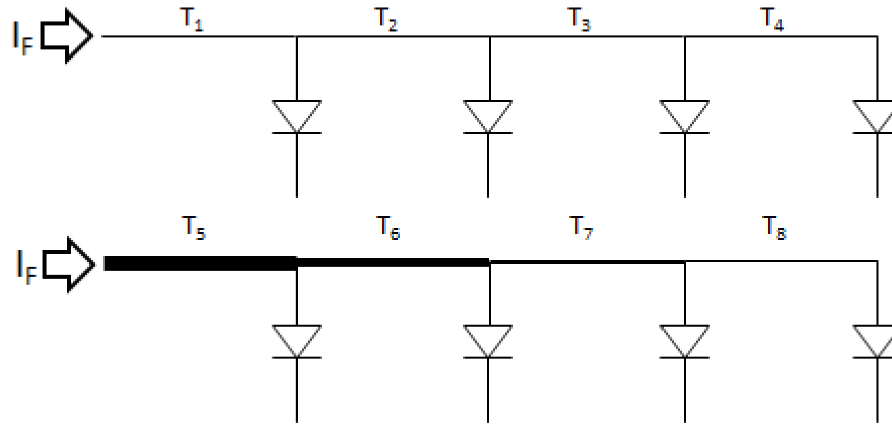

Figure 7. Top and bottom drawing each show four LEDs connected in parallel. Each LED is assumed to have the same forward voltage and same current flowing. T_1 to T_8 sections represent copper trace width. Thicker line means wider copper trace width. Top drawing has poor electrical layout since more heat is generated in T_1 than T_2, etc due to higher current flowing in T_1 than T_2, etc. Temperature in $T_1 > T_2 > T_3 > T_4$. Bottom drawing represents good electrical layout. Since more current flows in T_5 than T_6, the trace width in T_5 is made correspondingly larger than T_6 and so on. Much easier will be to make the trace width the same (larger) for all of T_5 to T_8. Note that as the copper trace area is increased, this may lead to increase PCB board capacitance and may interact with other transient tests such as electrical surge immunity test.

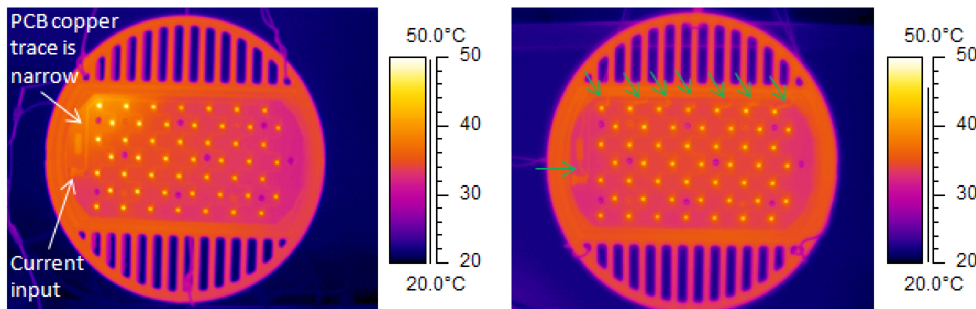

Figure 8. A real life example of an application design concept as described in Figure 11. Left and right pictures are thermal images of the same board. The narrow PCB copper trace as indicated in the left picture carries very high current to feed several LEDs connected in parallel. Right picture with green arrows shows a modified electrical trace routing (in this case, soldering the right wire size to each node of the LEDs). Notice that the right picture shows more uniform temperature distribution than the left picture after adjusting the electrical power distribution to each LED.

4. Thermal Measurement Guidelines

4.1 Stencil Design

The typical thermal resistance $R\theta_{(j\text{-thermal pad})}$ between the junction and thermal pad for LUXEON M is 1.25K/W. With this information, the junction temperature T_j can be easily determined according to the following equation:

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

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

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In typical applications it may be difficult, though, to measure the thermal pad temperature $T_{thermal\ pad}$ directly. Therefore, a practical way to determine the LUXEON M junction temperature is by measuring the temperature T_s of a predetermined sensor pad on the PCB right next to the LUXEON M emitter with a thermocouple (see Figure 9). The recommended location of the sensor pad is 0.5mm from the edge of the LUXEON M emitter, on the center line between anode and cathode. The thermocouple must make direct contact with the copper of the PCB onto which the LUXEON M thermal pad is soldered, i.e. any solder mask must be first removed before mounting the thermocouple onto the PCB.

The thermal resistance $R\theta_{j\text{-}s}$ between the sensor pad and the LUXEON M junction was experimentally determined to be approximately 3.0K/W on a MCPCB. The junction temperature can then be calculated as follows:

$$T_j = T_s + 3.0 \cdot P_{electrical}$$

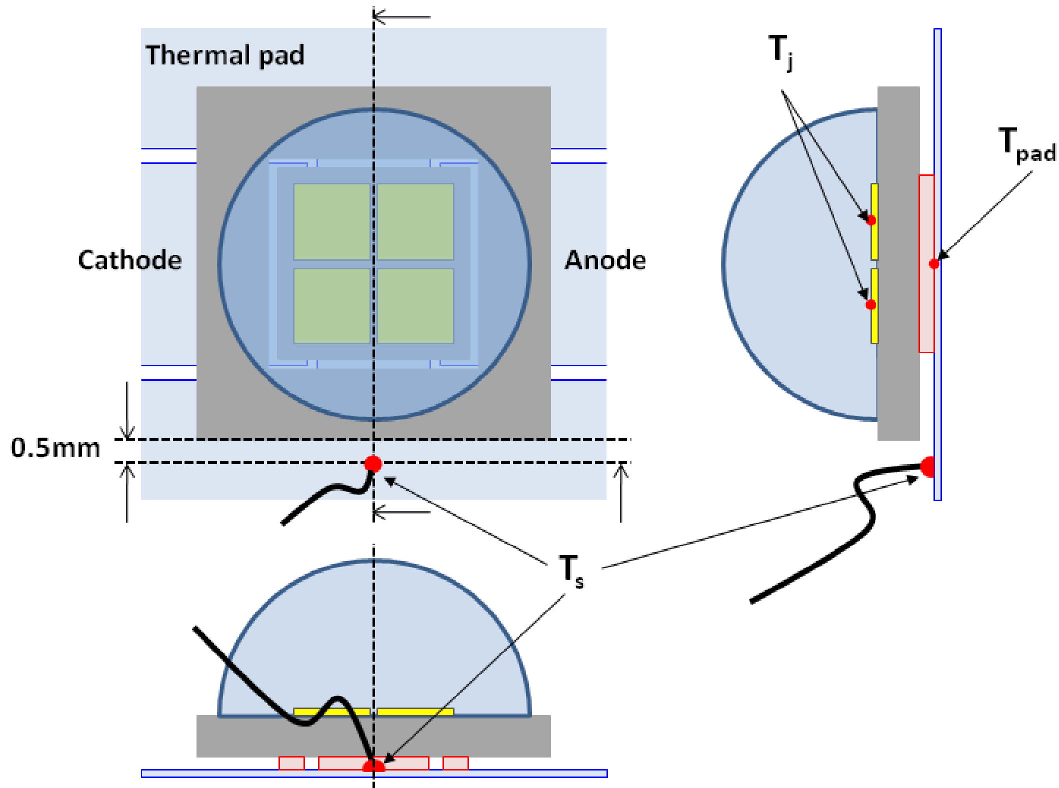

Figure 9. The recommended temperature measurement point T_s is located next to the LUXEON M emitter on the thermal pad of the PCB.

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5. Assembly Process Guidelines

5.1 Stencil Design

Figure 10 shows the recommended stencil design for LUXEON M. The recommended stencil thickness is 125μm.

5.2 Solder Paste

Lumileds recommends lead-free solder for the LUXEON M emitter. Lumileds has successfully tested SAC305-OM338 from Alpha Metals with satisfactory results. However, since application environments vary widely, Lumileds recommends that customers always perform their own solder paste evaluation in order to ensure it is suitable for the targeted application and operating conditions.

5.3 Pick-and-Place

Automated pick and place equipment provides the best placement accuracy for LUXEON M emitters. Figure 11 – Figure 14 show various pick and place nozzle designs and corresponding machine settings which were successfully used for LUXEON M emitters with pick and place equipment from Panasonic, Yamaha, Juki and Samsung. Each nozzle is designed to pick the LUXEON M emitter up from the flat area around the dome without making any contact with the silicone dome.

Note that pick and place nozzles are customer specific and are typically machined to fit specific pick and place tools.

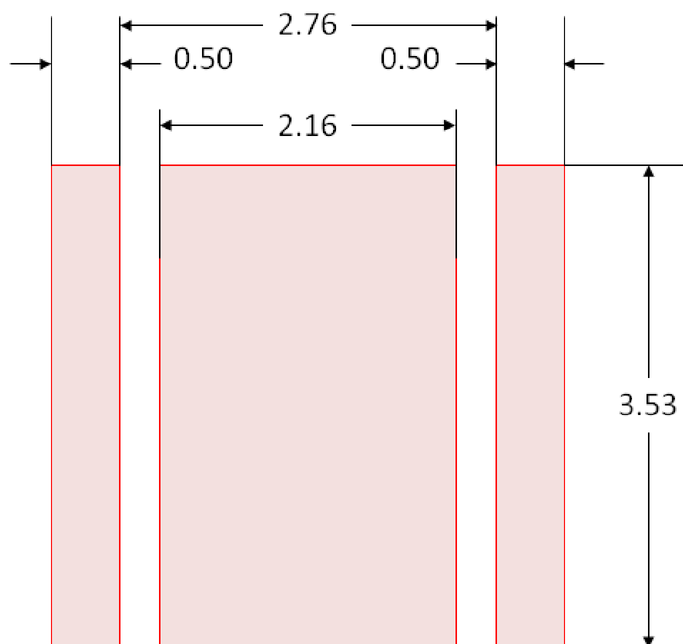

Figure 10. Recommended stencil design for LUXEON M. All dimensions in mm.

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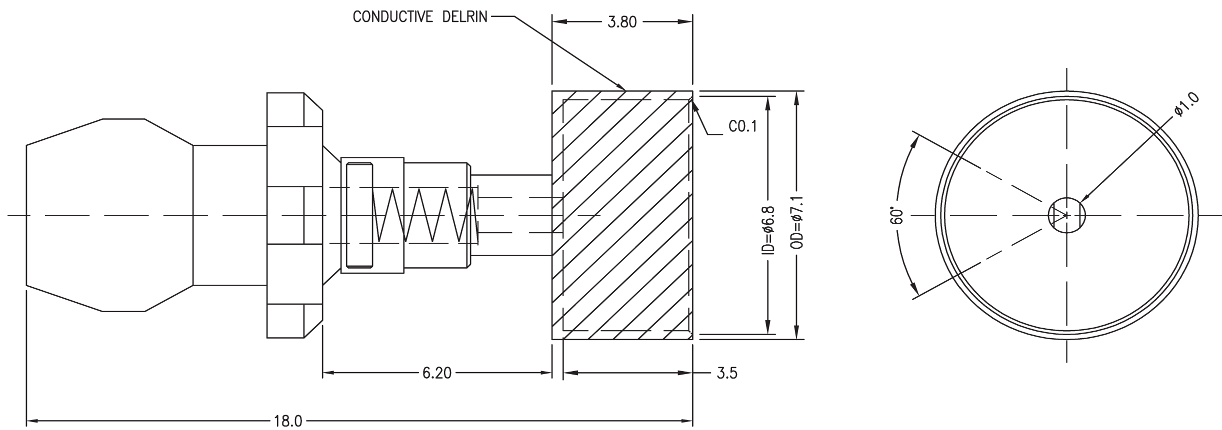

PICK AND MOUNT INFORMATION	
Pick timer	0.3 s
Mount timer	0.3 s
Pick height	2.5mm
Mount height	-1.0mm
Mount action	QFP
Mount speed	50%
Pickup speed	50%
Vacuum check	Normal Chk
Pick vacuum	30%
wMount vacuum	50%

VISION INFORMATION	
Alignment group	Chip
Alignment type	Std.Chip
Alignment module	Fore & Back & Las
Light selection	Main + Coax
Lighting level	5/8
Comp. threshold	30
Comp. tolerance	30
Search area	0.8mm
Comp. intensity	116
Auto threshold	Use

Figure 11. Pick and place nozzle design and machine settings for Yamaha YV100X. All dimensions in mm. Nozzle drawing courtesy of Ching Yi Technology Pte Ltd (part #: YMH-0078/12).

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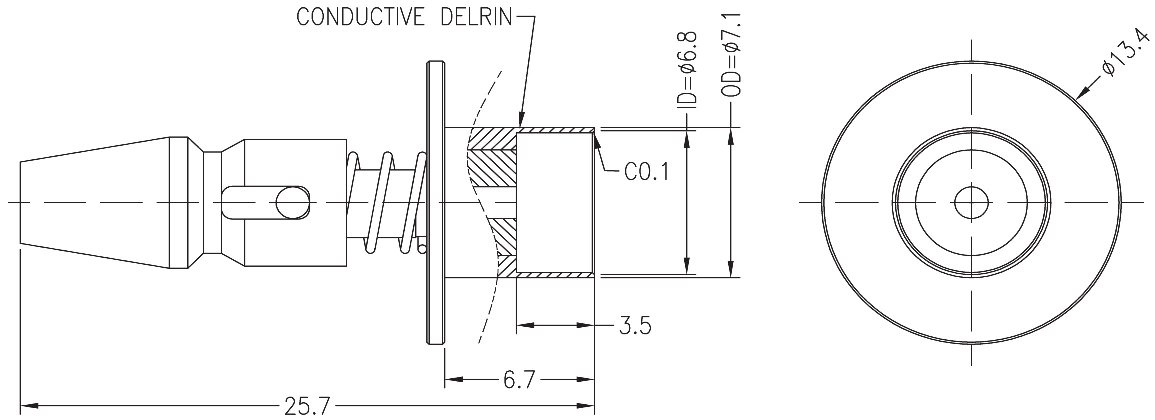

PICK AND MOUNT INFORMATION	
Pick Height	-3.5mm
Mount Height	1mm
Delay – Pick Up	300msec
Delay - Place	100msec
Delay - Vac Off	0
Delay – Blow On	100msec
Speed – XY	2
Speed – Z Pick Down	2
Speed – Z Pick Up	2
Speed – R	2
Speed – Z Place Down	2
Speed – Z Place Up	2
Z Align Speed 2	2
Soft Touch	Pick & Mount
Mount Method	Normal

VISION INFORMATION	
Camera No	Fly Cam5
Side	11
Outer	8

Figure 12. Pick and place nozzle design and machine settings for Samsung SM421. All dimensions in mm. Nozzle drawing courtesy of Ching Yi Technology Pte Ltd. (part #: SAM-1313/11).

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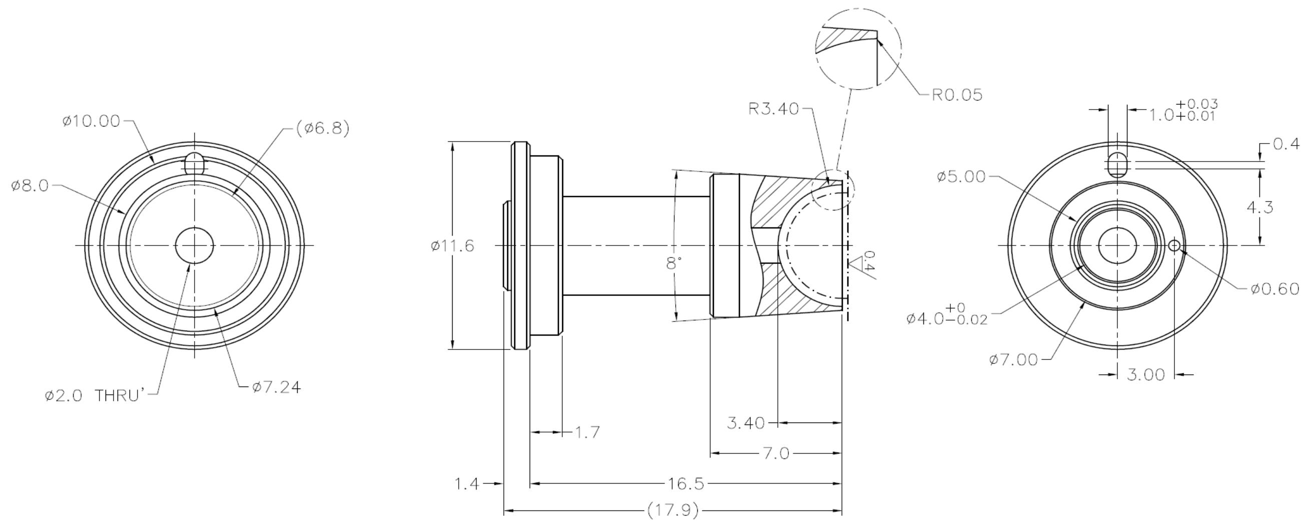

PICK AND MOUNT INFORMATION	
XY speed	1
Theta speed	1
Nozzle movement – pickup	1:
	Descend 1 stroke
	Ascend 1 stroke
Nozzle movement – mount	1:
	Descend 1 stroke
	Ascend 1 stroke
Pickup – height	0.6mm
Pickup – thickness	0.6mm
Pickup – depth	0mm
Pickup – height allowance	0mm
Pickup – height offset	-3.0mm
Mount height	1.0mm

VISION INFORMATION	
Camera	2D Large FOV
Upper L	0
Middle L	1
Lower L	3

Figure 13. Pick and place nozzle design and machine settings for Panasonic BM221. All dimensions in mm. Nozzle drawing courtesy of Micro-Mechanics Pte Ltd (drawing #: 19-MT-10053-01).

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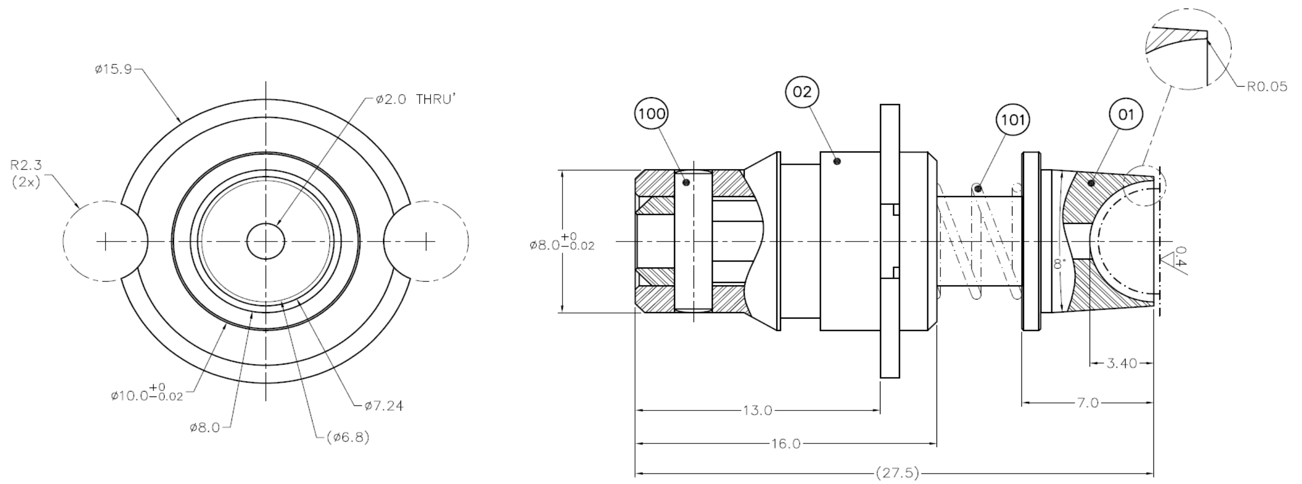

PICK AND MOUNT INFORMATION	
Placing stroke	1.0mm
Picking stroke	2.5mm
XY speed	Fast
Picking Z down	Fast
Picking Z up	Fast
Placing Z down	Fast
Placing Z up	Fast
Laser position	-0.11

Figure 14. Pick and place nozzle design and machine settings for Juki KE750. All dimensions in mm. Nozzle drawing courtesy of Micro-Mechanics Pte Ltd (drawing #: 19-MT-10043-01). A production pick and place machine will typically include a vision camera system to recognize the bottom pads of the package. However, the Juki KE750 pick and place machine used in this study is a dedicated test machine and did not include any vision camera system. Consequently, no detailed vision information is available for this machine.

5.4 Solder Reflow Profile

The LUXEON M emitter 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, 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. For detailed information on the recommended reflow profile, refer to the IPC/JEDEC J-STD-020C reflow profile in the LUXEON M datasheet.

5.5 Placement and Reflow Accuracy

In order to achieve the highest placement accuracy Lumileds recommends using an automated pick and place tool with a vision system that can recognize the bottom metallization of the LUXEON M emitter.

Global fiducials on a PCB panel can be used to calculate the reflow accuracy of the LUXEON M emitter with respect to its theoretical board position. Lumileds has determined that the typical placement accuracy of a LUXEON M emitter after reflow is well within 100µm in the x- and y-direction for the footprint in Figure 4.

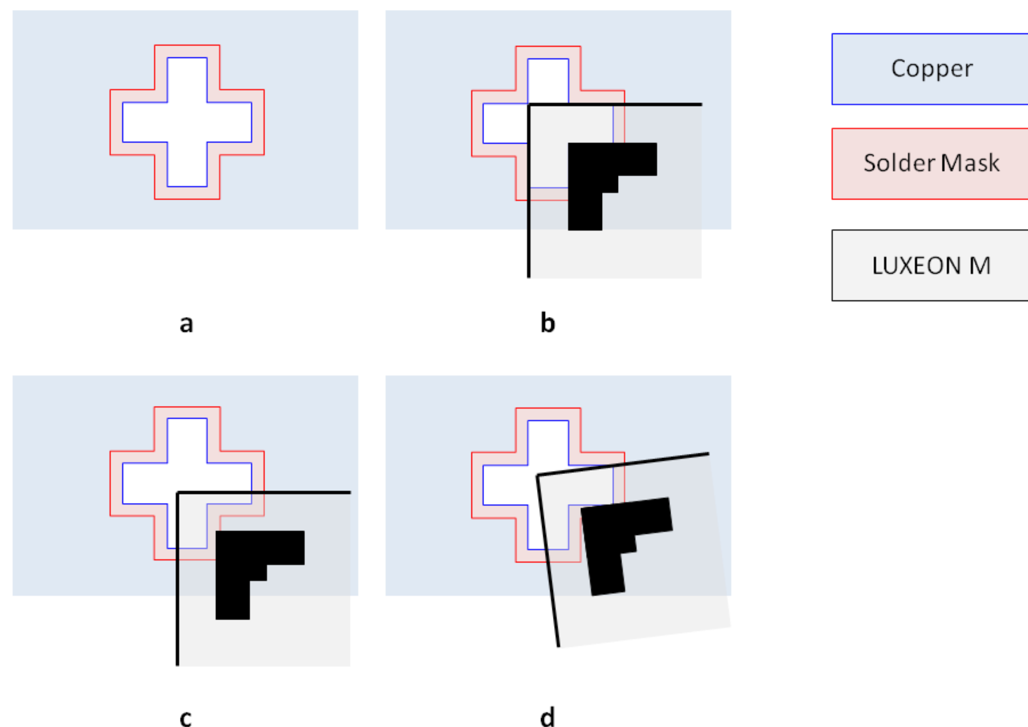

Figure 15. Alignment crosses on the PCB (a) help estimate the placement accuracy of the LUXEON M emitter on the PCB before and/or after reflow. The outer corner of the staircase style fiducials on the LUXEON M ceramic substrate align with the inner corner of the alignment crosses on the PCB for a properly placed LUXEON M emitter (b). Placement errors in x- and y-direction (c). Rotation errors in additions to placement errors in x- and y-direction (d).

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The PCB design in Figure 4 contains three alignment crosses, which correspond to the location of the three staircase style fiducials on the ceramic substrate of the LUXEON M emitter (see Figure 1). These alignment features enable visual verification of the proper orientation of the LUXEON M on the PCB. In addition, these features help approximate the placement accuracy of the LUXEON M before and/or after reflow, see Figure 15.

5.6 JEDEC Moisture Sensitivity Levels

LUXEON M emitters have a JEDEC moisture sensitivity level of 1. This is the highest level offered in the industry and highest level within the JEDEC standard. This ensures ease of use since the user no longer needs to be concerned about bake out times and floor life.

6. LUXEON Emitter Drivers

6.1 Introduction

LED is best driven with current source. This mode of operation provides the best control of the amount of current flowing through the LEDs at any operating temperature. A voltage source does not provide a predetermined current, may vary significantly and depends on the forward voltage and the operating temperature of the LEDs. However a voltage source can be assembled with few passive components such resistor, capacitor and bridge rectifier, assuming incoming AC power supply. Such configuration is cheap and compact but has poor power efficiency and poor current control. This section discusses LED current drivers via active controls (more common) incorporating transistors and linear ICs such as constant current regulators (CCRs).

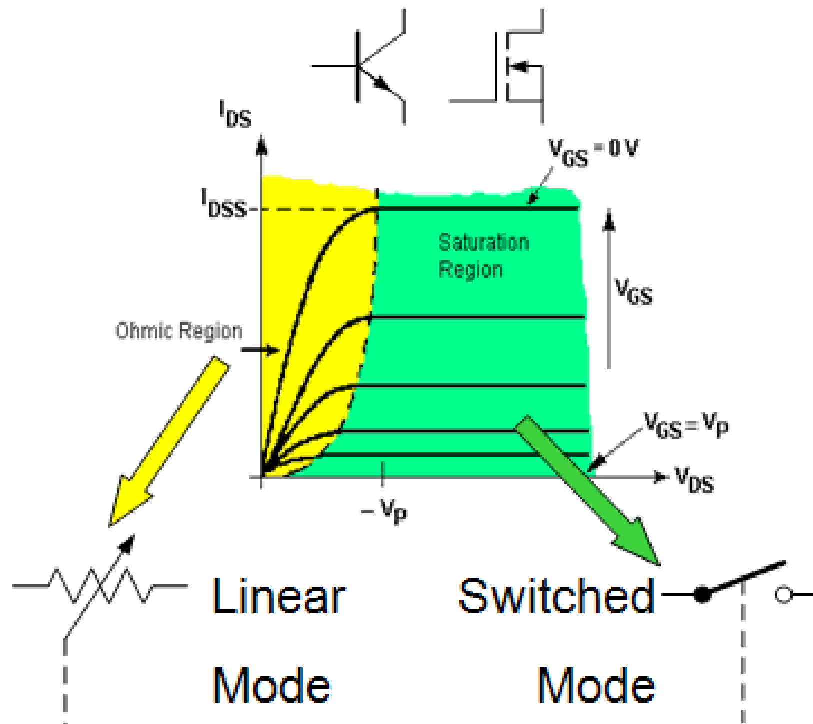

Figure 16. Typical transistor operation regions. Ohmic or linear region is shaded in yellow while the saturation or switching region is shaded green.

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6.2 Active Control LED Current Driver

There are two types of active control LED current drivers:

a. Linear regulated power supply

b. Switch mode power supply

The main difference is how the power supply is being regulated. In linear regulated power supply, the transistor connected to a load is used to control the output voltage or current. In order to do this, the transistor must operate in the ohmic or linear region as shown in Figure 16. Since there is current flowing through the transistor (operating in ohmic region), the transistor behaves like a variable resistor and generates heat.

In a switched mode power supply, as the name implies, the transistor is used as a switch to either switch in or out electrical storage elements such as inductor (current source) or capacitor (voltage source) to a load. In order to achieve this, the transistor must be operating in the saturation region as shown in Figure 16. In the "ON" or close switch, there is hardly any resistance through the transistor and hence does not generate any heat when a current flows through it. In "OFF" or open switch, no current is flowing through the transistor. This type of power supply has high power efficiency than the linear regulated power supply. However due to the switching of the circuit, it generates electromagnetic interference (EMI) which must be taken into account and minimized during the design stage. There are several switch mode power supply configurations such as buck, boost and buck-boost convertor.

A summary of the major differences between these two active control LED current drivers is given in Table 2 below.

Table 2. Comparison of a typical linear regulated versus switch mode power supply.

	LINEAR	SWITCH MODE
Cost	Cheap	Expensive
EMC	None	Potential
Circuitry	Simple	Complicated
Power Efficiency	Low (~50…~70%)	High (~75%… 95%)
Size & Weight	Big and heavy*	Small and light

*: if magnetics are used to step down the voltage before the regulator.

A typical example of an AC-DC LED system block circuit may consist of a bridge rectifier, transient circuit protection (e.g. varistor), dimming circuit (triac) and a control circuit (either passive or active control) with flicker-free, over-voltage protection, filters and/or feedback loop circuits. Figure 17 shows an example of a system block diagram of a typical LED driver circuit. Lumileds maintains a list of various linear IC driver manufacturers.Examples of various driver circuit designs are provided by each manufacturer. To access this information, go to Lumileds website at lumileds.com. Go to the "Support" tab and select "Design Tools." Click on the "Eco-system" and then the "Drivers" tab. Registration is required to access this list.

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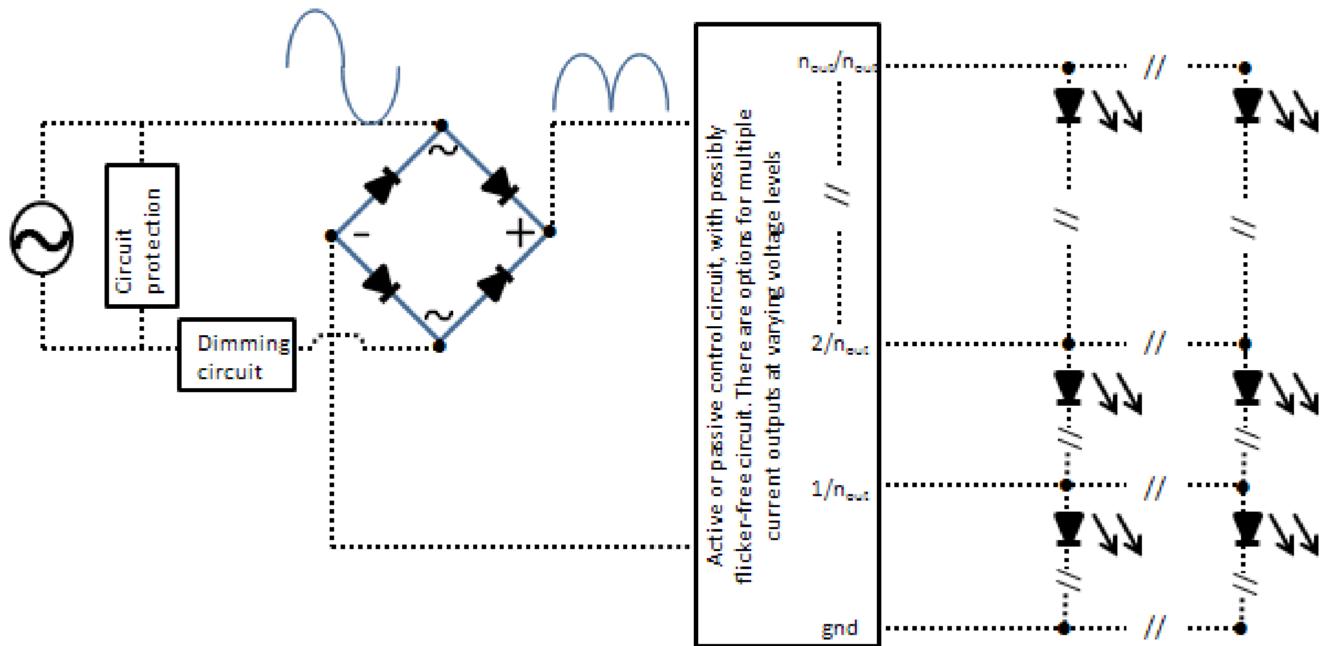

Figure 17. A typical system block diagram of one example of a LED driver circuit.

7. Packaging Considerations — Chemical Compatibility

The LUXEON M package contains a silicone overcoat and dome 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 in LUXEON M 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 M 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 dome. Under heat and "blue" light, the VOCs inside the dome 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 dome 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 3 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 3 are typically not directly used in the final products that are built around LUXEON M 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 heat sinks. 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 3. List of commonly used chemicals that will damage the silicone overcoat of LUXEON M. Avoid using any of these chemicals in the housing that contains the LED package.

CHEMICAL NAME	NORMALLY USED AS
Acetic acid	acid
Hydrochloric acid	acid
Nitric acid	acid
Sulfuric acid	acid
Ammonia	alkali
Potassium hydroxide	alkali
Sodium hydroxide	alkali
Acetone	solvent
Benzene	solvent
Dichloromethane	solvent
Gasoline	solvent
MEK (Methyl Ethly Ketone)	solvent
MIBK (Methyl Isobutyl Ketone)	solvent
Mineral spirits (turpentine)	solvent
Tetracholorometane	solvent
Toluene	solvent
Xylene	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
Cyanoacrylate (super glue)	adhesive

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For 100 years, Lumileds commitment to innovation has helped customers pioneer breakthrough products in the automotive, consumer and illumination markets.

Lumileds is shaping the future of light with our LEDs and automotive lamps, and helping our customers illuminate how people see the world around them.

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