

LED Application Guide

1st Edition



LED
APPLICATION
GUIDE

The cover image shows a modern, illuminated structure at night, possibly a transit station or a public space. The structure features a large LED display panel that displays the text "LED APPLICATION GUIDE" in a bright red, pixelated font. The background is filled with various lights and architectural details, creating a vibrant and futuristic atmosphere.

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1. Handling during pick and place process

During the automatic pick and place process, the influence of mechanical stress on the surface must be minimized as much as possible. LEDs with a silicone resin provide many advantages. Compared to other reflector areas of Surface Mount LEDs, silicone is generally softer. Due to this fact, the handling area of the nozzle should only contact the Plastic Leaded Chip Carrier (PLCC) surface directly and is not allowed to touch the silicone encapsulation of the component (see Figure 1, grey is disallowed area). Therefore the inner diameter of the nozzle (A) should be bigger or equal than the disallowed area (see Figure 2, nozzle diameters). It is recommended to use a nozzle for PLCC LEDs in size 3528 with an inner diameter of $A \geq 2.4$ mm. Affected match codes are WL-SMTW, WL-SBTW and WL-SFTW. For ceramic components in size 3535 it is recommended to use a nozzle with an inner diameter of $A \geq 3.2$ mm. There are no restrictions in regards of the shape of the nozzle, except that the mechanical pressure on the surface of the silicone must be avoided totally. In general, the nozzle must be larger than LEDs reflector. In cases of contact the LED might be damaged or in worst cases the LED will not light as usual and may affect reliability.

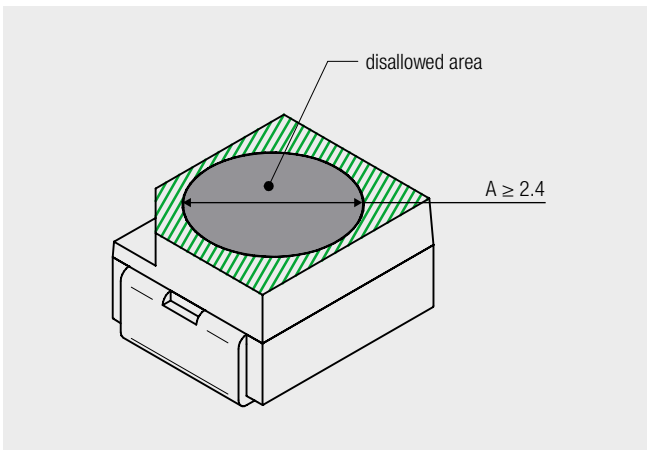


Figure 1: Allowed and disallowed area of LED

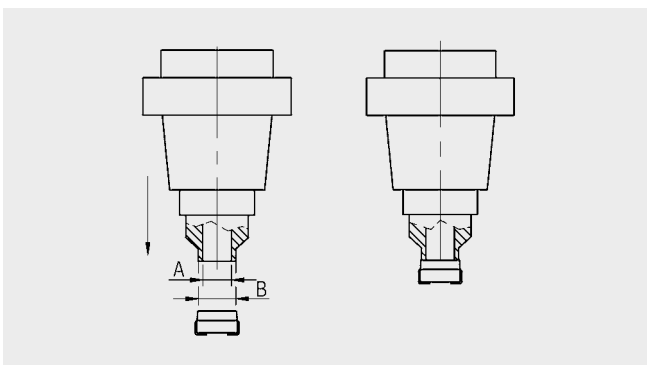


Figure 2: Recommended nozzle diameter

2. Handling Precautions for Silicone encapsulated LEDs

2.1. Handling tweezers

In general, the silicone encapsulation should not be pushed or punctured with sharp items like tweezers. Sharp items might damage and scratch the surface. The improper handling of the LED can damage the die and wire bond of the LED, which can cause premature LED failure. During assembly, the component should be held only on the body. Please check the below pictures for visual instructions. Affected match codes are WL-SBTW, WL-SFTW, WL-SMTW, WL-SWTC and WL-SWTP.

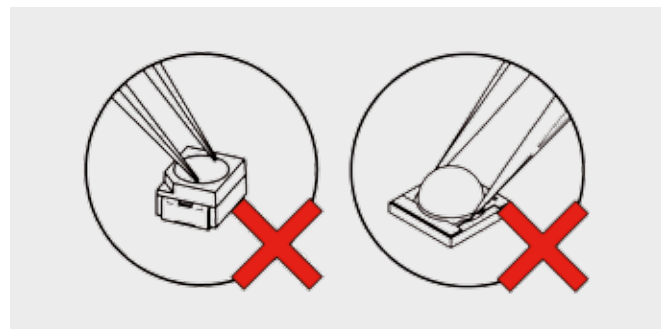


Figure 3: Handling Precaution 2.1 wrong

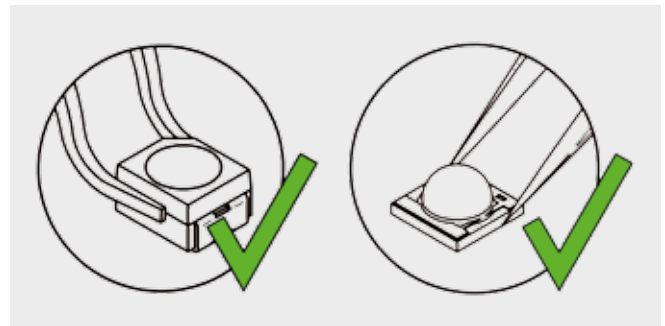


Figure 4: Handling Precaution 2.1 correct

2.2. Manual Handling

LEDs are ESD sensitive and should therefore be handled with an ESD conform tweezers. If handled, please wear anti-static wrist strap and finger gloves to avoid ESD stress and dust. Prevent touching the LED silicon resin at all times. LEDs should be handled and picked up gently and grabbed only from the side (package body). Incorrect handling on the silicone encapsulation cause mechanical stress on the die and wire bond of the LED. Affected match codes are WL-SBTW, WL-SFTW, WL-SMTW, WL-SWTC and WL-SWTP.

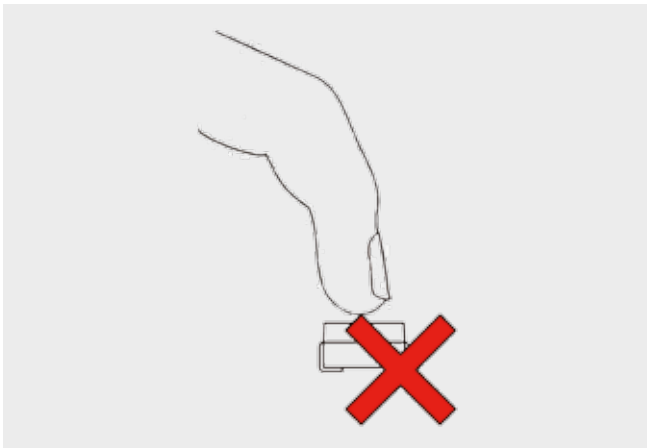


Figure 5: Handling Precaution 2.2

2.3. Storage PCB

By stacking the PCB boards, the silicone might be deformed or delaminated due to mechanical stress. In addition, the components on the bottom side may press on the silicone of the LEDs. Use a proper and suitable rack to keep the finished and assembled PCB boards correctly. For visual instructions please note Figure 6. In general this applies for all kind of LEDs of Würth Elektronik.

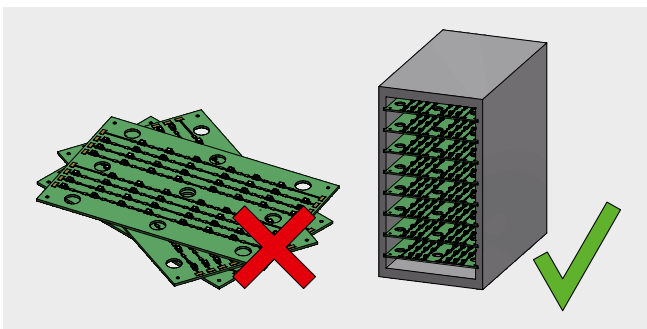


Figure 6: Storage PCB and suitable rack

3. Storage

3.1. Storage – Before opening the Moisture Barrier Bag

To ensure the components functionality they must be stored under sufficient ambient condition. Therefore, the components must be stored under ambient conditions which not exceed temperatures of $< 40\text{ °C}$ and 90% RH (Relative Humidity) and must be used within the calculated shelf life time of 12 months (see from bag seal date on the label). Before the packing process, the components are baked as finished products to remove any moisture which may be present inside the package. The Moisture Barrier Bag (MBB) shall be kept sealed until the contained LEDs in the

bag are prepared to be used. The MBB protects the devices from absorbing moisture during transportation and storage. A moisture barrier bag, Humidity Indicator Card (HIC) and desiccant (e.g. silica gel) is strongly recommended at all times while keeping the components under warehouse conditions as well as both are included in each MBB.

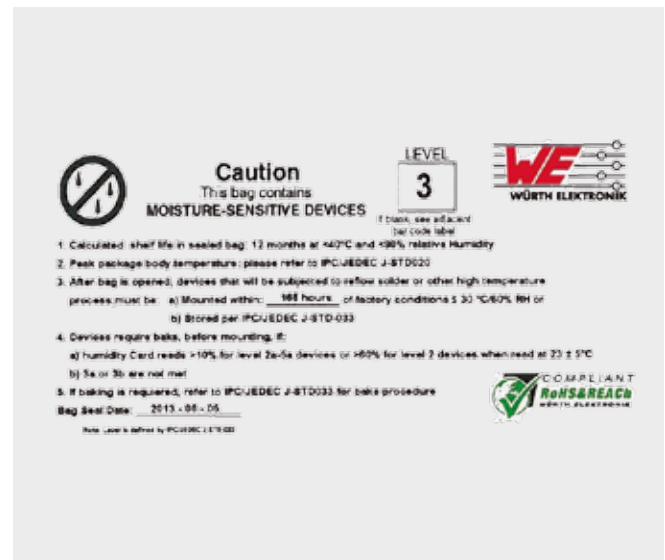


Figure 7: Moisture Sensitive Identification Label (MSID)

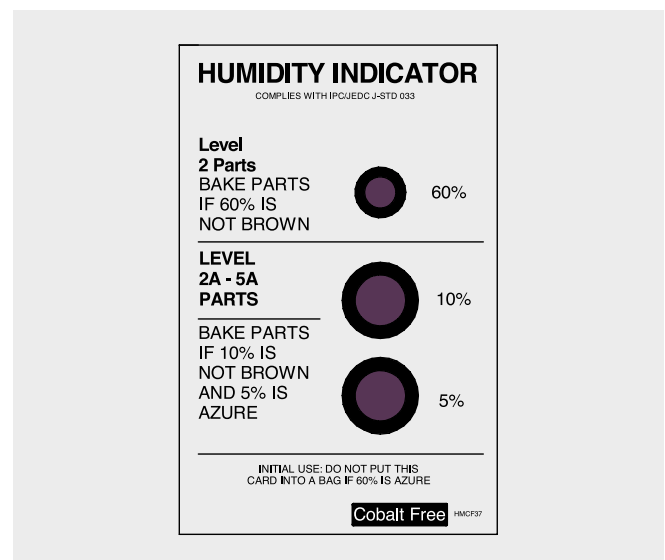


Figure 8: Example of Humidity Indicator Card (HIC)



Figure 9: Example of Desiccant

The humidity indicator card (HIC) with sensitive dots turns its color according to described color change on the HIC whenever the specific relative humidity is exceeded. The desiccant reduces the presence of moisture in the bag at no greater than 10% RH thus protecting the devices during shipment and storage.

After all necessary opening of the outside bag (e.g. IQC, prototyping, etc.), it is mandatory to use a new humidity indicator card and new desiccant before closing and seal the bag properly.

3.2. Storage – Inspection of the Moisture Barrier Bag

The bag should be inspected in kind of any damage to ensure the integrity of its content. Please check the bag while holes, tears, incorrect sealing or any other kind of mechanical damage might have a fatal influence to the components inside the bag.

Use a scissors to open the bag and cut across the alignment on the top of the bag. Be careful not to damage the content with sharp objects and reseal the MBB again afterwards.

3.3. Storage – After opening the Moisture Barrier Bag

The HIC shall be checked immediately after opening the MBB to determine if there is any humidity inside the MBB. If the humidity indicator card shows more than 10% RH and turned its color, the components must be rebaked (See chapter 3.5). LEDs should be kept under $\leq 30\text{ }^{\circ}\text{C}$ and $\leq 50\text{--}60\%$ RH (relative humidity depends on physical structure). The PCB and PLCC components should be soldered within 168 hours (Moisture Sensitive Level 3) after opening the moisture barrier bag, ceramic components

within 24 hours. The floor life is the cumulative time the components are used in any uncontrolled environment unless the components are rebaked. The floor life time has to be controlled strictly. Once the components are removed from the MBB, the total exposure time till mounting should not exceed the recommended floor life, which is specified on the Moisture Sensitive Identification Label (MSID) on the MBB. Please check below Moisture Classification Level and Floor Life table. The desiccant should be replaced after the bag is opened for more than 30 minutes.

Moisture Sensitivity Level	Floor Life (out of bag) at factory ambient $\leq 30\text{ }^{\circ}\text{C}/60\%$ RH or as stated Level
1	Unlimited at $\leq 30\text{ }^{\circ}\text{C}/85\%$ RH
2	1 year
2a	4 weeks
3	168 hours
4	72 hours
5	48 hours
5a	24 hours
6	Mandatory bake before use. After bake, must be reflowed within the time limit specified on the label.

Table 1: Moisture classification and floor life (extract from industrial standard J-STD-033C, Table 5-1, page 11)

LEDs are sensitive to any static electricity. The MBB is also sealed and is antistatic shielding material. Electrostatic sensitive device warning symbols are on the label and on the MBB cover.

Moisture-sensitive components are shipped under vacuum and in heat-sealed moisture barrier bags packed with a desiccant (e.g. silica gel) and a humidity indicator card. Both, the Würth Elektronik label as well as the Moisture Sensitive Identification Label (MSID) identify the sealing date of the bag and the Moisture Sensitivity Level with the cautions and warnings signs of the component. Both labels are either on the reel or MBB.

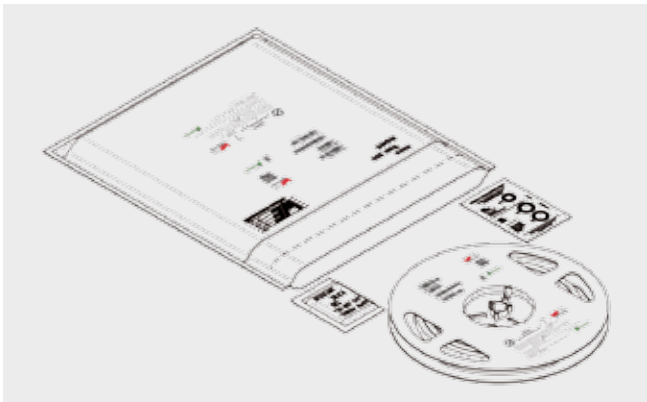


Figure 10: Example of Moisture Barrier Bag and contents (Illustrations may differ from the original)

3.4. Storage – Resealing

If any unused LEDs remain on reel after assembly or after rebaking process, they must be stored immediately in MBB or stored in a desiccator at $< 5\%$ RH. It is strictly recommended to return those LEDs into the original moisture barrier bag and seal the MBB by commercial heat- and vacuum equipment. If the original humidity indicator card sensitive dots changes the color, a new humidity indicator card and new desiccant (silica gel) must be added into the MBB. The floor life can be paused if stored like described in chapter 3.6.

If the mentioned floor life is expired and greater than specified on the label then the floor life time has to reset by rebaking process.

3.5. Storage – Rebaking process

Rebaking treatment has to be done if the humidity indicator card (HIC) 10% dot is not changed and the 5% dot is changed. This applies for MSL 2a–5a whenever a reflow method is used. If the HIC indicates a RH less than 10%, the components are ready for processing.

Rebaking is also necessary if the LEDs are exposed to conditions of $> 30\text{ °C}$ and $> 60\%$ RH at any time and also the floor life is exceeded more than the soak of the respective Moisture Sensitive Level.

For the affected match codes WL-SBTW, WL-SMCW, WL-SFTW, WL-SMRW, WL-SMSW and WL-SMTW, perform the rebaking process with the following conditions: $65\text{ °C} \pm 5\text{ °C}$ for 24 hours. For the affected match codes WL-SWTP, WL-SWTC and WL-SMDC, perform the rebaking process with the following conditions: $60\text{ °C} \pm 5\text{ °C}$ for 4 hours.

In any special case, please still do not exceed the maximum condition of $80 \pm 5\text{ °C}$ and 24 hours. Do not rebake the reels

staked over one another. It is strictly recommended to hang up the reels on a bar and keep distance between each reel of at least 1 cm. The reels should not touch the heated plate of the oven because of the melting danger of the reels. The Humidity control of the oven must be $\leq 5\%$ RH when rebaking the LED under recommended condition. Otherwise the dehumidification of the components will not occur.

After rebaking process is completed, the reel and the embossing tape (carrier tape and cover tape) may be lightly deformed and the taping material will obstruct the mounting process. Please be careful and do not stress the components.

The rebaking process is at one's own risk. Please note that Würth Elektronik eiSos GmbH will not guarantee its products under such condition. Refer to each respective datasheet for each LED components' storage condition before and after opening.

3.6. Flow Chart – Moisture Handling of SMD LEDs

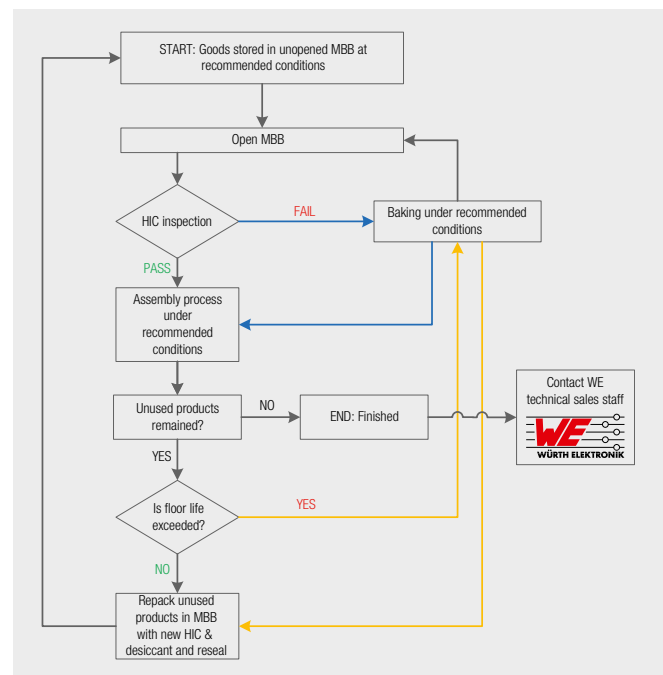


Figure 11: Flow Chart Moisture Handling of SMD LEDs

By opening the Moisture Barrier Bag (MBB) the floor life time starts. If partial unfinished components are remaining, store into MBB with desiccant and resealed it. The floor life clock is paused. After the rebaking process under recommended condition the floor life is reset.

Recommended total time frame (total floor life clock paused time) for the exposure components out of controlled conditions are:

- For WL-SMCW, WL-SMSW and WL-SMRW: FLC1+FLC1+FLC \leq 24 hours
- For WL-SMTW, WL-SBTW and WL-SFTW: FLC1+FLC1+FLC \leq 6 hours
- For WL-SWTC and WL-SWTP: FLC1+FLC1+FLC \leq 24 hours

4. Moisture Sensitivity

4.1. Moisture Sensitive Introduction

In general, surface mounted LEDs are susceptible to moisture absorption due to its hygroscopic encapsulation materials. LEDs absorb moisture from atmospheric surrounding humidity by diffusion and capillarity while being unprotected in the surrounding environment.

During soldering process, the rapid temperature rise may cause immediate moisture expansion, which leads into delamination between the die and plastic encapsulation and its result of open connections like broken wire bonds. Furthermore, failures like degradation of the optical characteristics caused by bubbles, cracks and crazings in the silicone till reliability failure or other serious damages may happen.

This phenomenon is also being known as popcorn effect. The moisture will vaporize which stress the internal package structure enormously and cause package cracking during the soldering process due to immediate volume expansion.

Referenced documents and standards of Moisture/Reflow Sensitive Surface Mount Devices for classification, handling, packing, shipping and use of Moisture/Reflow Sensitive are defined clearly in the industry standards IPC/JEDEC J-STD-020 and IPC/JEDEC J-STD-033B.

The MBB with the components should be only opened close to before production process. After the bag is opened, each component must be assembled and soldered within the specific time frame which given by Moisture Sensitivity Level. The time frame after opening the heat sealed MBB is known as floor life. The floor life is the amount of time in which the temperature related process is completed including rework process. Different LED package types are classified in different sensitivity levels to ingress of moisture and its effects. The table about the Moisture Sensitive Levels is shown and explained in the industry standard IPC/JEDEC J-STD-020.

5. Electrostatic Discharge – ESD

LEDs are highly sensitive against electrostatic discharge which requires a careful handling when removed from the antistatic shielding moisture barrier bag. The components are shipped in ESD protective packaging and should be stored in it until mounting process. Static electricity can affect the component's reliability, increase reverse current, decrease forward voltage and deteriorating optical characteristics. In worst case, it may cause severe damage to the LED and or premature failure.

One of the most common ESD issues is static electricity. Static electricity is often generated by triboelectric charging. It may occur while two surfaces in contact will be separated and one of it must be a non-conductor. To attract a static charge to release a discharge, it must expose with a conductive surface (for e.g. metallic materials or human skin). ESD is the rapid and instantaneous discharge of two differently-charged objects with an energy sparkover.

LED components with an InGaN die are susceptible to damage and are highly sensitive against surge voltage and require special handling. Refer to each respective datasheet for its individual ESD classification. A dry environment is more likely to cause static electricity and also non-conductive surfaces. Conductive surfaces and wave soldering does not cause electrostatic discharge.

Suggestion to prevent ESD damage to ESD sensitive LED components are:

- Avoid touching by hands and usage of common plastic containers, transport mediums or tools
- Avoid friction to minimize static charges between product, surrounding and environment (for e.g. synthetic materials or non-conductive materials)
- Work in an ESD protective area, place conductive mattress (grounding resistance $< 1 \times 10^{11} \Omega$) if necessary and use an air ionizer to avoid any static electricity
- Use anti-static packaging for protection during storage and transportation
- All devices, equipment and machinery must be properly electrically grounded (grounding resistance $1 \text{ M} \Omega$, which is described in industry standard IPC-A-610)
- For manual handling use conductive wrist strap, anti-electrostatic clothes and equipment that are covered with ESD protective pads. Make sure the wrist strap is used according to its manual
- Use an air ionizer to remove all possible static charge

- Maintain a humidity level of $\geq 50\%$ RH or higher in production areas to prevent the static electricity generated due to dry air
- Only trained personnel staff should be allowed to handle these components during manufacturing process

An easy “rule of thumb” where ESD controls have to occur is: Machine, Material, Method, Employee and Environment.

The electrostatic sensitive devices warning labels are on the label of the reel and MBB.

6. Recommended Reflow Soldering Process

The recommended reflow soldering profile is shown in the specific datasheet. Please check the appropriate datasheet for the recommended land pattern and do not repeat the heating process more than 2 times with the recommended profile. The components should be placed within 72 hours at factory conditions if floor life is not lower specified.

Avoid any mechanical stress after soldering which may cause damage to the LED component, especially stacking of the boards and do not also warp the Printed Circuit Board (PCB). Also avoid mechanical pressure which could influence solder performance. It may occur to dislocate the components until the solder paste is hardened. The silicone resin of the LEDs is not stable immediately after soldering process. After reflow process it is mandatory to apply a complete cool down phase to room temperature (23 °C). It is recommended to use lead-free solder paste at all times.

SMD components are only compatible with reflow soldering and THT components are only compatible with wave soldering. Please contact our technical sales staff if the LED will face other soldering processes as recommended. Recommended condition for soldering is soldering land pattern temperature $>$ package temperature.

7. Design Considerations

7.1. For SMD

Each recommended land pattern design of the LED can be found in the associated data sheet or LED catalogue of Würth Elektronik.

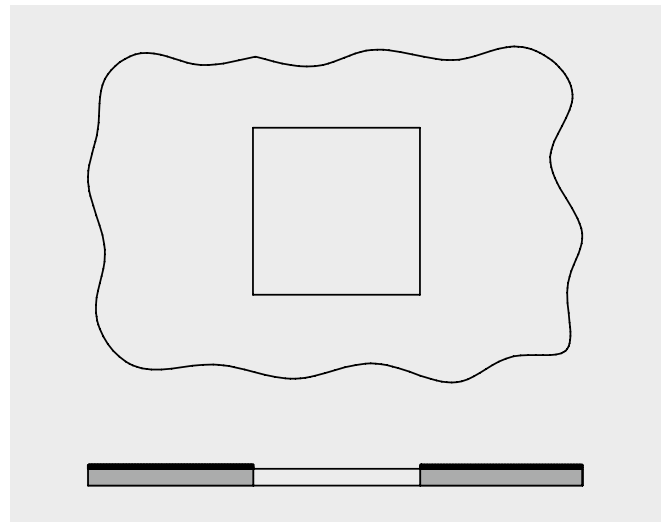


Figure 12: Recommended solder mask

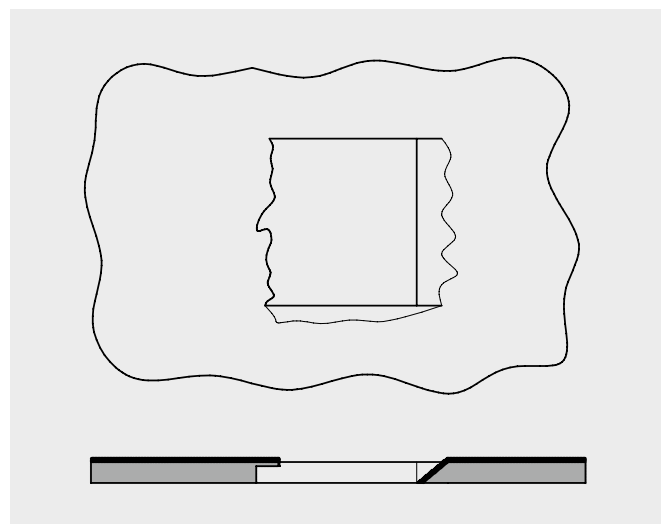


Figure 13: Insufficient solder mask

To ensure proper solderability and correct positioning of the component, the solder paste must be evenly plotted to each recommended land pattern (see Figure 12).

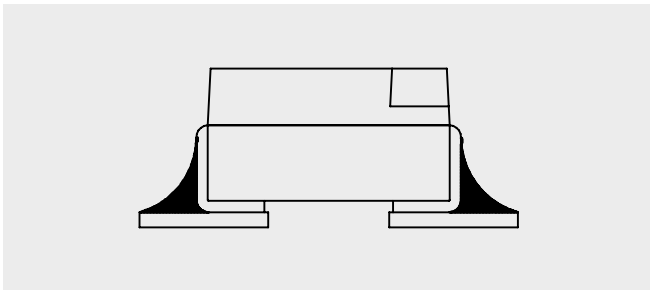


Figure 14: Correct self-centered

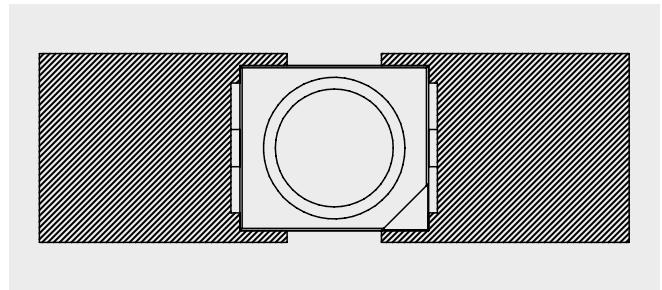


Figure 18: Land pattern too long

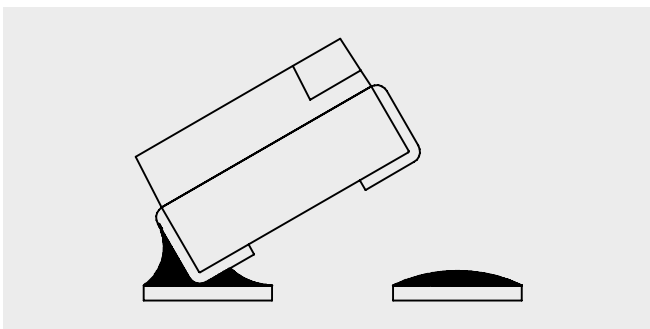


Figure 15: Tombstone effect

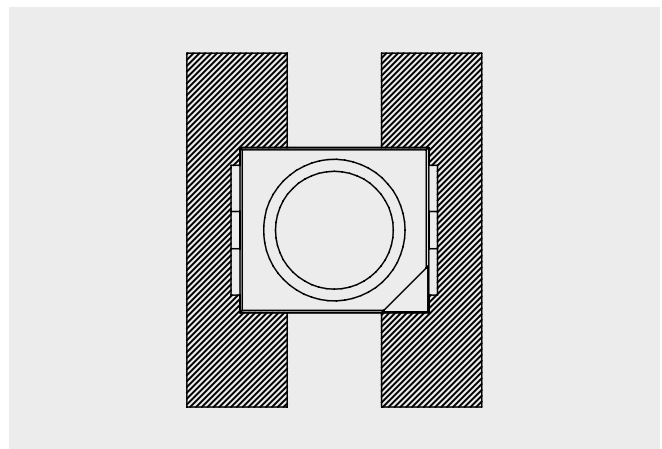


Figure 19: Land pattern too wide

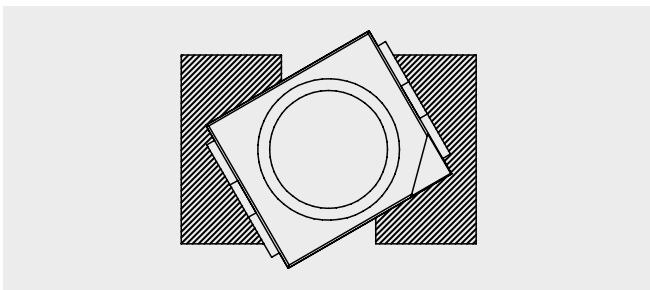


Figure 16: Skewed component

To prevent crocodile or tombstone effect or other effects of soldering, take care about correct positioning of the component. Avoid also vibration or any other impact of the mounted board after the components were mounted on the substrate before soldering process.

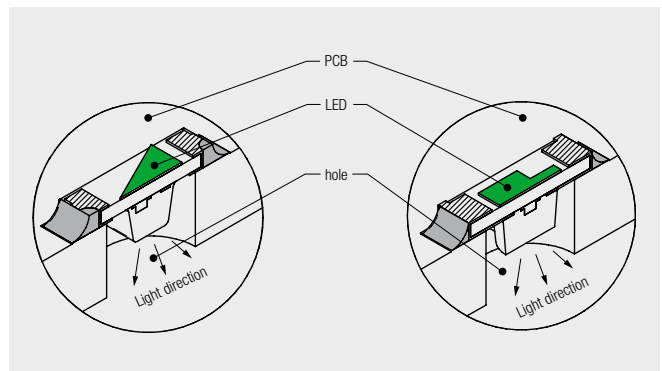


Figure 20: Recommended design – Reverse mount LEDs (rectangular & cylindrical)

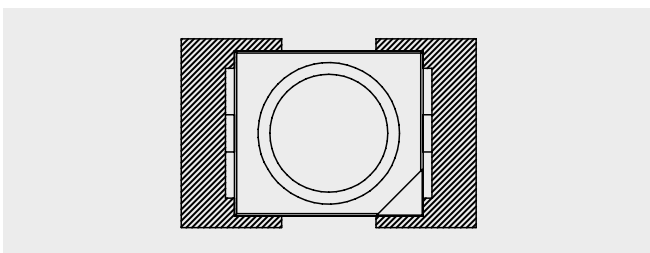


Figure 17: Recommended land pattern

To ensure the recommended size of the hole in the PCB please check the respective datasheet. Figure 20 is for illustration.

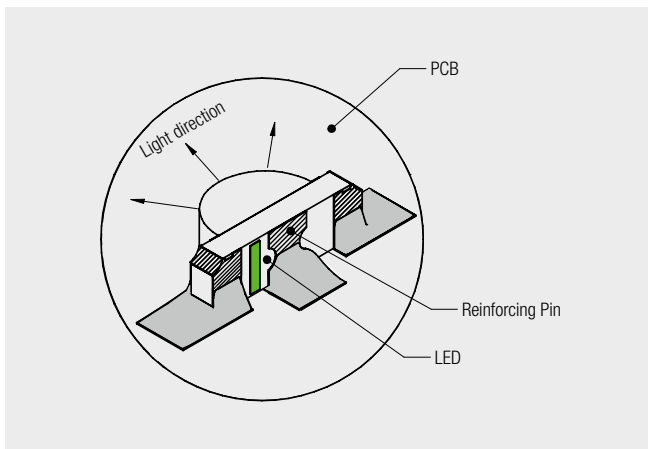


Figure 21: Recommended design – Side view

The reinforcing pin has no electrical connection or function, only for improvement of the stationary strength of the component.

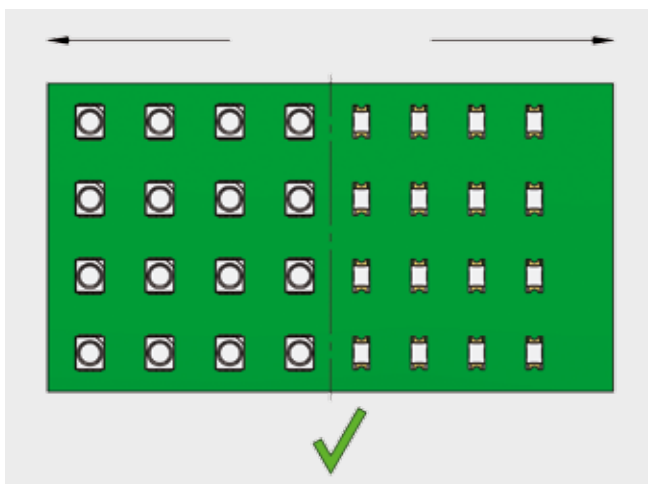


Figure 22: Correct curve direction

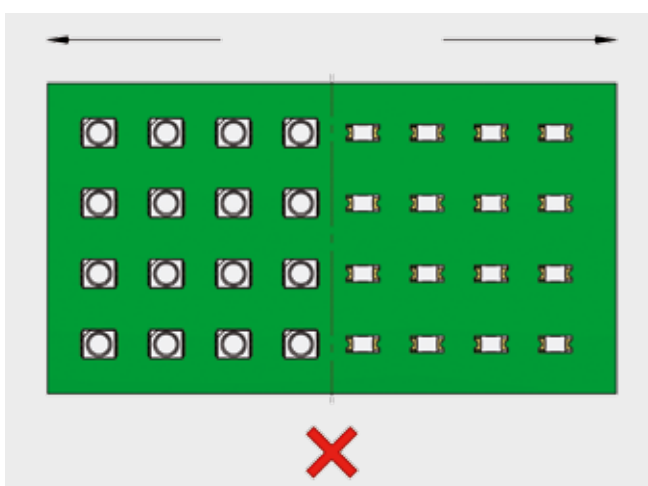


Figure 23: Not correct curve direction

To archive optimal results during soldering process of SMT components, make sure that the leads are aligned perpendicular to the direction of the PCB to ensure the solder paste on each lead melts simultaneously.

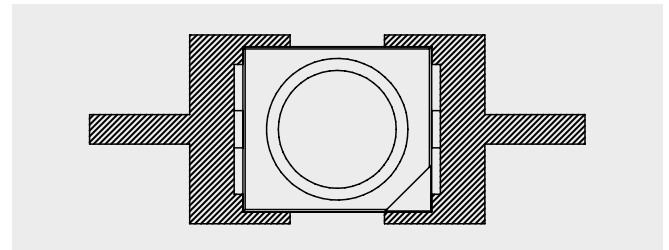


Figure 24: Recommended design

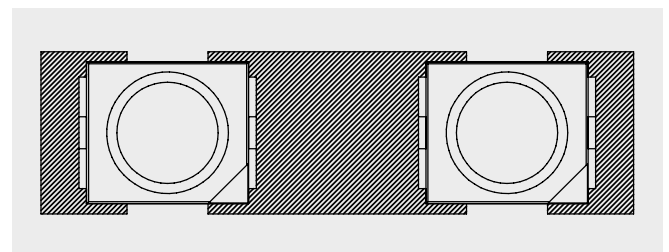


Figure 25: Insufficient design

Optimal usage of LED components requires careful design to guarantee function. For high-power LEDs, take account of optimizing the heat dissipation. High temperatures reduces performance and reliability. The operating current must be chosen by considering the maximum ambient temperature of the environment. Also to stress the components over the absolute maximum rating will damage the LED. Please check each respective datasheet.

7.2. For THT

Forming the lead to ensure alignment between the leads and the hole on board, so that stress against the LED is prevented (Figure 26). Bending or lead forming must be done before soldering.

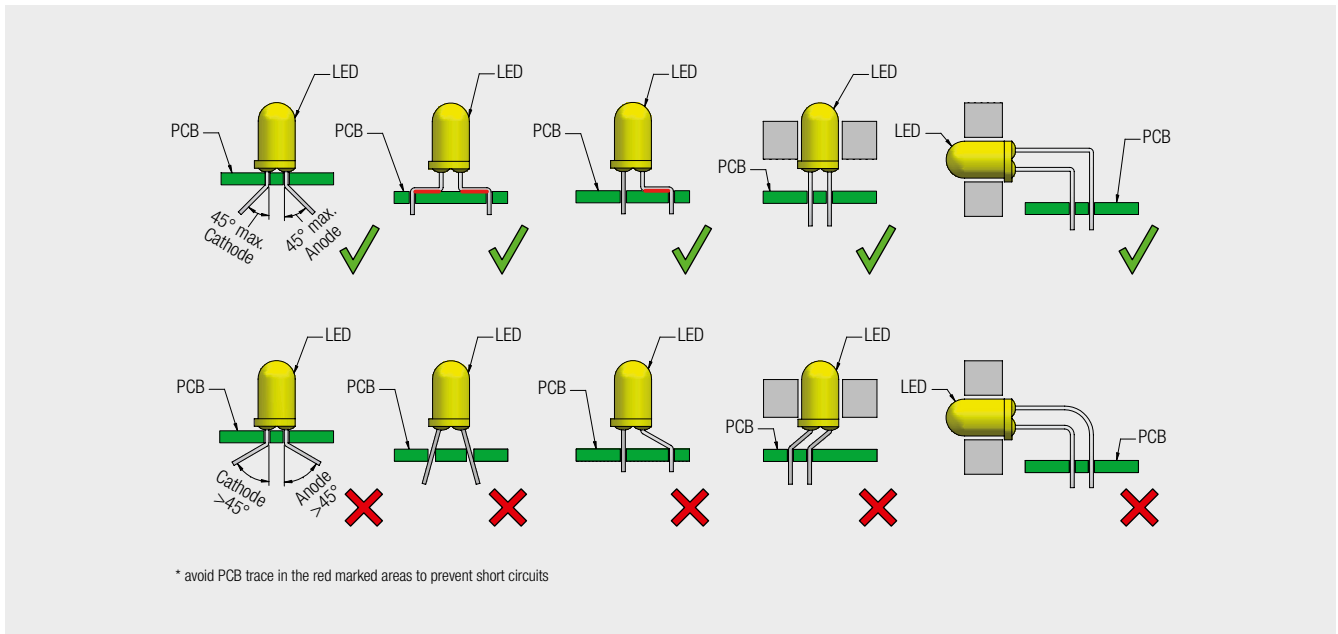


Figure 26: LED forming

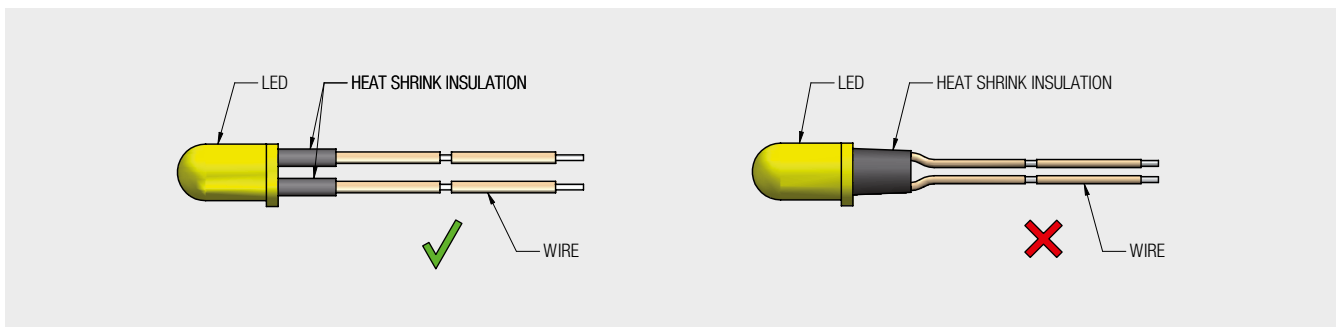


Figure 27: LED with stand-off or spacer

Heat-shrink tubing must be used to insulate the leads when soldering wire to the LED to prevent accidental contact short circuit (Figure 27).

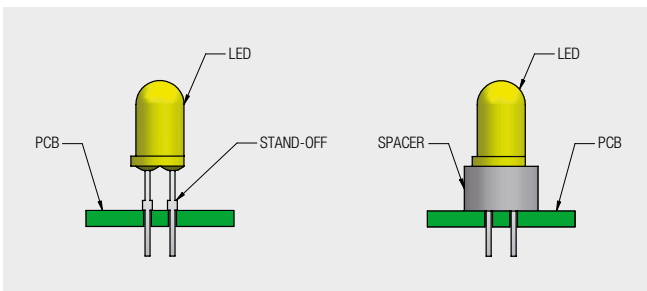


Figure 28: LED with stand-off or spacer

Use LEDs with stand-off or spacer (Figure 28) to position the LEDs.

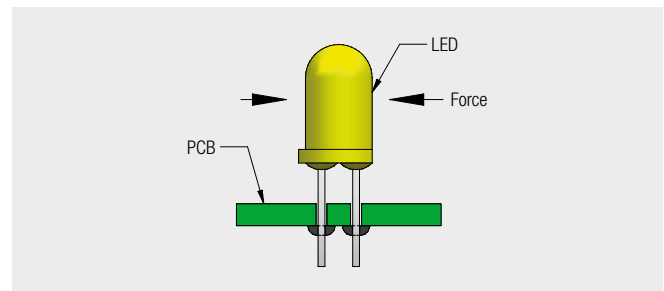


Figure 30: LED after soldering

Do not apply any force to the LED immediately after soldering. Let it cool down to 50 °C. The LED must be protected from any excessive force in general (Figure 30).

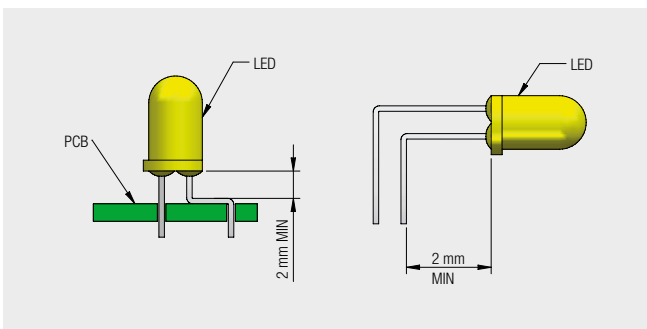


Figure 29: Minimum distance LED

Ensure that there is a minimum of 2 mm clearance distance between the lead bend and the LED lens (Figure 29).

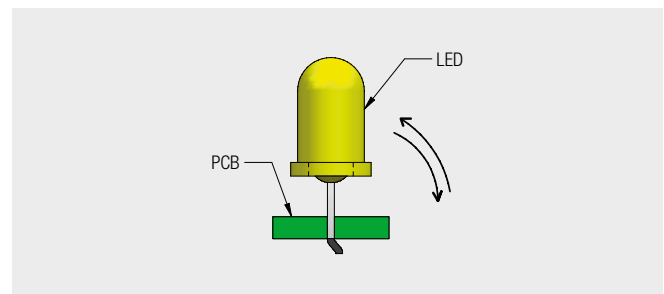


Figure 31: Bending of LED

Do not bend the leads more than twice (Figure 31).

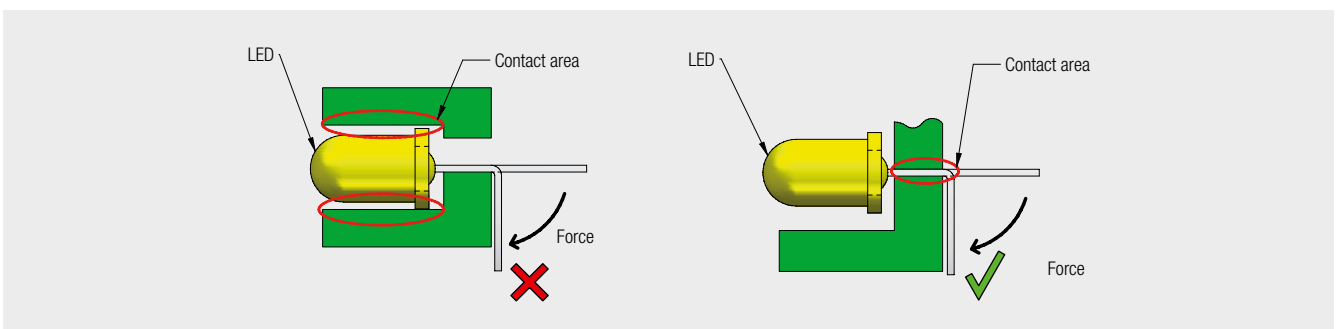


Figure 32: Stressing of LED

Avoid stress on the LED lens during the bending process (Figure 9) but use the upper lead part instead (Figure 32).

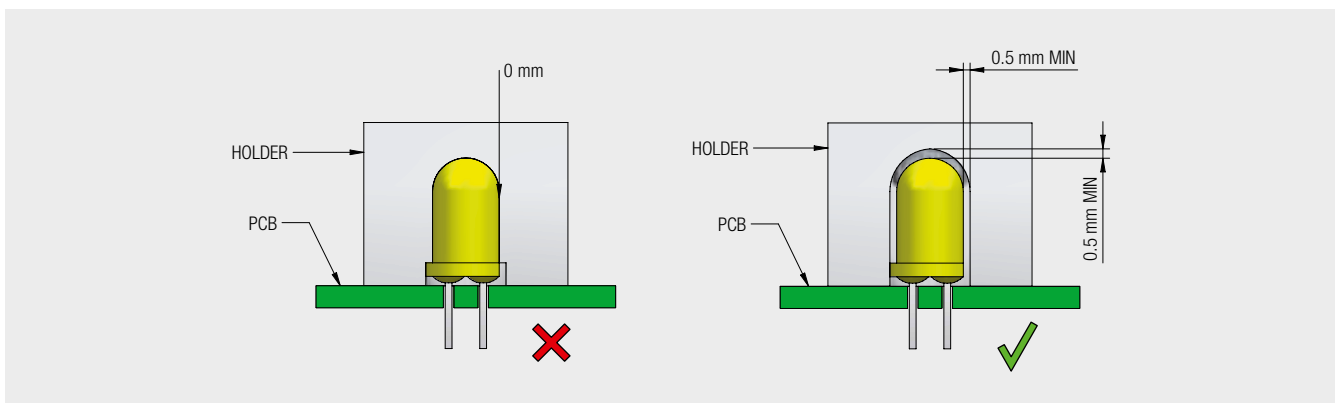


Figure 33: After soldering

Do not stress the LED during soldering to avoid damage (Figure 33).

8. Hand Soldering/Rework

Manual soldering process is only allowed in case of repair and rework purposes. During iron solder process the operator must wear a wrist strap. Usually ESD damages occur when proper handling is not in place. The grounded temperature controlled soldering iron should be always used.

General recommendation for correct soldering:

- If repairing is unavoidable, double head soldering iron must be used
- The soldering iron temperature must be less than $< 320\text{ °C} \pm 5\text{ °C}$ and do not contact the soldering iron on the component more than 3 seconds within once
- Use appropriate amount of solder paste on the designed land pattern to prevent incorrect connection and mounting position as well as flux residues
- Do not break, cut or pulverize the LED component
- Do not stress the LED during heating otherwise the reliability will highly influenced
- Do not warp the PCB after soldering
- Do not touch the component especially the lens of the LED with the soldering iron
- After soldering process, please make sure that the component can cool down minimum 3 minutes to room temperature before further operations
- All repairs must be done at one time
- Avoid solder balls which may short anode, cathode or thermal pad
- Do not hand solder ceramic components (match code WL-SWTC and WL-SMDC)
- Do not reuse an unsoldered component

- If after hand soldering and rework process a cleaning process is necessary, please go to chapter “Cleaning” to ensure functionality of the components afterwards.

9. Environmental Influences

If components are contaminated with corrosive gas or influenced by erosion it might cause any major problems on its solderability, as well as changes of its optical characteristics and other individual functions. The component should not be used directly in any type of fluid such as water, oil, organic solvents or etc., and must be stored in a clean environment.

10. Thermal Management

Introduction

Many times LED fails due to its operation at high junction temperature in overtime. High temperature is caused by electrical currents which dissipates power in the form of heat in all semiconductor devices. Even if good design practices and reliable components are in place, system reliability can take a hit if proper thermal management is not ensured. According to Arrhenius Model each 10 °C rise in the system, failure rate increases by 50 % and vice-versa although at certain junction temperature the LED can be destroyed irreversibly. The goal of thermal management system is to control the temperature of LED which can be done by transferring heat from high temperature region to low temperature region, also called heat transfer.

Heat Transfer

In general there are three types of heat transfer: *conduction*, *convection* and *radiation*. Conduction is the collisional transfer of energy between atoms in which heat transfers through direct contact of particles of matter. Convection is the motion of molecules in air or fluids i.e., transfer of thermal energy from one material to the other. Radiation is the transfer of heat energy through space in the form of electromagnetic waves. In practical LED applications heat transfer through radiation technique is not usually employed. Convection is the type of heat transfer usually employed in cooling semiconductor based systems. Mediums used in this type heat transfer are heat sinks, thermal interface materials and thermoelectric modules.

metal fins for effective heat flow and often thermal paste or tape is placed between heat sink and LED package to avoid any air bubbles and at the same time to ensure good thermal coupling and heat flow. Combined with right surface area, the metals high thermal conductivity transfers the heat from the semiconductor to the heat sink which will be cooled by the surrounding air. The heat sinks ability to transfer heat also depends on its material, geometry, and overall surface heat transfer coefficient. Typically aluminum is used due to its relatively low cost, lighter and easy to shape in different geometries compared to copper. The heat flow from LED to heat is one dimensional as shown in Figure 34.

Heat Sink

The most common thermal management device for an LED system is the heat sink, unless the size is the limiting factor for each particular application. In most cases heat sinks for LEDs have

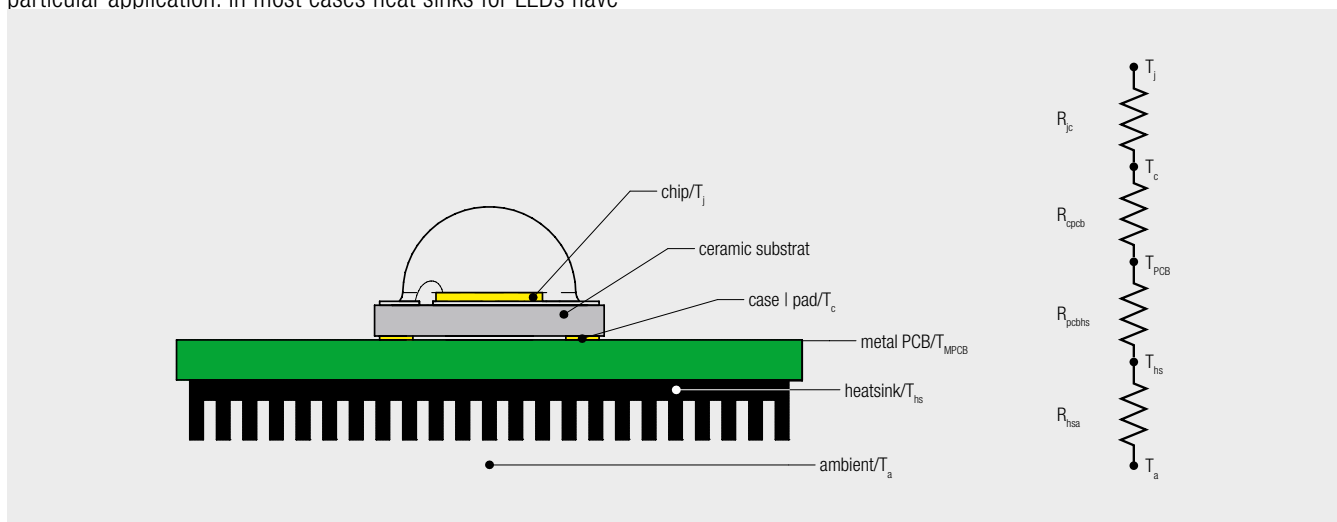


Figure 34: Thermal resistance for one dimensional heat flow till heat sink

Thermal Resistance

Heat passes from the LED case to the heat sink before it's emitted into the air. Thus, the heat sink increases the effective heat dissipation area and removes heat from the LED, permitting it to operate at higher power levels. Thereby, the heat sink provides a low thermal resistance path from the semiconductors case to the ambient air. A key parameter when using a heat sink concerns the thermal resistance of the associated LED package. Thermal resistance is analogous to the electrical resistance, just like current, thermal energy takes path of least resistance. Hence, the heat sink's thermal resistance is a key parameter which refers to its ability to conduct heat away into the surrounding environment.

Mathematically, thermal resistance is the rise in the LED p-n junction temperature above the case temperature per unit of power dissipated in the device as shown in below equations.

$$R_{jc} = \frac{(T_j - T_c)}{P_{Diss}} \quad \text{Formula 1}$$

$$R_{ja} = \frac{(T_j - T_a)}{P_{Diss}} \quad \text{Formula 2}$$

Explanations:

- R_{jc} is the thermal resistance from junction to case in °C/W
- R_{ja} is the thermal resistance from junction to ambient in °C/W
- T_j is the Junction temperature of LED package in °C
- T_a is the ambient air temperature in °C
- T_c is the LED case temperature in °C
- P_{Diss} is the power dissipation in the LED package.

Power dissipation in the LED package simply is $V_F * I_F$. In practice the entire power is not converted in to heat as the part of the energy is emitted in the form of photons

V_F is the forward voltage applied to the LED Package

I_F is the forward current of a LED

The main goal of this topic is to estimate the thermal resistance of the system and junction temperature of LED package. The thermal model of an LED system is put in the simplified form as shown in Figure 35.

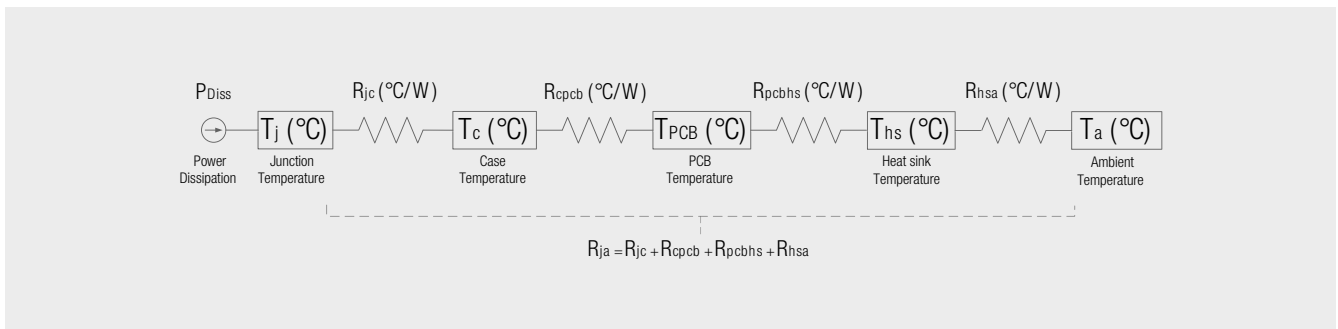


Figure 35: Thermal model of a single LED system

Explanations:

- T_h is the heat sink temperature in °C
- T_{pcb} is the FR4 PCB temperature in °C
- R_{cpcb} is the thermal resistance from LED case to PCB in °C/W
- R_{pcbhs} is the thermal resistance from PCB to heat sink in °C/W
- R_{hsa} is the thermal resistance from heat sink to ambient air temperature in °C/W
- R_{ch} is the thermal resistance from case to heat sink in °C/W.

From the above model thermal resistance from LED junction to ambient air temperature can be solved as:

$$R_{ja} = R_{jc} + R_{cpcb} + R_{(pcbhs)} + R_{(hsa)} \quad \text{Formula 3}$$

From equation 3, Junction temperature is calculated as:

$$T_j = (R_{ja} * P_{Diss}) + T_a \quad \text{Formula 4}$$

Using multiple LEDs on same heat sink is similar to resistors connected in parallel.

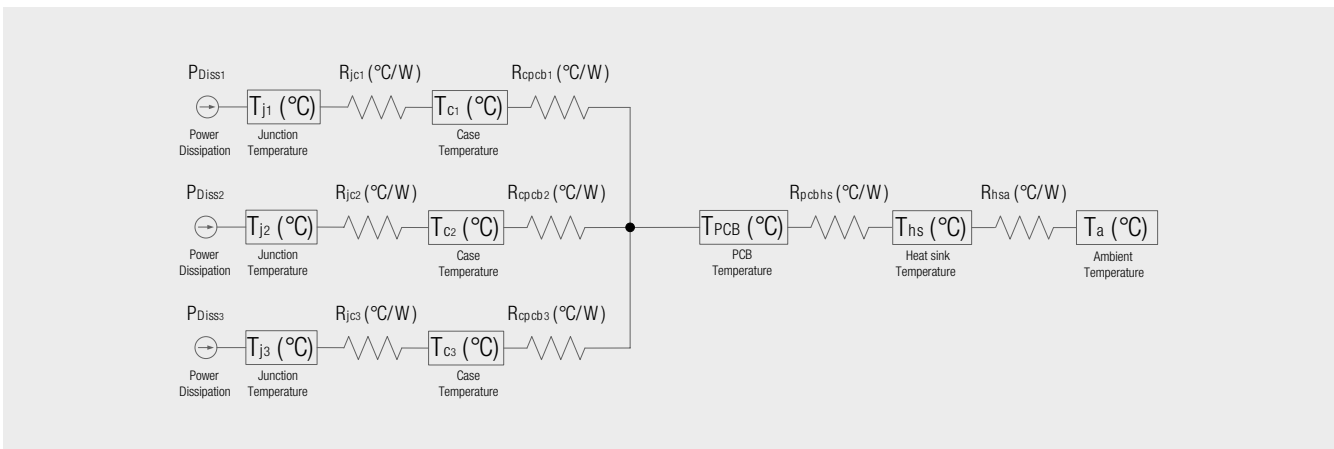


Figure 36: Thermal model of a multi LEDs system

The R_{ja} will be written as:

$$R_{ja}(\text{total}) = \frac{R_{jc} + R_{cpcb}}{n} + R_{pcbhs} + R_{hsa} \quad \text{Formula 5}$$

n is number of LEDs. When designing the heat sink for LED the thermal resistance of heat R_{hsa} must be less than $R_{ja} - ((R_{jc} + R_{chsr}))$ to ensure proper heat flow from LED package to the heat sink.

Since the heat flow is one dimensional, the thermal resistance R_{th} of any material is given by:

$$R_{th} = \frac{d}{\lambda \cdot A} \quad \text{Formula 6}$$

Where d is the material thickness in mm, λ is the thermal conductivity of the material in W/mK and A is the conducting area in cm^2 .

From equation 6, Thermal resistance can be varied by factors like surface area. Thickness and thermal conductivity coefficient, based on the design concerns one should choose the heat sink by considering the above factors.

In addition, Harry Lythall found empirically a “rule of thumb” calculation formula for R_{hsa} of homemade U-shape folded aluminum sheet. Based on his equation, the required surface area in cm^2 is $A = (50/R_{hs-a})^2$.

In general, the main optimization criteria are to maximize the exposed heat exchanger’s surface area, and to minimize its weight and the mean distance of the exposed surface from the component to be cooled.

Example:

Calculation of the junction temperature by assuming the operation of an LED system using Würth Elektronik’s *WL-SWTC SMD (p/n 158353030)* white ceramic LED which is dissipating P_{Diss} 2.52 W at 700 mA (see datasheet) on metal-PCB with $JS/R_{jc} = 8$ $^{\circ}\text{C}/\text{W}$.

Assuming maximum PCB temperature $T_{pcb} = 80$ $^{\circ}\text{C}$, which will be close to the maximum case temperature of T_c . If WL-SWTC SMD white is mounted on 1.57 mm thickness PCB with area of 250 mm^2 , according to the equation 6, thermal resistance R_{pcbhs} of the metal-PCB is 2.98 $^{\circ}\text{C}/\text{W}$.

From above equations we can write:

$$R_{pcbhs} = \frac{(T_{pcb} - T_{hs})}{P_{Diss}} \quad \text{Formula 7}$$

Consequent:

$$T_{hs} = T_{pcb} - (R_{pcbhs} \cdot P_{Diss}) \quad \text{Formula 8}$$

Plugging in above values gives us the heat sink temperature T_{hs} as 72.49 $^{\circ}\text{C}$ and thermal resistance from heat sink to ambient temperature R_{hsa} is 8.92 $^{\circ}\text{C}/\text{W}$ since smaller heat source size is considered. In this case, the limiting factor is the PCB dielectric. If we consider multiple LEDs with larger heat sink area the thermal resistance for heat sink will be less.

From equations 3 we calculation of the Junction Temperature R_{ja} :

$$R_{ja} = R_{jc} + R_{pcbhs} + R_{hsa} \quad \text{Formula 9}$$

R_{pcb} is ignored as the temperature difference between LED case and PCB is negligible. Hence R_{ja} is 19.92 °C/W.

From equation 4, the Junction temperature is calculated as $T_j = (19.92 \text{ °C/W} * 2.52 \text{ W}) + 50 \text{ °C} = 100.2 \text{ °C}$.

The LED junction temperature is well below the maximum temperature which is 125 °C despite operating at maximum power. To achieve low junctions temperatures at desired operations, thermal resistance of heat sink is a key factor which can also be improved by adding thermal paste for better coupling.

11. Cleaning

Generally during handling and use, keep the environment clean. If it is necessary to clean the LEDs, the use of Ethyl alcohol and Isopropyl alcohol are suitable to remove dust particles or slightly dirt from the lens. Use a lint-free swab to clean if necessary. Do not use other harsh solvents because of environmental concerns and the possible negative impact on the LED package as acetone, thinner, trichloroethylene and others.

The total cleaning process should not exceed the duration of 1 minute, in an unpowered state and take place at room temperature. Do not apply pressure onto the surface of the component. Normally a small amount of particles of the LED can be unattended because the small amount of particles does not affect the optical characteristics. Contact with oxides or nitrides are also strictly not allowed. Dry cleaning of silicone encapsulated LEDs is not recommended because the slightly sticky surface of the silicone is more likely to attract dust and dirt. Also ultrasonic cleaning is not recommended for encapsulated LED. Do not dissolve LEDs in chemical solvents.

If other cleaning solutions are used, their appropriateness must be tested beforehand. Please contact our technical sales staff in case of any information which is not listed.

12. Photobiological Safety of LED Light Sources

Photobiological Hazard according to EN 62471: 2008 (CIE S009) reflects the state of the incoherent light source nowadays and is recommended for immediate use.

The standard sets out requirements in terms of limiting values, methods of measurement and classification criteria. The classification of luminaires is based on hazard values reported at a distance which produces 500 lux illuminance, but not at a distance less than 200 mm.

For the photo-biological parameters (e.g. risk of photochemical retinal damage) of each risk group, wavelength-weighted emission limits have been defined as a basis for classification. The individual risk groups are defined as follows:

- Exempt group: Luminaires present no photo-biological hazard
- Risk group 1 (Low-Risk): Luminaires present no hazard due to normal behavioral limitations on exposure
- Risk group 2 (Moderate-Risk): Luminaires present no hazard due to the aversion response to very bright light sources or due to thermal discomfort
- Risk group 3 (High-Risk): Luminaires present a hazard even for momentary or brief exposure. Use in general lighting service is not allowed

LED light sources for general lighting are not normally IR or UV radiators, so the table in each specific LED catalogue confined to hazards that may actually be presented – does not include infrared and ultraviolet hazards.

Avoid looking directly at the LED when it is operating, as it may damage the retina of the eyes. Please check our LED catalogues for further details. If you need further information or documents please contact our technical sales staff.

13. Restrictions/Notes

These recommendations and processing indications should prevent our customers of wrong handling and damages hence premature failure of the LED. Special precautions and treatment should be adhered during assembly of silicone encapsulated LED products. Würth Elektronik eiSos GmbH makes continuous efforts to improve the quality of its products. Nevertheless semiconductor components can fail due to their inherent electrical sensitivity and vulnerable to physical stress. Ensure that the components are used within specified operating values. Do not dissolve LEDs in chemical solvents. Appearance and specification of the products may be modified for improvement without further notice.

For the large product portfolio, please refer to mentioned LED catalogue or visit on our website www.we-online.de.

The Application Note is based on our knowledge and experience of typical requirements concerning the areas, serves as general guidance and should not be construed as a commitment for the suitability for customer applications by Würth Elektronik eiSos GmbH & Co. KG. This document and parts thereof must not be reproduced or copied without written permission, and contents thereof must not be imparted to a third party nor be used for any unauthorized purpose. The information in the Application note is subject to change without notice.

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The technical specifications are stated in the current data sheet of the products. Therefore the customers shall use the data sheets and are cautioned to verify that data sheets are current. The current data sheets can be downloaded at www.we-online.com. Customers shall strictly observe any product-specific notes, cautions and warnings. WE reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services.

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