

Recommendations for Assembly of Infineon TO Packages

Additional Information

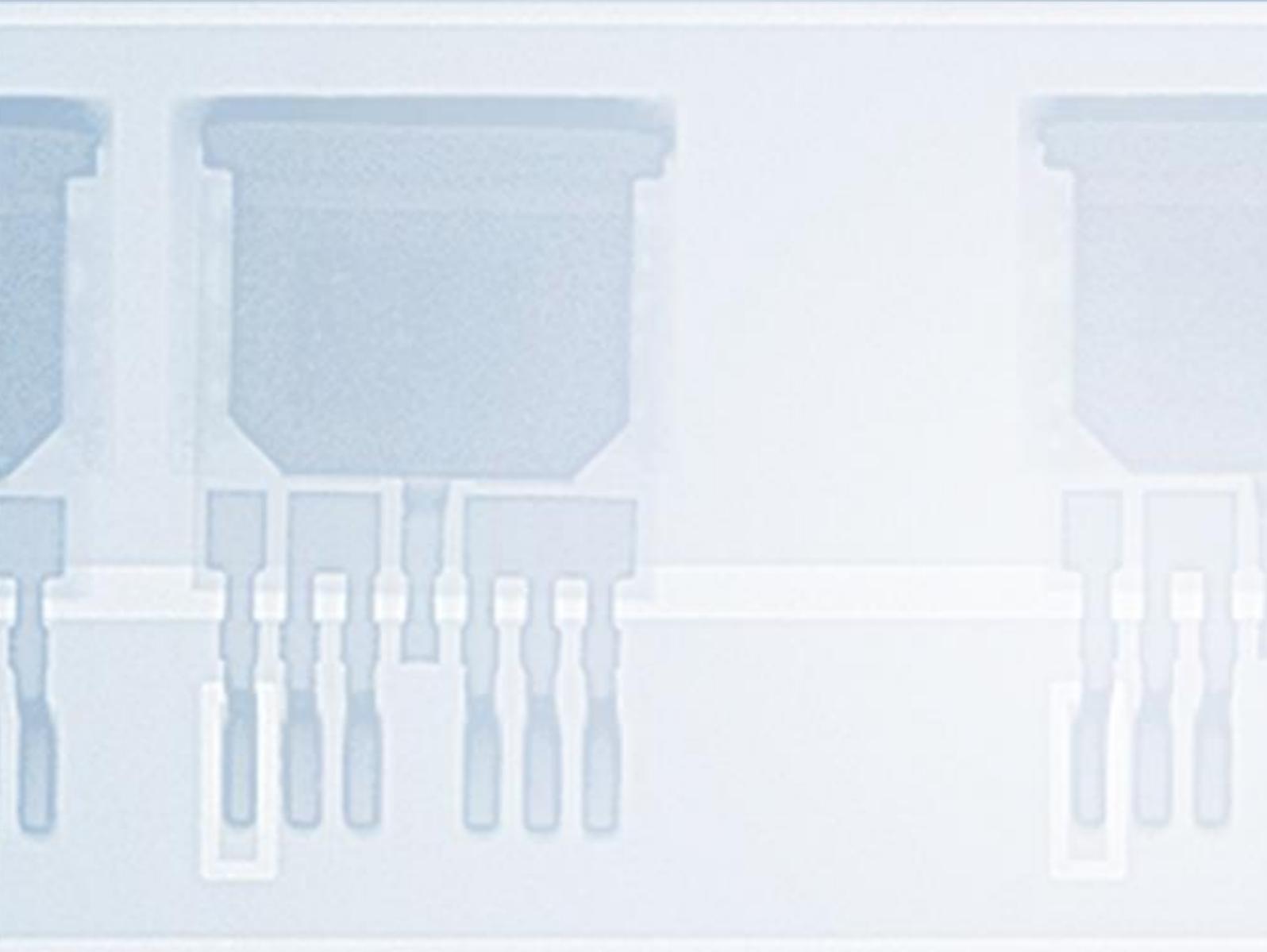




Table of Contents

1	Package description and thermal performance	3
1.1	Package description	3
1.2	Thermal performance	4
1.2.1	Insulating material	4
1.2.2	Thermal grease.....	5
1.2.3	Mounting torque	5
2	Pre-mounting processes and mounting materials.....	6
2.1	Lead cutting.....	6
2.2	Lead bending.....	6
2.3	Heat sink requirements.....	8
2.4	Attachment holes for heat sink screw mounting	8
3	Mounting of through-hole PG-TOs.....	9
3.1	Main influences on through-hole PG-TO assembly quality	9
3.2	Placement of through-hole PG-TOs.....	9
3.3	Heat sink mounting.....	9
3.3.1	Heat sink screw mounting	9
3.3.1.1	General information about heat sink screw mounting	9
3.3.1.2	Double sided heat sink mounting	12
3.3.2	Heat sink clip mounting.....	12
3.4	Soldering of through-hole PG-TOs	13
3.4.1	Wave soldering and selective soldering of THDs	13
3.4.2	Other soldering techniques	14
3.4.3	Pin-in-Paste	14
3.4.4	Heat sink mounting by reflow soldering.....	14
4	Mounting of surface-mount PG-TOs	15
4.1	Main influences on surface-mount PG-TO assembly quality.....	15
4.2	Pad definition and solder mask layer	15
4.3	Solder paste application.....	16
4.4	Solder paste inspection	17
4.5	Component placement	17
4.6	Reflow soldering.....	17
4.7	Wave soldering of surface-mount PG-TOs	18
5	Cleaning.....	19
6	Inspection after soldering	20
7	Rework	21

Package description and thermal performance

1 Package description and thermal performance

1.1 Package description

PG-TOs are available as two general types, Surface-Mount Devices (SMDs) and Through-Hole Devices (THDs). Heat slugs, exposed die pads, and gullwing leads in SMDs can be mounted on one side of a PCB. Most commonly, mounting is done by solder paste printing, pick-and-place, and reflow soldering. In THDs, the leads are longer and straight-shaped at the end, so that they can be inserted in drilled holes of PCBs and be soldered. Wave soldering is often used to mount THDs.

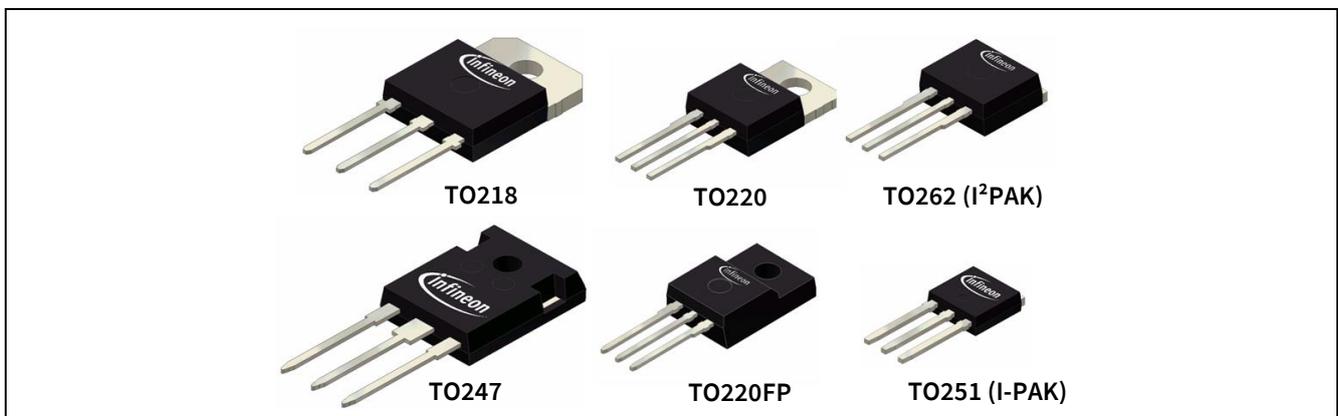


Figure 1 Examples of through-hole PG-TO packages.

An extra heat sink can either be mounted on the heat slug or the exposed die pad, or PCB pads can be used for heat dissipation. Depending on the process and technology, this may require an extra step before or after soldering the leads.

Figure 1 shows examples of through-hole PG-TO packages. In Figure 2 examples for surface-mount PG-TO packages can be seen.

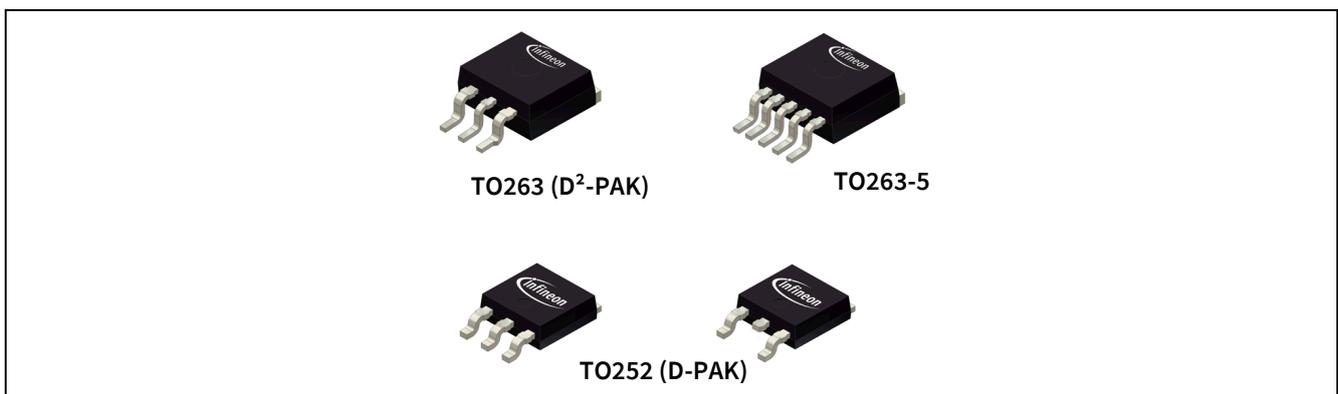


Figure 2 Examples of surface-mount PG-TO packages

Semiconductor devices are sensitive to excessive electrostatic discharge, moisture, mechanical handling, and contamination. Therefore they require specific precautionary measures to ensure that they are not damaged during transport, storage, handling, and processing. For details, please refer to the General Recommendations for Assembly of Infineon Packages in “Package Handling” (available at www.infineon.com/packages).

Package description and thermal performance

1.2 Thermal performance

The overall thermal performance of a package with a heat sink is characterized by a junction-to-ambient thermal resistance R_{thja} . The R_{thja} can be calculated with equation (1) (Figure 3).

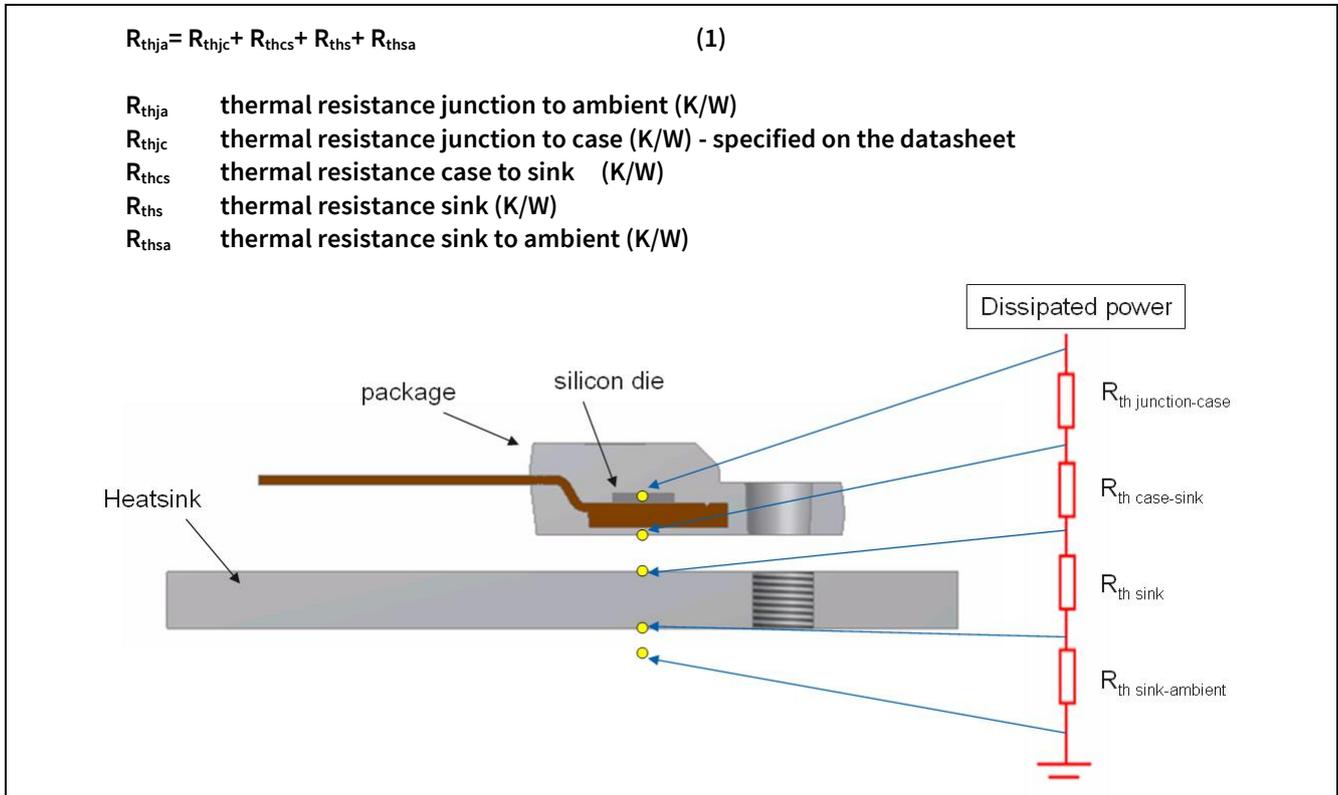


Figure 3 Thermal model

When mounting a package on a heat sink, it is important to consider the interface resistance R_{thcs} . In an ideal case, R_{thcs} is zero. In real application cases, there will be a small air gap between the package and the heat sink for the following reasons:

The package and heat sink have some roughness, the package and heat sink are never perfectly flat and the package may have some misalignment due to mounting.

Therefore, R_{thcs} will always exceed zero.

For the insulated package TO220FP, the use of thermal grease is recommended to fill the air gap between the package and the heat sink. Measurements show that the usage of thermal grease reduces the interface resistance by 1.2-1.5 K/W.

In many applications, the package must be electrically isolated from its mounting surface. The isolation material has a comparatively high thermal resistance, which raises junction operating temperatures.

1.2.1 Insulating material

Commonly used insulating materials are mica and rubber. Mica is much harder than rubber. For softer materials, the mounting torque in particular needs to be controlled very carefully in order to avoid high mechanical stress and damage to the package (Figure 4).

Package description and thermal performance

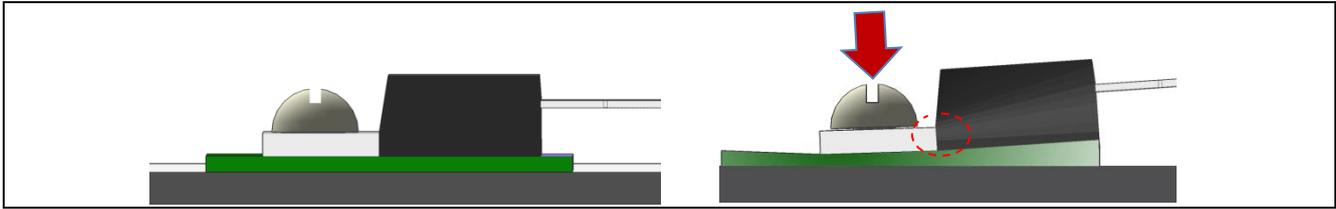


Figure 4 Schematic view of the influence of the insulating material (left mica, right rubber) on the generation of mechanical stress

1.2.2 Thermal grease

A specific amount of grease must be applied. The amount should be determined during customer process evaluation. When the amount is correct, a very small amount of grease should appear around the perimeter of each surface as the assembly is slowly torqued to the recommended value. Examination of a demounted assembly should reveal even wetting across each surface.

1.2.3 Mounting torque

The thermal contact resistance between the two surfaces is maximized by increasing the contact pressure between the package and its heat sink. Increasing the mounting torque in the fastening screw, or using a clip with a high spring constant will result in lower contact resistance areas that provide solid conduction heat flow paths compared to air conduction through the air gap.

Applying the proper mounting torque is the key factor in obtaining an adequate contact pressure along the contact surfaces of the package and the heat sink to minimize the contact thermal resistance. If the mounting torque is too low, the contact thermal resistance increases due to poor thermal connection under insufficient contact pressure. If mounting torque is too high, the package head and mounting tab are deformed so that the package may be lifted away from the heat sink (Figure 5), also increasing the contact thermal resistance. Hence, an appropriate range of mounting torque values must be used to ensure minimal thermal resistance. This prevents package destruction or changes in thermal and electrical device characteristics.

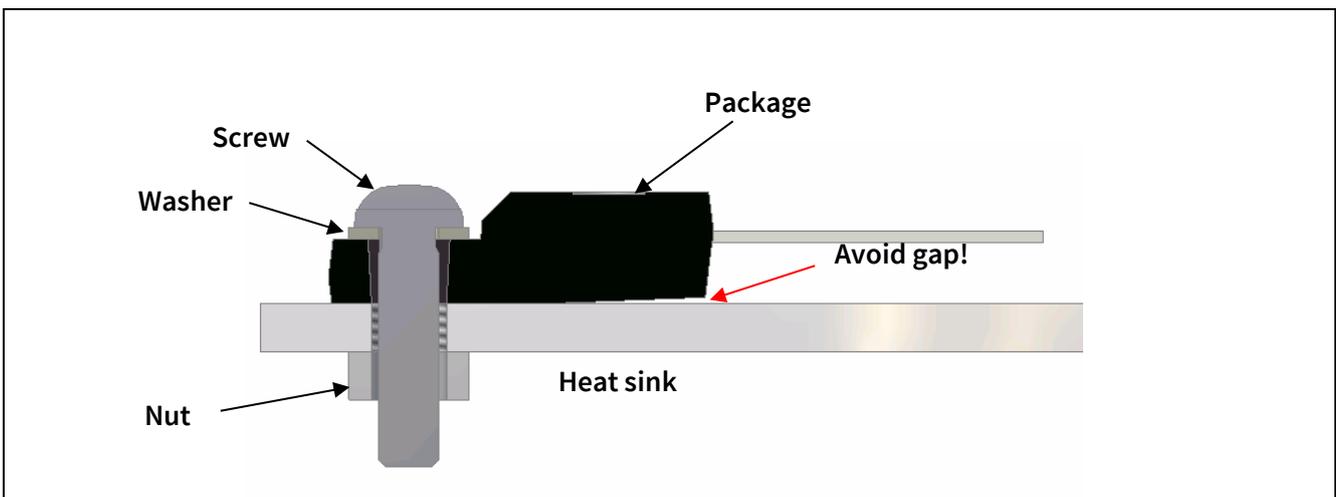


Figure 5 Example of a heat sink assembly in screw mounting

2 Pre-mounting processes and mounting materials

2.1 Lead cutting

The leads of THDs can be cut before mounting or after mounting and soldering.

In case of cutting after soldering, the leads are embedded in the solder joint. Severe mechanical mishandling during the cutting process could cause solder joint failure, but generally does not harm the component body. When cutting prior to mounting, the leads have to be fixed by a clamp that should be similar to a clamp used for lead bending (please refer to Section 2.2)

2.2 Lead bending

To insert the terminals of THDs in the holes of the PCB, the terminals may have to be bent to match the pitch of the respective PCB holes.

It is very important to comply with the following guidelines:

- If the package has an increased lead width next to the package body, the bending distance needs to be greater than the length of the increased lead width (L_1 in Figure 6).
- In other cases, the minimum distance between the package body and the first bend should be 2.5 mm (Figure 7 a & b). The leads must not be bent immediately adjacent to the package (Figure 7 c).
- The minimum bend radius needs to be 0.5 mm.
- A clamp should be used when bending to avoid excessive mechanical forces such as pulling and shearing between the leads and the package body. Between the point of bending and the package edge, tensile stress during the bending process needs to be relieved (Figure 8 a & b). Avoid slippage due to weak clamping, as well as weakening of the lead due to overly strong clamping.
- A properly designed clamping tool helps to make the bend shape reproducible.
- The maximum force applied to the leads between the clamp and the point where the bending force is applied should not exceed a certain limit. This maximum force is mainly dependent on the cross-sectional area of the lead. A typical maximum force is 20 N.
- Bending the leads parallel to the lead plane is not allowed (Figure 8 c).
- Bending manually is acceptable if the guidelines above are followed.
- Clamping, bending and cutting need to be done sequentially in that order; a subsequent process is not allowed to be initiated before the preceding process is finished (Figure 9).

Pre-mounting processes and mounting materials

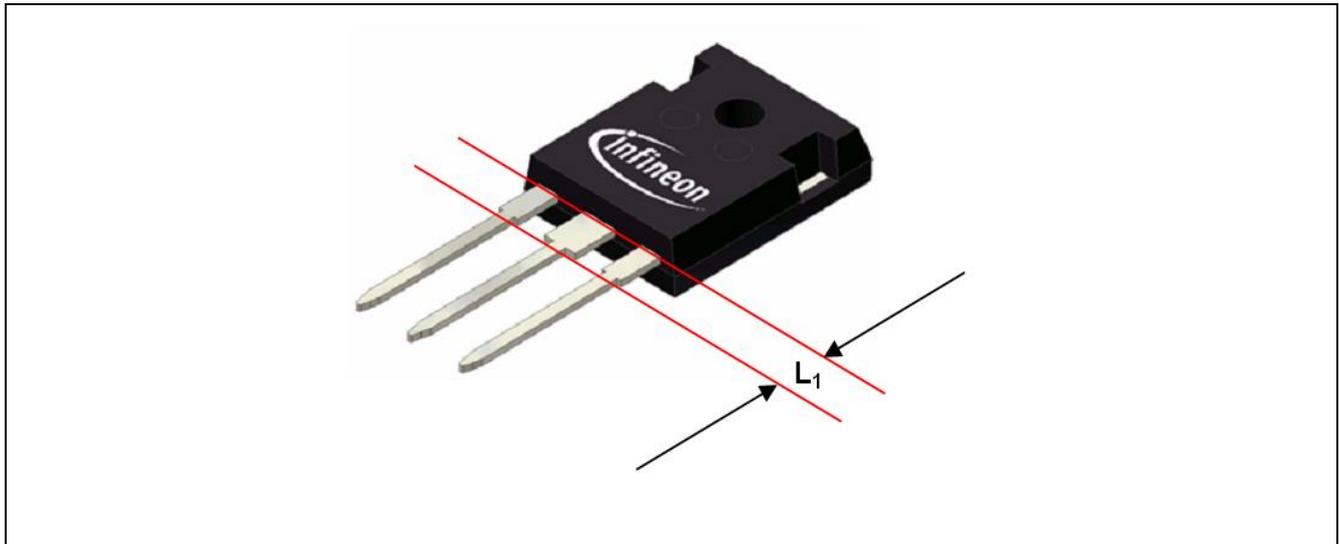


Figure 6 Minimum cutting and bending distance given by the distance between package body and narrow leads

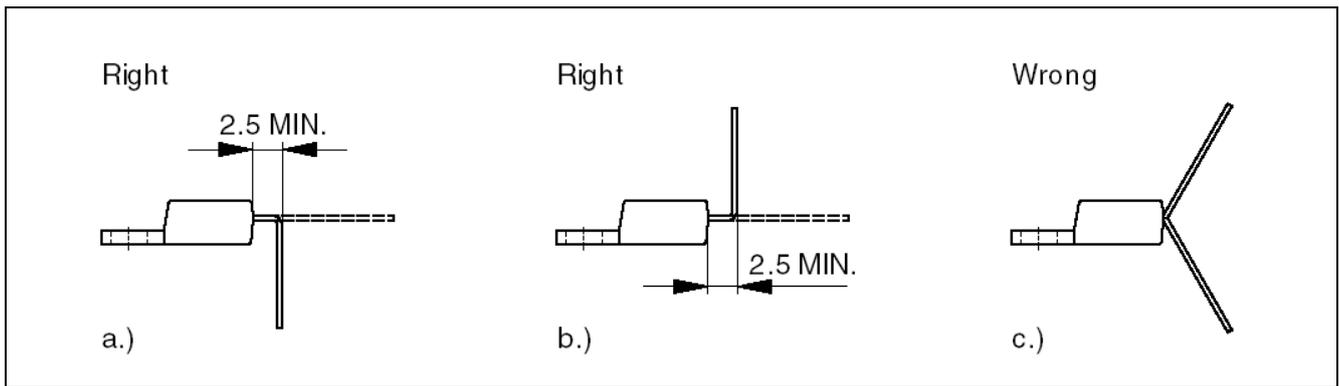


Figure 7 Examples of correct and incorrect lead bending for THD packages

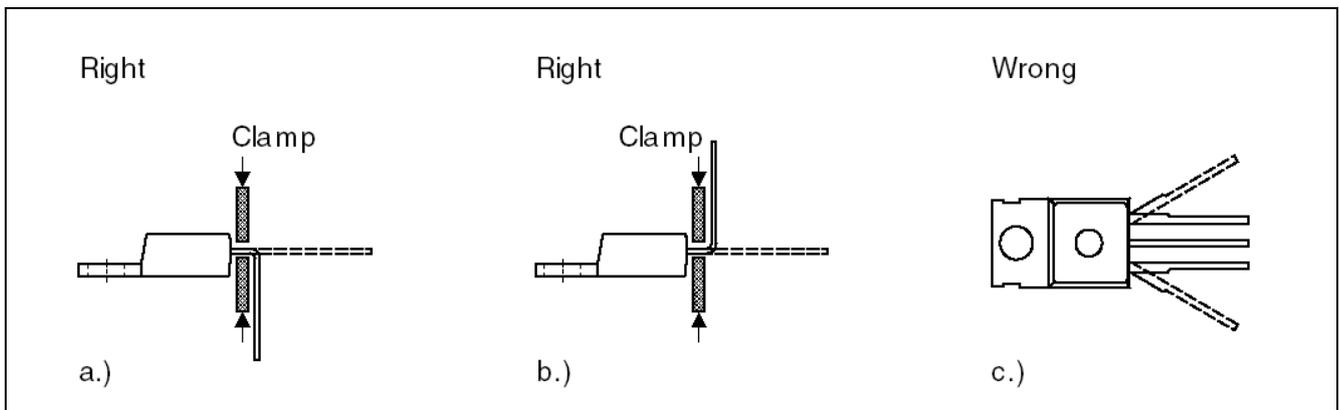


Figure 8 Examples of correct and incorrect clamping and lead bending for THD packages

Pre-mounting processes and mounting materials

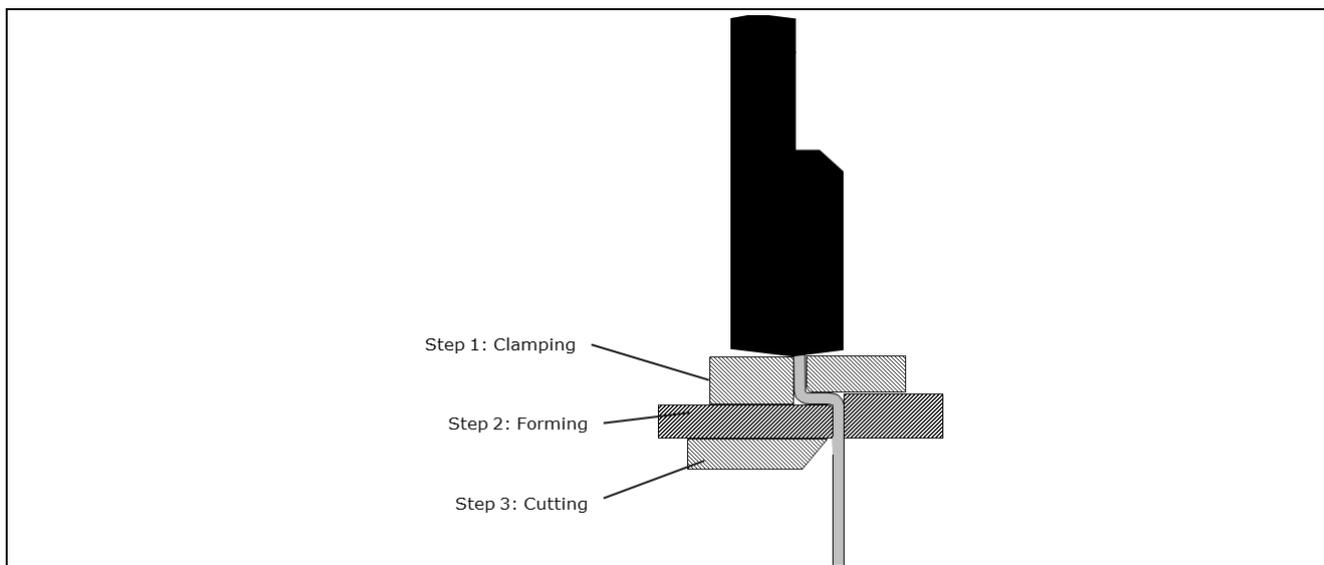


Figure 9 Lead clamping, forming, and cutting process steps

2.3 Heat sink requirements

The contact areas of the package and the heat sink must be free of any particles and damage as well as any other contamination. The following surface conditions are recommended:

Heat sink Roughness $RZ \leq 10 \mu\text{m}$

Heat sink Flatness $\leq 10 \mu\text{m}$ (reference length 15 mm)

2.4 Attachment holes for heat sink screw mounting

Drill holes should be as small as possible. Using drill holes that are too big will reduce the effectiveness of the heat sink.

The flatness and effectiveness of the heat sink will also be reduced by intrusions and/or burrs around the hole. These are caused by the punching or drilling process and should be less than the specified heat sink roughness and flatness.

If intrusions or large drill holes are unavoidable, a fitting square washer should be used to get a good and flat contact between heat sink and package.

Mounting of through-hole PG-TOs

3 Mounting of through-hole PG-TOs

3.1 Main influences on through-hole PG-TO assembly quality

The following factors have to be taken into account to achieve the best quality assembly for a given application:

- Insulating material (e.g. washers, spacers)
- Screws
- Thermal grease
- Mounting torque
- PCB and heat sink (please refer to Section 3)
- Attachment holes for heat sink screw mounting (please refer to Section 3)
- Soldering method, especially temperature profile

3.2 Placement of through-hole PG-TOs

THDs are inserted either with special automatic equipment or manually. During this insertion, special care has to be taken that excessive deformation or violent bending is avoided. The diameter of the drill holes in the PCB has to be appropriate for the tolerances of component leads, drill hole position placement accuracy, and properties of the solder alloy used.

In some cases after insertion, the leads must be bent a little to attach the component to the PCB until it is soldered in place. Please take care that mechanical stresses do not result in any defects at the interface between leads and package body.

3.3 Heat sink mounting

For special packages with high power dissipation, heat sinks can be mounted before or after soldering the leads.

3.3.1 Heat sink screw mounting

3.3.1.1 General information about heat sink screw mounting

Screw mounting is a traditional assembly method using a screw, nut and washer, following these guidelines:

- Self-tapping screws should not be used.
- It is recommended that a plane washer is inserted between the screw head and the mounting tab. Care must be taken to ensure that the washer does not damage the plastic body of the package during the mounting process.

The screw should be properly tightened in a controlled process to ensure that the package makes good contact with the heat sink.

Figure 10 illustrates the correct mounting components for a TO220 and a TO220FP.

Mounting of through-hole PG-TOs

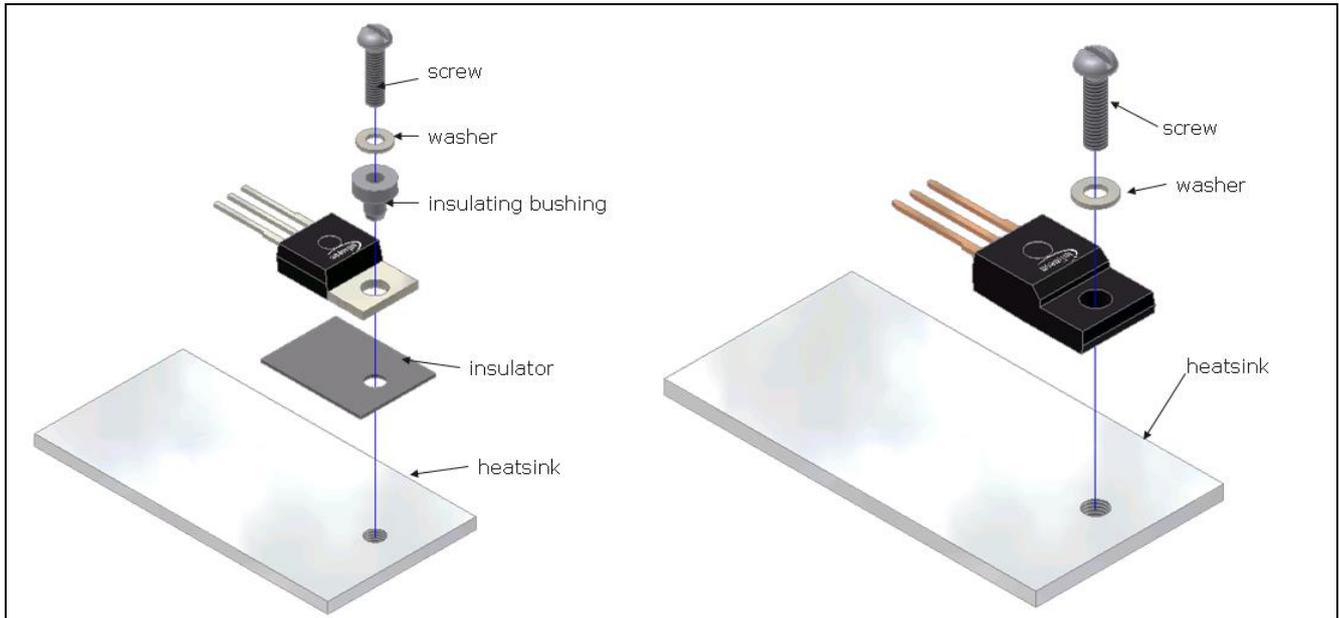


Figure 10 Screw-mounted TO220 (left) and TO220FP (right)

Improper mounting can damage a die. Molding compound can delaminate due to external mechanical stress, e.g. mounting on warped heat sink (Figure 11).

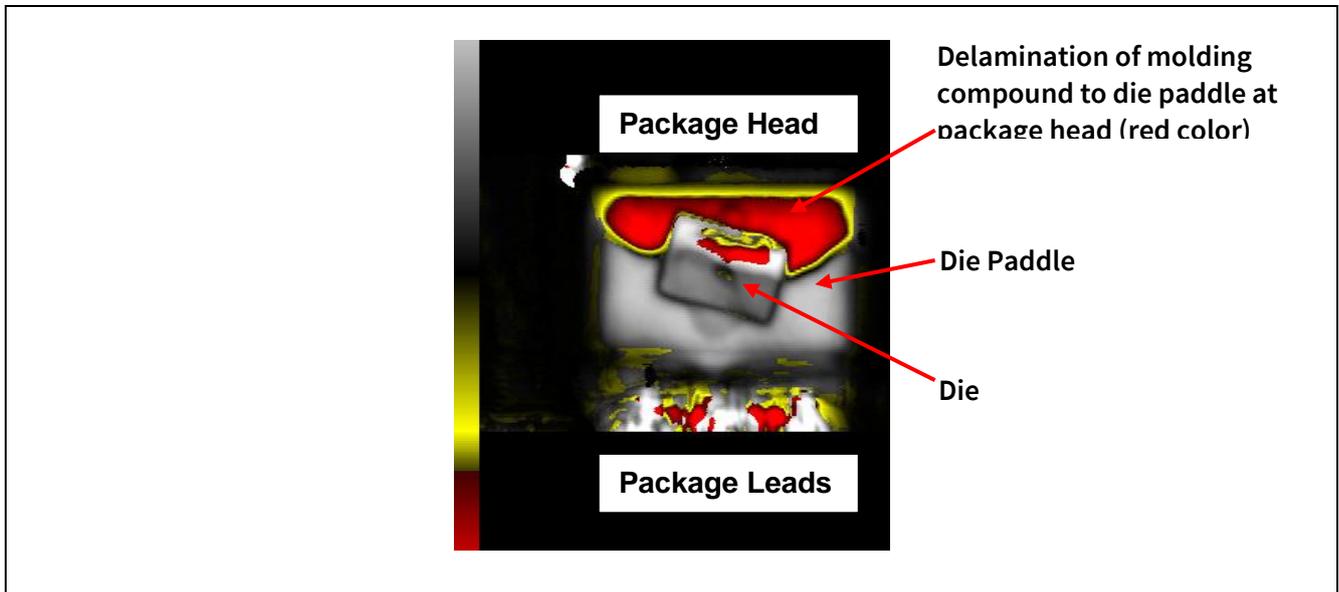


Figure 11 C-Scanning Acoustic Microscopy (CSAM) image showing delamination of molding compound to die paddle at package head (TO220)

Mounting of through-hole PG-TOs

A maximum torque used for heat sink mounting of 1.0 Nm is recommended. Higher mounting torque does not directly result in lower R_{th} values (see Figure 12) but may at the worst cause package damage depending on the insulation material used.

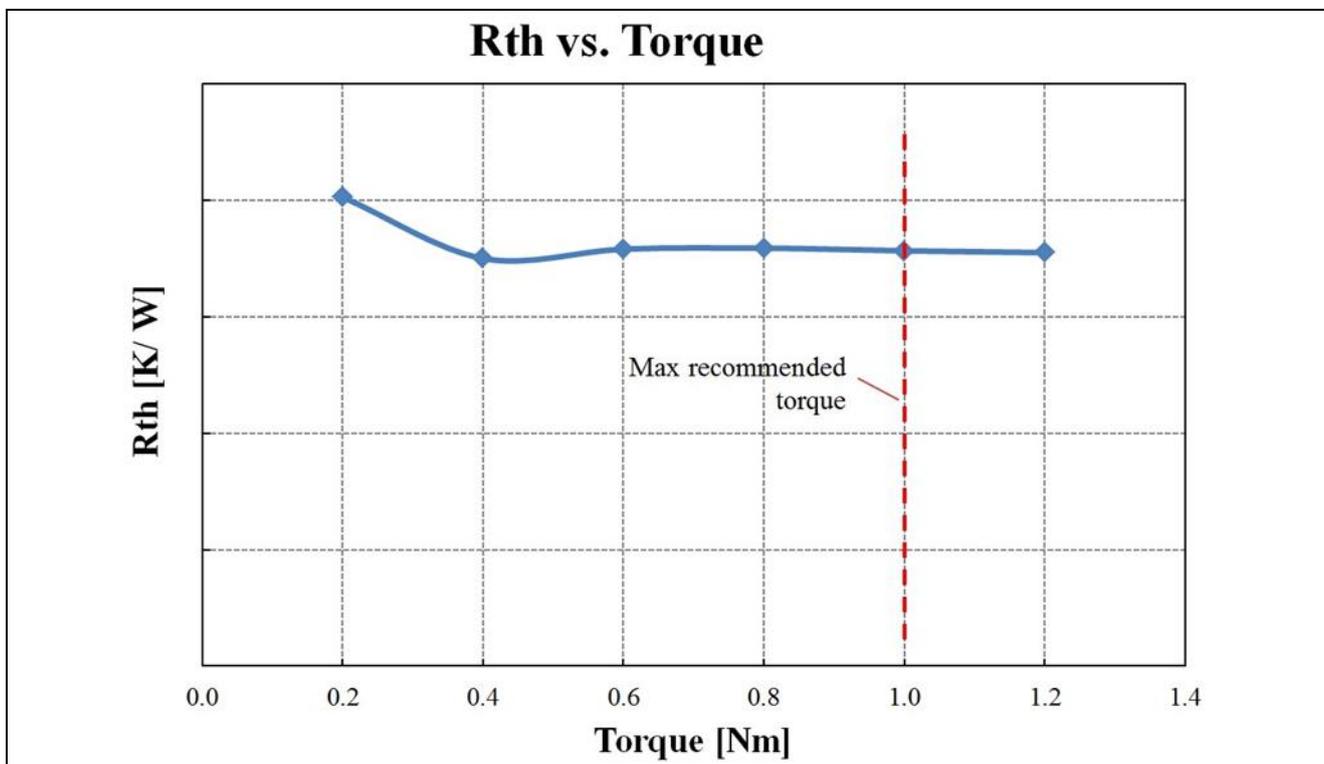


Figure 12 Effect of torque on the R_{th} between package and heat sink

Mounting of through-hole PG-TOs

3.3.1.2 Double sided heat sink mounting

Double-sided heat sink mounting is not recommended. In case of unsuitable mechanical heat sink properties, high mechanical stress may occur, resulting in package damage (Figure 13).

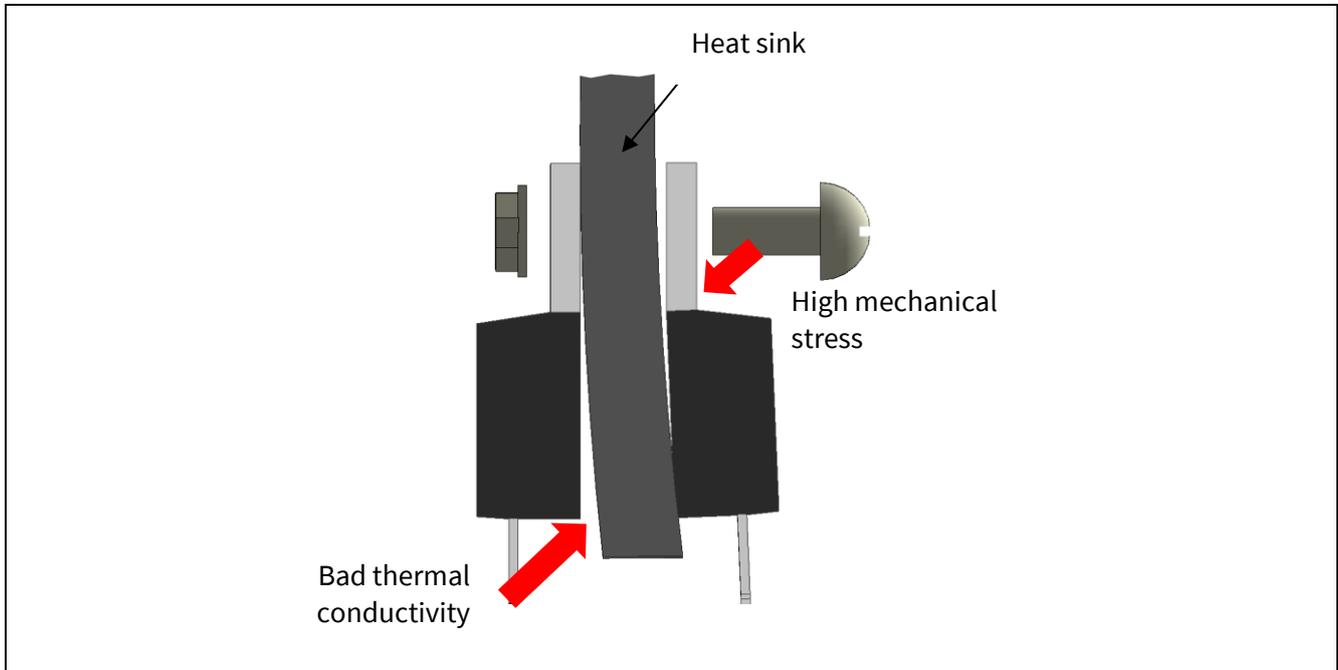


Figure 13 Negative effects of double-sided assembly on improper heat sink material

3.3.2 Heat sink clip mounting

The clip mounting method has become popular because it is simple and reliable. The process is fast and appropriate for mass production assembly. The screw mounting is applied at one end of the package during fastening and can cause uneven contact pressure and bad thermal contact, whereas the clip is mounted on the package center and therefore results in more uniform contact pressure (Figure 14).

If clips are used, the contact area between the plastic case and the clip is important. Clips should be round or smooth in the contact area to avoid concentrated loads on the plastic body of the package.

For some applications it is necessary to have the package electrically isolated from the heat sink or PCB.

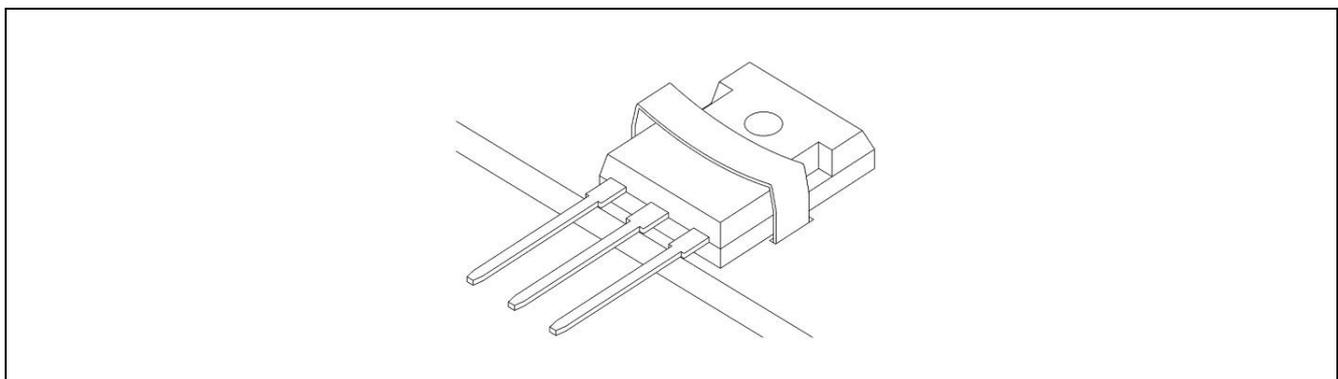


Figure 14 Schematic drawing of TO247 package with clip mounting

Mounting of through-hole PG-TOs

3.4 Soldering of through-hole PG-TOs

THDs are designed for wave soldering and not for reflow soldering (see Section 4).

However, the number of THDs on each board has been decreasing in some applications, and making wave soldering less cost effective. But the few remaining THDs (mostly connectors and special components) are soldered with selective or wave soldering, or with the pin-in-paste technique plus reflow soldering.

Through-hole PG-TOs in particular are often mounted on a carrier or submount that has special features enabling it to serve as a good heat sink. In this case, special processes are needed to attach the component.

3.4.1 Wave soldering and selective soldering of THDs

These processes use a tank holding molten solder. The components are inserted into the PCB and the loaded PCB is passed across a pumped wave or cascade of solder. The solder wets the exposed metallic areas of the board (those not protected with solder mask), creating a reliable mechanical and electrical connection.

In the case of through-hole PG-TOs, only the leads that reach through the drilled holes in the PCB are directly in contact with the hot solder. The body of the package only gets heated by the hot leads. As a result, the package body is cooler than in case of reflow soldering, and the temperature gradient between leads and body and inside the package is steeper compared to reflow soldering.

Therefore for wave-solderable through-hole PG-TOs, the heat resistance is tested according to JESD22-B106 and IEC668 2-20 (typically 260°C for 10 s). This gives the maximum acceptable temperature and time for selective/wave soldering (e.g. for dual wave: max. time in wave1 + max. time in wave2 < 10 s).

Attention: Immersing the whole PG-TO package body into the molten solder is not recommended. This would result in a temperature shock of the package body, which is not rated for this stress.

There are many types of wave soldering machines. The basic components and operating principles of these machines are the same. A standard wave solder machine has three zones: the fluxing zone, the preheating zone, and the soldering zone. An additional fourth zone, cleaning, may be used depending on the type of flux applied. Dual-wave soldering is the most commonly used wave soldering method.

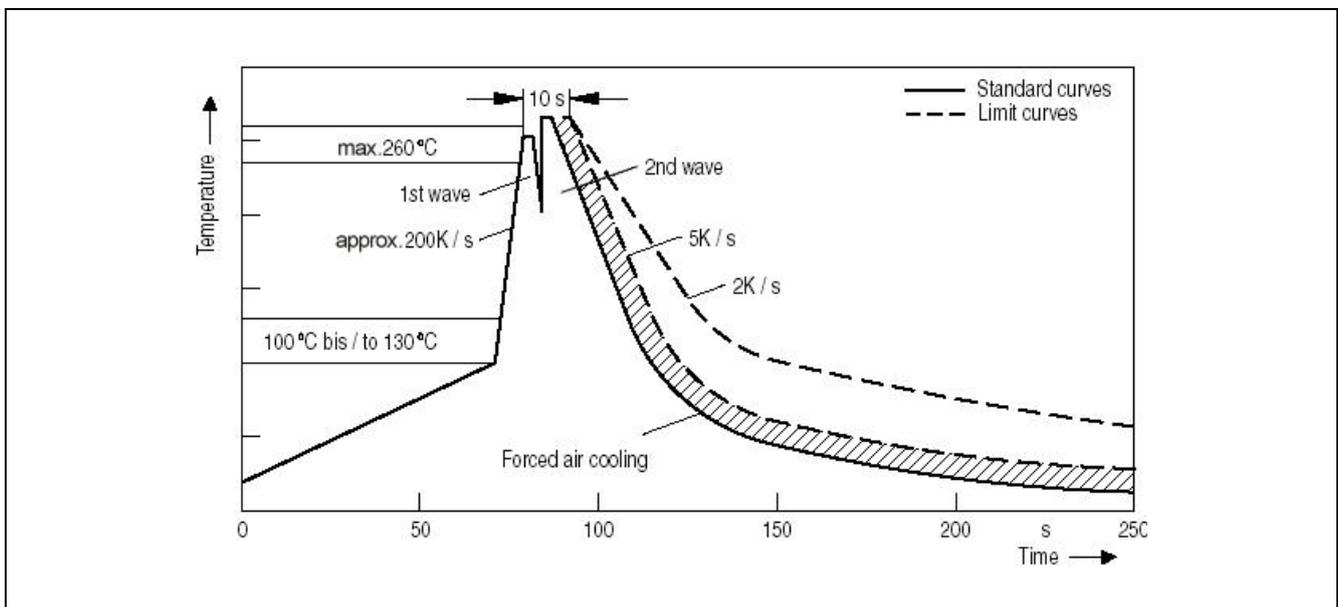


Figure 15 Dual-wave soldering profile used for qualification purposes (acc to: JESD22-B106)

Mounting of through-hole PG-TOs

The peak temperatures, ramp rates and times depend on the materials used and on the wave soldering equipment (Figure 15). The first wave has a turbulent flow and therefore guarantees wetting of nearly all shapes of leads and board pads, but also results in a large number of solder bridges. These solder bridges must then be removed by the second, laminar wave. When using Pb-free solder alloys, a nitrogen atmosphere is recommended.

Selective soldering is typically used when only a few THDs have to be soldered onto the board. Generally this is done after the other components are already soldered by reflow soldering. These components must be protected while undergoing selective soldering. This protection can be achieved either by using special fixtures and deflectors for the PCB or/and by creating a small wave shape in the machine by using special wave-guiding tubes or covers.

3.4.2 Other soldering techniques

Beside the wave and reflow soldering previously described, other techniques are used in special applications. Examples include selective soldering, laser welding and laser soldering, hot bar soldering and manual soldering with a soldering iron and hot air guns.

Some general guidelines should be followed for a wide variety of soldering techniques that can not be tested for every component:

- The maximum temperature of the package body and leads must not exceed the maximum allowed temperature for reflow or wave soldering.
- The maximum allowed time at high temperatures must not exceed the maximum allowed time for reflow or wave soldering.
- If heat is applied to the leads, the maximum temperatures in the package and of the package body must not exceed the maximum allowed temperatures during reflow or wave soldering.
- For details and special arrangements, please refer to the product data sheet and/or qualification report

If long contact and heating times are unavoidable, the resulting temperature on various leads near the package body should be measured and must not exceed the temperature and duration experienced during wave or reflow soldering.

Infineon has done some evaluation studies for PG-TO packages (subset of typical temperatures and times when using a soldering iron). Please ask your local sales.

3.4.3 Pin-in-Paste

Another technique used to solder THDs is to print solder paste onto a PCB near or over drill holes through which the leads are then inserted. The reflow of the solder paste is done together with soldering the surface mount components and therefore they have to go through the reflow temperature profile. Consequently, the temperature is nearly the same for the whole package in contrast to wave soldering, and the time for which the peak temperature is applied to the package is much longer compared to wave soldering.

3.4.4 Heat sink mounting by reflow soldering

In special applications the heat sink of high-power THDs can be mounted to the board by solder paste printing, pick-and-place, and reflow soldering. In this case, the packages undergo a reflow profile (see also Section 4).

Attention: Through-hole PG-TOs are qualified for wave soldering and not for reflow soldering. Therefore it is not recommended to use reflow soldering for heat sink mounting for through-hole PG-TOs.

4 Mounting of surface-mount PG-TOs

4.1 Main influences on surface-mount PG-TO assembly quality

The following factors have to be taken into account to achieve the best assembly quality for a given application:

- PCB design
- Footprint and Stencil layout
- Solder paste formulation
- Solder paste application and inspection
- Component placement
- Reflow soldering process, especially the reflow profile

4.2 Pad definition and solder mask layer

Generally, two basic types of solder pads are used.

- „Solder-mask-defined“ (SMD) pad:
The copper metal pad is larger than the solder mask opening above this pad. Thus the pad area is defined by the opening in the solder mask.
- „Non-solder-mask-defined“ (NSMD) pad:
Around each copper metal pad there is solder mask clearance.
Dimensions and tolerances of the solder mask clearance have to be specified such that no overlapping of the solder pad by solder mask occurs. The particular size of the clearance depends on PCB manufacturer's capabilities.

Using a solder mask reduces the risk of solder bridging and therefore a mask should be applied between all copper pads that are electrically separated. Solder mask can also be used to divide large copper areas into smaller wettable areas. This often helps to improve processability and results in better balanced solder joints.

We additionally recommend SMD pads for soldering the exposed die pad because of its improved possibilities for heat distribution without violating the recommended dimensions for the wettable surface. For power-consuming and heat-dissipating products in TO packages, it is necessary to have wide conductor paths or even big metal areas that can be easily divided by solder masks into a certain size for the wettable surface.

Generally it is possible to lay out the board pad in an area ratio of 1:1 relative to the exposed die pad. If the exposed die pad protrudes on one or more sides of the package body, it can be helpful to increase the board pad slightly in this area to improve self-centering of the component during reflow soldering. If the exposed die pad is completely hidden under the package body or even surrounded by peripheral pads, it may be helpful to decrease the board pad to get more space for routing and plated through-holes (vias) for these peripheral pads.

Vias are used to connect the exposed die pad thermally and electrically directly to inner and/or bottom copper planes of the board. They help to distribute the heat into the board area, which penetrates from the chip over the package die pad and the solder joint to the thermal pad on the board. A typical hole diameter for thermal vias is 0.2 to 0.5 mm. This diameter and the number of vias in the thermal pad depend on the thermal requirements of the end product, the power consumption of the product, the application, and the

Mounting of surface-mount PG-TOs

construction of the printed circuit board. However, an array of thermal vias with pitch 1.0-1.2 mm can be a reasonable starting point for most products/applications for further optimization. Thermal and electrical analysis and/or testing are recommended to determine the minimum number needed.

If the vias remain open during board manufacturing, solder may flow into the vias during board assembly (“solder wicking”). This results in lower stand-off which is mostly controlled by the solder volume between package die pad and thermal pad on PCB. Together with this lower stand-off, the number and size of voids in the solder joint usually is reduced compared to solder joints without vias. This is a result of the combination of the resulting lower stand-off and the effect of open vias to act like venting holes for gases developed during soldering. When placing vias in one or more exposed pads below the package, it is necessary to create a uniform distribution of the vias. A non-uniform distribution of open vias may result in a horizontal package tilt due to the above described lower stand-off effect. To control the solder wicking it is beneficial to put a wettable surface around the via on the opposite side of the board. This acts as a buffer for potential solder flowing through the open via.

If it is preferred to use closed vias, PCB manufacturers offer several technologies such as plugging or tenting. Investigations have shown that with plugged vias, the voiding level of the solder joint will be comparable to exposed pads without vias. In case of tenting, the vias should be closed from both PCB sides, because one-sided tenting from the bottom side of the PCB results in a significantly higher voiding rate. Tenting can be a beneficial solution if it is combined with a well-designed exposed pad (exposed pad separated into several smaller pads by solder mask dams).

If it is not necessary to have a direct connection from the solder pad under the exposed die pad to the inner layers of the PCB, it is possible to place the vias near the package and cover them with solder mask.

For more information on PCB pad design for the leads and especially the exposed die pads, please refer to the Infineon Web Page: www.infineon.com/packages

4.3 Solder paste application

For packages in which all leads are the same size, a typical stencil aperture is reduced to ~90 % of the landing pad size. For packages in which the leads are of various sizes, the solder paste volume has to be matched properly by using appropriate stencil apertures to avoid swimming, tilting, solder beading, or tombstoning.

Large exposed pads in the center of the component tend to tilt the component if the solder paste volume is not reduced sufficiently. Molten solder always tends to form a spherical shape (lowest surface tension) and therefore big pads that are fully covered with solder paste will give a higher stand-off after reflow than smaller pads will. Tilting of the component can result, and the different solder depots will have to be adjusted to avoid this.

Segmentation of the stencil for exposed pads or other big pads is shown in the following sketch (Figure 16). In case of open vias, it is recommended to avoid printing on top of the hole to avoid solder flowing into the vias.

Mounting of surface-mount PG-TOs

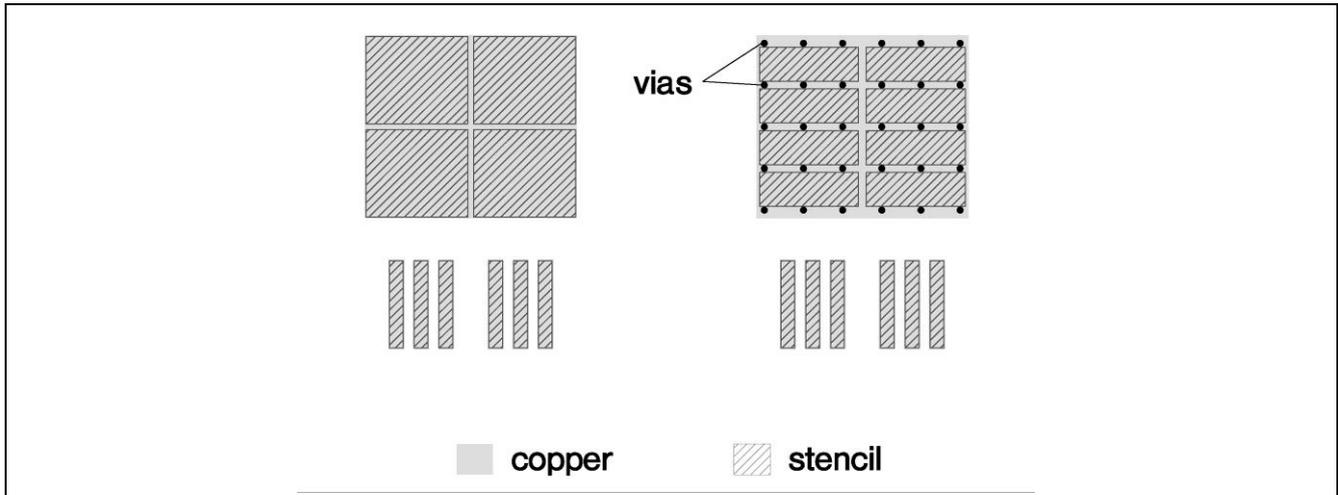


Figure 16 Example of a stencil design for a PG-TO263-7-2 package without and with vias in pad

Because the stand-off also depends on the wetting behavior of the board finish as well as the via technology used, the optimum volume may differ from the given recommendation and therefore should be determined by the customer.

4.4 Solder paste inspection

For inspection of solder paste depots after printing, vision systems can be used which are either integrated into the printer or separate Automated Solder Paste Inspection (SPI) equipment. The solder paste x-y-cover and solder paste volume can be measured. Adequate acceptance criteria have to be defined based on the manufacturing setup.

4.5 Component placement

Generally it is beneficial to follow the recommendations of the pick-and-place equipment vendor. The pick-up nozzle should be chosen according to the package size. The nozzle should be slightly smaller than the package mold body.

For PG-TO packages, most of the time the nozzle position needs to be in the center of the mold body and not in the center of the overall package due to the fact that PG-TO packages typically only have gullwing pins on one side.

4.6 Reflow soldering

The temperature profile of a reflow process is divided into several phases, each with a special function (Figure 17). The individual parameters are influenced by various factors, not only by the package. It is essential to follow the solder paste manufacturer’s application notes. Additionally, most PCBs contain more than one package type and therefore the reflow profile has to be matched to the requirements of all components and materials. We recommend measuring the solder joint temperatures by thermocouples beneath the respective packages. Components with large thermal masses do not heat up at the same speed as lightweight components. In addition, the position and the surrounding of the package on the PCB, as well as the PCB thickness, can influence the solder joint temperature significantly.

Mounting of surface-mount PG-TOs

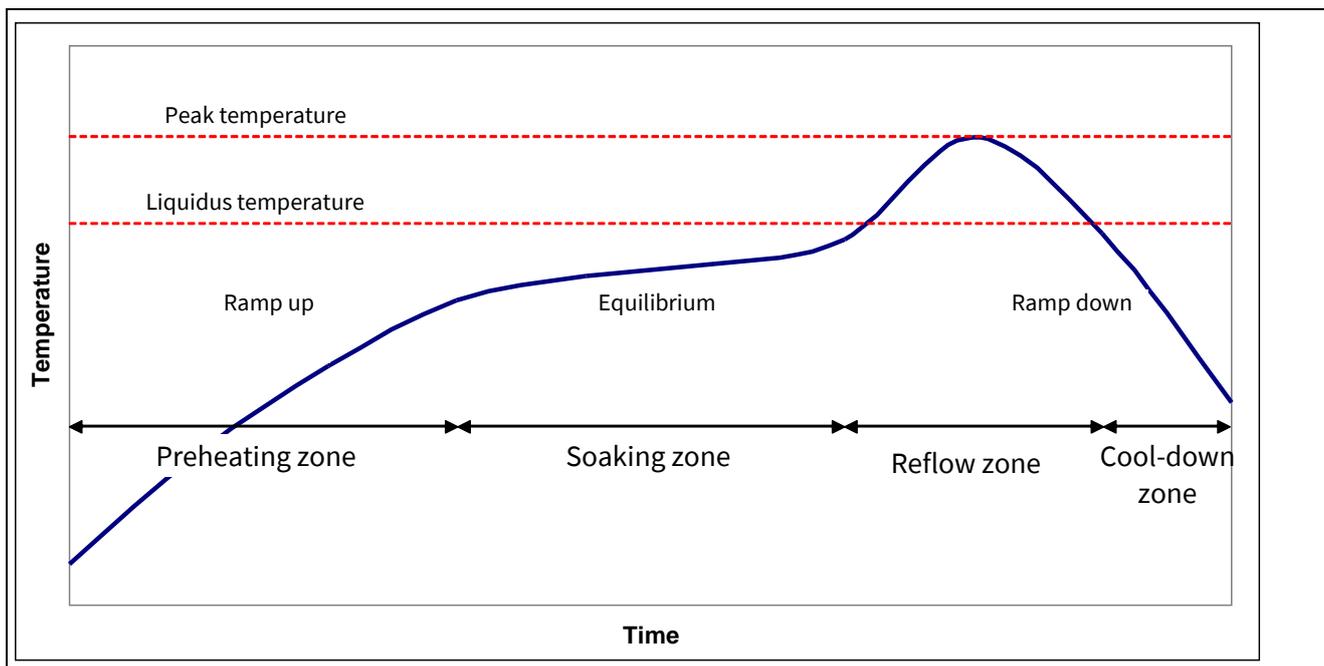


Figure 17 Various phases of a reflow solder profile

Infineon’s surface-mount packages are qualified according to the J-STD020 standard. The temperature profile and especially the peak temperature mentioned in this standard is no recommendation for an actual reflow profile but specifies the maximum thermal loading which the packages can withstand during reflow soldering.

4.7 Wave soldering of surface-mount PG-TOs

In general, Infineon’s surface-mount PG-TO packages are not designed to withstand a wave soldering process in which the whole package body will be immersed in the molten solder.

If you would like to wave solder an Infineon surface-mount TO package, this will need to be investigated individually on a per-product basis. In such a case, please contact your Infineon sales representative.

Cleaning

5 Cleaning

After the soldering process, flux residues can be found around the solder joints. If a “no-clean” solder paste or flux has been used, the residues usually do not have to be removed after the soldering process. However, if the solder joints have to be cleaned, the appropriate cleaning method (e.g. ultrasonic, spray or vapor cleaning) and solution will depend on the packages to be cleaned, the flux used (rosin-based, water-soluble, etc.), and environmental and safety aspects. Even small residues of the cleaning solution should also be removed or dried very thoroughly.

Contact the flux or solder paste manufacturer for recommended cleaning solutions. Cleaning of the solder joints of the exposed die pad could be more difficult than cleaning the leads, which are more exposed to outside treatment.

Inspection after soldering

6 Inspection after soldering

The solder joint fillet of the leads of PG-TOs can be inspected by optical microscope or Automated Optical Inspection (AOI). Acceptable solder joints are described in international standards such as IPC-A-610. Figure 18 shows a THD lead with optimal wetting. It has to be assured that a metallized via is filled properly. This cannot be detected by visual inspection, only by x-ray and/or examining cross sections.

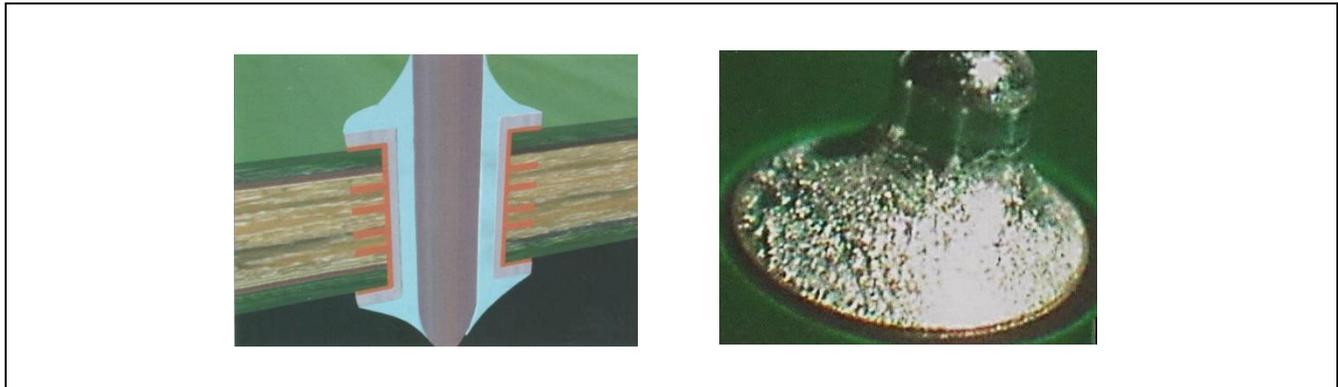


Figure 18 Example of an optimally wetted THD lead

Figure 19 shows an SMD lead with optimal wetting. For surface-mount PG-TOs, it may also be necessary to assess the joint quality under leads with x-ray and/or cross sections.

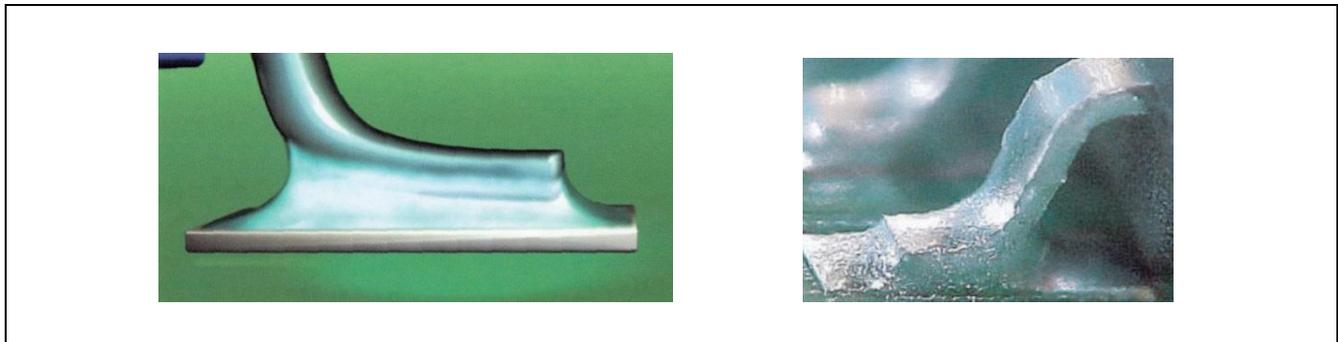


Figure 19 Example of an optimally wetted SMD lead

If exposed die pads are soldered, an X-ray is the only reliable method to inspect the whole solder joint. Figure 20 shows an example of a PG-TO package. The only visible areas are leadframe parts that stick out beyond the package body.

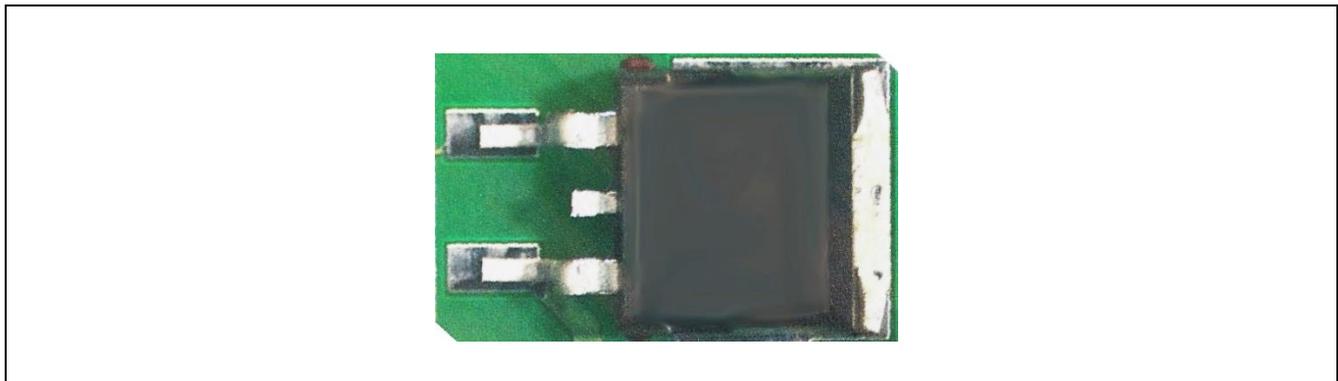


Figure 20 Example of an optimal wetted surface-mount PG-TO package

Rework

7 Rework

In general, solder joints of Infineon's TO packages are reworkable. For details regarding rework, please refer to "[General Recommendations for Assembly of Infineon Packages](#)"

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