

Mounting Considerations For International Rectifier's Power Semiconductor Packages

by Pamela Dugdale and Arthur Woodworth, International Rectifier

Introduction

It is important that power semiconductors are correctly mounted if full functionality is to be achieved. Incorrect mounting may lead to both thermal and mechanical problems. The aim of this Application Note is to describe good practise in the mounting of power semiconductors.

Making Good Thermal Contact

One of the major considerations when mounting all power semiconductor packages is the dissipation of heat. This is because the junction temperature of the die and the glass transition temperature of the plastic limit the performance of the device. Indeed there are maximum allowable temperatures above which the device functionality cannot be guaranteed. The way in which a device is mounted can have a large effect on the thermal contact between the header and the heat sink and hence on the ability of the package to dissipate heat. This is often referred to as the contact thermal resistance and is quoted in datasheets. A full discussion of all of the components that make up the thermal resistance of a power semiconductor package is given in International Rectifier Application Note [AN-997](#) "Mounting Guidelines for the Super-247". In the present note we shall concentrate on the thermal resistance between the case and the heat sink as this is the most dependent on the mounting technique.

The physical source of the contact resistance is a result of the fact that surfaces are never perfectly flat. The recommended flatness for the mounting surface is 0.02mm in 10mm. Particular attention should be paid to ensuring that no damage occurs during the manufacture of mounting holes. Even for two well-prepared surfaces contact only actually occurs at several points separated by large air gaps. This is shown in Figure 1. As air is a very good thermal insulator this is undesirable and increases the thermal resistance. There are two ways of reducing the volume of air trapped between the surfaces. One is to increase the force holding the two surfaces together and the other is to improve the quality of the contact area by filling in the gaps. In the case of the former this can be done by either applying a force above the die with a clip or by increasing the torque on the screw, which mounts the tab to the heatsink. The way in which the thermal resistance varies as a function of the torque on the mounting screw or the clip force is shown in Figs. 2 and 3. Over tightening the mounting screw may lead to deformation of the semiconductor package and hence an increase in the thermal resistance. This is shown in Fig. 2 which gives the thermal resistance as a function of torque for the PowIRtab™, showing a minimum at 1.1Nm for dry mounting and 0.8Nm for wet mounting. Other package types behave in a similar way. Details of how to correctly mount down a semiconductor to avoid this and other problems are given in this application note.

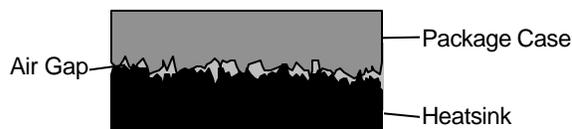


Figure 1. Cross section showing the source of the thermal contact resistance between a package case and the heat sink.

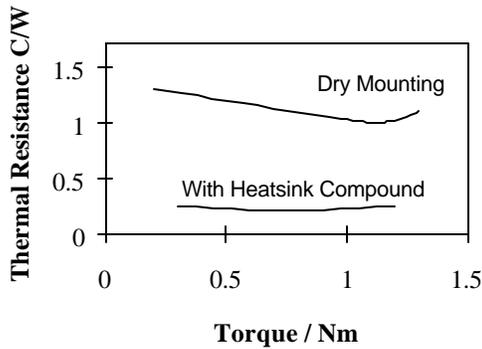


Figure 2. Contact thermal resistance as a function of mounting screw torque for a PowIRtab™ package mounted to a heat sink showing both dry mounting and mounting using heat sink compound.

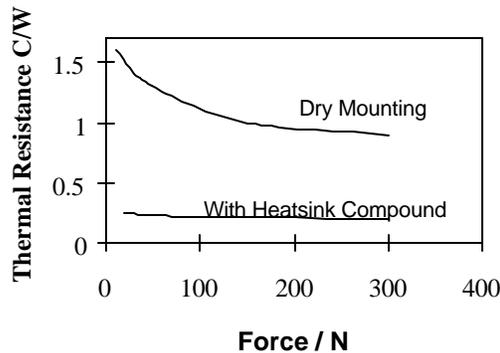


Figure 3. Contact thermal resistance as a function of clip force for a PowIRtab™ package mounted to a heat sink showing both dry mounting and mounting using heat sink compound.

The second technique requires the use of a heat sinking compound. This is usually a silicone grease loaded with electrically insulating, thermally conductive material such as alumina. The purpose of the grease is to fill the gaps without increasing the distance between the two surfaces. If the layer of grease is too thick then the thermal resistance will be increased. To determine the correct amount of grease for a particular application a series of experiments should be performed. Several power packages and heat sinks should be assembled using different amounts of grease applied evenly to one side of each mounting surface. This can be achieved using a small rubber roller. When the amount is correct a very small amount of grease should appear around the perimeter of the device

as it is slowly torqued or clip mounted to the heat sink. Excess compound should be carefully removed.

An alternative to grease is the use of thermally conductive pads. These are conformal under pressure and tend to fill the air voids in the same way as grease. The main advantage of this approach is the ease of handling, however as many of these pads are silicone based the thermal resistance of this solution tends to be higher than it would be if grease were used. In addition to this, the silicone pads provide electrical isolation, which can be either an advantage or disadvantage depending on the specific application. An alternative approach is to use a phase change material. These materials are solid until they are heated to temperatures in the range 50°C to 60°C at which point they start to flow, filling the air gaps. Such materials are available on their own or as coatings on silicone or other thermally conductive pads. For the case when electrical isolation is not required, the phase change material is available as a thin coating on aluminium foil. The relative performance of thermal grease, phase change materials and silicone conductive pads and is given in Table 1. These results were measured by International Rectifier engineers at the Assembly R&D lab.

Interface Material	Electrical Properties	Thermal Resistance Junction to Heat Sink
Heat sink Compound	Non - Conducting	0.7°C/W
Phase Change Thermal Compound	Non - Conducting	1.2°C/W
Aluminium Foil Coated in Phase Change Compound	Conducting	1.2°C/W
Thermal Interface Pad	Isolating	1.6°C/W
Thermal Interface Pad	Conducting	1.6°C/W

Table 1. Performance of thermal interface materials.

Correct Mounting Procedures

In this section the correct mounting procedures for the TO220 package will be discussed. This will include advice on clip mounting, screw mounting and the requirements for isolation. By

using the TO-220 as an example most of the common issues relating to the mounting of power packages will be covered. Problems that are specific to the other power packages, including the International Rectifier PowIRtab™ and Super packages, will be discussed in the next section.

General Rules

- The TO-220 package should always be fastened to the heat sink before soldering the leads to the PCB.
- When bending the leads they must be clamped tightly between the package and the bending point to avoid strain on the package. The leads must be bent at a minimum distance of 2mm from the plastic for standard packages, and 3mm from the plastic for the TO-273. The TO-274 is not normally lead formed because of the design of the leg.
- The leads should be bent no more than 90° and should never be bent more than once.
- The radius of curvature should not be less than the thickness of the leads and ideally should be greater than 2 times the thickness of the leads.
- Lateral lead forming is not advisable. The pin spacing of the leads should be adhered to when mounting to a PCB.
- It is recommended that in the case where a device is rigidly secured to a PCB and also to a heat sink mounted on the PCB, a bend is put in the leads to allow for differences in thermal expansion.
- Care should be taken not to cause any mechanical damage to the package or any surface finishes.
- Heat sink compound or some other thermal interface material should be used.

Screw Mounting

- For the TO-220 a M3 screw should be used. Self-tapping screws should not be used.
- It is recommended that a rectangular 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 recommended mounting torque is 1.1Nm. This should not be exceeded.
- When electrical isolation is required insulating pads and insulating bushes should be used.

Figures 4 and 5 show the suggested mounting hardware for the TO-220.

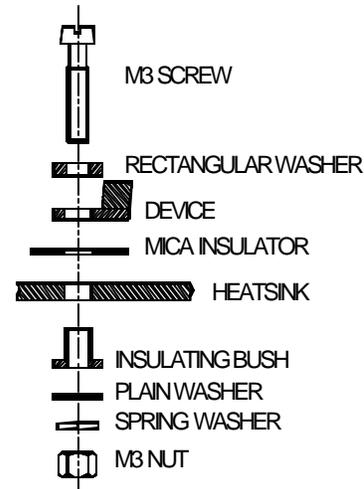


Figure 4. Screw mounting through a heat sink using a nut.

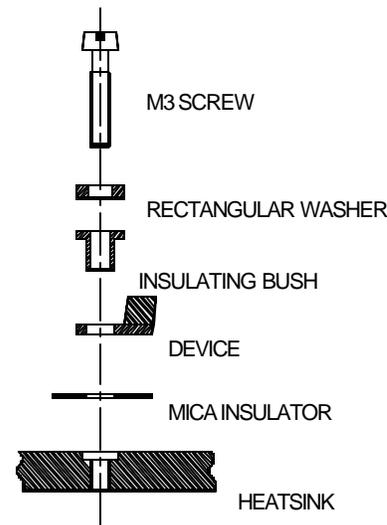


Figure 5. Screw mounting into a tapped heat sink.

Clip Mounting

This section is applicable to the TO-220 and Super220™ (TO-273) packages.

- Using clip mounting ensures that the force is applied above the silicon and that the thermal contact is good.

Application of force off-centre (i.e. bolting a device to heatsink) leads to uneven thermal contact. Using clip mounting ensures that the force is applied above the silicon and that the thermal contact is good.

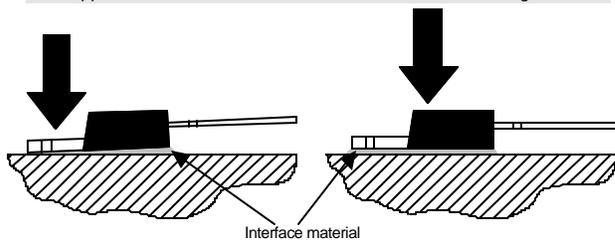


Figure 6. The effect of the position of the applied force.

- Increasing the force supplied by the clip will ensure reduced thermal resistance. This is shown in Figure 3. However the increased cost of stronger clips is not always worth the performance improvements and a minimum force of 20N and typically up to 50N is recommended.
- Isolation is safely achieved by the use of an insulating pad and without the use of bushes.
- Isolation between the bond wires and the mounting clip is provided by the mould compound. The minimum thickness of plastic between a bond wire and the clip is greater than the thickness of the plastic on the header of a fullpak device. This provides 4kV dc isolation which is equivalent to 2.5kV rms ac.
- For heat sinks less than 5mm in thickness saddle clips should be used. These produce contact forces of between 15N and 50N.

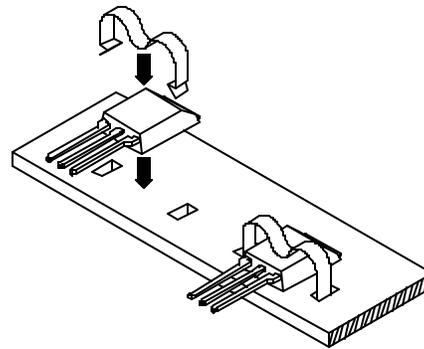


Figure 7. Saddle clip mounting of a Super220™ package.

- For heat sinks greater than 5mm in thickness, U clips are used. These produce contact forces of between 15N and 50N.

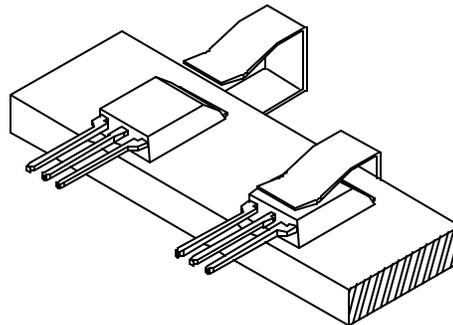


Figure 8. U-Clip mounting of a Super-220™ package.

- There are a number of proprietary clip solutions where the clip is anchored in a feature in an extruded heat sink. Forces of between 25N and 50N can be achieved.

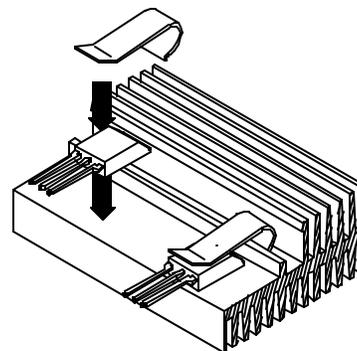


Figure 9. Customized Clip Mounting of a Super-220

Pop Riveting

- It is recommended that press rivets made of a soft material are used rather than pop rivets.
- The hole in the heat sink should be smaller than the device mounting hole, within acceptable tolerances. This ensures that the rivet squeezes more tightly on the heat sink than on the device,

Soldering

A separate application note covers soldering down power semiconductor packages “Surface Mounting of Larger Devices.” In general devices that are being mounted to aluminium heat sinks must be either screw or clip mounted. A new technology, Powersites™, allows solderable power semiconductor packages to be mounted to aluminium heat sinks.

Additional Information for Other Package Types

- Full-Pak devices do not require isolation pads or bushes as the package is isolated by design
- The Super220™ (TO-273) does not have a hole for screw mounting and should be mounted using clips. The ‘hole – free’ design allows the package to carry more current. Full instructions for mounting the Super220™ (TO-273) package are given in [AN-1000](#) “Mounting Guidelines for the Super-220”
- The Super247™ (TO-274) does not have a hole for screw mounting and should be mounted using clips. The ‘hole – free’ design allows the package to carry more current. Full instructions for mounting the Super247™ (TO-274) package are given in [AN-997](#) “Mounting Guidelines for the Super-247”
- Mounting instructions for the PowIRtab package are given in [AN-1010](#) “PowIRtab™ Mounting Guidelines.”
- This is a high current package suitable for mounting to bus bars.

Mounting SOT227

The SOT227 is a power module with some special mounting requirements.



- The package has two mounting holes and four connection terminals.
- Fasten the device to the heat sink before connecting the leads.
- The maximum allowable torque is 1.3Nm on the terminals and on the mounting base.
- M4 screws should be used with lock washers. These are included with the packages.
- The separation of the centre of the mounting holes is 30mm ± 0.2mm. Full details of the dimensions are given on the datasheet.
- The first mounting screw should be tightened to one third of the maximum torque, the second screw should then be tightened to the same torque. Full tightening of both of the screws can then be completed.
- The case to sink thermal resistance at the recommended mounting torque is 0.05C/W for a greased surface.