Mounting Guidelines for the SUPER-220

by Andrew Sawle and Arthur Woodworth

The impressive gains in power density born from the development of the ‘SUPER’ type power packages, *i.e. the SUPER-247*, has lead to a similar development of the TO-220 package. The removal of the hole and incorporation of new innovative ideas has lead to the SUPER-220. This new power package can now house areas of silicon that previously would have called for the use of a TO-247. These increases in power density allow designers to realise cost savings through reducing the number of paralleled devices required for a desired current rating and also reducing the areas of costly circuit board needed for their designs. Hence reductions in both the size and cost of designs are possible through the use of the SUPER-220 package.

However, increasing the power density within a design will mean that the designer needs to make careful consideration of the thermal aspects of the design aswell as the electrical. As with the SUPER-247 (see Application Note AN997) the SUPER-220 does not have a screw hole to facilitate bolting to a heatsink and therefore the package will need to be clip mounted. Clip mounting facilitates mass production techniques and good thermal performance but the latter will only be the case if the designer has made careful use of the thermal options available.

This Application Note is intended to outline the thermal options available to designers with regard to interface materials, clip types and the contact forces required to give good thermal contact and the performance that they might expect from each. The following topics will be covered:

- ➜ A brief revision of thermal resistance and its effects on system perfomance.
- ➜ Clip mounting of SUPER-220 devices to heatsinks, suppliers and interface materials.

Thermal Resistance and its Effects on System Performance

The thermal resistance ($Rth_{(junction-ambient)}$) of a system (system = package through to heatsink) is made up from a number of component parts as shown in Figure 1.1 below.

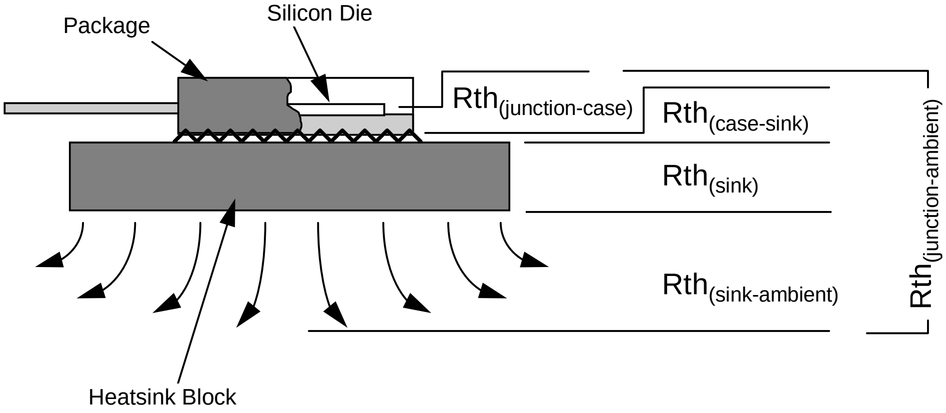

Figure 1.1 - Build-up of Thermal Resistance in a System

The designer of a system has varying amounts of influence over the component parts of the overall thermal resistance of his design:

- **Rth$_{(junction\text{-}case)}$** - this has been determined during the design and manufacture of the product. The system designer has no direct influence.
- **Rth$_{(case\text{-}sink)}$ (or Contact Thermal Resistance)** - determined by the size and quality of the contact areas between the package and the sink, the use of intermediate materials and the contact pressure. Hence, the system designer can have a large influence over this parameter.
- **Rth$_{(sink)}$ and Rth$_{(sink\text{-}ambient)}$** - determined by heatsink design, *i.e. material and shape.* The selection of a heatsink is done by trading off performance and cost requirements.

The thermal resistance of a system will determine the amount of power that can be dissipated by a device without exceeding the maximum junction temperature. Operating at temperatures above $T_{j(max)}$ will reduce the reliability of the device. Therefore by optimising the thermal performance of a system, a greater amount of power can be dissipated by each device thereby minimising the number of devices that need to be used.

Clip Mounting of the SUPER-220 Package

The removal of the hole from the TO-220 package to facilitate the greater area of silicon in the SUPER-220 package means that the new package can **NOT** be bolted to a heatsink. However the package lends itself to clip mounting, a technology that is quickly becoming popular as it holds a number of advantages over the older 'bolting' technology:

- Clips are quick to apply and therefore lend themselves to mass production assembly techniques.
- Clips maintain a constant assembly force even if the intermediate material deteriorates, unlike bolt assembly where the force diminishes.
- Clips impart their force on the central part of the package over the silicon, distributing the pressure evenly which creates a good thermal contact with the heatsink. Bolts however, impart the force at one end of the package and the pressure is uneven, see Figure 1.2.

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

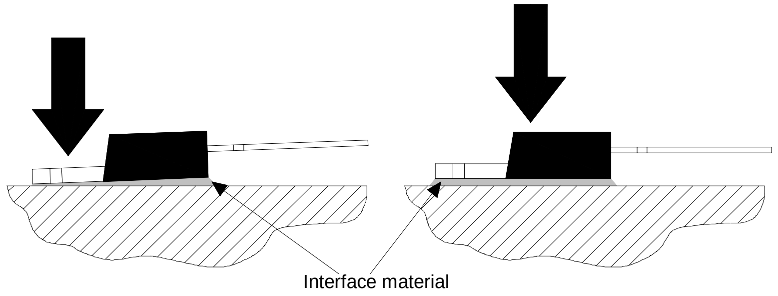

Figure 1.2 - Position of Force Application

The contact force and the way in which it is applied is therefore very important to the thermal performance of a system.

Why and How Does Contact Force Affect Thermal Resistance?

Package cases and heatsink surfaces are never perfectly flat. Hence contact between the two will only occur at several points allowing an air gap between the surfaces (as illustrated in Figure 1.3). Since air is a very good thermal insulator this means that the contact thermal resistance is much greater than it would be if the two surfaces were in perfect contact (no air gap). However, as the contact force (pushing the two surfaces together) increases then so will the number of points at which the two surfaces contact one another and the air-gap will be reduced, in turn reducing the contact thermal resistance.

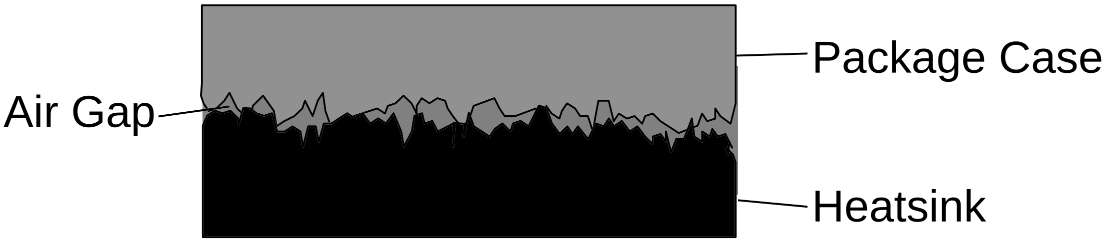

Figure 1.3 - Diagram Showing the Effect (Under High Magnification) When Two Non-perfect Surfaces Meet.

What is the minimum contact force that should be applied to gain good thermal contact

The minimum force required for a good thermal contact will vary from package to package as it will depend on the surface finish, flatness of contact surface and area of contact. Contact thermal resistance reduces with increased contact force but the relationship is non-linear. In essence, diminishing returns in reduced thermal resistance are seen for increases in force. This relationship for the SUPER-220 on a heatsink with NO interface materials, *i.e. 'dry' conditions*, is shown in Figure 1.4. A minimum contact force of 20N is recommended.

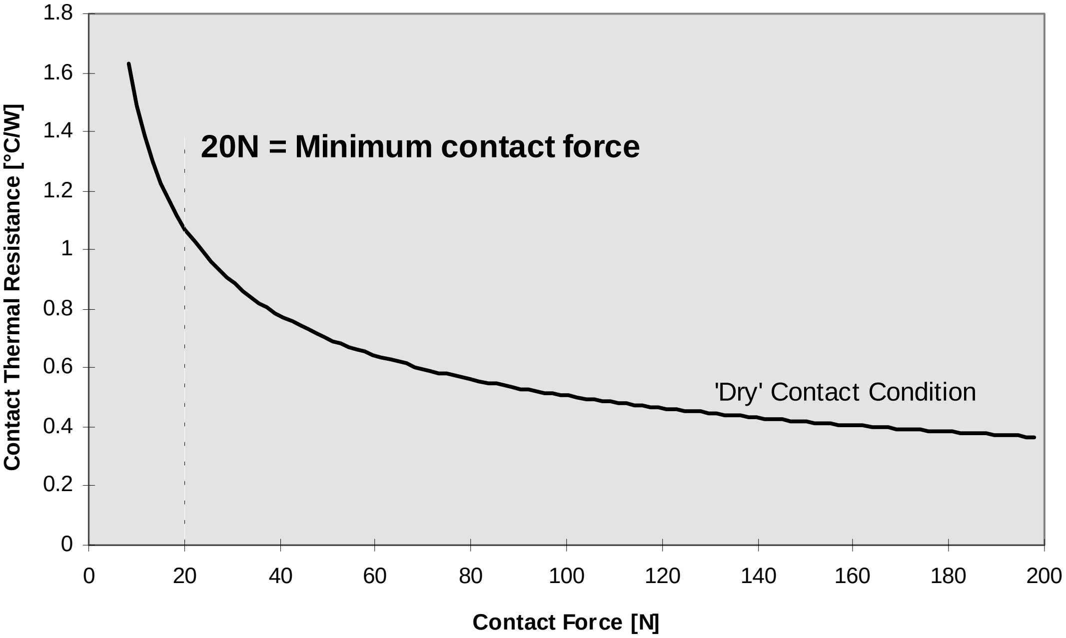

Figure 1.4 - Minimum Contact Force

Maximum Contact Force

The minimum contact force of 20N mentioned above is purely that, the MINIMUM force. Any force applied above that figure will still show gains in reduced contact thermal resistance until the maximum force that the package can withstand before the device characteristics are altered or the package is destroyed. This maximum limit figure has been measured to be 200N TYP. However, these gains are not free, for in general terms a greater contact force means a larger, more expensive clamping system. A contact force should therefore be chosen that optimises both the thermal and the cost requirements of the system.

Contact Conditions

As mentioned previously, the contact conditions between the package and the heatsink will affect the contact thermal resistance. Contact conditions encompass a number of areas including: surface roughness, surface cleanliness, paint finishes and intermediate materials. The surface roughness of the heatsinking material should be no greater than 0.02mm over the area where the device is to be mounted. Surface cleanliness during assembly of package and heatsink is imperative, even if a thermal grease or other material is subsequently added. Unclean surfaces can be held apart by dirt or grease thus increasing the thermal resistance. However, normal paint finishes (up to 50 mm thick) have been shown to have little effect on thermal resistance, this therefore leaves intermediate materials as an area for discussion.

Interface Materials

Figure 1.4 above shows the force vs Rth relationship for 'dry' conditions, however, the use of no interface materials in an assembly is rare and usually one of two conditions is required:

- An interface material to improve the thermal performace of the contact area between device and heatsink.
- An interface material providing electrical isolation between the device and heatsink whilst minimising the adverse effects that it will have on the the thermal performance of the contact area. Isolation is usually required where more than one device is going to share the same heatsink.

Heatsink compound

A number of different companies offer heatsinking compound, these usually consist of silicon grease loaded with some electrically insulating, good thermally conducting material such as alumina. Thinly applied, these compounds are advantageous as they fill the air gaps and do not further increase the distances between the surfaces. Thickly applied they can hold the two surfaces apart and increase the contact thermal resistance. The following graph displayed in Figure 1.5 shows the contact thermal resistance for 'dry' conditions (no compound) and the thermal resistance using compound, both are plotted against contact force.

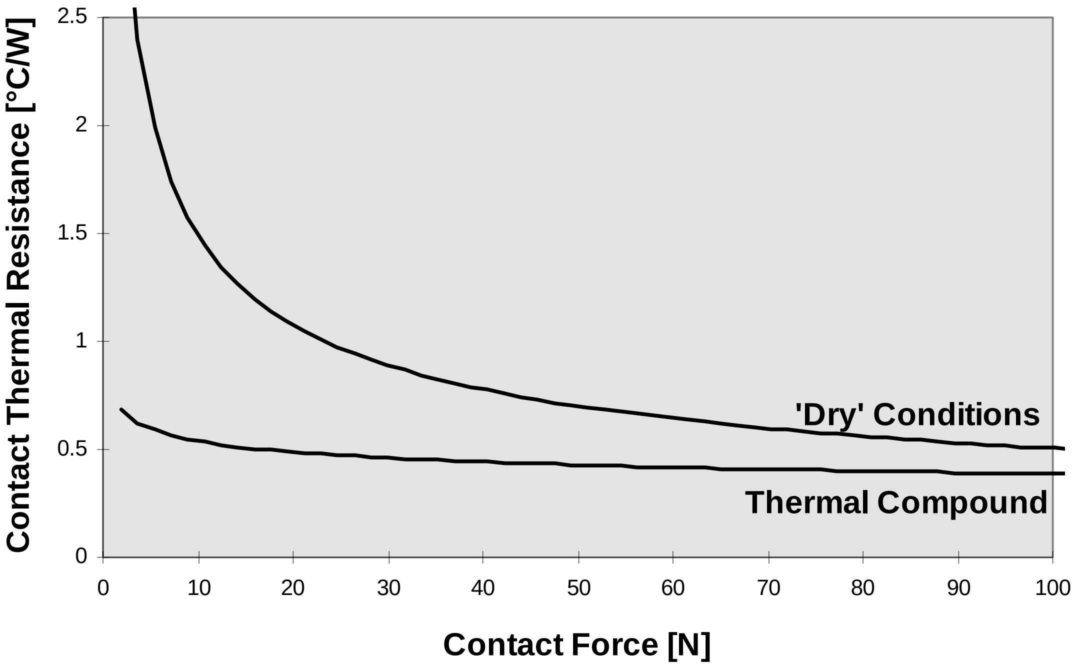

Figure 1.5 - Contact Thermal Resistance for 'Dry' and Compound Conditions, Plotted Against Contact Force

Interface Pads

The metal heatspreader on the back of the SUPER-220 package is non-electrically isolated from the pinouts of the device within, *i.e. the case is the drain contact for a MOSFET.* Hence in cases where devices are not electrically paralleled but share the same heatsink, it is necessary to insert an electrically isolating material between the package and the heatsink block. The isolator usually takes the form of a pad and many companies offer a range of pad material types and sizes dependant on requirements.

The pad obviously has a direct and detremental effect on the contact resistance as insertion adds an extra resistance into the build-up. Again, the contact thermal resistance is dependant on contact pressure. The following graph, shown in Figure 1.6, illustrates the higher thermal resistance when using an isolator pad. The isolator used for the line plot was a typical silicone loaded pad. Therefore, it should be noted that when electrically isolating a device from a heatsink the thermal resistance of the system will increase.

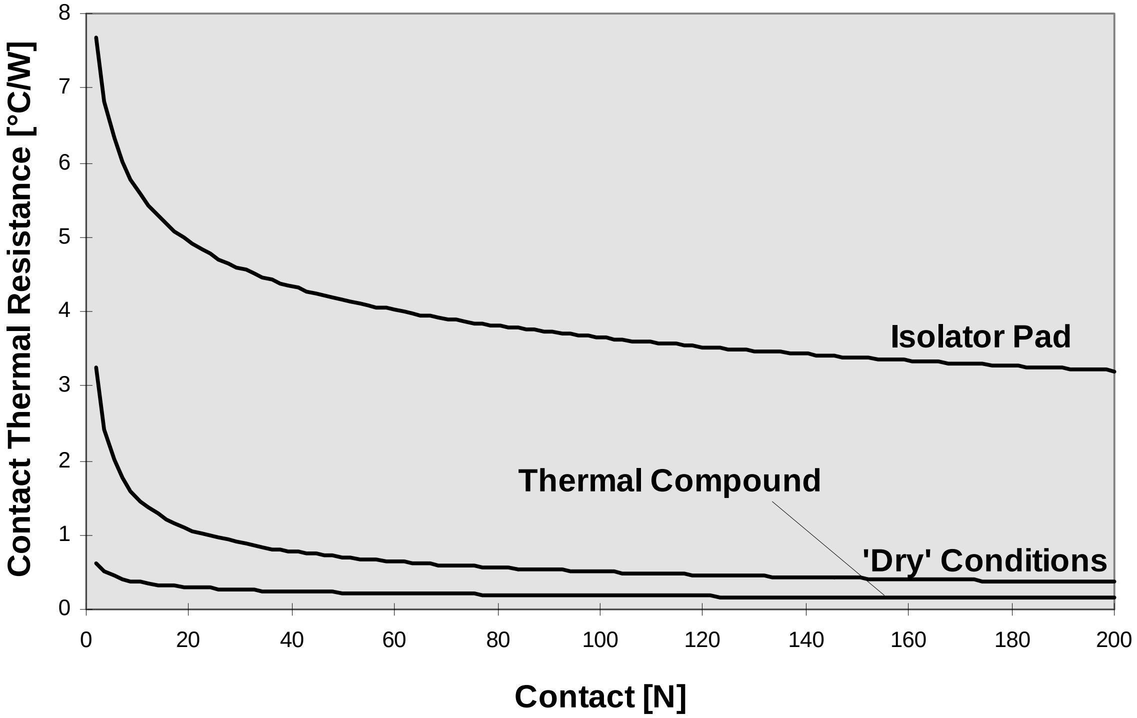

Figure 1.6 - Contact Thermal Resistance Plotted Against Contact Force

Phase Change Materials

One of the problems that interface pads have is that the forces required for good thermal contact are very high. This is because it is difficult to gain the amount of pad deformation necessary to fill the air-gaps in the heatspreader/pad and pad/heatsink interfaces. One of the solutions being offered by a number of suppliers is that of PHASE-CHANGE materials.

Phase change materials are a solid in nature until raised above a certain temperature (~50-65°C) at which point they become a viscous fluid, this change from solid to viscous occurs every time the temperature goes to this level. This fluidity means that with an adequate contact force the air-gaps can easily be filled and good thermal contact can be made. This good contact is maintained once the temperature is reduced as the material solidifies in place, filling the gaps.

The following chart in Figure 1.7 shows the contact thermal resistance using a typical phase-change isolating pad and a non-isolating pad.

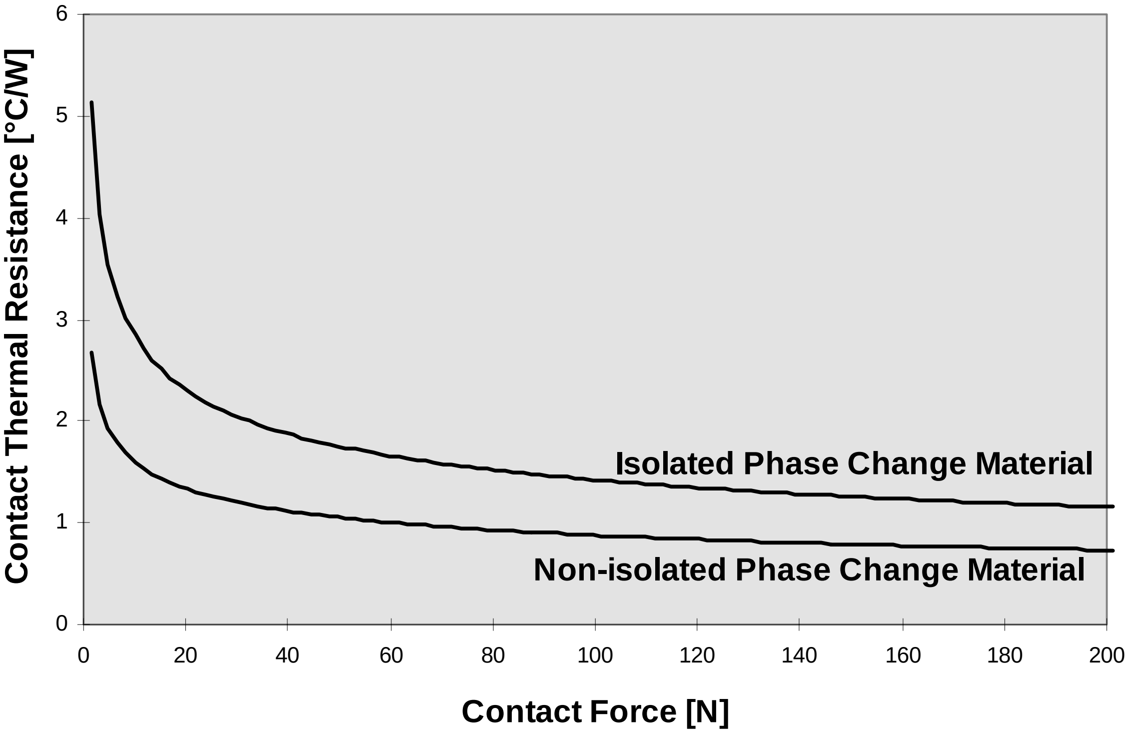

Figure 1.7 - Contact Thermal Resistance for Isolated and Non-isolated Phase Change Materials

It can be seen that phase change materials can offer lower contact thermal resistances when isolation is required over regular isolation pads. Two current manufacturers/suppliers of phase change materials are **Berquist** and **Orcus Inc**.

Heatsinks and Clips

A range of heatsinks and clips have been developed by a number of suppliers for the SUPER-220 package type. A number of these clip types are shown in the following diagrams. However, the clips shown are only a small selection and by no means encompass all available types and solutions.

Saddle Clips

An example of a SUPER-220 mounted to a heatsink using a saddle clip is shown in Figure 1.8.

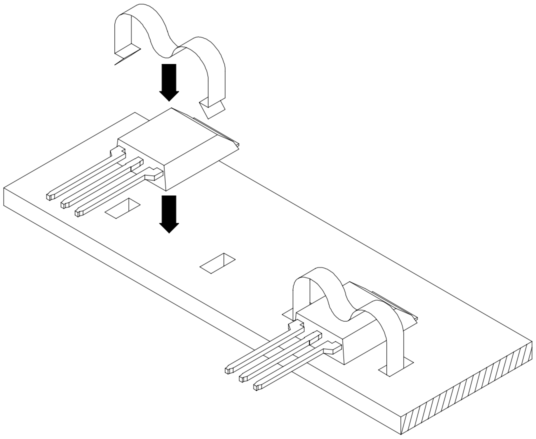

Figure 1.8 - SUPER-220 Mounted to Heatsink Using Saddle Clip

When using saddle clip type solutions, the heatsink materials are thin in cross-section, typically less than 5mm in thickness. The clips push into holes cut into heatsink material and lock against the back face of the heatsink. These clips produce contact forces in the range 15-50N.

'U' Clips

An example of a heatsink assembly utilising a 'U' clip is shown in Figure 1.9.

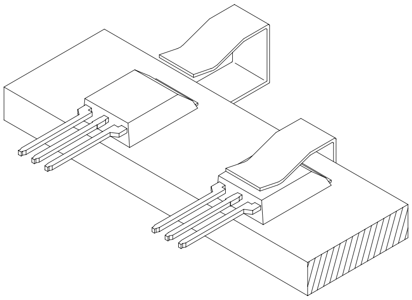

Figure 1.9 - SUPER-220 and a 'U' Clip Assembly

This clip type clamps the device and the heatsink material together. Variations on this clip type allow devices to be clamped to the front and back of the heatsink block using the same clip. 'U' clips can offer contact forces in the range 15-50N.

Extrusion Mounted Clips

There are a number of proprietary clip solutions offered where the clip is anchored in a feature in an extruded heatsink. One such solution is to use rails on extruded sinks for clip anchorage. This method is shown in Figure 1.10.

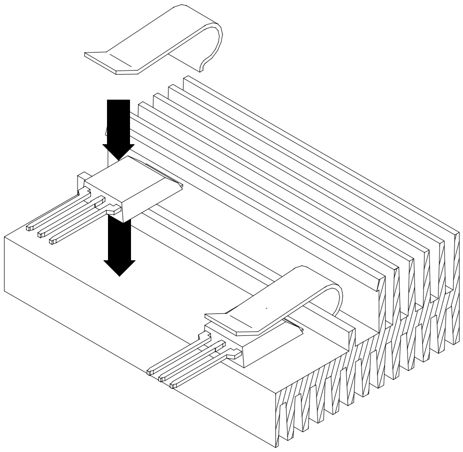

Figure 1.10 - Extrusion Mounted Clip (Rail Anchorage)

Clips on extruded sinks can offer contact forces in the range 25-50N

Typical Clip Solution Suppliers

Redpoint Thermalloy
Cheney Manor,
Swindon,
Wiltshire. SN2 2QN
England

Thermalloy, Inc.
2021 W. Valley View Ln.,
Dallas, TX 75234
USA

Avvid Thermal Technologies
Corporate Headquarters,
One Kool Path,
Laconia,
New Hampshire, USA

Austerlitz Electronic gmbh
Ludwig Feuerbach-Straße 38, 90961
Nüenburg,
Postfach 1048, GERMANY