Heat Sink Attachment Options

What Are They and What Do You Need to Know about them?

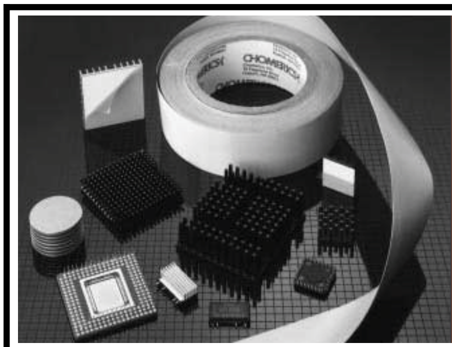
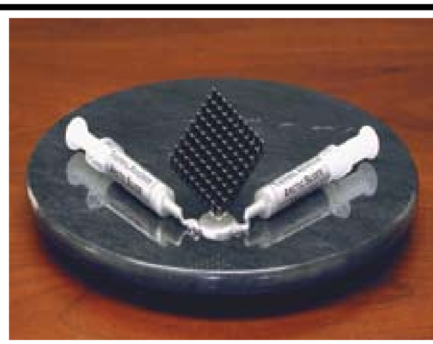
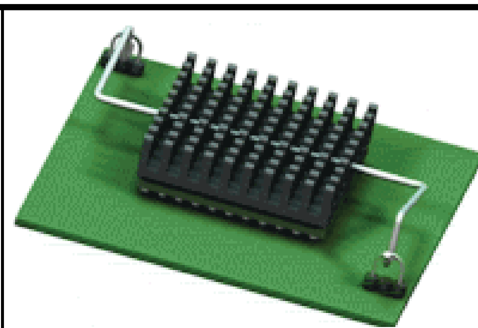
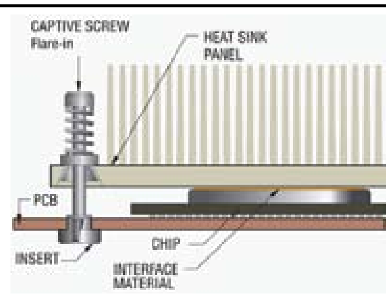
Introduction

As power levels for board components have risen, thermal engineers have been forced to design larger and more innovative heat sinks than ever before. Along with the thermal challenge has come the mechanical challenge of attaching these heat sinks to the components in a reliable fashion. There are many traditional as well as new attachment methods that the designer can choose from. In this article, we will explore some of the commonly available attachment options on the market along with their respective advantages and disadvantages [1].

Discussion

There are a multitude of heat sink attachment solutions available. Table 1 shows some of the possibilities.

Table 1. Different Heat Sink Attachment Solutions [1].

		
Thermal Tape	**Epoxy**	**Wire Form "Z-Clips"**
Pressure sensitive adhesive tape, acrylic	Single or dual-part mixed adhesive with thermally conductive fillers	Stainless steel wire formed clip
		
Clips	**Threaded Stand-Offs (PEMs) and Compression Springs**	**Push-Pins & Compression Springs**
Plastic or plastic/wire clips that grip the components	Threaded mechanical assemblies that offer the highest level of retention and stability	Plastic or brass push-pins that offer quick and easy mechanical attachment

Thermal Tape

Thermal tape is the most cost effective of the heat sink attachment solutions, and is suitable for low-mass heat sinks and for components with low power dissipation. It consists of a thermally conductive carrier material with a pressure sensitive adhesive on each side. The tape is applied to the base of the heat sink and then the heat sink is attached to the component. For tape to work well, proper cleaning of the component surface and the base of heat sink is required. Also, it is usually necessary to apply the tape with a certain amount of pressure. Insufficient pressure can result in areas of non-contact and high interfacial resistance. Finally, thicker tapes tend to provide better "wettability" with uneven component surfaces as shown in Figure 1.

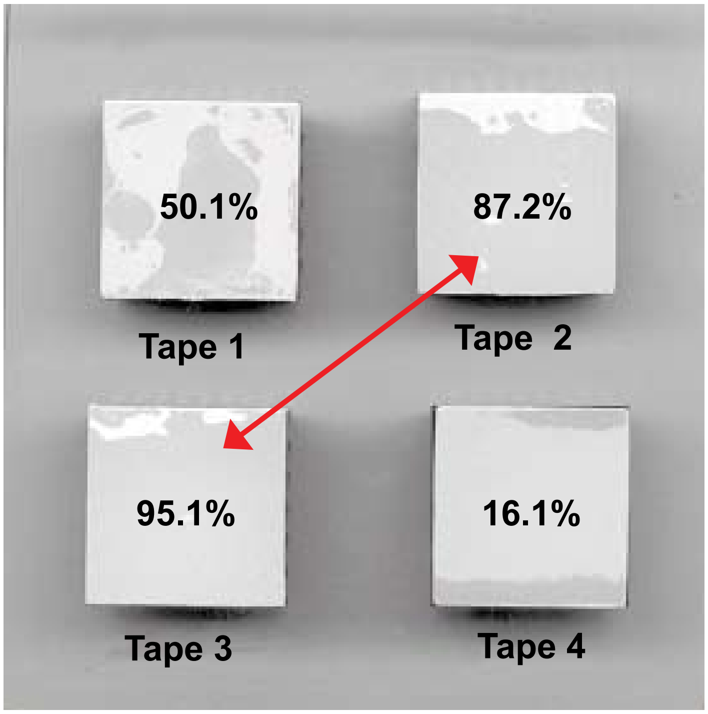


Figure 1. Picture of Contact Area as a Function of Tape Thickness (Tape1 = 0.005", Tape 2 = 0.010", Tape 3 = 0.015"). Dark areas show adhesive wetout. [2].

However, this causes a thermal penalty because thicker tapes have increased thermal impedance (Figure 3).

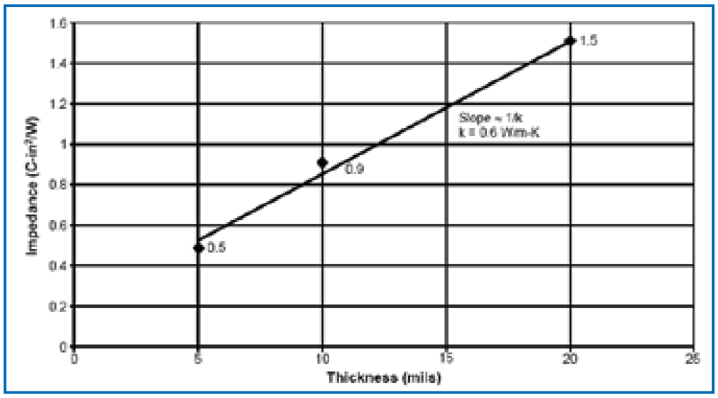


Figure 2. Graph of Tape Thermal Impedance with Respect to Tape Thickness.

From a design standpoint, it is best to strike a balance by selecting a tape thickness that provides maximum "wettability" with minimum thermal impedance.

Epoxy

Epoxy is more expensive than tape, but provides a greater mechanical bond between the heat sink and component, as well as improved thermal conductivity (typically two to three times better). Most epoxies are two-part liquid formulations that must be thoroughly mixed before being applied, and then cured for a specified amount of time (anywhere from two to forty-eight hours). Often times, to obtain faster curing times, additional heat is required during the process. As with tape, the heat sink and component surfaces must be clean. The bond between the heat sink and component is semi-permanent/permanent when epoxy is used, making component re-work very difficult and at times impossible. Both in the case of tape and epoxy, the most typical damage caused by the re-work is the separation of the heat spreader from its package.

Wire Form z-clips

More expensive than tape and epoxy, wire form z-clips add additional mechanical attachment not offered by tape or epoxy. As the name suggests, the z- clip is typically a wire bent in the form of a "Z" though many custom variations abound. In a typical application, a solder-anchor is installed in the board at opposite corners of the component, providing mounting points for the z-clip (Figure 3).

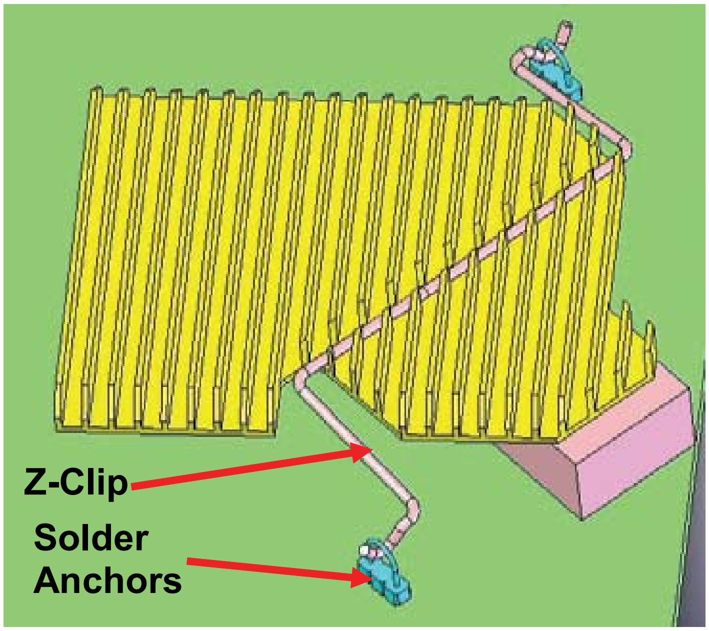


Figure 3. Heat Sink with Z-clip and Solder Anchors.

Once installed, the deflected clip develops a spring load on the heat sink. This consistent spring pressure allows for the use of higher performance phase-change thermal interface materials. Some typical z-clip loads are shown as a function of chip height and heat sink base thickness in Figure 4.

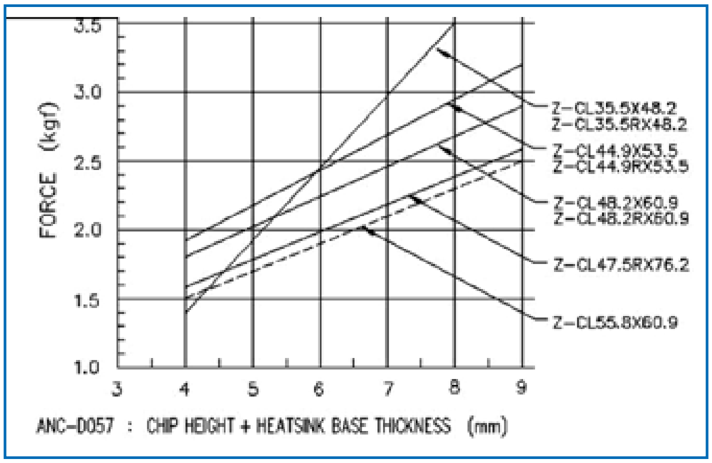


Figure 4. Typical Loads for Z-clips [3].

One caveat in the use of z-clips is the need for holes in the

PWB, and the other is the availability of the solder anchor. The latter is further amplified as the industry is moving towards RoHS approved solder which does not exhibit the same mechanical strength.

Clips (Includes maxiGRIP™)

Comparable with z-clips in price, clips that attach directly to the component provide an advantage over z-clips in that no holes are required in the PWB, and they usually allow for easy re-work of components. The ATS maxiGRIP™ is an example of such an attachment. The maxiGRIP™ uses a plastic frame clip that attaches directly to the component and provides a mounting platform for a custom spring clip (Figure 5).

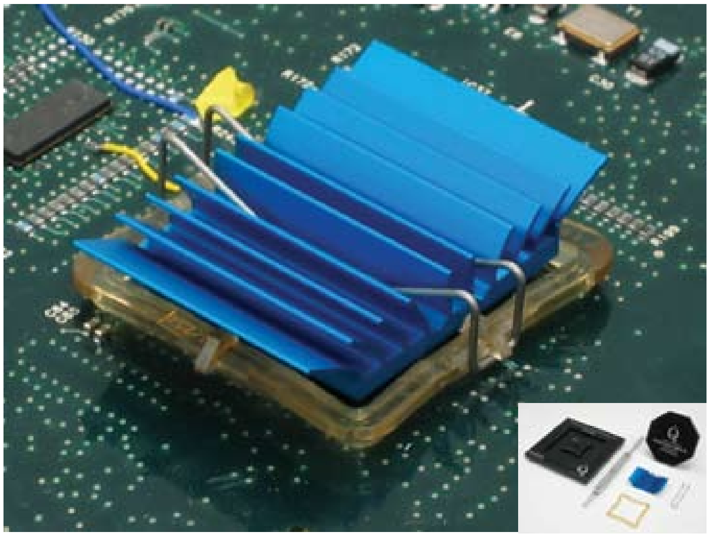


Figure 5- maxiGRIP™ Heat Sink Attachment Solution.

The frame clip can be installed by using a special tool which expands all four sides of the clip simultaneously, allowing the clip to be placed directly over the component package (A keep out area is usually required). Once released, tabs on each side engage and secure the clip to the component, creating a secure mounting platform for the spring clip. The spring clip, which is designed to provide a very precise load, is then installed to hold the heat sink in place, maintaining continuous pressure at the heat sink component interface. The maxiGRIP™ assembly has a big advantage over other heat sink attachment methods in that it allows for the use of high performance phase change interface materials.

Extensive FEA and shock and vibration testing of the maxiGrip™ assembly have been done to provide a carefully engineered heat sink attachment solution with a high-level of reliability.

Push Pins & Compression Springs

For larger heat sinks and higher pre-loads, push-pins with compression springs are the most effective. The push-pin is typically made of brass or plastic with a flexible barb at the end that is designed to engage with a pre-drilled hole in the PWB (Figure 6).

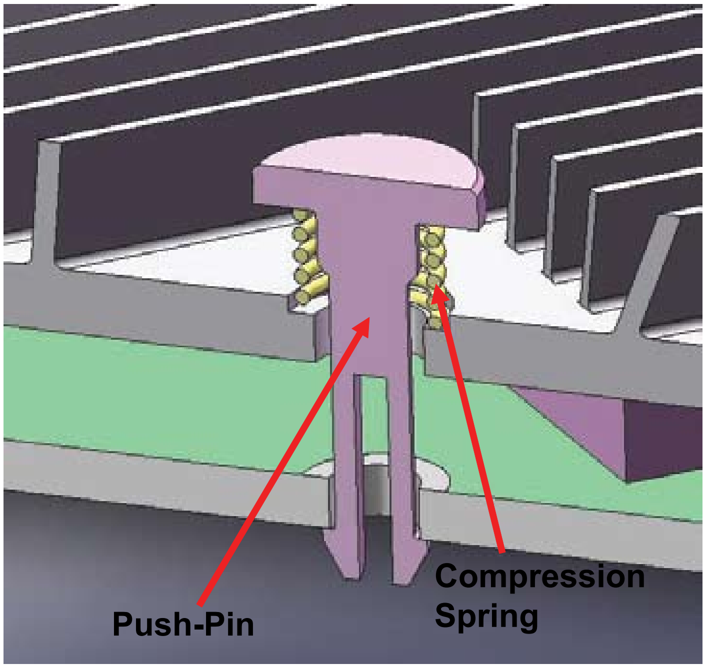


Figure 6. Cross Section View of Push-Pin & Compression Spring Attachment.

The compression spring adds the necessary spring force to hold the assembly together. The force exerted by the compression spring can be described by the following simple equation:

$$F = k \cdot x \quad (1)$$

Where,
F = Compression force
k = Spring rate (typically reported in manufacturers brochures)
x = Spring deflection

By selecting push-pins of different heights (which effects x), and different compression springs (with fixed or variable k), it is possible to vary the spring force on the heat sink as required to maintain consistent pressure.

Care must be taken, however, to select a push-pin and compression spring combination that will not exert too much force on the component; so as to crack the die, resulting in component failure is possible in these instances.

Threaded Standoffs and Compression Springs

For very large heat sinks, there is no substitute for the threaded standoff and compression spring attachment method. A threaded standoff is essentially a hollow metal tube with internal threads. One end is secured with a screw through a hole in the PWB. The other end accepts a screw which depresses the compression spring, completing the assembly (Figure 7).

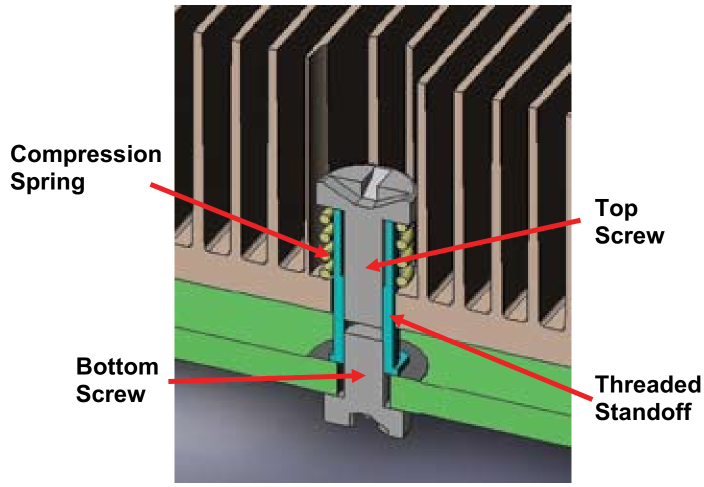


Figure 7. Cross Section View of Threaded Standoff with Compression Spring.

A typical heat sink assembly uses two to four standoffs, which tends to make this the most costly heat sink attachment

Table 2. Summary Table of Heat Sink Attachment Solutions [1].

Method	Pros	Cons	Cost
Thermal Tape	• Easy to attach • Inexpensive	• Does not perform well with heavier heat sinks • Surface must be cleaned for optimal adhesion • Moderate to low thermal conductivity	$
Epoxy	• Strong mechanical adhesion • Relatively inexpensive	• Makes board rework difficult and can damage the component • Surface must be cleaned for optimal adhesion	$$
Wire Form (Z-Clips)	• Strong mechanical attachment • Easy removal/rework • Applies a preload to the TIM, improving thermal performance	• Requires holes in the board or solder anchors • More expensive than tape or epoxy • Custom designs	$$$
Clip-on	• Applies a preload to the TIM, improving thermal performance • Requires no holes or anchors • Easy removal/rework	• Must design in the attachment for proper keep-out zone around BGA • Extra assembly steps	$$$
Push-pin w/ Compression springs	• Strong mechanical attachment • Highest TIM preload • Ideal for large HS • Easy removal and installation	• Requires holes in the board, limiting amount of trace on the PCB • Cost	$$$$
Stand-offs w/ Compression Springs	• Strongest mechanical attachment • Highest TIM preload • Ideal for large HS	• Requires holes in the board, limiting amount of trace on the PCB • Complicated assembly • Cost	$$$$$

solution. Another disadvantage is the need for holes in the PWB.

A summary of the various heat sink attachment solutions and their pros and cons is shown in Table 2.

Conclusion

As component power levels continue to rise, there is a greater need for larger heat sinks and better thermal interface materials to meet these thermal demands. This trend has required designers to pay closer attention to the type of heat sink attachment used to make sure all of the mechanical, thermal, and cost requirements are met. In this article, we explored six of the most common attachment solutions, and summarized the relative strengths and weaknesses of each. In general, Thermal Tape and Epoxy adhesive methods are the most cost effective, but are only useful on small (low mass) heat sinks. Z-Clips, and especially clip-on methods (including the maxiGRIP™), have a wide range of applicability and are moderately priced. Finally, push pins and standoffs, with compression springs, are useful for large heat sinks, but the cost can be significantly higher.

References:

1. Mennucci, J., Heat Sink Selection Made Easy, ATS Thermal Webinar Series Presentation, April 30, 2008.
2. Mennucci, J., Haskell, M., Innovative Thermal Management of Cooling Flip Chip Packages, Nov., 7, 2007.
3. Clip Load for Heat Source, http://www.alphanovatech.com/c_zclipe.html, Alpha NovaTech, Inc. 2007.