

This application note provides guidance on thermal management and mechanical handling of lidless flip chip ball-grid array (FCBGA) for Altera® devices.

This application note includes the following sections:

- “Lidless FCBGA Overview”
- “General Properties of Thermal Interface Materials”
- “Attaching Heat-Sinks” on page 4
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- “Handling and Transfer for Lidless FCBGA” on page 13
- “Vendors List” on page 14

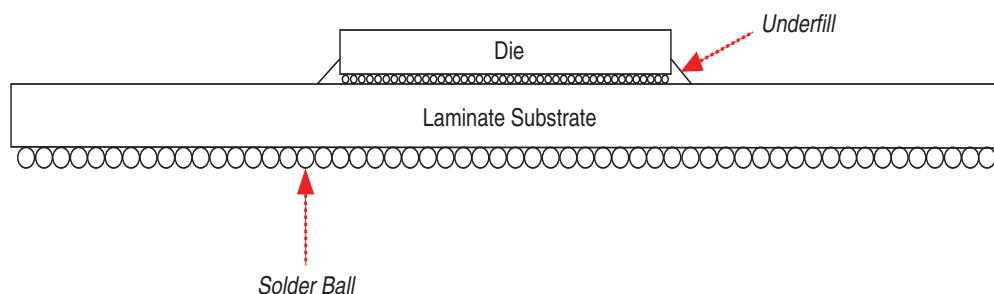
## Lidless FCBGA Overview

Lidless FCBGA packages maximize PCB real estate by allowing closer spacing between passive components and the flip chip die. Lidless FCBGA packages enable the die to contact with an external heat sink, ensuring the thinnest band line and best thermal impedance between the flip chip die and the attached heat sink.

Altera produces the lidless FCBGA package in an exposed die configuration. This configuration maintains the excellent thermal performance of bare die for the lidless FCBGA and provides a support surface around the bare die for a direct heat-sink attachment.

Figure 1 shows the cross section of the lidless FCBGA.

**Figure 1. Cross Section of the Lidless FCBGA**



The coplanarity specification limits for lidless FCBGA less than or equal to 35 mm x 35 mm: 8 mils (0.20 mm). [Table 1](#) lists an example of the coplanarity data measured from production of an Arria II GX EP2AGX260 device in F1152 package.

**Table 1. Coplanarity Data**

Yield	Min (mil)	Max (mil)	Average (mil)	Std Dev	Std Dev + 3 $\Sigma$	Cpk
100%	4.74	6.71	5.73	0.40	6.93	1.89

## General Properties of Thermal Interface Materials

Altera recommends considering the suitable thermal interface material (TIM) type early in your design. TIMs can be the limiting factors in the expense of thermal management designs. You can use TIM effectively to help reduce the size of the heat sinks and the need for larger cooling fans. The extended benefit of an effective TIM is a solution that is faster, easier to apply, and less costly than changing heat sinks or redesigning a chassis.

[Table 2](#) lists the types of TIM and their advantages and disadvantages.

**Table 2. TIM Type Advantage and Disadvantage (Part 1 of 2)**

TIM Type	Description	Advantage	Disadvantage
Thermally Conductive Adhesive or Epoxy	<ul style="list-style-type: none"> <li>Thermally conductive adhesive is silicone-based formulation that contain filler. Thermally conductive adhesive offers a superior mechanical bond.</li> <li>Epoxy is particle-laden, one-or two-component materials that you can apply through dispensing or stencil printing.</li> </ul>	<ul style="list-style-type: none"> <li>Provides structural support, eliminating the need for mechanical clamping.</li> <li>Cured to allow for cross-linking of the polymer, which provides the adhesive property.</li> </ul>	<ul style="list-style-type: none"> <li>May not provide sufficient bond strength because of the small contact area.</li> <li>The relative high impedance might affect the thermal performance significantly.</li> <li>Device rework is very difficult and may result in damaging the device.</li> </ul>
Thermal Tape	Filled pressure sensitive adhesives (PSAs) coated on a support matrix such as polyimide film, fiberglass mat, or aluminum foil.	<ul style="list-style-type: none"> <li>Convenient for heat-sink attachment with mid-range thermal performance.</li> <li>Does not require mechanical clamping.</li> <li>Works best on flat surfaces.</li> </ul>	<ul style="list-style-type: none"> <li>Plastic ICs are usually concave in the center, and heat-sink surfaces may vary. This unevenness can result in air gaps in the interface.</li> <li>May not provide sufficient bond strength without the help of mechanical attachment, causing the heat sink to fall off.</li> <li>Device rework is very difficult and may result in damaging the device.</li> <li>Heat sinks may come off over time because of the heat and weight of the heat sinks for vertically-mounted PCBs.</li> </ul>

**Table 2. TIM Type Advantage and Disadvantage (Part 2 of 2)**

TIM Type	Description	Advantage	Disadvantage
Thermal Grease	Contains silicone oil loaded with thermally conductive filler.	<ul style="list-style-type: none"> <li>Low thermal resistance.</li> <li>Does not require curing.</li> <li>Flows and conforms to surfaces.</li> <li>Offers a reworkable thermal interface layer.</li> </ul>	<ul style="list-style-type: none"> <li>Requires mechanical clamping.</li> <li>Messy and difficult to apply because of its high viscosity.</li> <li>Can degrade, pump-out, or dry out during extended operation and over time, causing the thermal performance of the TIM to suffer significantly.</li> </ul>
Thermal Gel	Low modulus, paste-like material that is lightly cross-linked.	<ul style="list-style-type: none"> <li>Low thermal resistance.</li> <li>Conforms to surfaces, while displaying reduced material pump-out.</li> </ul>	Requires mechanical clamping.
Thermal Pad	<ul style="list-style-type: none"> <li>Fabricated by molding non-reinforced silicone with conductive fillers.</li> <li>Reinforcements for thermal pads include woven glass, metal foils, and polymer films.</li> </ul>	<ul style="list-style-type: none"> <li>Pre-cut.</li> <li>Offers gap-filling functionality.</li> </ul>	<ul style="list-style-type: none"> <li>Requires mechanical clamping.</li> <li>Limited thermal performance.</li> <li>Sensitive to pressure.</li> </ul>
Phase Change Material (PCM)	Undergoes a transition from a solid to a semi-solid phase with the application of heat and pressure. The material is in a liquid phase at die-operating conditions.	<ul style="list-style-type: none"> <li>Low thermal resistance.</li> <li>Able to conform to mating surfaces.</li> <li>Does not require curing</li> </ul>	<ul style="list-style-type: none"> <li>Requires mechanical clamping.</li> <li>Rework is difficult.</li> </ul>

## Recommended TIMs

Table 3 lists the TIMs recommended by Altera TIM vendors. Factors such as gap-filling capability, conductivity of materials, compatibility with molding compound, and ease of use determine the typical application recommendations.

**Table 3. TIMs Recommended for the Lidless FCBGA Package (Part 1 of 2)**

Vendor	Product	Type	Conductivity	Format	Typical Application
Laird Technologies	Tpcm 780	Phase change	5.5 W/m <sup>2</sup> K	Pad	Desktop and laptop PCs
Laird Technologies	Tpcm 780SP	Phase change	5.5 W/m <sup>2</sup> K	Liquid	Desktop and laptop PCs
Laird Technologies	Tpcm 580	Phase change	3.8 W/m <sup>2</sup> K	Pad	CPUs, custom ASIC, and GPUs
Laird Technologies	Tgrease 980	Thermal grease	3.8 W/m <sup>2</sup> K	Grease	CPUs, custom ASIC, and GPUs
Laird Technologies	Tgrease 880	Thermal grease	3.1 W/m <sup>2</sup> K	Grease	CPUs, custom ASIC, and GPUs
Laird Technologies	Tgrease 2500	Thermal grease	3.8 W/m <sup>2</sup> K	Paste	High-performance CPUs and GPUs
Bergquist	3500S35	Gap filler (2 parts)	3.6 W/m <sup>2</sup> K	Pad	PCBA to housing
Chomerics	T777	Phase change	3.5 W/m <sup>2</sup> K	Pad	CPUs, GPUs, and chipsets
Chomerics	976	Gap filler	3.0 W/m <sup>2</sup> K	Pad	CPUs, GPUs, and chipsets
Chomerics	579	Gap filler	1.5 W/m <sup>2</sup> K	Pad	CPUs, GPUs, and chipsets

**Table 3. TIMs Recommended for the Lidless FCBGA Package (Part 2 of 2)**

Vendor	Product	Type	Conductivity	Format	Typical Application
Chomerics	T411	Thermal conductive tape	0.5 W/m <sup>2</sup> K	Tape	CPUs, GPUs, and chipsets
Laird Technologies	T Flex HR600	Gap filler	3.0 W/m <sup>2</sup> K	Pad	Cooling to chassis, frames
Laird Technologies	T Flex HR400	Gap filler	1.8 W/m <sup>2</sup> K	Pad	Cooling to chassis, frames



To prevent the die from chipping or cracking, ensure that the TIM is enough to cover the edges of the die when applying TIM to the heat sink and package.

## Attaching Heat-Sinks

You can attach a heat sink to a heat source in several ways. For efficient heat dissipation, you must consider the advantages and disadvantages of each heat sink attachment method.

When attaching a heat sink to a heat source with a small contact area such as the lidless FCBGA package, you must consider the following factors:

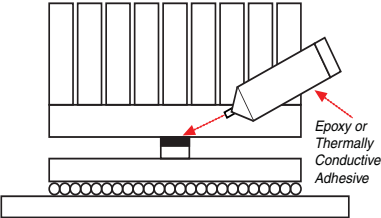
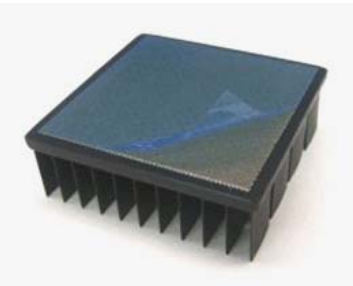
- Possibility of the heat sink tipping or tilting
- Possibility of damaging the exposed die during the heat sink installation
- Contact area can be too small to form a strong bond with an adhesive or a tape attachment

## Heat-Sink Attachment Methods


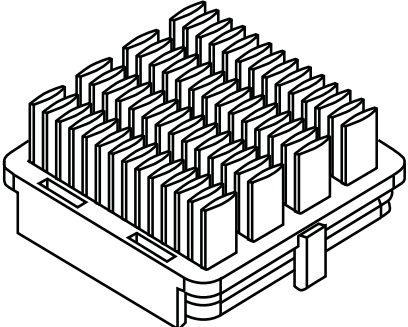
You can use two types of heat-sinks attachment; mechanical and non-mechanical.

**Table 4** lists the types of heat-sink attachments, typical attachment methods, advantage and disadvantage of the attachment methods and their suitability for lidless packages.



**Table 4. Advantage and Disadvantage for Each Attachment Method (Part 1 of 3)**

Attachment Method	Attachment Type	Advantage	Disadvantage or Risk	Suitability for Lidless Package
Epoxy or Thermally Conductive Adhesive 	Non-Mechanical	Requires no additional spaces on the PCB.	<ul style="list-style-type: none"> <li>■ Harder to control the application process.</li> <li>■ Rework is very difficult.</li> <li>■ May damage the die.</li> <li>■ For more information about the risks, refer to “Non-Mechanical Heat-Sink Attachment Risks and Disadvantages” on page 8.</li> </ul>	<ul style="list-style-type: none"> <li>■ Does not provide sufficient bond strength because of the small contact area.</li> <li>■ May cause the heat sink to tip or tilt. For more information, refer to “Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages” on page 9.</li> </ul>
Thermal Tape 	Non-Mechanical	Requires no additional spaces on the PCB.	<ul style="list-style-type: none"> <li>■ Relatively high impedance of tape significantly affects the thermal performance.</li> <li>■ For more information about the risks, refer to “Non-Mechanical Heat-Sink Attachment Risks and Disadvantages” on page 8.</li> </ul>	<ul style="list-style-type: none"> <li>■ Does not provide sufficient bond strength because of the small contact area.</li> <li>■ Not suitable for applications in which the PCB or heat sink is perpendicular to the ground, especially for lidless package.</li> <li>■ May cause the heat sink to tip or tilt. For more information, refer to “Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages” on page 9</li> </ul>

**Table 4. Advantage and Disadvantage for Each Attachment Method (Part 2 of 3)**

Attachment Method	Attachment Type	Advantage	Disadvantage or Risk	Suitability for Lidless Package
<p>Z-Clip</p> 	Mechanical Attachment	Provides stable attachment to heat source and transfers load to mounting anchors or the PCB.	Requires additional space on the PCB for anchor locations; however, Z-clip requires lesser space than other mechanical attachment types, such as push pins and shoulder screws.	May cause the heat sink to tip or tilt. For more information, refer to “ <a href="#">Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages</a> ” on <a href="#">page 9</a>
<p>Talon Clip</p> 	Mechanical Attachment	Provides stable attachment to heat source and transfers load to mounting anchors or the PCB.	Requires additional space on the PCB for anchor locations; however, Talon-clip requires lesser space than other mechanical attachment types, such as push pins and shoulder screws.	May cause the heat sink to tip or tilt. For more information, refer to “ <a href="#">Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages</a> ” on <a href="#">page 9</a>

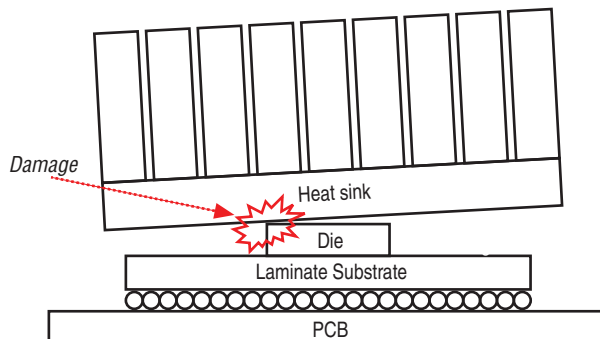
**Table 4. Advantage and Disadvantage for Each Attachment Method (Part 3 of 3)**

Attachment Method	Attachment Type	Advantage	Disadvantage or Risk	Suitability for Lidless Package
Push Pin 	Mechanical Attachment	<ul style="list-style-type: none"> <li>■ Provides a stable attachment to a heat sink and transfers load to the PCB.</li> <li>■ Allows for tight control over mounting force and load placed on chip and solder balls.</li> </ul>	Requires additional space on the PCB for push pin locations.	May cause the heat sink to tip or tilt. For more information, refer to “ <a href="#">Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages</a> ” on page 9
Shoulder Screw 	Mechanical Attachment	<ul style="list-style-type: none"> <li>■ Provides stable attachment to heat sink and transfers load to the PCB, backing plate, or chassis.</li> <li>■ Suitable for high mass heat sinks.</li> <li>■ Allows for tight control over mounting force and load placed on chip and solder balls.</li> </ul>	Requires additional space on the PCB for shoulder screws locations.	May cause the heat sink to tip or tilt. For more information, refer to “ <a href="#">Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages</a> ” on page 9

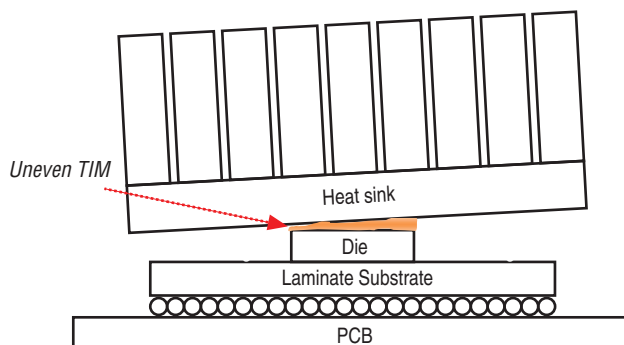
## Non-Mechanical Heat-Sink Attachment Risks and Disadvantages

Figure 2 and Figure 3 show the risk of die damage and poor thermal performance due to uneven heat sink placement for non-mechanical heat-sink attachment.

**Figure 2. Die Damage**

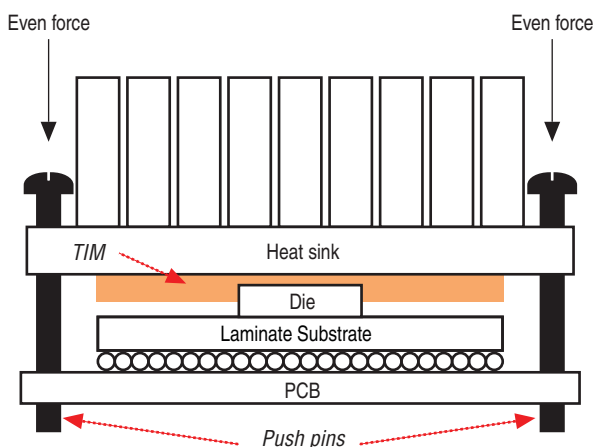


**Figure 3. Uneven Bond Line Thickness of TIM**



With mechanical heat-sink attachments, the force on all sides of the heat sink is even, resulting in an even bond line thickness of the TIM and even dissipation of heat from the heat sink. Figure 4 shows the even compressive force on the heat-sink mount with mechanical attachment.

**Figure 4. Mechanical Heat-Sink Attachment**



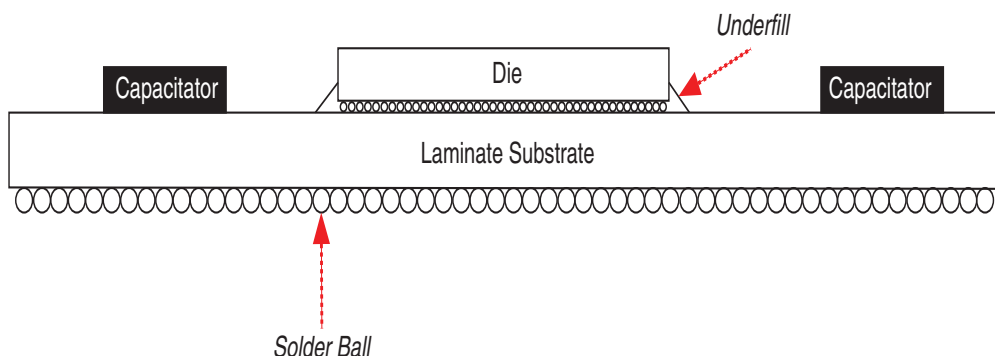


## Designing Heat-Sink Attachment for Lidless FCBGA Package

When designing heat sink attachments for a lidless package, you must consider the height of the die above the substrate and also the height of decoupling capacitors (in some devices).

Figure 5 shows a cross-sectional view of a lidless FCBGA package (with optional capacitors).

**Figure 5. Cross-Sectional View of a Lidless FCBGA Package**



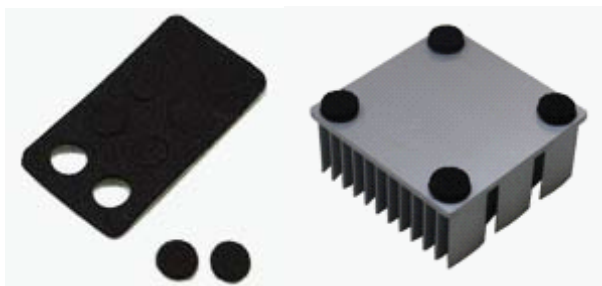
For more information about package information, refer to the [Altera Device Package Information Data Sheet](#).

## Overcoming Heat Sink Tipping or Tilting for Small Heat Source and Lidless Packages

When you attach a heat sink to a small heat source or a lidless package, the heat sink can tip or tilt; thus damaging the die. You can apply sponge pads (small compressible foam pads) to the heat sink to prevent the heat sink from tipping or tilting. The sponge pad helps to stabilize the heat sink during attachment. For heat sinks attachment on a lidless package, you must consider using compressible foam pads to prevent die chipping.

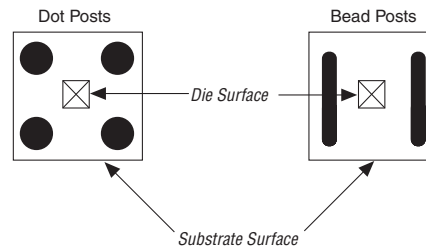
Figure 6 shows a type of sponge pad.

**Figure 6. Sponge Pad**



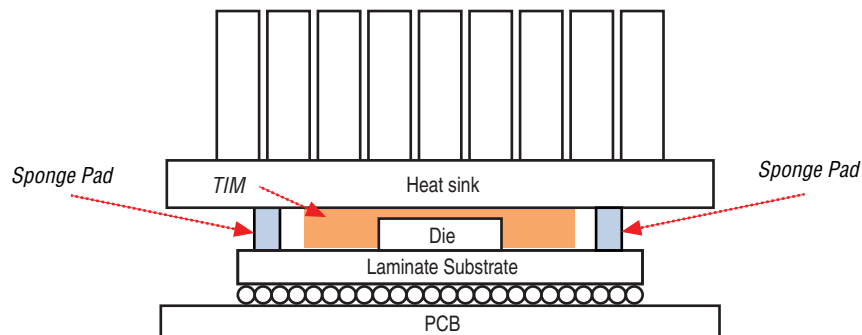
The thermally conductive epoxies method requires an adhesive dispense on the center of the chip, followed by separate dots or beads along opposing corners or edges in one of the following patterns shown in [Figure 7](#):

**Figure 7. Dispense Patterns for Thermally Conductive Epoxies**



These methods help to stabilize the heat sinks attachment to the lidless package. A commonly-used thermally conductive epoxy is Loctite 3873-EN with Loctite 7387-EN as a surface activator.

**Figure 8. Heat Sink Attachment with PCM and Sponge Pads at Four Corners for Stability**



## Selecting Heat Sink for Small Heat Source

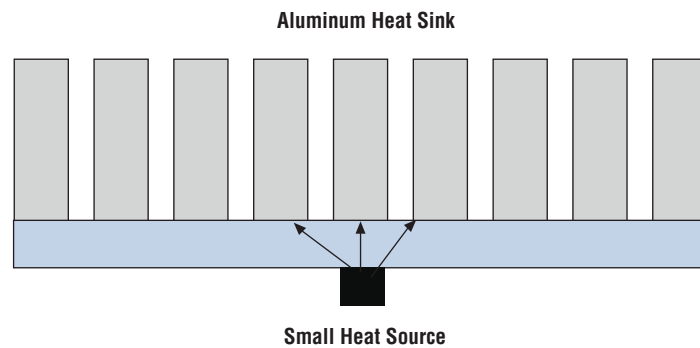
It is difficult to cool a smaller sized heat source because the base material of the heat sink resists the spreading of the heat, through the base, to the outer fins.



Current Altera devices with small heat source are the lidless FCBGA and also flip chip molded ball-grid array (FCMBGA).

Figure 9 shows an aluminum heat sink and a small heat source.

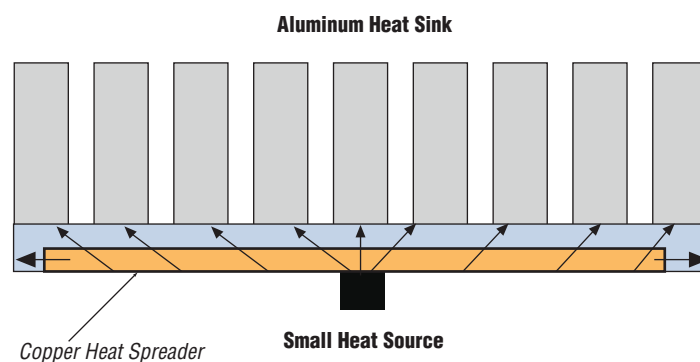
**Figure 9. Aluminum Heat Sink**



To spread the heat from a small heat source to the entire base, some vendors offer efficient and reliable copper embedded heat sinks.

Figure 10 shows a copper embedded heat sink.

**Figure 10. Copper Embedded Heat Sink**



## Compression During Heat-Sink Attachments

Most TIMs require loads of less than 50 psi to interface the heat sink with the die. Altera recommends the following maximum loads for heat-sink attachments:

- During heat sink application, the maximum load should not exceed 20 g/solder ball.
  - Failures observed at this load in PCB bending test; tested on 93 mils thick PCBs result in ~1400 microstrains at the package corner
  - May cause solder joints to open

- During continuous load, the maximum load should not exceed 4 g/solder ball.
- Solder deformation observed after 2,000 hours of stress; tested for 2,000 hours at 125° C with components in sockets and a back pressure of 10 g to 12 g per solder ball.
- Data extended (assuming linearity in yield strength) to 100,000 hours at 100° C.
- May cause solder ball shorting

## Device Reworkability

Table 5 lists the reworkability of different combinations of heat sinks and TIMs.

Although non-mechanical heat sink attachment requires less PCB space, you must consider the possibility of damaging the device or PCB during rework. However, reworking the heat sink with mechanical heat sink attachment is very straight forward and easy.

**Table 5. Heat Sink and TIM Reworkability**

Heat Sink Types	TIM Type	Application	Rework
Non Mechanical Attachment	<ul style="list-style-type: none"> <li>■ Thermally Conductive Adhesive</li> <li>■ Epoxy</li> </ul>	Difficult to control the bond line thickness. May not have optimal thermal performance.	High risk of damaging the device or PCB.
	Thermal tape	Must be larger than die size. Need sponge pads for stability. May not have optimal thermal performance.	High risk of damaging the device or PCB.
Mechanical Attachment	PCM	Pre-cut to size. Need sponge pads for stability. Good thermal performance	Easy to remove.
	Gap filler	Pre-cut to size. Conform to contour of the device. May not have optimal thermal performance	Easy to remove.
	Thermal grease	High performance. Conform to contour of the device. Pump-out concerns.	Easy to remove.

## Reworking or Removing Heat Sinks

To remove a heat sink attached with a thermal conductive tape or epoxy, follow these steps:

1. Soak the device in isopropyl alcohol for 45 minutes to soften the TIM.
2. Carefully insert the edge of a razor blade into the TIM bond line between the heat sink and the device.
3. Slowly twist the blade to exert upward pressure on the package while moving the blade inward as the heat sink begins to separate.
4. Check for die edge damage.

To remove a heat sink attached with PCM or thermal gap filler, follow these steps:

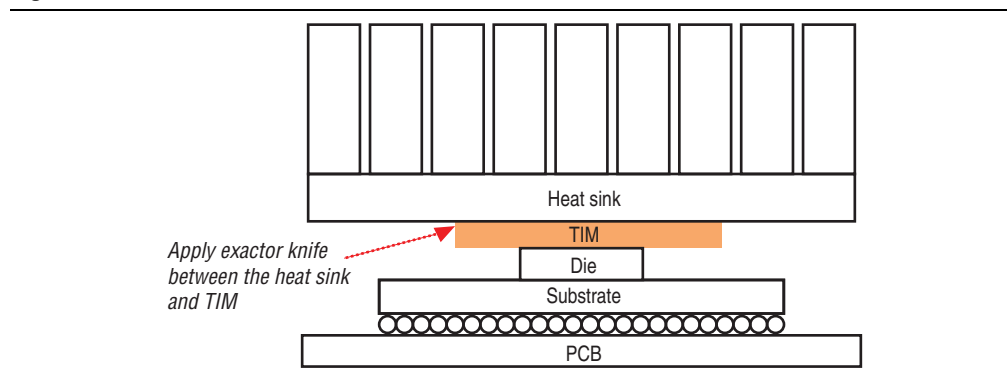
1. Remove the push pins or clips that hold the mechanical attached heat sink.
2. Insert a single-edge razor blade into the TIM bond line between the heat sink and the component.

3. Slowly twist the blade forward with an upward tilt force to separate the heat sink and the component.
4. Check for die edge damage.



Do not use a heat gun to remove heat sinks with mechanical or non-mechanical attachments. High temperature from the heat gun may cause delamination to the underfill of the lidless FCBGA device, destroying the device in the process.

**Figure 11. Removal of heat sink with exactor knife or razor blade**



## Handling and Transfer for Lidless FCBGA

You must always handle lidless FCBGA devices with great care. Lidless FCBGA devices must remain secure in the tray carriers except during transfer operations from tray to tray. You must also use the correct lidless FCBGA trays.

Table 6 lists the lidless FCBGA tray specifications for different packages.

**Table 6. Tray Specifications**

Package Size (Pin Count)	Tray Part Number
17 mm x 17 mm (U358, M1019)	Daewon 1F1-1717-A19
23 mm x 23 mm (F484)	Daewon T0812012
25 mm x 25 mm (F572)	Daewon 14Y-2525-119
29 mm x 29 mm (F780)	Kostat KS-880466
35 mm x 35 mm (F1152)	Daewon 125-3535-919

Do not use tweezers of any form to pick up the lidless FCBGA device. Tweezers can cause mechanical damage to the die, whether as scratches to the top of the die or to the bulk silicon in the form of chipped-outs, micro-cracks, or cracks. Altera recommends that you handle the devices manually with suitable design tools such as vacuum pencils with rubberized tips for pick-ups.

You must use a soft silicon or rubber tip for an automated pick-and-place machine. To prevent damage to the die area of the device, minimize the pressure of the pick-and-place machine.

If you must replace the existing solder balls of the device, use the correct fixture to prevent the die from chipping on the device.

## Vendors List

The following list contains recommended TIM vendors:

- Laird Technologies ([www.lairdtech.com](http://www.lairdtech.com))
- Chomerics ([www.chomerics.com](http://www.chomerics.com))
- The Bergquist Company ([www.bergquistcompany.com](http://www.bergquistcompany.com))
- 3M ([www.3m.com](http://www.3m.com))
- ShinEtsu MicroSi ([www.microsi.com](http://www.microsi.com))

The following list contains recommended heat sink vendors:

- Alpha Company ([www.alphanovatech.com](http://www.alphanovatech.com))
- Malico ([www.malico.com.tw](http://www.malico.com.tw))
- Aavid Thermalloy ([www.aavidthermalloy.com](http://www.aavidthermalloy.com))
- Radian Heatsinks ([www.radianheatsinks.com](http://www.radianheatsinks.com))

The following list contains recommended FCMBGA tray vendors:

- Daewon ([www.daewonspic.com](http://www.daewonspic.com))
- Kostat ([www.kostat.com](http://www.kostat.com))

## Document Revision History

Table 7 lists the revision history for this document.

**Table 7. Document Revision History**

Date	Version	Changes
March 2012	1.0	Initial release.