MARCH 2010

App News

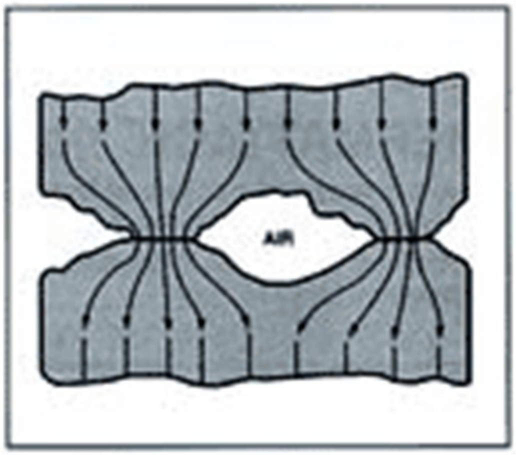
DESIGN ACTIVITY

What's Under the Heat Sink

Heat sinks are carefully designed and manufactured but they must also be properly mounted to be effective. The thermal interface between the heat sink and the heat source is vital but sometimes not fully understood, so here are some basic explanations and guidelines to help.

Key factors: Surface Finish, Flatness, Pressure and TIM

Surface Finish is a measurement of how even a surface is at a microscopic level . The more even the surface of the heat sink (and the heat source) the lower the gaps between the surfaces and thus more heat can transfer between the surfaces. In the first sketch you can see microscopic voids between the two surfaces. The lower the finish number, the smaller the voids will be. Any void between these two surfaces is otherwise filled with air and remember that air is one of the best heat insulators around, air in the interface is not our friend!

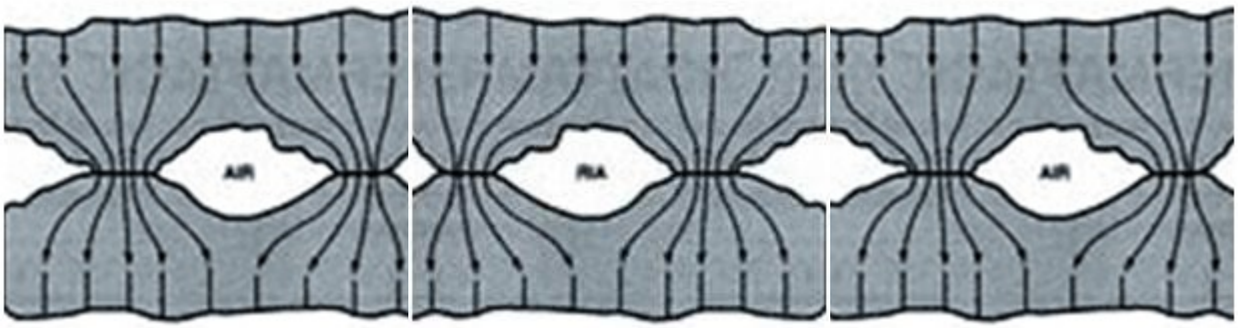


Some typical values for finish are:

Extruded Aluminum	64-128
Machined Surfaces	32-64
Carefully Machined	16-32
Lapped/Polished	8

A common misconception is that Surface Finish and Flatness are the same, they are separate and independent factors in heat transfer. A part can have a low surface finish measurement yet not be flat at all, a good example of this would be a curved stainless steel shaving mirror. In order to reflect an image the surface finish is a very low number (probably around 4), yet it is not flat at all. So if this curved surface were used as a heat interface, there would be good contact at only the touch point, everywhere else would have no thermal transfer at all.

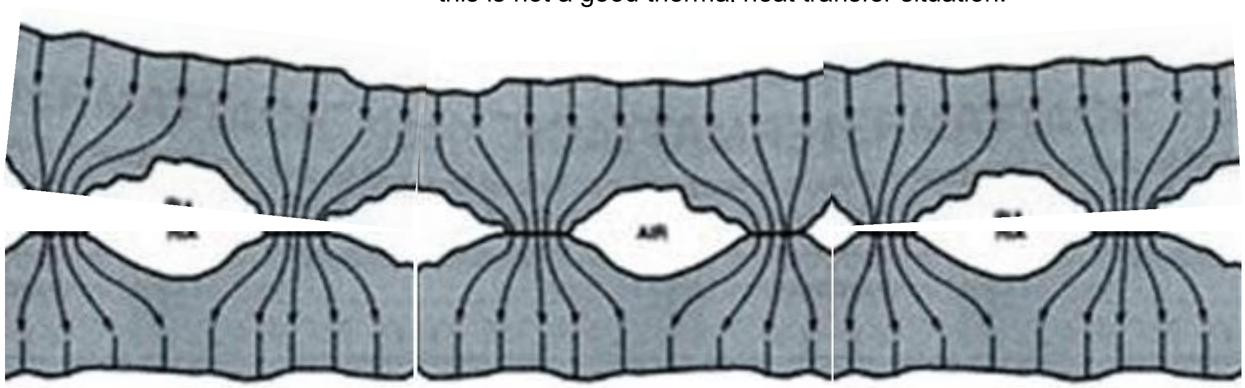
Flatness is a measurement of the overall surface. Using the example of the shaving mirror, having the entire surface in thermal contact is obviously a much better situation. Another way to look at this is that the flatness magnifies the microscopic individual surface contact by the contact area. In the sketch below the two surfaces are flat and contacting each other in many locations, this with minimal voids is the ideal situation. If we could fill the air voids with something that was thermally conductive, it would be even better.



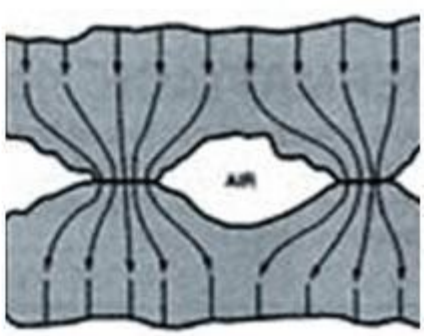
What’s Under the Heat Sink, cont...

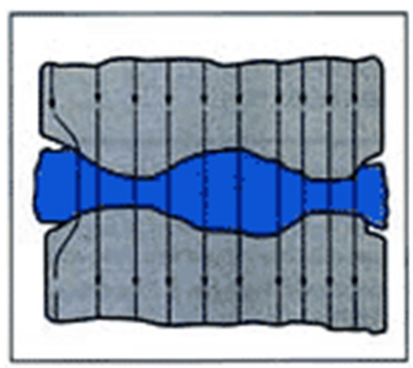
Flatness cont...

Both surfaces must be parallel to each other for the individual contact points to touch over the larger area. If only one surface is flat and the other curved then heat transfer will only occur in the touching areas. In the sketch below only one surface is flat and so heat transfer only occurs at the center and not all over the part, this is not a good thermal heat transfer situation.



TIM is an abbreviation for Thermal Interface Material, very simply it fills any voids between the heat source and the heat sink. Using the same sketches below we show the highly magnified views of two such mating surfaces, on the left, the parts are simply pressed together and you can see the insulating air voids along with some direct point contact between the two surfaces. On the right are the same surfaces with a layer of TIM in between. Even though the part on the left has some direct point contact areas with high heat transfer, the insulating effect of the air voids is so high that the part on the right hand will have better heat transfer as it utilizes the entire contact area.





Obviously the flatter the components and the better the surface finishes of the mating parts, the smaller the insulating air voids will be but there will always be insulating air voids unless they are filled with our friends in the TIM family.

There are many types of TIM and it’s correct selection will depend on the application, desired thermal performance and the heat sink attachment method. All TIM’s work to fill the air voids.

TIM’s are typically poor thermal conductors but still much, much better than air voids. The trick to using TIM is to only use the minimum thickness that you need for your application. It is for this reason that many TIM’s have published performance data that is in Thermal Resistivity, not Thermal Conductance. Thermal Resistivity already takes into account the thickness of the TIM.

If one looks at Thermal Conductivity only, traditional TIM’s are in the 0.5 to 2 W/mK range, compared to Aluminum 6063 Alloy at 203 and Copper at 380. The highest performing gap pad fillers are 4-11 W/mK, far below that of the heat sink metals themselves. Again, the trick to using TIM is to only use the minimum thickness that you need for your application.

What's Under the Heat Sink, cont...

TIM cont...

Grease—Thermal greases typically provide the best thermal performance because when properly applied, as it only fill the voids and still allow some direct contact of the two surfaces. The installed grease thickness is very thin at only .001" to .002" so there is very little temperature drop across the TIM, it can be as low as 1 degree C. The grease will not hold the heat sink on the source, so there must be a separate mechanical attachment. Greases are commonly used in computer CPU's, power transistors and high power IGBT applications. One word of caution, the greases can be messy, I have ruined more than one pair of trousers by accidentally touching a grease pad and then my clothing.

PCM—Phase Change Material, basically a wax loaded with thermally conductive compounds, similar to grease but in solid form for handling and application. The solid form means that it can be applied as a tape for example which is often much cleaner and faster. At operating temperatures, the wax melts and then acts much like grease. The working thickness is typically .002" to .004", so it could have 2 to 4 times the temperature drop across the TIM (more temperature drop is not good, less is better).

Thermal Epoxy—Heat sinks are simply glued to the heat source with glues that are loaded with thermally conductive compounds, such as aluminum dust, to enhance heat transfer. A wide variation is available from two part epoxies, frozen pre-mixed epoxies, UV cured, super-glues and thickened super-glue gels. These can be clean or messy to apply, they do provide decent thermal performance but in most cases are not reworkable which is their major drawback. Thickness of the TIM typically runs .002" to .010".

PSA—Pressure Sensitive Adhesive is basically a thermal adhesive tape that sticks to the heat sink. Tapes are available with single and double sided adhesive, the double sided adhesive can be used for heat sink attachment. Care must be taken to select the correct type of adhesive for the mounting surfaces, heat sinks are normally metal but the mounting package can be plastic, metal or ceramic. Typically acrylic adhesives are used for metal and ceramic but a silicon based adhesive can be better for plastic packages as it may be more compatible with any release agents used in the chip over-molding process. For plastic packages especially, care must be taken by the assembler to ensure that the parts are clean so that the tapes adhere properly.

Single sided PSA's are used with additional mechanical attachment of the heat sink.

Easy to apply, inexpensive but with lower thermal performance, typical .005" to .012" thickness.

Gap Filler—in some instances there may be unavoidable or varying dimensions between the heat sink and the heat source. Reasons for this could be a heat sink mounted on standoffs where the tolerances stack ups of the all parts can result in a range for the TIM to fill, there may be multiple heat sources at different heights, the TIM may need to be compressible to fill a gap range, these are examples where a gap filler may be the best solution. Gap pad fillers are typically silicone RTV type compounds, loaded with thermally conductive materials and then partially cured to varying levels. They can be also be supplied as gels which are dispensed or injected to fill areas that vary beyond the compressible range of a standard thickness sheet. The higher the thermal conductivity of the gap filler, the greater the thermal compound content and the harder (aka less compressible) the pad becomes. Typically gap fillers are used in thicknesses in of .020" to .200".

Electrically Isolating Pads—used to electrically isolate power transistors where multiple devices are attached to the same heat sink. Typically made from Kapton or polyester based films, these are .005" to .012" thick, not great thermal conductors but they do provide the isolation needed.

YOUR MILEAGE MAY VARY—please consult individual TIM manufacturers data sheets for more details.

What's Under the Heat Sink, cont...

Pressure that the heat sink exerts upon the package is an often forgotten key factor. By way of an analogy, if I hold up a household electric iron and ask you to place you hand against it, touching it lightly may be acceptable but leaning on the iron (applying more pressure) transfers a lot more heat and is not recommended. Do not try this at home—we are trained professionals!

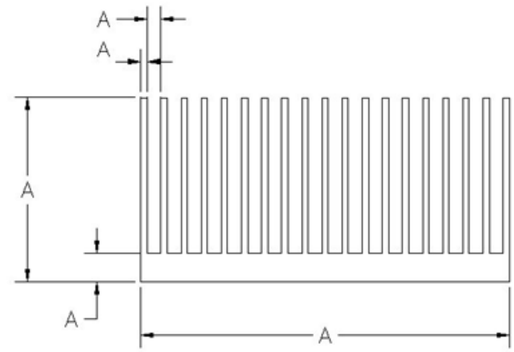
Traditionally the magic minimum number is 10 psi for good performance.

PSA tapes and Epoxy do not apply any pressure to the part, which is one reason why they have limited performance.

Greases and PCM improve with increased pressure. Gap Fillers can crack/separate at higher pressures

The TIM suppliers often test their products at up to 100 psi so you will need to read their data sheets carefully.

Tolerances



Extruded Aluminum Profile tolerances vary with the type and width of the extrusion. This chart shows industry basic standards for raw extrusion. The larger the part, the larger the tolerance needed. If your customers can work within these general guidelines, they will not incur additional machining or finishing costs.

TYPICAL TOLERANCES FOR FLATTNESS AND ROUGHNESS

ALUMINUM SURFACE	FLATTNESS [IN/IN] (mm/25.4mm)	SURFACE ROUGNESS [RMS]
As Extruded	004 (0.10)	125-64 (3.2-1.6)
Sanding	.002-.003 (0.51-0.76)	64-32 (1.6-0.8)
Machined	.001 (.025)	64 - or better (1.6 -)

TYPICAL TOLERANCES FOR 6063-T5 EXTRUDED ALUMINUM ALLOY

Dimension A (inches)/(mm)	**+/- Tolerance (up to 10" circle size) (inches)/(mm)**
0.000- 0.125 / 0.00-3.18	.006 / 0.15
0.125-0.249 / 3.18-6.35	.007 / 0.18
0.250-0.499 / 6.35-12.70	.008 / 0.20
0.500-0.749 / 12.70-19.05	.009 / 0.23
0.750-0.999 / 19.05-25.40	.010 / 0.25
1.000-1.499 / 25.40-38.10	.012 / 0.30
1.500-1.999 / 38.10-50.80	.014 / 0.35
2.000-3.999 / 50.80-101.60	.024 / 0.61
4.000-5.999 / 101.60-152.40	.034 / 0.86
6.000-7.999 / 152.40-203.20	.044 / 1.12
8.000-9.999 / 203.20-254.00	.054 / 1.37