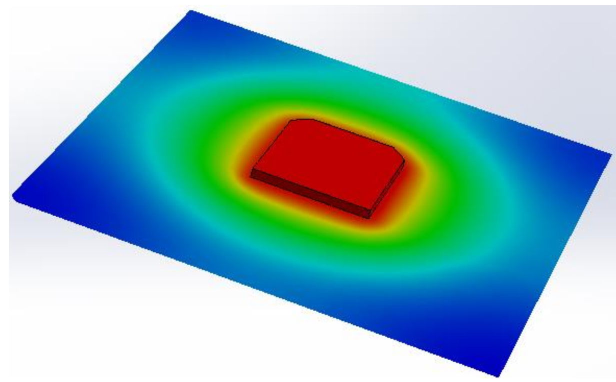
Application note:

Using PCB copper area to dissipate the heat produced by surface mount components. Rev1.



Removing heat from surface mount components during the initial phase of product development can significantly add to the design work and rework. In this paper we briefly describe the thermal behavior of surface mount components on a single sided PCB. We produced graphs to help the designer choose the PCB specifications that would satisfy the thermal requirement. The graphs also show the limitations of using the copper area on the PCB as a Heatsink.

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Besides the manufacturing and mechanical advantages of using surface mount component there is a major thermal benefit as well. This benefit is using a larger copper pattern than electrically required to sink the thermal energy away from the component. To leverage the thermal benefits, we have to be aware of all the parameters affecting the thermal behavior and of the limitations of such approach. One factor that may be sacrificed by maximizing the copper area for thermal requirements is board area real-estate.

There are three modes of heat transfer from the surface mount components to the ambient surrounding. These modes are by conduction, convection and radiation. Where conduction is the thermal energy traveling through a material, convection where the heat is transferred to a fluid and radiation where the heat is transferred by radiation. Vertical heat transfer due to conduction is described by

$$q_y'' = -k\frac{dT}{dy}$$

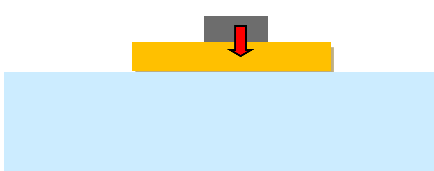


Figure 1

Where $q_y''$is the heat flux in $\left(\frac{W}{m^2}\right)$perpendicular to the path. For the surface mount component this would be the power dissipation in the component divided by the interface area between component and the copper. k is the thermal conductivity of the material in $\left(\frac{W}{m*K}\right)$. For copper the value is 400 $\frac{W}{m*K}$. $\frac{dT}{dy}$ is the temperature gradient in the y direction. This equation can be written as

$$q_y = -kA_{tr}\frac{dT}{dy}$$

Where $q_y'' = \frac{q_y}{A_{tr}}$ and A_{tr} is the area of the transistor surface that mates with the PCB copper pattern. Rearranging the equation above to get the thermal resistance $\emptyset = \frac{\Delta T}{q}$ we get

$$q_y = \frac{\Delta T}{\frac{1}{kA_{tr}}\Delta y}$$

$$\emptyset_{vert} = \frac{\Delta y}{kA_{tr}}$$

Lateral energy transport due to conduction is described by

$$q_x'' = -k\frac{dT}{dx}$$

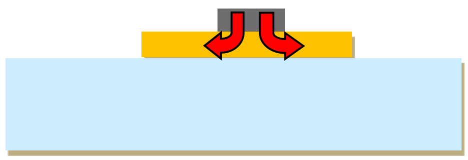


Figure 2

Where $q_x$is the heat transfer in the horizontal direction going towards the perimeter of the copper area on the PCB.And $\frac{dT}{dx}$ is the temperature gradient parallel to the surface of the copper area. The thermal resistance in the lateral (x) direction is

$$\emptyset_{lat} = \frac{\Delta x}{kA_{Cu1}}$$

Where A_{Cu} is the thickness of the copper time the distance to the perimeter of the copper area. That is the path length of the heat transfer. For a transistor mounted in the center of a square copper land pattern with side W and copper thickness t_{Cu}, $A_{Cu} = W * t_{Cu}$. The total conduction thermal resistance is

$$\emptyset_{vert} + \emptyset_{lat} = \emptyset_{cond}$$

$$\emptyset_{cond} = \frac{\Delta y}{kA_{tr}} + \frac{\Delta x}{kA_{Cu}}$$

Thermal resistance in Convective heat transfer. Heat transfer due to convection is described by

$$q = hA(T_s - T_\infty)$$

Thermal resistance in convection heat transfer $\emptyset_{conv} = \frac{\Delta T}{q}$

$$\emptyset_{conv} = \frac{1}{hA_{Cu2}}$$

Where A_{Cu2} is the surface area of the copper that would be exposed to convective heat transfer.

The total thermal resistance of the system $\emptyset = \emptyset_{conv} + \emptyset_{cond}$

$$\emptyset = \frac{1}{hA_{Cu2}} + \frac{\Delta y}{kA_{tr}} + \frac{\Delta x}{kA_{Cu}}$$

The plot below shows the thermal resistance VS copper thickness from 1Oz through 8Oz for I 1 inch square copper area. Notice that the as the thickness of the copper increases so does the performance.

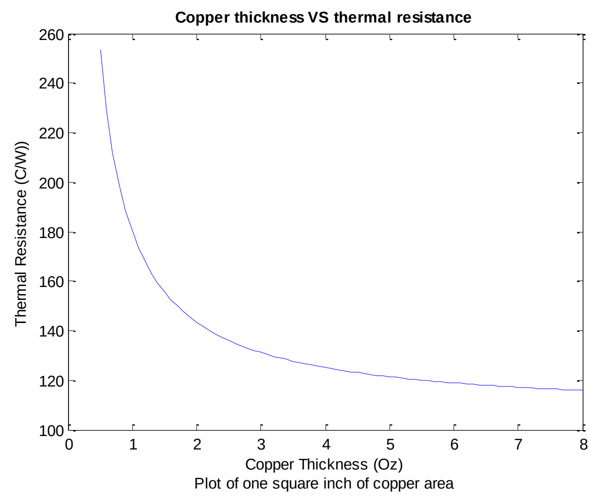


Figure 3

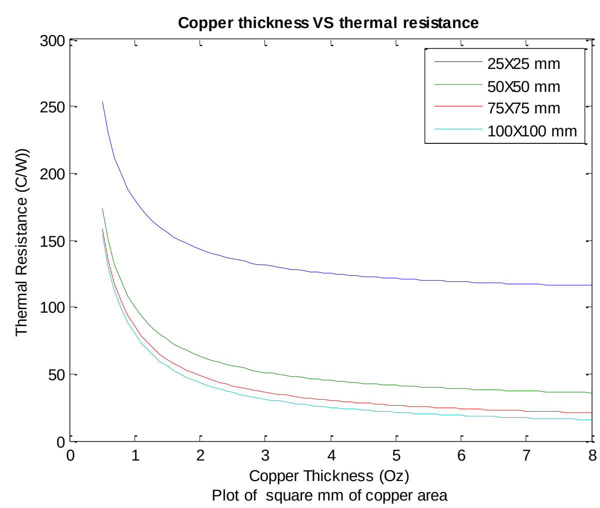
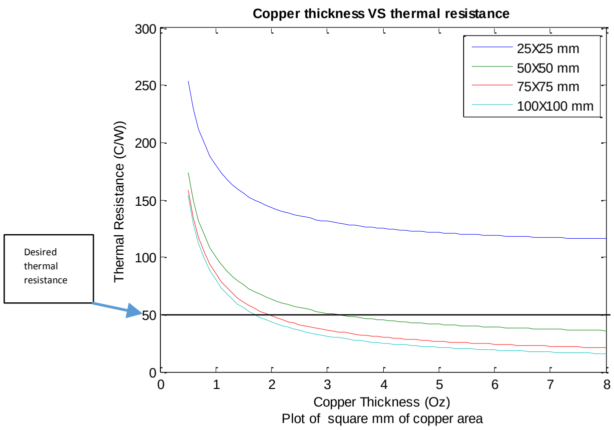


Figure 4

From the graph we see that thermal optimization during PCB development for a one-sided PCB can be directly estimated from the graph. Increasing copper thickness and copper area will reduce the thermal resistance of the board and will reduce the operating temperature of the component. For initial estimates during the design phase, the desired thermal resistance should be chosen from the y axis of figure 4 and the required copper thickness and surface are chosen from the plot.



From the desired thermal resistance shown above, the designer has the option to use the following PCB and copper area:

Option1	Copper area(mm X mm)	Copper thickness (Oz.)
1	100 X 100	1.75
2	75 X 75	2
3	50 X 50	3

These options can be factored in during the PCB selection and layout.

Please feel free to contact us for more literature or help in your design at

http://www.iaasr.com/contact-us/

References:

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Thermal Considerations for Surface Mount Layouts
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