FUNDAMENTALS:

BASIC DEFINITION OF THERMAL RESISTANCE

DEFINITION OF THERMAL RESISTANCE

Thermal resistance is an important property of heat transfer. Its importance can be understood when one tries to tie in thermal design to electronics equipment. Incorporating thermal design requires analysis of different thermal resistances that reside along the thermal path [1]. The thermal path in this case is the path of cooling that is between a heat generating area (in electronics, considered the “die”) and the “ground”, which ultimately in most cases is the ambient air or the device enclosure. In electronics cooling, the main thermal resistances of a thermal path are associated with the junction to case, case to heat sink, and heat sink to ambient. The aforementioned thermal resistances were defined from the first old power electronics and are still being used today in modern electronics.

The equation for absolute, or overall, thermal resistance of the example above is defined as:

$$R_{total} = \frac{T_j - T_\infty}{q} \quad R_{jc} + R_{ch} + R_{hs} \qquad [\frac{k}{w}] \tag{1}$$

where T_j is junction temperature, T_∞ is ambient temperature, q is component power, R_{jc} is the junction to case resistance, R_{ch} is the case to heat sink resistance, and R_{hs} is the heat sink to ambient resistance [1]. Some of the different subsets of thermal resistance, which can make up a thermal path, are conduction, convection, radiation, and spreading resistances.

THERMAL RESISTANCE IN A SOLID DUE TO CONDUCTION

Thermal resistance in a solid due to conduction can be expressed as,

$$R_{cd} = \frac{L}{kA} \qquad [\frac{k}{w}] \tag{2}$$

where L is the heat transfer path length, k is the thermal conductivity of the solid, and A is the cross-sectional area [1].

THERMAL RESISTANCE FROM A SURFACE DUE TO CONVECTION

Thermal resistance from a surface due to convection can be expressed as,

$$R_{cv} = \frac{1}{hA} \qquad [\frac{k}{w}] \tag{3}$$

where h is the convection coefficient and A is the surface area [1].

THERMAL RESISTANCE OF A HEAT SINK

When cooling an electronic component with a heat sink, the heat sink itself is considered as just one part of the thermal path. However, a heat sink has its own thermal resistances and detailed thermal path associated with it. When looking at the heat transfer mechanisms of a heat sink, one can observe that a simple object can become quite detailed.

The thermal resistive network, or thermal path, that makes up a heat sink consists of conduction, convection, radiation, finned, and flow resistances all summed up. The thermal resistance of a heat sink (including radiation) can be expressed as,

$$R_{hs} = \frac{\eta h A + 2\dot{m}c_p}{2\eta h A\dot{m}c_p + \eta h h r A^2 + 2hrA\dot{m}c_p} \qquad [\frac{k}{w}] \qquad (4)$$

where η is the overall fin efficiency, h is the convection coefficient, h_r is the radiation coefficient, A is the surface area, $\dot{m}$ is the mass flow rate, and c_p is the specific heat capacity.

In short, thermal resistance can help define the thermal path of a system, which when analyzed correctly can aid in heat transfer optimization. With the use of a thermal resistive network, this optimization becomes possible as relatively high resistances of a system can be singled out and improved, achieving a cooler and potentially more free flowing system.

REFERENCE

Kraus, A.D., and Bar-Cohen, A. “Design and Analysis of Heat Sinks”. New York: John Wiley and Sons, 1995. Print.