Experimental Determination of Heatsink Characteristics

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Often a designer will want to verify the thermal performance of an electronic system. A critical component in most power electronics is the heatsink, an often overlooked component.

R_{SA}, the thermal resistance between a heatsink and the ambient environment, is usually given by a heatsink manufacturer. Even with the manufacturer's specifications in hand, it is generally a good idea to verify thermal performance on a prototype. Because of the enclosed construction of electronic equipment, manufacturer's specifications may be not directly applicable! Often finished electronics equipment is contained within an enclosure that limits the ambient air flow across power devices and their associated heatsinks. The net result is that the power devices run hotter than originally designed, and failure rates are increased.

Fortunately, it's relatively easy to measure R_{SA}; the model for power dissipation and temperature leads to a method for doing this. Figure 1 shows the classic electrical analog for the thermal system:

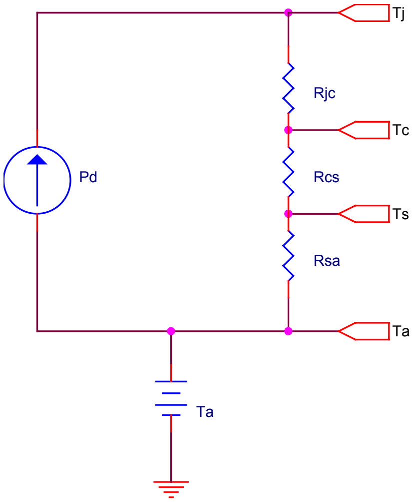

Figure 1: Electrical Model of Thermal System

(Eq. 1) $T_S = T_A + P_D R_{SA}$

Equation 1 describes the heatsink temperature as a function of power dissipation and thermal resistance between sink and environment. Note that as long as the power dissipation is known, and R_{CS} and R_{JC} are held constant, no other factors need to be included to describe the ambient-to-heatsink temperature rise.

Now suppose that we were to supply two different (but known) power levels to the system. At power level 1, the sink temperature would be:

(Eq. 2) $T_{S1} = T_A + P_{D1}R_{SA}$

And at power level 2, the temperature would be:

(Eq. 3) $T_{S2} = T_A + P_{D2}R_{SA}$

The corresponding change in heatsink temperature can be expressed by subtracting Equations 2 and 3:

(Eq. 4) $\Delta T_S = T_{S1} - T_{S2} = (T_A + P_{D1}R_{SA}) - (T_A + P_{D2}R_{SA}) = R_{SA}(P_{D1} - P_{D2})$

Very nicely, T_A falls out of the equation, so we can now express R_{SA} directly:

(Eq. 5) $R_{SA} = \dfrac{\Delta T_S}{P_{D1} - P_{D2}}$

Practical Application

To apply Equation 5, it's best to use two identical prototypes:

- Set up each with identical conditions and known, accurate power dissipation. The prototypes should be mechanically identical in construction.
- Let the prototypes "soak" up to their final temperatures completely. Avoid a testing area with moving air, if possible; both prototypes may not experience exactly the same air flow.
- Use an accurate thermometer to measure the heatsink temperatures. If the sink is large, measure the *average* temperature over several measurements.
- Two prototypes are not absolutely necessary. The measurements can be carried with a single unit, under two different power settings, with the precaution that the ambient temperature not be allowed to vary for the entire duration of the test. This is inherently hard to achieve.

As an example, two identical prototypes were set up on a lab bench. Unit A was dissipating 17 W and its final heatsink temperature was 172 F (77.7 C). Unit B was dissipating 24.9 W and its heatsink temperature was 208 F (97.7 C) after soaking for one hour. The heatsink performance was therefore:

$$R_{SA} = \frac{\Delta T_S}{P_{D1} - P_{D2}} = \frac{20C}{7.87W} = \underline{\underline{2.5^o C/W}}$$

Conclusion

With thermal data in hand, it is much easier to predict the temperatures in an electronic system. This knowledge can help designers to appropriately choose power devices, verify heatsink capabilities, and confirm operating temperature limits. Using thermal data to design power electronics helps to ensure that devices are operated within their safe operating areas at all times, greatly enhancing reliability of the system.