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Thermal Design for Conduction Cooled Loads

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Loads are commonly used in combiners, switches and test systems for high power transmitting equipment, and require consideration for dissipation of heat

When considering a termination with conduction cooling, there are certain factors that must be considered. What is the impact on other components in the system? Will the heat from the load and the heat sink (or cold plate as the heat sink is sometimes referred to) impact other components in the system? Will the air-flow required for the heat sink impact any components that also require air-flow? Is there enough air flow for the dissipation through the heat sink? What changes might I see in the system due to the additional heating effect, such as overheating of components or wiring?

Conduction is heat transfer by means of molecular agitation within a material without any motion of the material as a whole. Heat transfer may also be achieved by motion of a fluid such as air or water. As the heated fluid moves away from the source of heat, it carries energy with it.

Heat transfer will use the lowest energy mode available. Typically this is a flow of heat in a direction opposite to the thermal gradient. In other words, the heat will flow from the highest temperature region to the lowest temperature region until the two regions reach the same temperature.

Although a conductive load is considered a passive-cooling device, using a fan along with the heat sink—becoming an active-cooling device—allows more cooling with less space.

When there is little space available but a heat dissipating device (load) is required, the answer could easily be a conductive cooled load or, depending on the application, could be convection-cooled. The conductive load is small and has a metal enclosure. It is typically used where heat-dissipating metal is readily available and/or space is limited. The convective load is larger than the conductive load, due to the fins designed to meet heat flow requirements, and needs no additional thermal contact for heat dissipation.

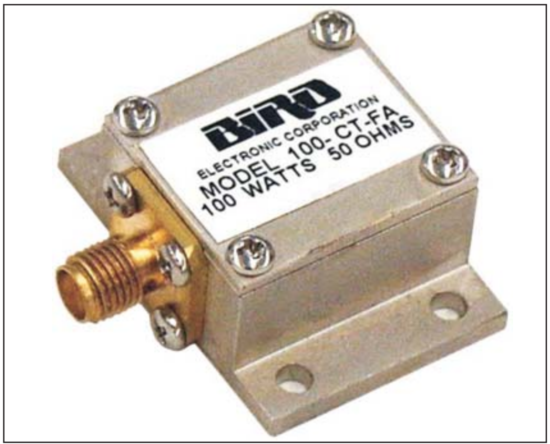

Figure 1 · Example of a conductive load, the Bird model 100-CT-FA.

What parameters do you need to know before using a conductive load? Important considerations are ambient temperature and how much free air-flow is available. One would also need to know the amount of heat needed to dissipate; for example, a transmitter with a 100 watt output would require a 100 watt load with the appropriate size heat sink. The heat sink can be constructed by the user, or from one of the companies that specialize in heat sink manufacturing.

It is possible to purchase a heat sink from

Conductive Load Power	100 minus Temperature (assumed to be 25°C)	Temperature Divided by Load Power	°C/W
25	25	0.0	0.0
100	25	0.75	0.75
150	25	1.25	1.25
300	25	2.75	2.75
500	25	4.75	4.75

Table 1 · Temperature vs. watt ratio.

Flange Temp. °C	De-Rated Power
100	20 watts
120	15 watts
130	10 watts
140	5 watts
150	0 watts

Table 2 · De-rated power of a 20 watt conduction load.

one of the heat-sink manufacturers. Typically the manufacturer will require the ºC/W ratio. This calculation is simply 100 (the maximum flange temperature allowed) minus the ambient room temperature divided by the power.

If the room temperature is assumed to be 25°C, the load can increase its temperature by the maximum flange temperature minus the ambient room temperature (100 – 25 = 75°C). For example, if the load is dissipating 100 watts, the 75°C/100 W = 0.75 (see example in Table 1). The heat sink will need to be rated at 0.75°C/W. Typically, these are the characteristics used by heat sink suppliers.

The next consideration is how large and what thickness of a heat sink do I need? The size is dependent on the amount of power that needs to be dissipated. For a small load, such as a 25 watt model, the heat sink is small, only 67 square inches and 1/8th inch thick, but for 500 watts the required heat sink is very large, 1,333 square inches and 1/2 inch thick. The large heat sink for the 500 watt unit could be a transmitter enclosure, dependent on the size of the enclosure, for proper dissipation.

Model	Ambient Temp. °C	Length (Inches)	Width (Inches)	Square In.	Thickness (Inches)	Material
25-CT-XX	25	8.2	8.2	67	1/8	Aluminum
50-CT-XX	25	11.6	11.6	133	1/8	Aluminum
100-CT-XX	25	16	16	267	1/8	Aluminum
150-CT-XX	25	20	20	400	1/8	Aluminum
250-CT-XX	25	26	26	667	1/2	Aluminum
300-CT-XX	25	28.5	28.5	800	1/2	Aluminum
500-CT-XX	25	36.5	36.5	1333	1/2	Aluminum

Table 3 · Approximation of sizes for cold plates.

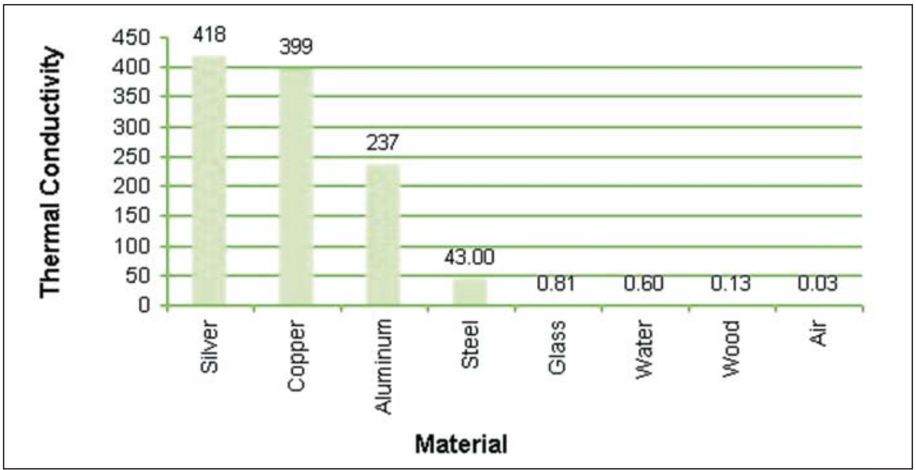

Table 4 · Thermal conductivity of various materials.

Typically, the medium for heat transfer is some type of metal already available in the application. For example, if you need to have a reject load inside a transmitter, a conductive load can be attached to the transmitter housing for heat dissipation. Typically, the transmitter is large enough that the heat being dissipated through the entire housing should not affect the outer temperature of the transmitter for loads 100 watts and below. If the power required is 300 watts or more, the temperature of the outside housing of the transmitter should be measured, and an additional internal heat sink or cooling fan included as required to keep the transmitter cool.

Using a conduction-cooled termination requires more than just connecting it to a transmitter output. These loads have very little heat dissipation when used alone. For example, a 150 watt conduction load with a type N connector will only dissipate 15 watts when used as a stand alone unit, and the majority of that heat flows through the N connector.

When using a conductive load (such as the Bird model 100-CT-FA shown in Figure 1) it is imperative to keep the flange temperature at 100°C or less. If this rating is exceeded, the film on the resistors inside the load may melt, changing the overall resistance of the load. It is always a good idea to use a thermocouple with the unit to assure that the flange temperature of the conductive load does not exceed 100°C during operation.

The power of the load de-rates quickly at a linear rate once you exceed the 100°C flange temperature. Table 2 shows an example of the de-rating of a 20 watt load. For any power rating, use the full rated power derated linearly to 0 watts at 150°C.

Table 3 shows approximate sizes for the heat sink. This is only an approximation. Remember that the free air flow and ambient temperature are also important characteristics to consider when using a conduction load.

Aluminum is the most commonly used heat sink medium as it is typically cost effective, readily available and provides good thermal performance, but there are other metals that can be used as well (see Table 4).

By looking at Table 4, you can see that silver has the best thermal conductivity. Silver is also very expensive and would only be used in a system where the conductivity was critical. Copper has nearly as good performance as silver and is used in both heat sinks and "heat spreaders" that are placed between concentrated heat sources and larger-area heat sinks. Copper's compatibility with common plumbing fittings makes it a good choice for water-cooled heat sink applications.

Looking across the chart, glass, water, wood and air have very low thermal conductivity and can be considered good thermal insulators. Therefore, these are almost never used for heat sinks.

Understanding your application and criteria for the heat sink when using a conductive load can eliminate problems down the road. Understanding the importance of the heat sink parameters required for proper operation will assure your needs are met in thermal performance, and will help eliminate any unwanted effects in the entire system.

References

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Author Information

Shirley Hazelett received her ASEE degree from Lorain Community College. She has worked with Bird Electronic Corp. since 1982. Through her tenure with Bird, she has developed technical product knowledge, currently filling the role of Applications Engineer with a specialty in the Bird Load and Attenuator products.