Forced Air Convection and Heat Sinking for Power Supplies

When evaluating the operating temperature ranges of power supplies one must consult component's datasheets. Datasheets state a "usable" operating temperature range typically given at full output load. In order to reach the upper limit of the temperature ranges without derating the load, some additional heat dissipation may be required.
Derating curves given in datasheets characterize by how much the load would need to be reduced in order to operate the power supply at higher temperatures. There exists two possibilities for improving heat dissipation: heat-sinking, and forced air convection with the addition of a fan or blower.

1. Heat Sink

A heat sink is an object that absorbs and dissipates heat from another object using thermal contact. Heat sinks function by efficiently transferring thermal energy ("heat") from an object at high temperature to a second object at a lower temperature. The rapid transfer of thermal energy quickly brings the first object into thermal equilibrium with the second, lowering the temperature of the first object. The most common design of a heat sink is a metal device with many fins. The high thermal conductivity of the metal combined with its large surface area result in the rapid transfer of thermal energy to the surrounding, cooler, air. This cools the heat sink and whatever it is in direct thermal contact with.

Heat sink performance is a function of material, geometry, and overall surface heat transfer coefficient. In common use, it is a metal object brought into contact with an electronic component's hot surface. In many cases, a thin thermal interface material is used between the two surfaces. Frequently thermally conductive grease is used to ensure optimal thermal contact.

Power Loss: The heat generated by a power supply is related to its efficiency. Efficiency is the difference between the output power and the input power, also know as Power Loss (Ploss).

Example 1:
Efficiency = 85% (0.85), therefore 15% of the input power is "lost" and turned into unwanted heat.
Vout =12Vdc
Iout=5A
Pout = 12V X 5A = 60W
Pin = Pout/Efficiency = 60/0.85 = 70.6W
Ploss = Pin – Pout = 70.6W –60W = 10.6W
The power supply is turning 10.6W of power into unwanted heat that may need to be dissipated.

Heat sink Characteristics: Heat sinks have a given a characteristic (also known as thermal resistance) in °C/Watt. If a heat sink has thermal resistance of 2°C/Watt, it means the temperature will increase by 2°C, plus the ambient temperature, for every watt it dissipates. The lower the heat sink thermal resistance the better its performance will be.

Temperature Rise with Heat sink: The temperature of a power supply will rise proportionally to its power loss and the thermal resistance of the heat sink installed on the power supply.

Δ T = Ploss x Thermal Resistance Heat sink (**eq 1**)
Temperature rise equals the power loss multiplied by the thermal resistance of the heat sink

Calculation of Required Heat sink Thermal Resistance
Example 2:
Ambient temperature is 30°C, Power Supply is dissipating 20W (Ploss), and the maximum case temperature of the Power Supply is 95°C
The maximum allowable rise of temperature is 95°C -30°C = 65°C
Rearranging equation 1 to solve for heat sink thermal resistance:
Thermal Resistance of Heat sink = Δ T $\div$ Ploss
The thermal resistance of the heat sink required to keep the case temperature at or below its maximum operating temperature is 65°C /20W = 3.25°C/Watt
In this example the power supply will not exceed its maximum case temperature of 95°C if a heat sink of 3.25°C/Watt is installed.

Estimating the Thermal Resistance of a Heat sink Based on its Geometry
Given a heat sink's length L (in inches) and surface area S (in $inch^2$) an estimated value of thermal resistance can be calculated.

Thermal Resistance (^oC/Watt) = 1 ÷ (S x 0.008√L). (**eq 2**)

Example 3:
L = 5 in, S = 20 in^2, then Thermal Resistance = 2.8. ^oC/Watt

Positioning of a Heat sink: A natural convection heat sink should be positioned so that heat can be dissipated upward through the fins with no significant obstructions to impede air flow. Any other heat-generating components near by the heat sink would increase the ambient air temperature. A black anodized finish on an aluminum heat sink can lower the thermal resistance of a heat sink by 4 %.

The thermal resistance is proportional to inverse of total surface area. It is desirable to use a heat sink as large as is practically possible without blocking the air flow. However, too reduce the thermal resistance by one-half; the extruded heat sink volume has to be increased by a factor of four.
The metal enclosure or mounting frame of a power supply can be used to remove heat from a device, however, this technique is effective for small amounts of heat only.

2. Forced Air Convection

When power supplies are operated at their maximum output power, excessive heat may be generated that will severely reduce the expected lifetime of the device. In order to achieve maximum performance without reducing the lifetime expectancy it is commonly recommended to use forced air convection to help dissipate the excess heat generated by the power supply.

Forced Air Convection with Heat sink: The cooling effectiveness of a heat sink can be achieved by the addition of forced air convection using a fan or blower. The thermal resistance can be reduced to below 0.2 ^oC/W using forced air convection.

When considering the installation of a fan or blower, there are two possibilities

- Mount the fan or blower to one side of the heat sink and force air through the heat sink parallel to the extrusion direction of the fins.
- Mount the fan or blower near the center of heat sink on top of the fins and force the air downward, or upward, through the two open sides,

How the fan or blower is installed depends on the specific application where it is used, many factors need to be considered to determine the best solution for a particular application.
The fan or blower has moving parts and therefore has a much lower MTBF (mean time between failures) than the power supply. An important consideration is accessibility to the fan or blower in order to facilitate ease of maintenance.

If forced air convection is used with a heat sink the calculation of the thermal resistance is as follows:
find the fan's airflow in Cubic Feet per Minute and calculate its airflow in Linear Feet per Minute. Linear Feet per Minute (LFM) equals to the Cubic Feet per Minute (CFM) of the fan or blower divided by the orifice area in square feet.

Calculating the thermal resistance of the same heat sink as used in example above with forced air convection:
Equation 2 becomes: Thermal Resistance (^oC/Watt) = 1 ÷ (S x 0.011 √(L x LFM/100))

Example 4:
CFM =400, orifice area =2 ft^2, LFM= 400/2 =200
Thermal Resistance = 1.4 ^oC/Watt

This example shows that the thermal resistance of the heat sink is half its value with the addition of a fan. Therefore the temperature rise is also half of its value with the addition of a fan.

Forced Air Convection without Heat sink: Power supply manufactures typically include in their product's datasheets information regarding external fan specifications for optimal performance and lifetime.

Figure 1 shows a typical Derating graph for free air convection and forced air convection using an 18CFM fan.

Figure 1

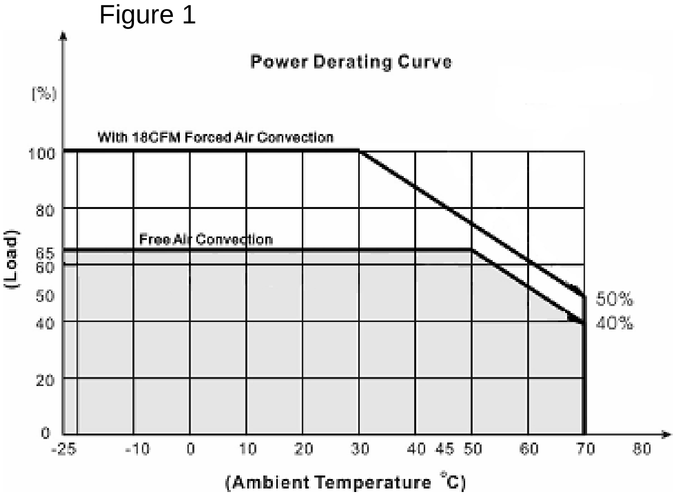

Figure 1 shows two curves, one for Free Air Convection and one for Forced Air Convection. The curve for free air convection indicates the power supply can operate at 65% of its maximum output power from -25^{o}C to +50^{o}C without the need for an external fan. Above 50^{o}C the output power needs to be "derated" as a percentage of its maximum. Derating means the load will need to be adjusted as to allow the power supply to output the required lower power. At +70^{o}C the power supply can provide 40% of its maximum power.

The derating curve with a 18CFM fan installed indicates the power supply can provide 100% of its maximum output power from -25^{o}C to +30^{o}C with derating up to +70^{o}C, with a maximum of 50% of its maximum output power at +70^{o}C.

With the addition of a fan the power supply can produce 10% more power at +70^{o}C than it can with only free air convection.
It can be demonstrated that using an external fan that meets the manufacturer's specifications will significantly improve the power supply's performance.