Principles of Heat Transfer

Heat transfer is a directed transfer of energy between mediums, liquids or gases of different temperatures where the natural flow of heat transfer is from high to low temperature.

Conduction

Conduction is a molecular movement within a medium undergoing a fall in temperature. The conduction and the resulting heat transfer depends on the material involved. The conductivities of materials are expressed as coefficients λ in [W/mK].

Material	λ in [W/mK]
Silver	408
Copper	365
Aluminium	209
Stainless steel	15
Air	0,02

The thermal resistance of a body is expressed in K/W and is dependent on its coefficient and the area and distance of heat flow. It describes the temperature rise of the body above the ambient for every Watt of power supplied.

Radiation

Radiation is the transfer of energy through electro-magnetic waves in the wavelength range from 0.8µm to 400µm. As opposed to conduction, radiation is not bound to a transfer medium. It depends on the temperature and surface of the radiating body. Rough bodies radiate stronger than smooth bodies. Radiation increases with temperature of the radiating body whereby dark bodies absorb and emit more heat than light bodies. The following energy retainment formula applies to radiation:

$$\varphi + \alpha + \vartheta = 1$$

φ = reflected quantity
α = ansorbed quanitiy
ϑ = transferred quantity

φ, α und ϑ depend on the material and the wavelengths of the radiation. Radiation from heat sinks is mainly peripheral as radiation between ribs is practically absorbed. To improve heat emission through radiation with natural convection and high surface temperature it is beneficial to black anodise the heat sink as the heat transfer coefficient depends on the ambient medium (air) and the type of heat sink surface and not on the heat sink material itself.

Convection

Convection is heat exchange within liquids, vapours or gases through molecular movement from cool to warm areas. Free convection is brought about by differences of air density caused by different temperatures. Air layers close to the surface become specifically lighter than deeper layers due to the heat from the heat sink fins. This causes a static pressure difference between the layers resulting in an upward air flow. If the heat seat fins are too close together they warm each other up and restrict free convection. Forced convection (forced cooling) requires a separate convection source in the form of a fan. To achieve optimal convection the heat sinks should be free-standing with vertical fins.

Laminated flow

Laminated flow is air movement in parallel streams or layers with internal friction but without turbulence.

Turbulent flow

Above a so-called critical speed a laminated flow changes to a turbulent flow whereby air currents can develop which work against the flow direction.

Turbulent flow is a major factor in achieving good heat dissipation through convection. Convection is more important in heat dissipation with heat sinks than radiation.

Thermal transfer

Before heat can be transferred from a heat sink to the ambient air a thermal resistance must be overcome. The resistance depends on the thermal coefficient of the material and the contact area, whereby the heat transfer is not proportionally increased by a larger contact area but is influenced by the fin construction of the heat sink. The effectiveness of the fins decreases towards their tips where the temperature fall decreases.

Heat dissipation through convection can be improved by increasing the air flow, changing its direction and by producing turbulence.