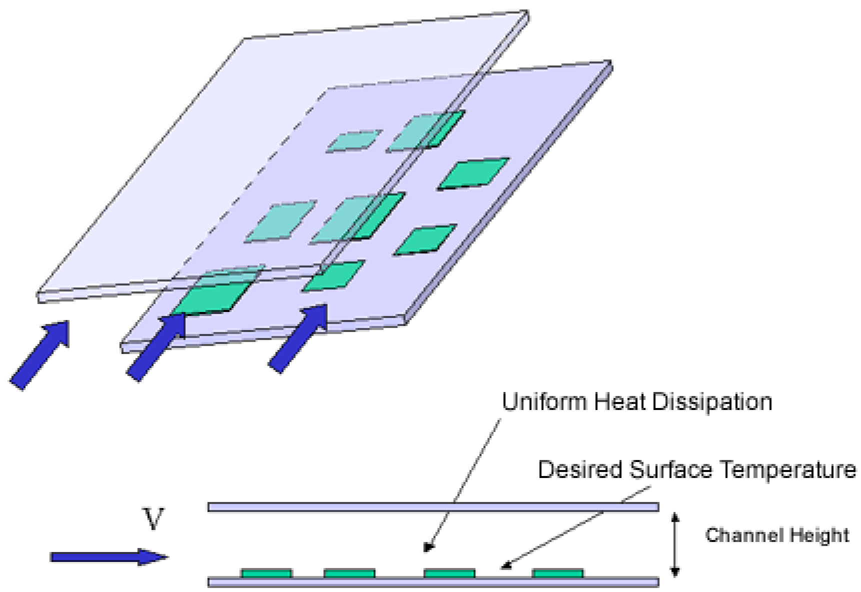
Heat Transfer from a Flat Plate Inside a Duct

This situation can be used for calculating heat transfer from a PCB in forced convection where the adjacent board is close enough that a channel-like behavior is created. The following schematic depicts the situation under consideration:



We are trying to find the minimum entrance velocity that can keep the surface temperature below a given maximum value for a known total power dissipation. We are assuming that the power is uniformly distributed over the board.

Since the velocity is not known, we don't know whether the flow will be laminar or turbulent. We will assume a turbulent flow to begin with. First, we have to calculate the heat transfer coefficient.

$\dot{Q} = h.A.(T_s - T_\infty)$ where T_∞ is the ambient temperature.

$$h = \frac{\dot{Q}}{A.(T_s - T_\infty)}$$

We can now calculate the Nusselt Number

$\overline{Nu} = \dfrac{h.D_h}{k}$ where k is the thermal conductivity of the fluid and D_h is the hydraulic diameter

Calculate the hydraulic diameter as $4A_{in}/P$ where, P is the wetted perimeter and A_{in} is the cross-sectional area of the flow.

We can now then use the following correlation to calculate the Reynolds number.

$$\overline{Nu} = 0.037\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.7} \quad \text{for } \mathrm{Pr} \geq 0.6$$

Where Pr is the fluid Prandtl number.

Using the calculated Reynolds number we can calculate the average approach velocity as:

$$\overline{V} = \frac{\mu\,\mathrm{Re}}{\rho D_h}$$

Where μ is the dynamic viscosity, ρ is the density and D_h is the hydraulic diameter.

Please note that this procedure applies to a flat plate under ideal and smooth conditions ignoring the effects of conduction, radiation, its use for the situations outside of this definition requires judgment.

Pleas remember to calculate the properties at the mean temperature.