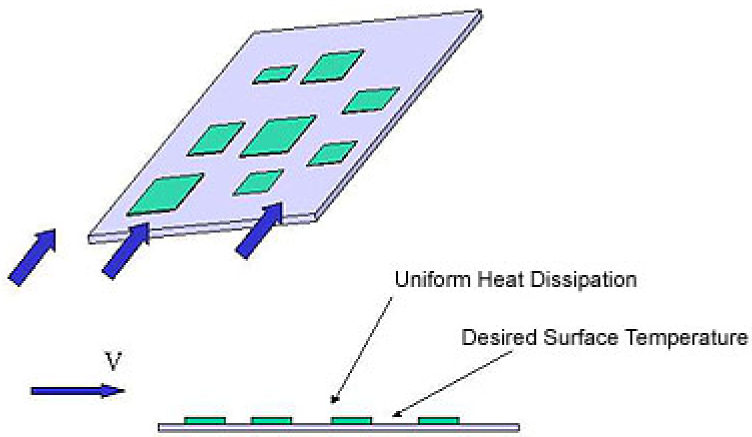
Flow Over a Flat Plate Representing a Printed Circuit Board (PCB) with Low Profile Components

This problem is a simplified version of a complex problem where air flows over a PCB in an open space. This applies to situations where the gap between two adjacent board is much bigger that the maximum boundary layer thickness that forms on both plates. The idealized situations is depicted below:



Often we have a maximum surface temperature in mind for a given total power dissipation and we are interested in estimating the average approach velocity of the cooling fluid that can maintain that surface temperature. Since we don't know the velocity, we have to make an assumption about the flow regime, laminar or turbulent. This is an important decision since the correlation that we will use depends on this choice.

To begin with, let's assume that the flow is laminar. The formulation for calculating the velocity is as follows:

Since the velocity is not Known, we don't know whether the flow must be laminar or turbulent. We will assume a laminar 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

$\overline{Nu} = \frac{h.L}{k}$ where k is the thermal conductivity of the fluid.

We can then use the following correlation to calculate the Reynolds number:

$$\overline{Nu} = 0.664\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3} \quad \text{for } \mathrm{Pr} \geq 0.6$$

where Pr is the fluid Prandtl number.

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

$$\overline{V} = \frac{\mu.\mathrm{Re}}{\rho.L}$$

Where μ is the dynamic viscosity, ρ is the density and L is the length of the plate in the direction.

For air (P_r=0.7) and the critical Reynolds number of 5x10^^{5} the average Nusselt number will be around 416. If the length of the plate is 20 cm (0.2m), this will result in a heat transfer coefficient of 54 w/m^2 - k.

Using this number and the knowledge of the desired temperature difference you can estimate the maximum power that can be dissipated by a laminar flow.

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

Also remember that all of the fluid properties should be calculated at the mean temperature (average of surface and ambient temperatures).