Thermal issues

Note Title — 10/28/2007

We previously saw that:

In general $\longrightarrow$ $U_{sw} = \dfrac{V_{off}\, I_{on}\, t_{sw}}{a}$ $\longrightarrow$ switching losses

Linear $\longrightarrow a = 6$

Rectangular $\longrightarrow a = 2$

Inductive (real diode) $\longrightarrow a = 1.5$

Total losses

$$P_{loss} = P_{cond} + P_{sw}$$ $\rightarrow$ average values

$$P_{sw} = \frac{U_{sw}}{T} = f_{sw}\, U_{sw}$$

$\hookrightarrow$ average power

$$P_{cond} = \frac{U_{cond}}{T} = \frac{I_{on}^2 R_{ds\,on}\, t_{cond}}{T} = D\, I_{on}^2 R_{ds\,on}$$

So for MOSFETS $P_{cond} = \dfrac{I_{on}^2 R_{ds\,on}\, t_{cond}}{T} = D\, I_{on}^2 R_{ds\,on}$

For DIODES $\longrightarrow$ $P_{cond} \simeq \dfrac{V_{fw}\, I_{on}\, t_{cond}}{T} = D\, V_{fw}\, I_{on}$

Now, let's see how we control these losses.

These losses produce heat.

<u>Heat transfer</u>

Heat flow $\longrightarrow q$ (in W/m^2) $\longrightarrow$ This is <u>not</u> charge.

Conduction → $q = k \nabla T$ → temperature gradient

k → thermal conductivity $W/(mK)$

Convection (fluid flow) → $q = h\,(T_{object} - T_{ambient})$

→ From one object to another

h → heat transfer coefinent

Radiation → $q = \varepsilon \sigma T^4$

ε → emissivity (1 for black body)

σ → Stephan-Boltzman constant → $\sigma = 5.67 \cdot 10^{-8} \frac{W}{m^2 K^4}$

→ Mainly in space applications

→ Primary heat dissipation mechanisms → Both linear

Leads to ohm's law analogy

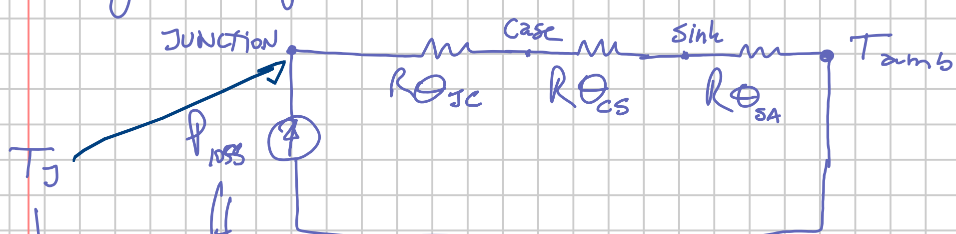
⇓

$$P_{heat} = \frac{1}{R_\Theta} \Delta T$$

P_{heat} → "current" measured in W

ΔT → "voltage" drop measured in K → Although usually is °C

Good things → P_{heat} low or $R\Theta$ low



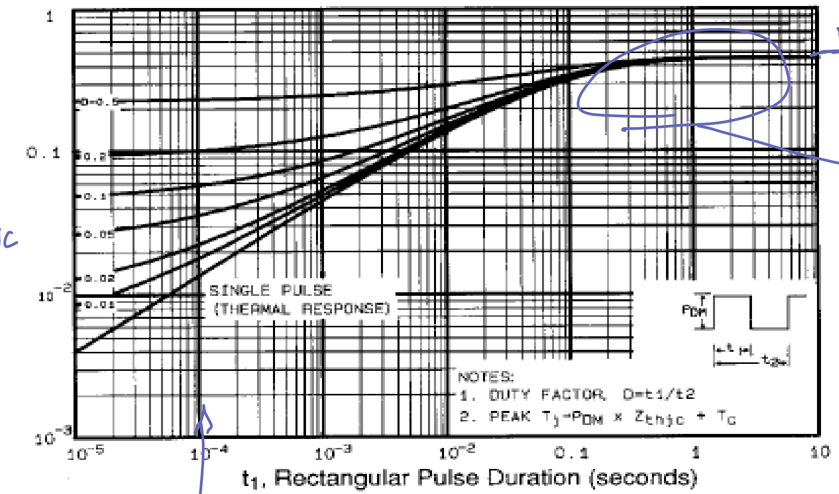
P_{loss} ⇕ $= P_{heat}$ different notation

Want T_J < specified Value

Θ_{JC} → given by switch manufacturer

Dynamic effects: →

$R_{\theta JC}$

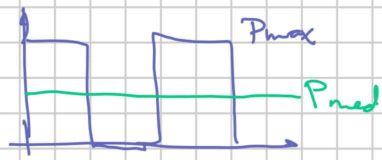


$R_{\theta JC_n}$

Here I use P_{med}

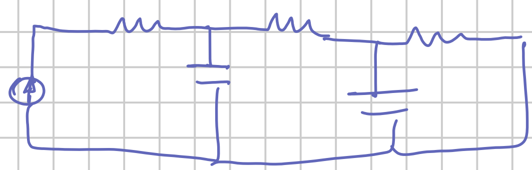
Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

this effect



$\rightarrow$ $P_{med} = P_{max} \cdot D$

Thermal inertia is represented with capacitors



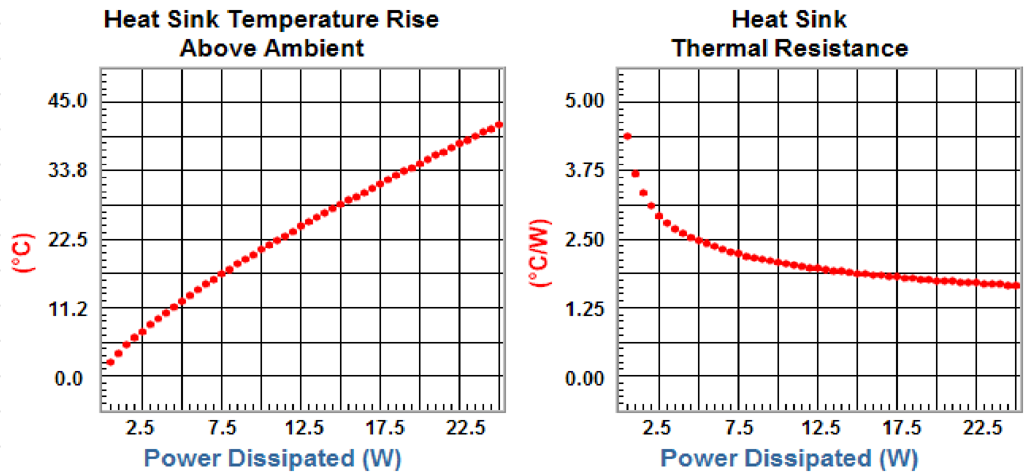
$R_{\theta_{CS}} \rightarrow$ Depends on how the device is mounted onto the heatsink.

$R_{\theta_{SA}} \rightarrow$ depends on
- $\rightarrow$ Shape of heatsink (fins)
- $\rightarrow$ Area of heatsink
- $\rightarrow$ Color of heatsink
- $\rightarrow$ Material of heatsink
- $\rightarrow$ Dissipated power (chimenee effect)

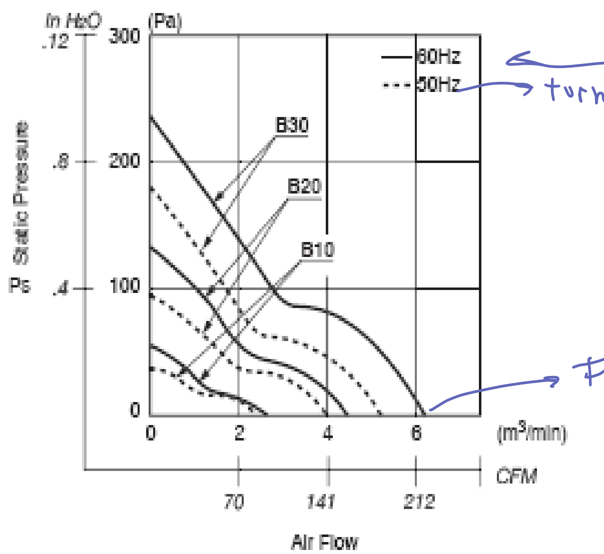
Design procedure:
1) Calculate P_{loss}
2) Choose a desired ΔT_{JA}
3) Look into device's datasheet for $R_{\theta_{JC}}$ and $R_{\theta_{CS}}$
4) Calculate $R_{\theta_{JA}} = \dfrac{\Delta T_{JA}}{P_{loss}}$
5) Calculate $R_{\theta_{SA}} = R_{\theta_{JA}} - R_{\theta_{JC}} - R_{\theta_{CS}}$

6) Find a heatsink such that for the specified P_{loss} : $R_{\theta_{Heatsink}} < R_{\theta_{SA}}$

Natural Convection



<u>Forced heat dissipation (with fans)</u>



turns slower than

Flow in Vacuum

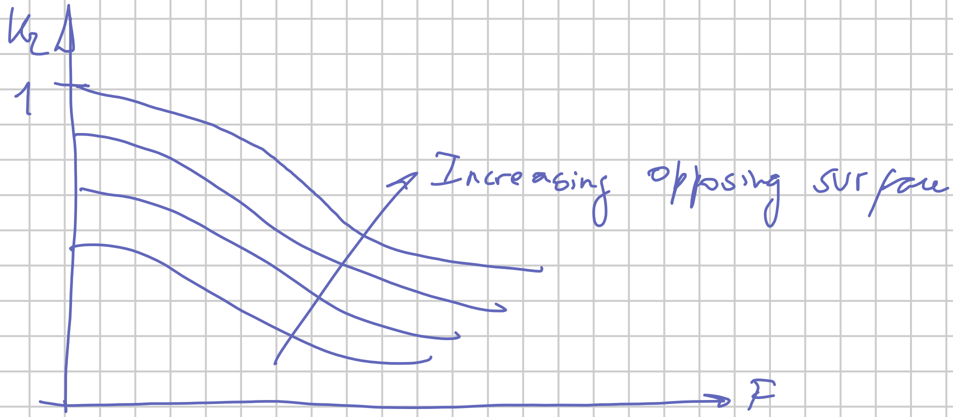
$$\Delta T = \underbrace{T_{air\ in}}_{T_{amb}} - T_{air\ out} = 1.89 \frac{P}{F}$$

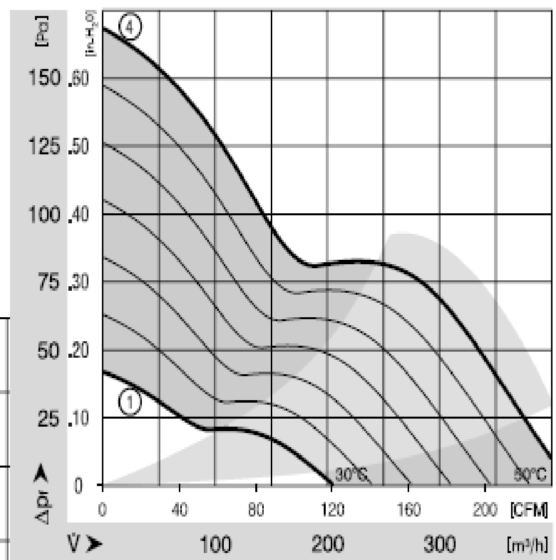
Again ΔT and P are related linearly

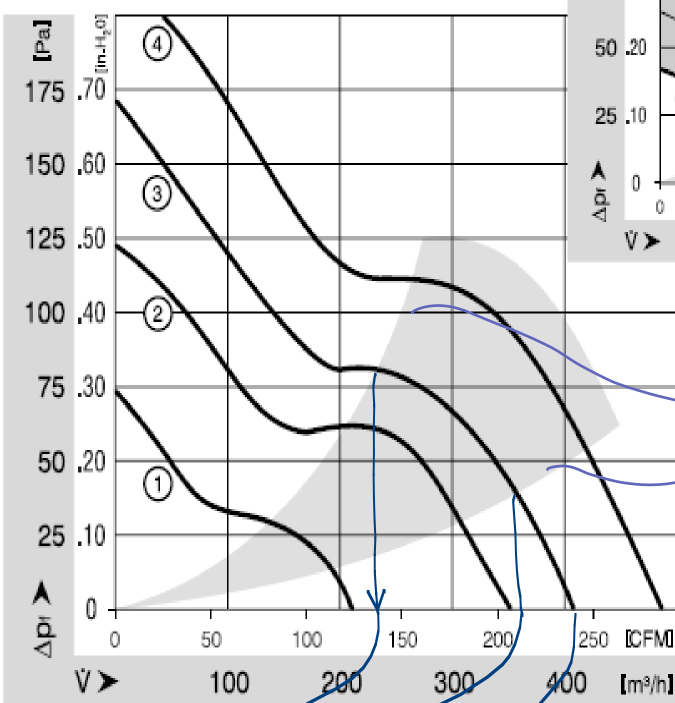
$$\frac{\Delta T}{P} = R_{\theta_{fan}} = \frac{1.89}{F}$$

F in CFM

If $k_2 = \dfrac{R_{\Theta \text{ forced dis.}}}{R_{\Theta \text{ natural convection}}} < 1$







pressure loss from object to be cooled

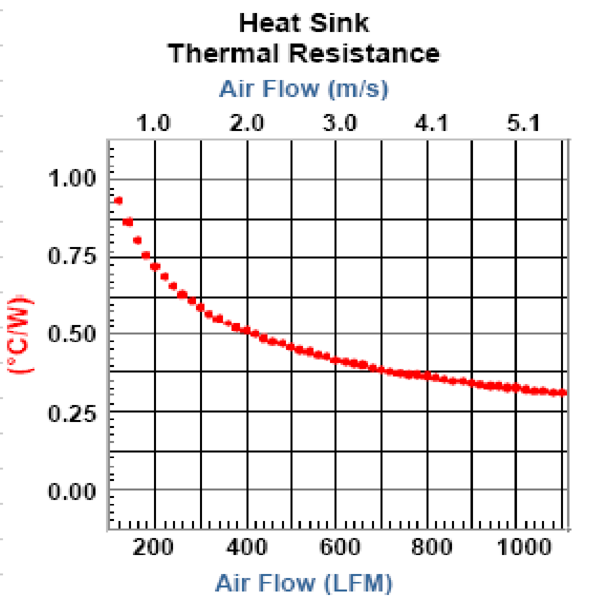
quadratic form but difficult to know

140 210 240

max

So a fan with a maximum air flow 1.3 to 2 times the required air flow is selected

what is required?



CFM → ft^3/minute

LFM → linear ft/minute

{ LFM = CFM/Area

Area in ft^2