Electronics and
Computer Science

ELEC2208 Power Electronics and Drives

Heating and Cooling

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Heating and Cooling

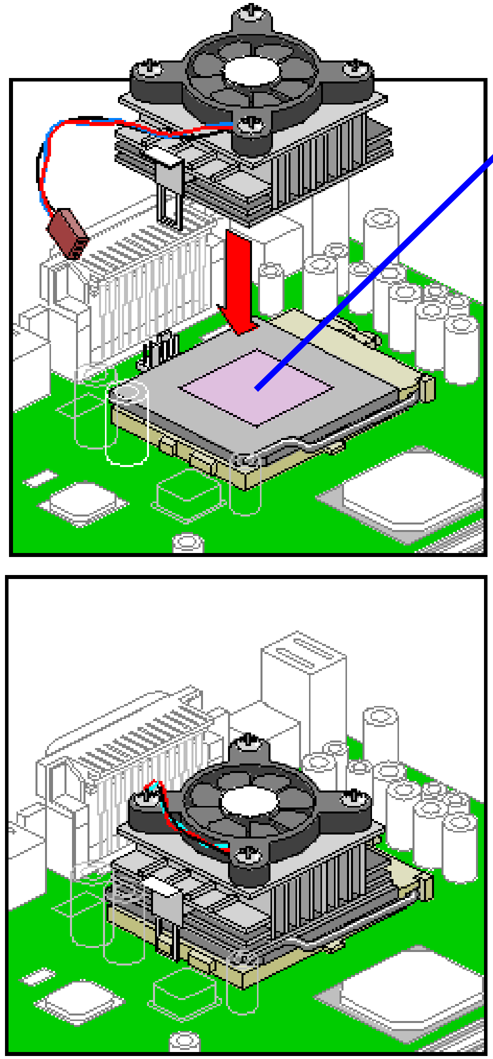
- Power losses in semiconductor devices are dissipated as heat energy.

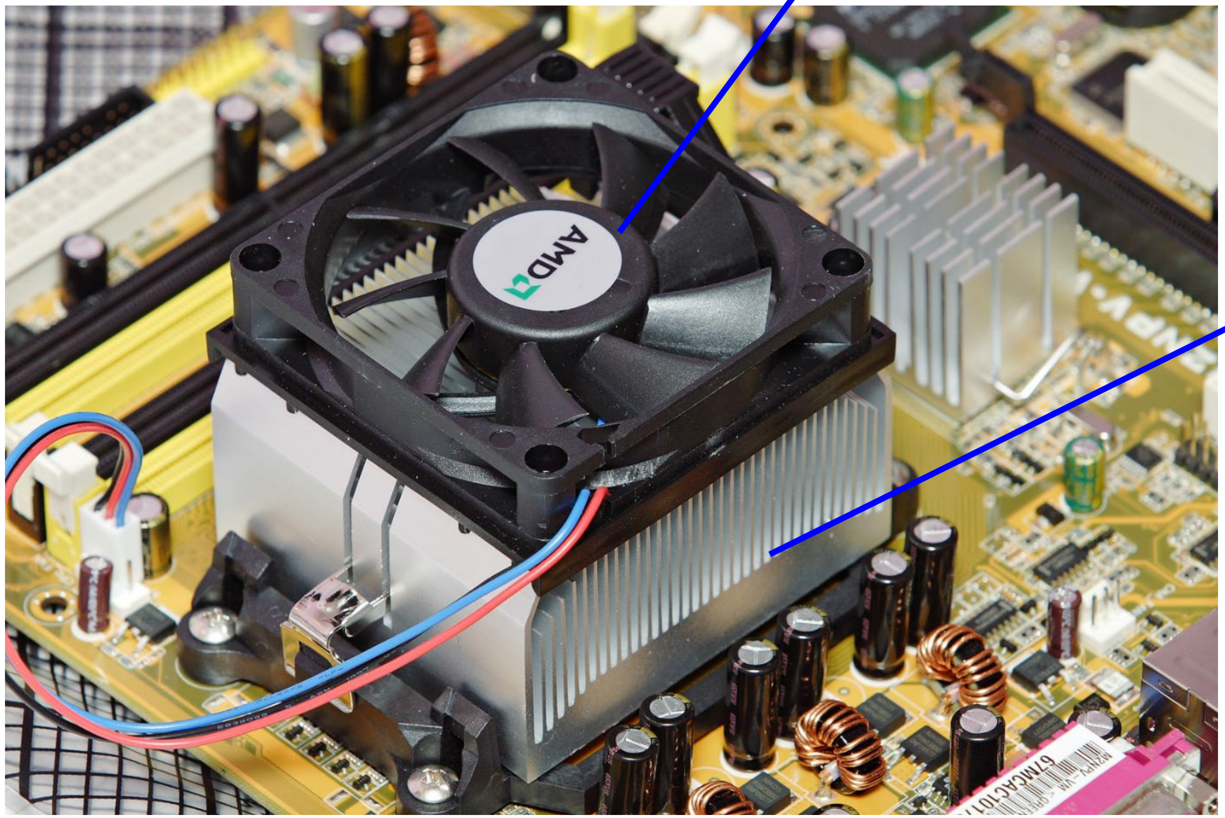
- The temperature inside the device is called junction temperature at PN junction.
- The maximum temperature at which the device can operate safely is typically 150 ^{o}C.

- Heat sink is normally attached to the base of semiconductor devices to dissipate heat into surrounding medium and to cool the device.

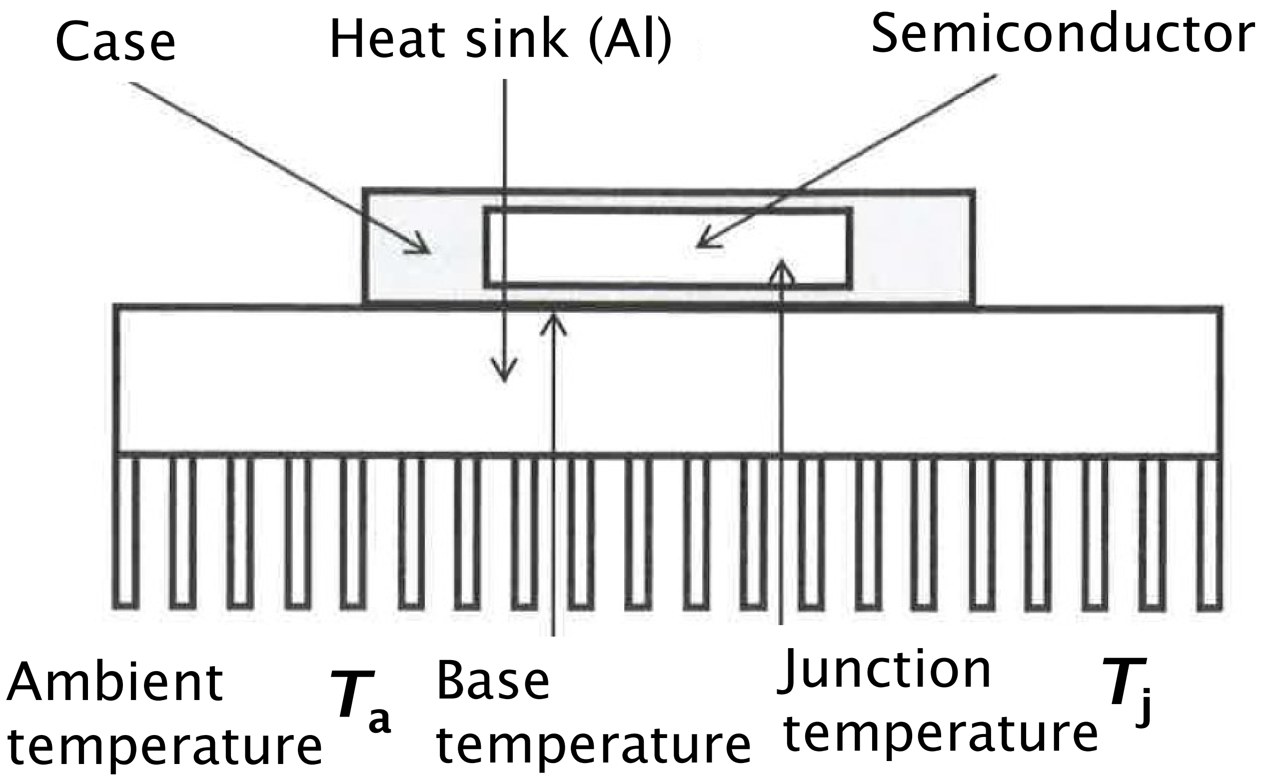
- The performance of cooling is affected by thermal resistance, measures of how good a material to resist heat flow.

Heat sinks in products





Heat sinks - Modelling



- Power (heat) P is assumed to be generated inside the semiconductor device.

- The temperature difference ΔT between the device and ambient should be proportional to the power provided.

$$\Delta T = T_j - T_a = PR_\theta$$

R_θ : **Thermal resistance**

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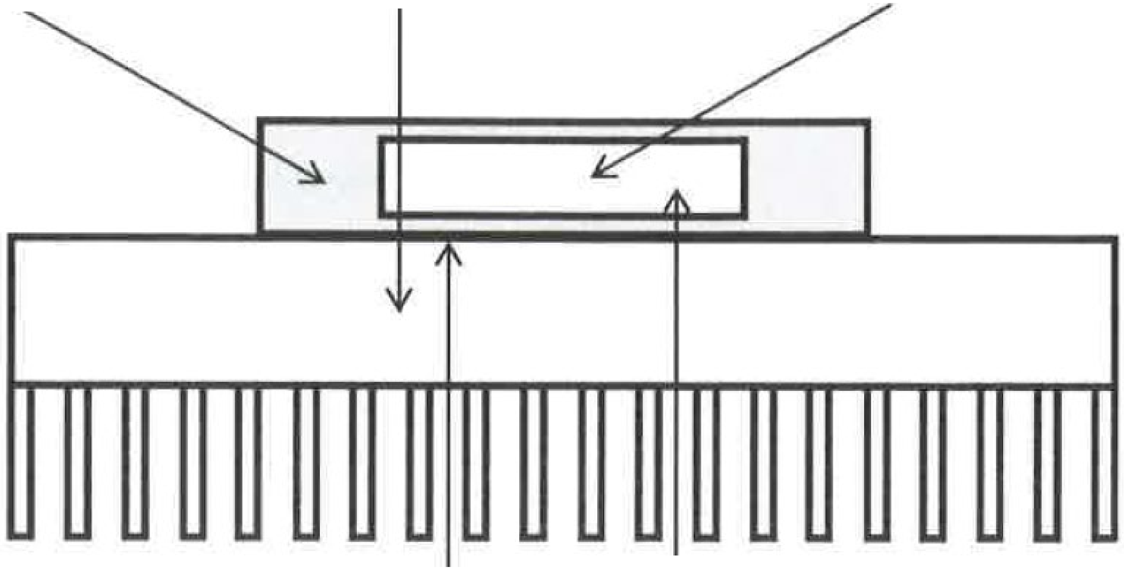
Thermal resistance



$$R_\theta = \frac{\Delta T}{P} = \frac{T_j - T_a}{P}$$

- For constant power, the temperature difference is low if the thermal resistance is low.
- Heat transfer is better if R_θ is low.

Lower R_θ suggests better cooling performance.

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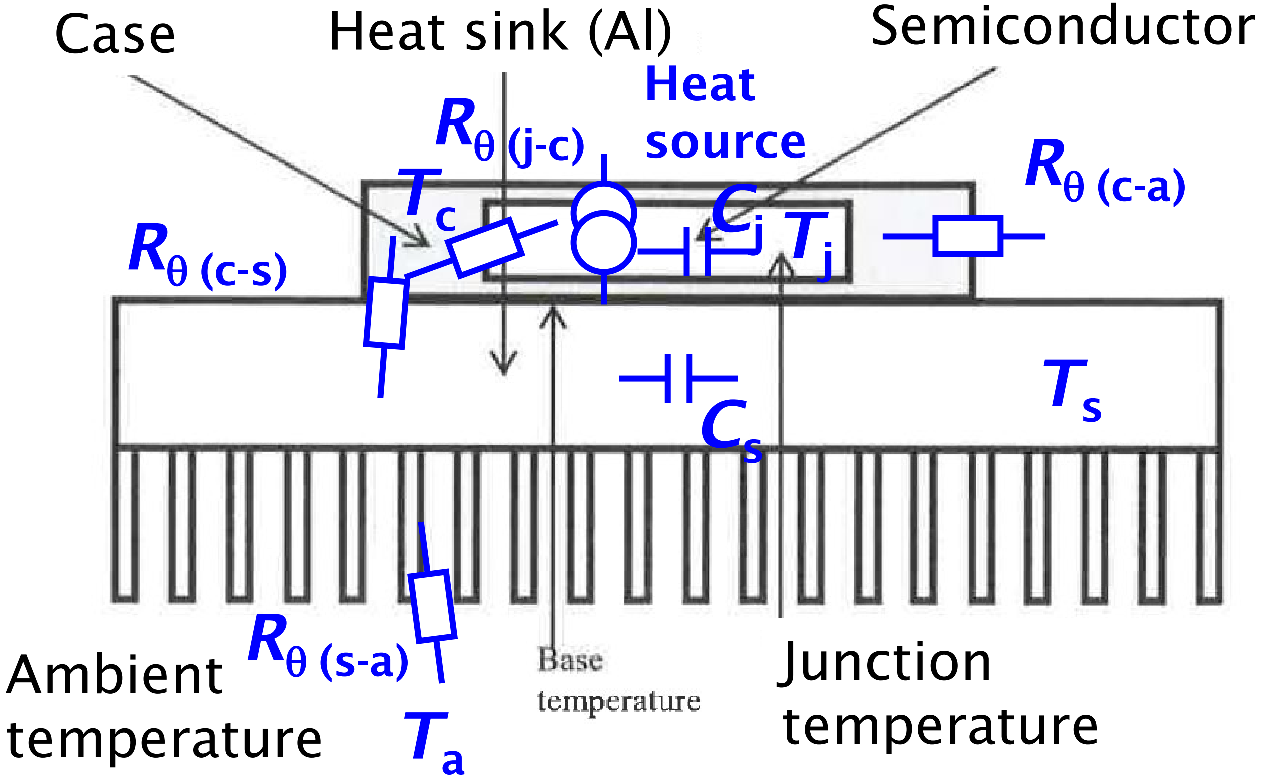
Equivalent electrical model



Parameters are defined according to the analogy to electrical circuits.

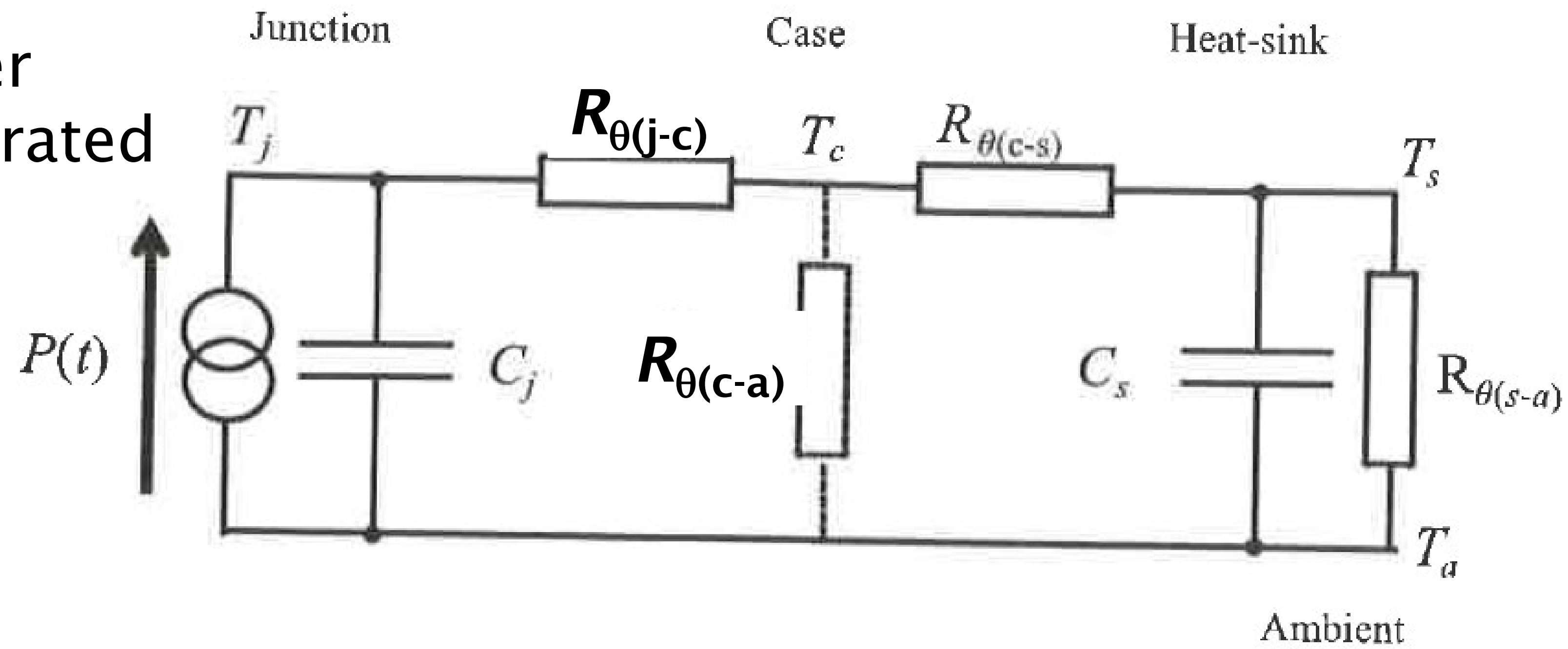
T: Temperature of a part

R_θ: Thermal resistance between two parts

C: Thermal inertia defined as the degree of slowness with which the temperature of a body approaches that of its surroundings.
(Linked with volumetric heat capacity)

Equivalent electrical model

Power generated P



T_c: Case temperature

T_s: Heat sink temperature

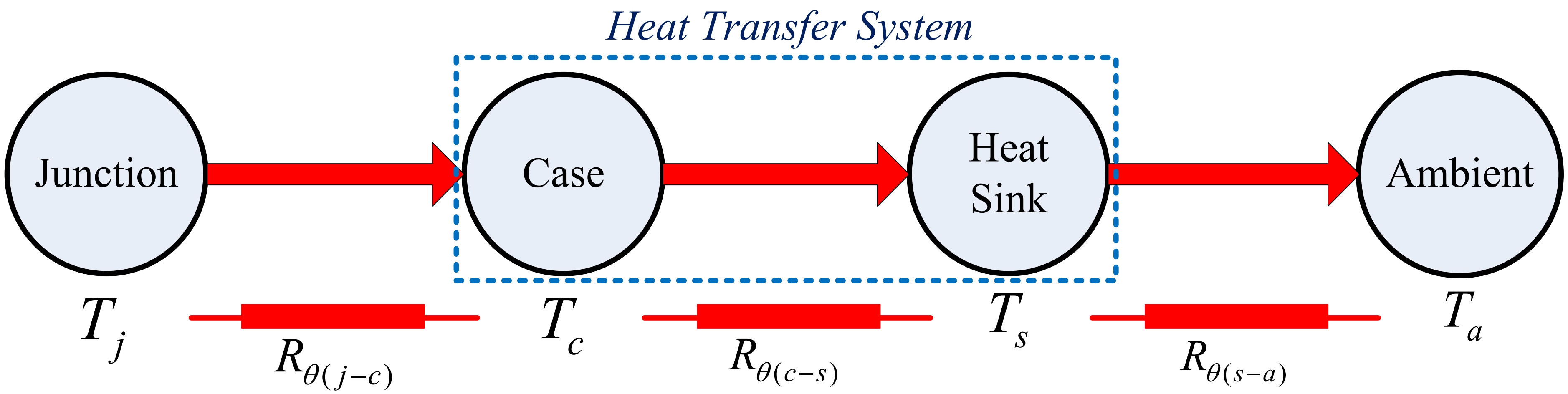
$R_{\theta(A\text{-}B)}$: Thermal resistance between A and B (°C/W)

A, B: Junction, Case, Heat-sink, Ambient

C_j: Thermal inertia of Junction (J/°C)

C_S: Thermal inertia of heat sink (J/°C)

Equivalent electrical model analysis



$\boxed{T_j - T_c = PR_{\theta(j-c)}}$ $\boxed{T_c - T_s = PR_{\theta(c-s)}}$ $\boxed{T_s - T_a = PR_{\theta(s-a)}}$

$$\Delta T = T_j - T_a = P\,(R_{\theta(j\text{-}c)} + R_{\theta(c\text{-}s)} + R_{\theta(s\text{-}a)}) = PR_{\theta(j\text{-}a)} = PR_{\theta(\text{total})}$$

We can analyze which part is dominant for total thermal resistance.

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Summary – Heating and Cooling

- Thermal management of power electronics circuits is important to secure safe operation of the devices and systems.
- Heat transfer systems can be modelled by equivalent circuits where thermal resistance and thermal inertia are defined in analogous to electrical circuits components.
- Analysis of thermal equivalent circuits can provide requirement for thermal management hardware to maintain safe operation of semiconductor power devices.