<u>Thermal Considerations</u>

Why is temperature such an important consideration when designing electronic systems?

FAILURE!! FAILURE!! FAILURE!! FAILURE!!

Enclosures with high power electronic components or systems usually require ventilation / forced air cooling / refrigeration. The cooling system is dependent primarily on:

- Power dissipated by system
- Ambient temperature

What components typically dissipate heat?

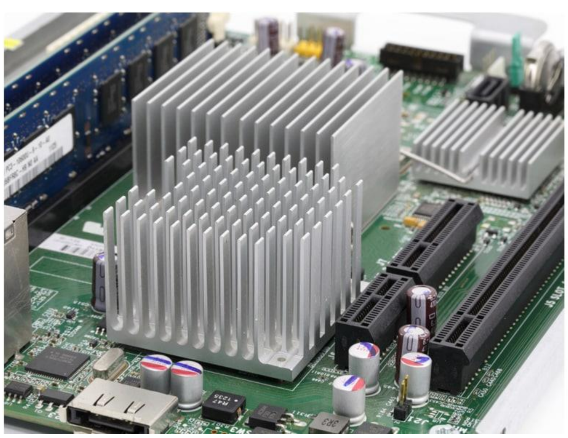
- Resistors
- Transistors
- Integrated Circuits

<u>Resistors</u> –

- Important to select proper Wattage rating
- Must provide proper spacing from other temperature sensitive components

<u>Transistors / Integrated Circuits</u> -

- Often require *Heat Sinks*
- Heat sinks often mounted on outside of enclosures to dissipate heat to ambient air. However, this is not always possible.
- You have probably seen heatsinks mounted on a processor; in our case we will use one that will mount on the voltage regulator:



CPU Heatsinks

TO-220 Heatsink

How is a Heat Sink selected?

1. Empirical approach. Randomly select a heat sink and see if part burns up. *Not so good…*

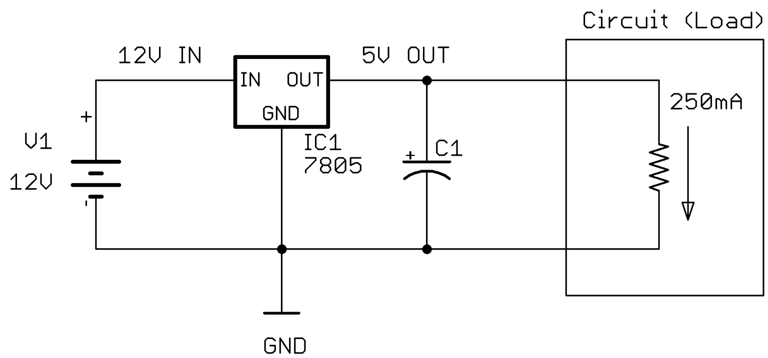
2. Perform power dissipation calculations and select the proper heatsink. *A better approach!*

Heatsink Selection:

Step 1: Calculate input power from source and power dissipated by device:

Example: A DC voltage regulator with 12V in and 5V out. The load (output circuit) requires 250mA of current.

** Note, the 7805 voltage regulator is a linear device which is always on. This means that the power in minus the power out is wasted as heat!



Calculate worst case values:

Input voltage = 12V
Input current = ~250mA

Output voltage = 5V
Output current = 250mA

Voltage drop across Vreg = (Vin – Vout) = 7V
Input Power = Input current x input voltage = ~0.25A x 12V = 3 Watts
Output Power = Output current x output voltage = 0.25A x 5V = 1.25 Watts

Power dissipated by Voltage regulator = $P_{IN} – P_{OUT}$ = 3W – 1.25W = 1.**75W**

In order to calculate the size of the heatsink there are a number of different factors that go into the calculation. At first this seems like a lot, but it's not that complicated – just understanding what the terms mean.

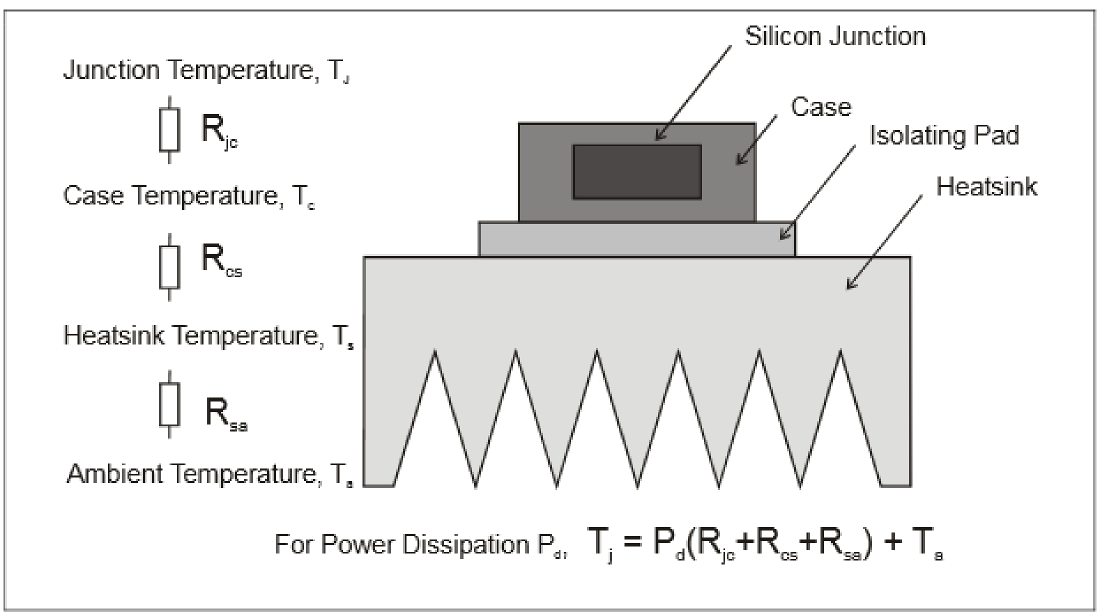
Thermal Terms:

θ = **Thermal Resistance**: Temperature increase for each Watt dissipated.

Example: if θ = 1 this means the temperature in the material goes up 1°C for each watt dissipated. This is based on thermal mass

P	Power that device must dissipate (*calculated from design above*)
T_J	Silicon Junction Temperature of the device – *Specified in data sheet* – maximum temperature before device is destroyed
T_A	Ambient Temperature – maximum temperature of air surrounding device
θ_{JC}	Thermal resistance between junction and case - *Specified in data sheet*
θ_{CS}	Thermal resistance between case and heatsink – *Calculated*
θ_{SA}	Thermal resistance between heatsink and air : *Heatsink value from mfg.*

Each of these values can be visualized as a resistor **R** that limits the heat transfer:



https://www.re-innovation.co.uk/docs/heatsink-calculations/

Let's look at the values from a 7805 datasheet:

- Maximum Power dissipated: 1.75 Watts (from previous calculations)
- Maximum T_J = 125°C (T$_J$ Max)
- T_A = 30°C ~ 86°F Room temp ~ 20°C, but adding some extra*
- θ_{JC} ~ 2.5°C / Watt (for a TO-220 package)

- θ_{CS} is calculated based on how the heatsink is attached to device. Typically, silicone grease and / or an insulator are applied. These *increase* the thermal resistance between the device and heatsink. Typical values: 2°C / Watt (silicone) + 2°C / Watt (insulator)

- θ_{SA} is what we are wanting to determine to select the correct heatsink.

Now that we understand these terms, we need to calculate the value of θ_{SA}. This will allow us to look at the values available from Heatsink manufacturers to find the smallest practical size of heatsink.

* Why? *Enclosure with no air circulation will increase temperature – examples: Exposure to sun / Under car hood*

Main Heat sink formula:

$$T_J = T_A + P(\theta_{JC} + \theta_{CS} + \theta_{SA})$$

Since we want to find out what θ_{SA} is, we can rearrange terms to calculate for this value.

$$\theta_{SA} = (T_{Jmax} - T_{amax}) / P_{Vregulator\ worst\ case} - \theta_{JC} - \theta_{CS}$$

$$\theta_{SA} = (125°C - 30°C) / 1.75W - (2.5°C / W) - (4°C / W)$$

$$\theta_{SA} = 47.7°C / W$$

This is the **largest thermal resistance** value for the heatsink that can be used without damaging the device. This is usually derated (i.e. a larger size is selected so we have some headroom).

Heat sink size	θ_{SA}
Smaller	Larger
Larger	Smaller

Let's look at the heatsink used for the clock project: (θ_{SA} = 24.4°C / W)

Avid 577202B00000G

This heatsink will get hot! 1.75 x 24.4 = 42.7°C + Ta = 72.7°C (that's ~163°F)!

BUT – it will keep the device from burning up!

Link to datasheet:

https://www.digikey.com/products/en?keywords=hs107-nd

Link to online calculator:

https://www.allaboutcircuits.com/tools/heat-sink-calculator/

In depth tutorial:

https://www.digikey.com/en/ptm/a/aavid-thermalloy/how-to-select-a-heat-sink/tutorial

Webtool example:

https://www.heatsinkcalculator.com/heat-sink-size-calculator.html