Studying Thermoelectric Generators

Anastasija Cumika
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Capstone Adviser: Dennis Sullivan

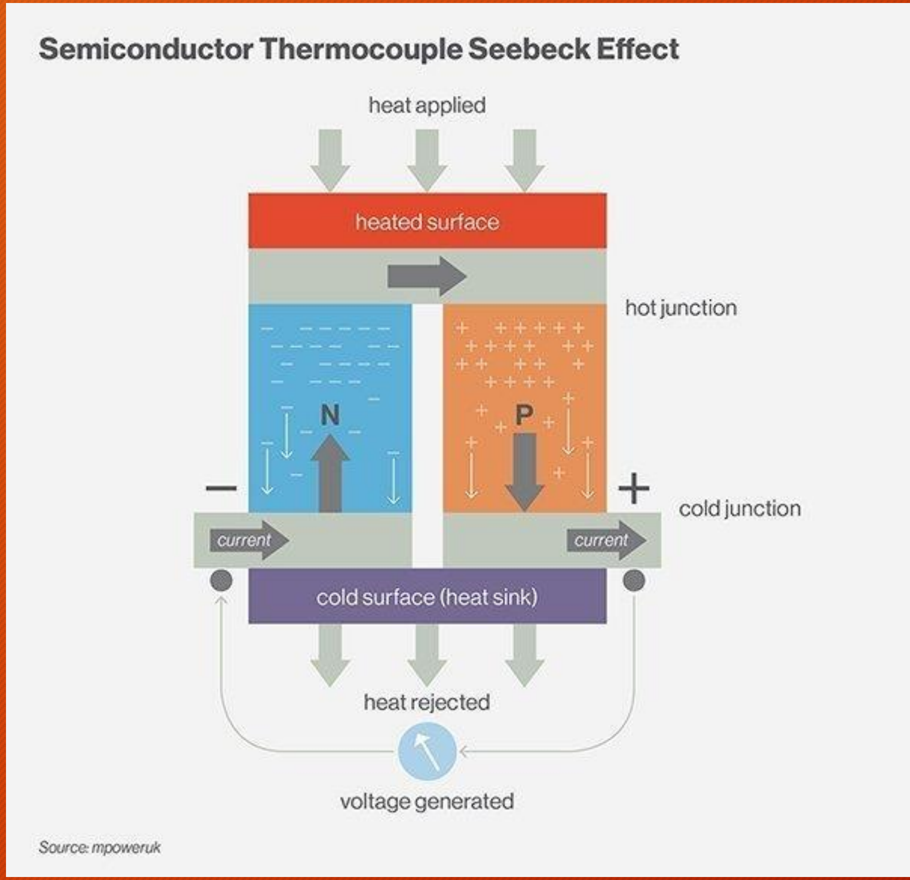
Project Overview

- The main purpose of the project was to analyze thermoelectric generators (TEGs), so someone who is developing application for the TEGs could use this material.
- To achieve this goal:
  - Theory on Seebeck Effect, TEGs and Heat transfer was studied
  - Out of the available materials, the best possible design for the electricity generating using TEG was created.
  - The outputs of the TEG were studied and analyzed under various conditions such as different loads, temperature differences, average temperatures and arrangements of the TEGs.

Seebeck Effect and ZT

Seebeck effect is the phenomenon when temperature difference between two junction of dissimilar electrical conductors produces emf (voltage).

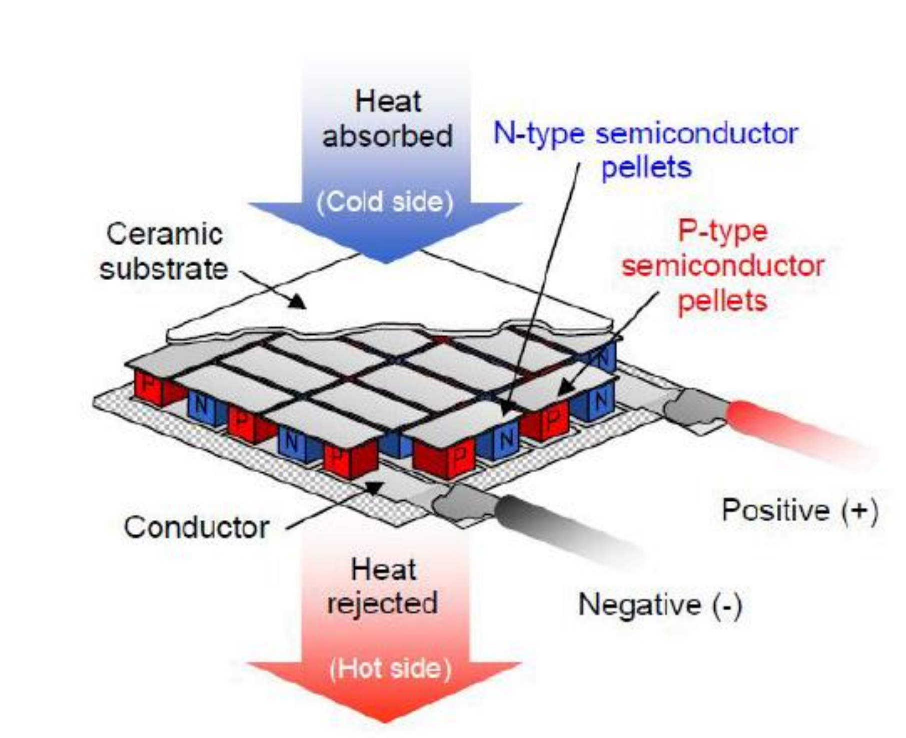
$$V = \alpha * \Delta T$$



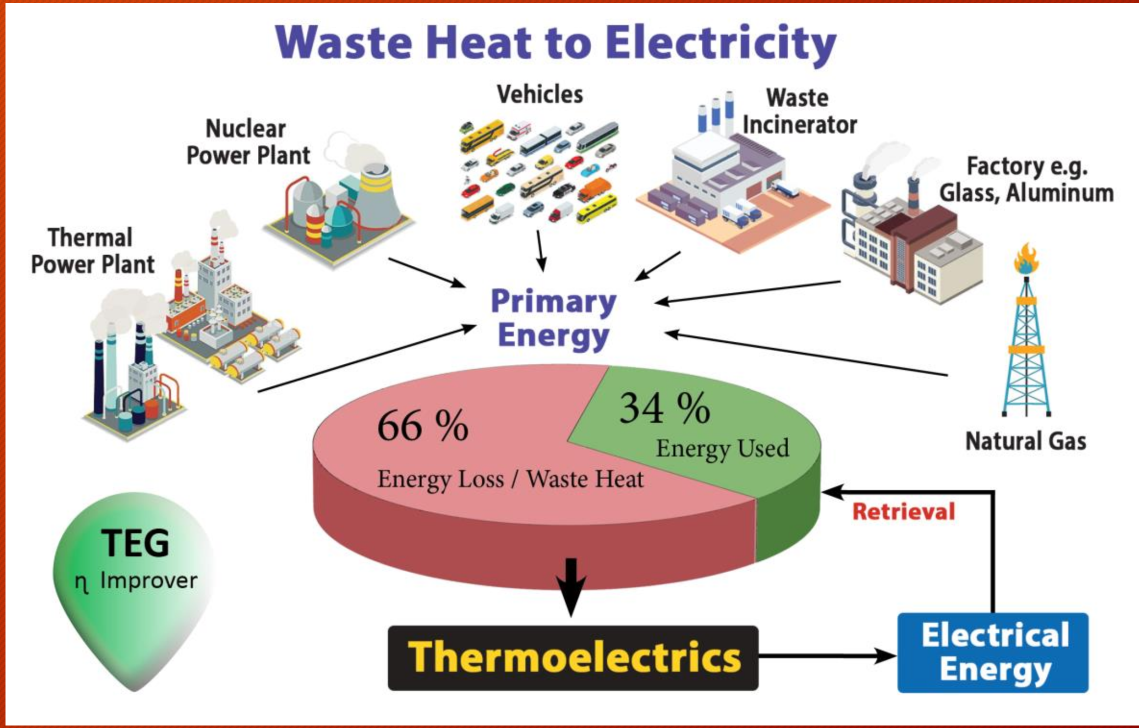
The dimensionless figure of merit (ZT) shows how effective a specific material is for the thermoelectric performance.

$$ZT = \frac{\alpha^2 \sigma T}{k}$$

Thermoelectric Generator



TEG does not have any moving parts, has no noise or vibration and it is very compact and environmentally friendly.



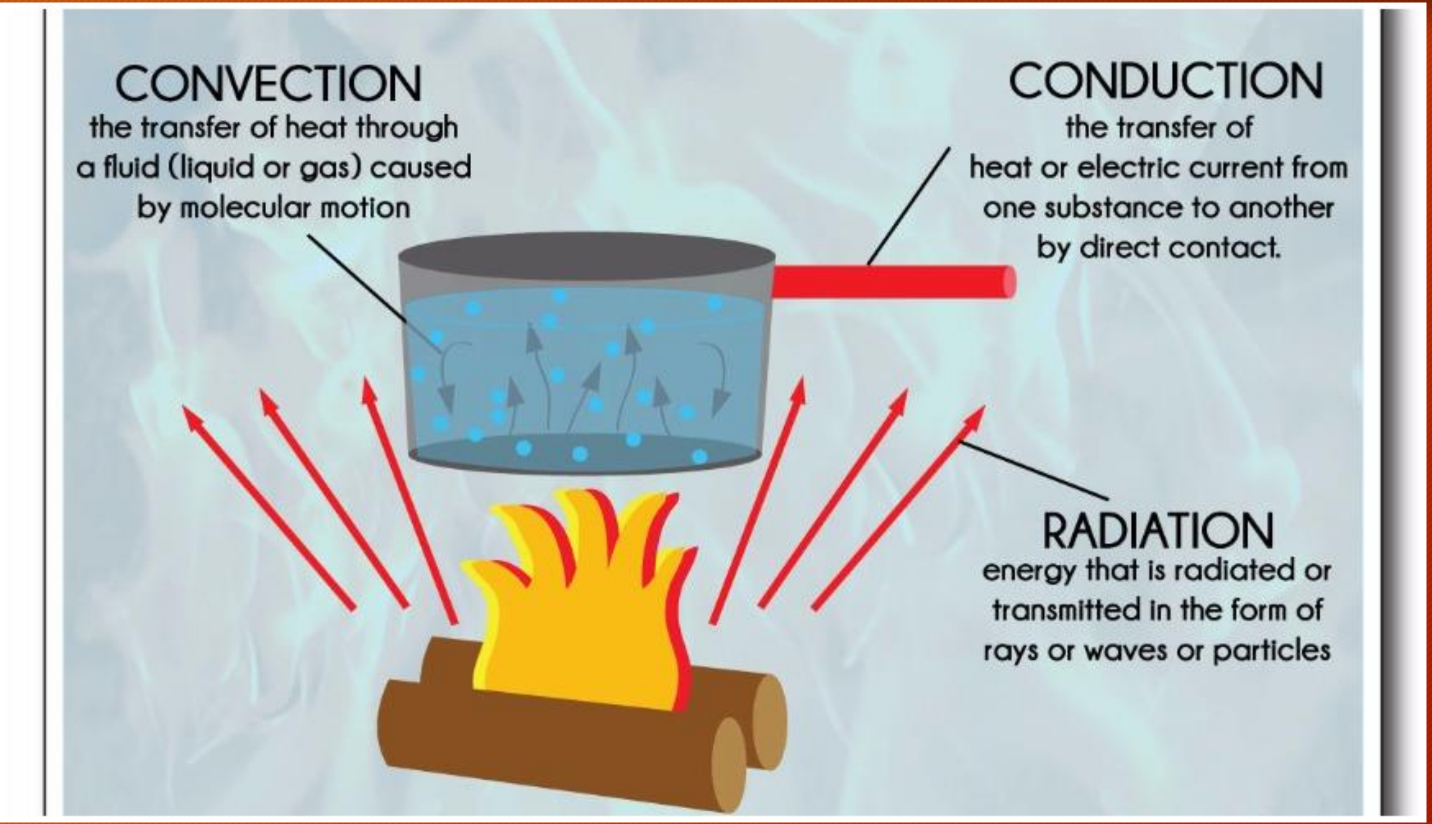
The most popular material is Bi_2Te_3, which allows temperature up to 320 degrees Celsius.

Heat Transfer

Two types of convection: forced and free (natural).

Comvection current: hot fluid rises, more dense cold fluid drops -> Circular motion.

$$q = -h * A * \Delta T$$



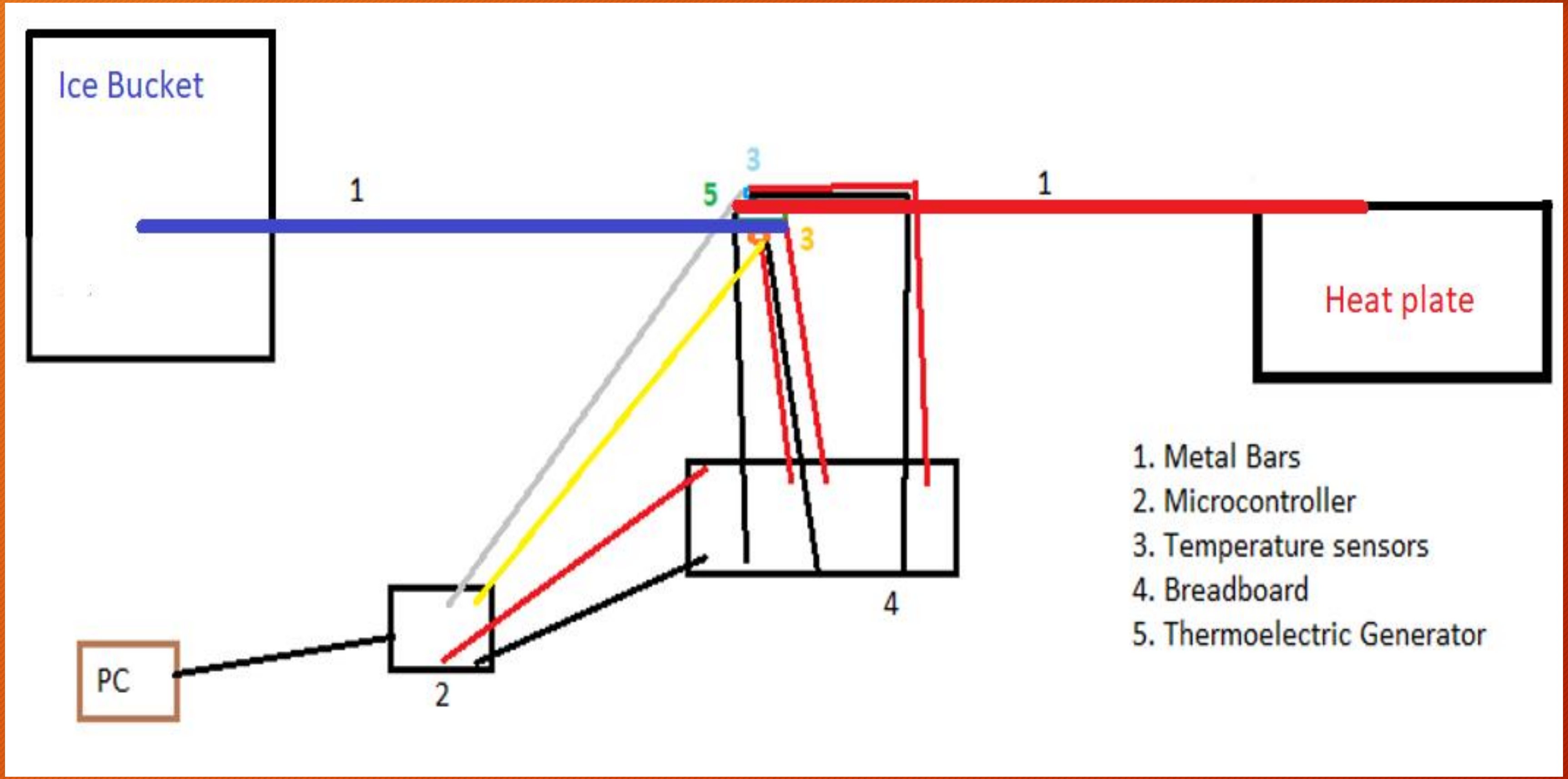
The conduction heat transfer is a result of the neighboring particles exchanging the kinetic energy through collisions.

$$q = \frac{-k * A * \Delta T}{\Delta x}$$

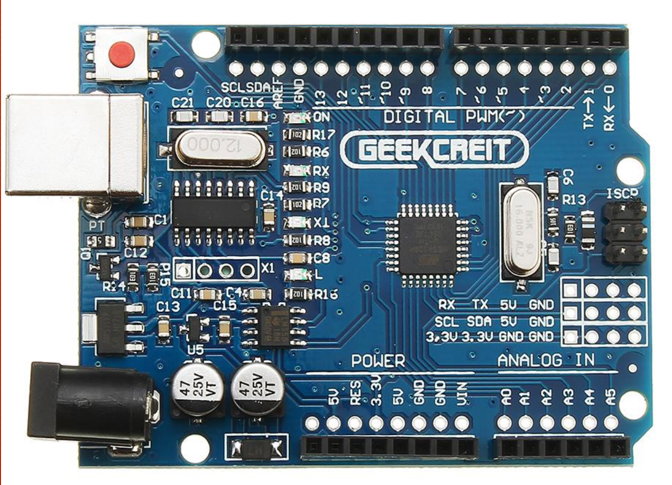
Newton's Law of Cooling: $T(t) = T_s + (T_i - T_s) * e^{-kt}$

Data Collection

Temperature Sensor LM35

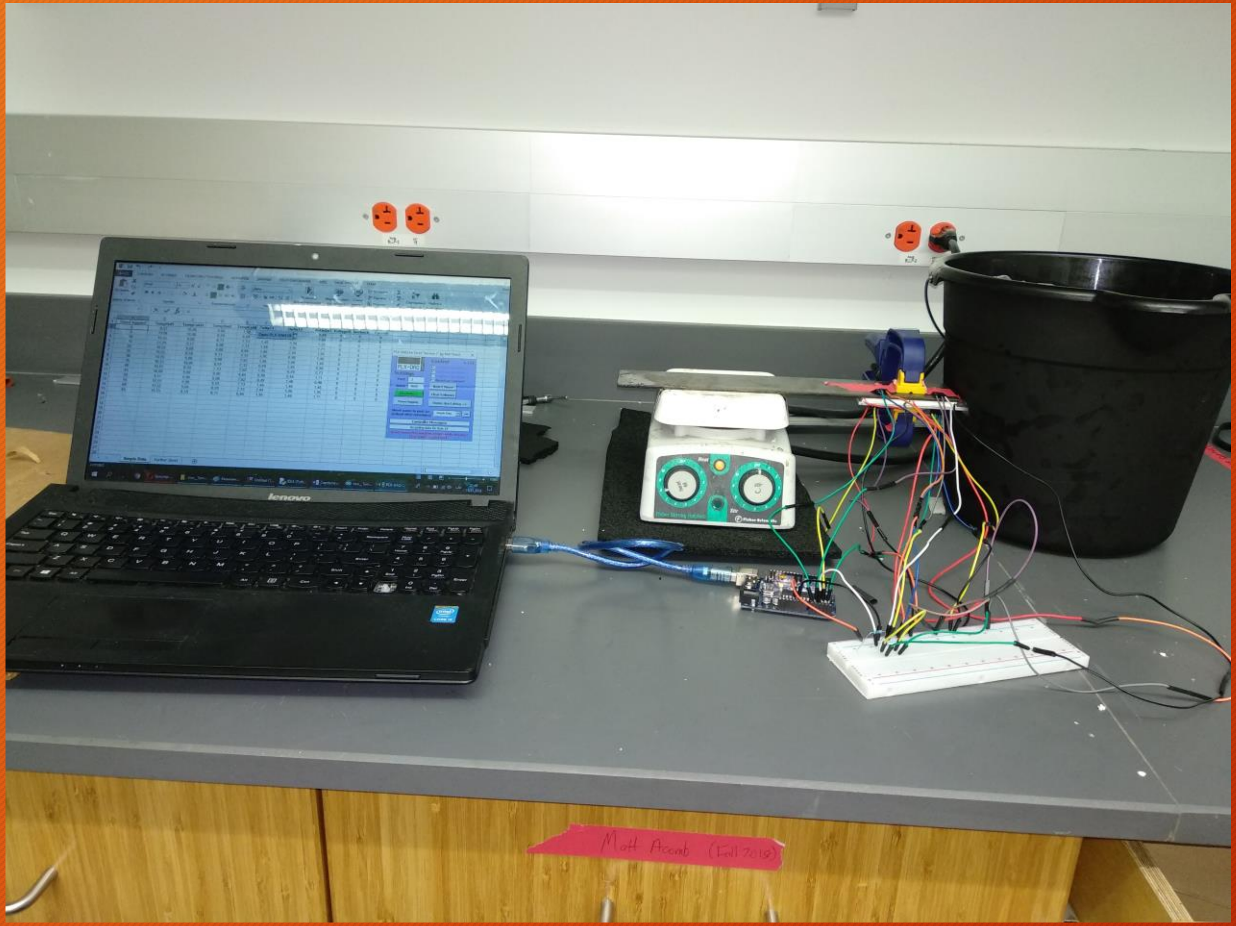


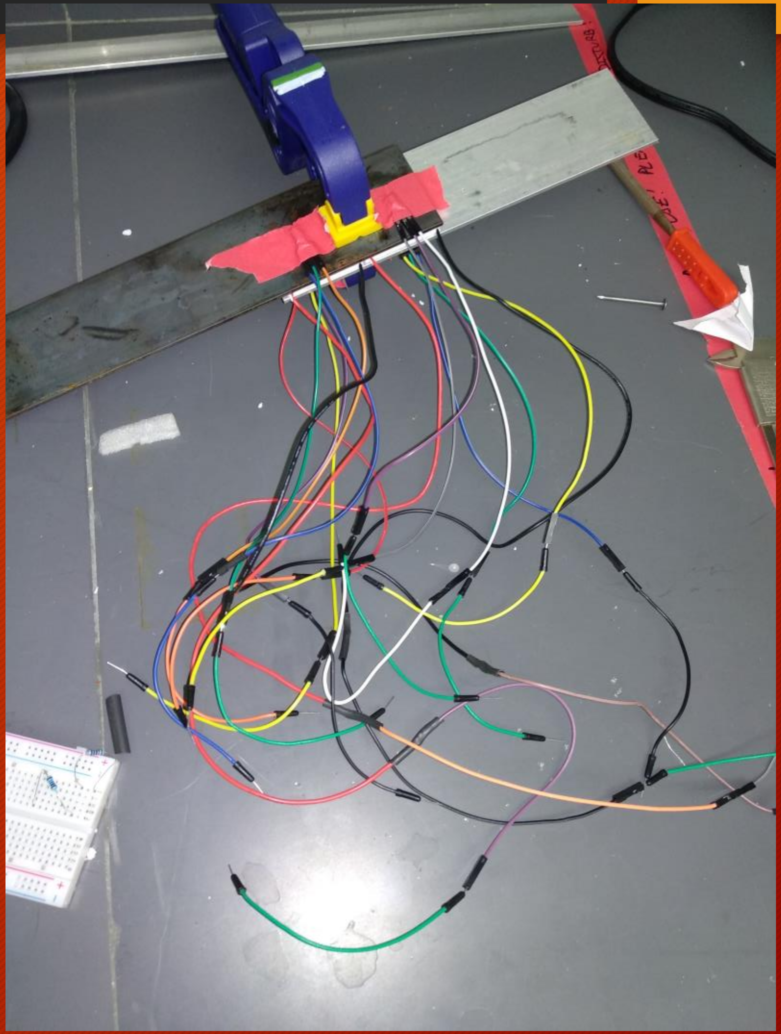
“Master” Setup



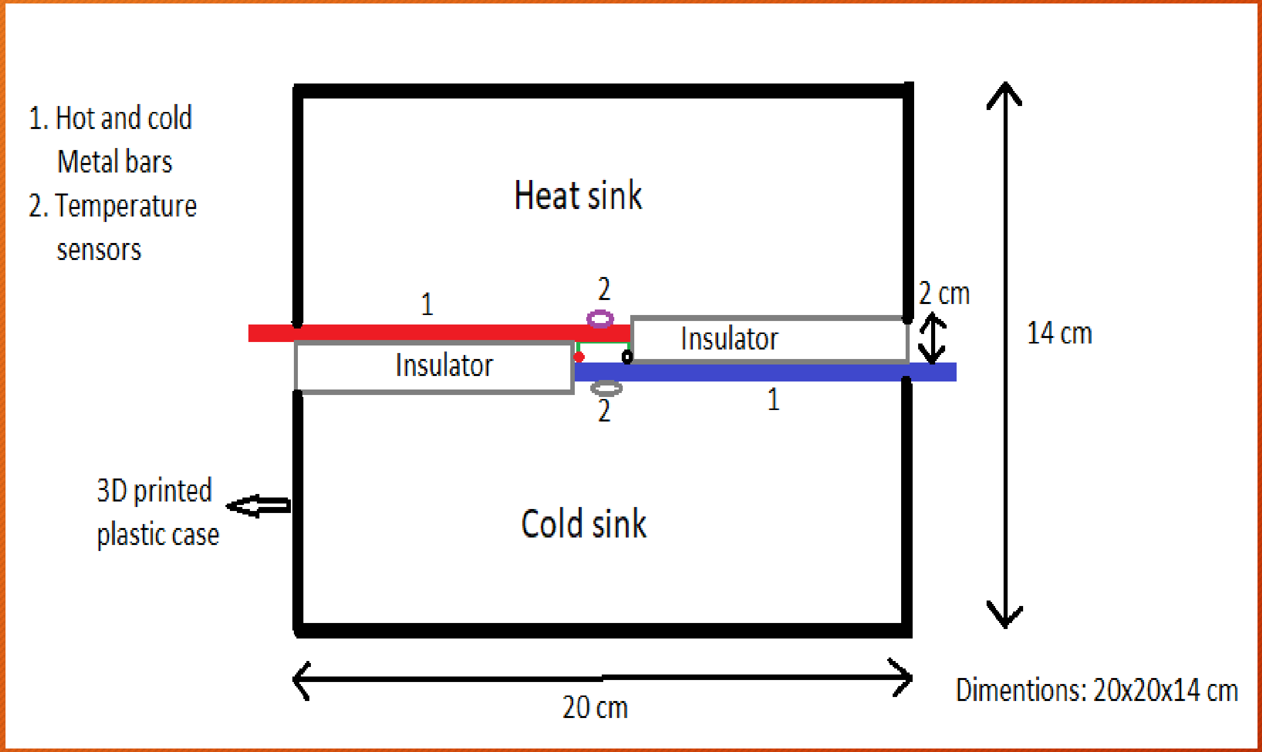
Geekcreit UNO R3
Microcontroller

Example: Experiment with 2 TEGs

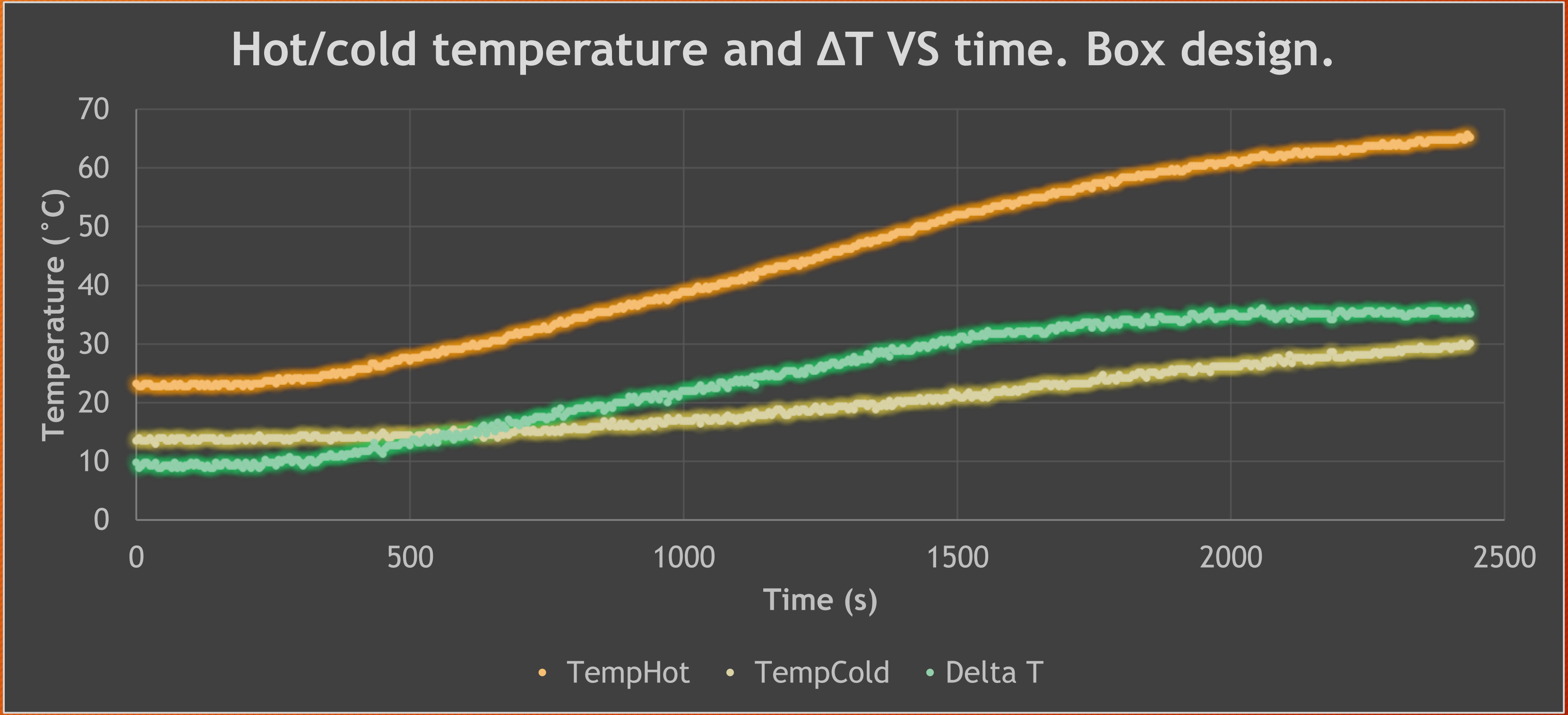




Does heat convection affect bars temperature?



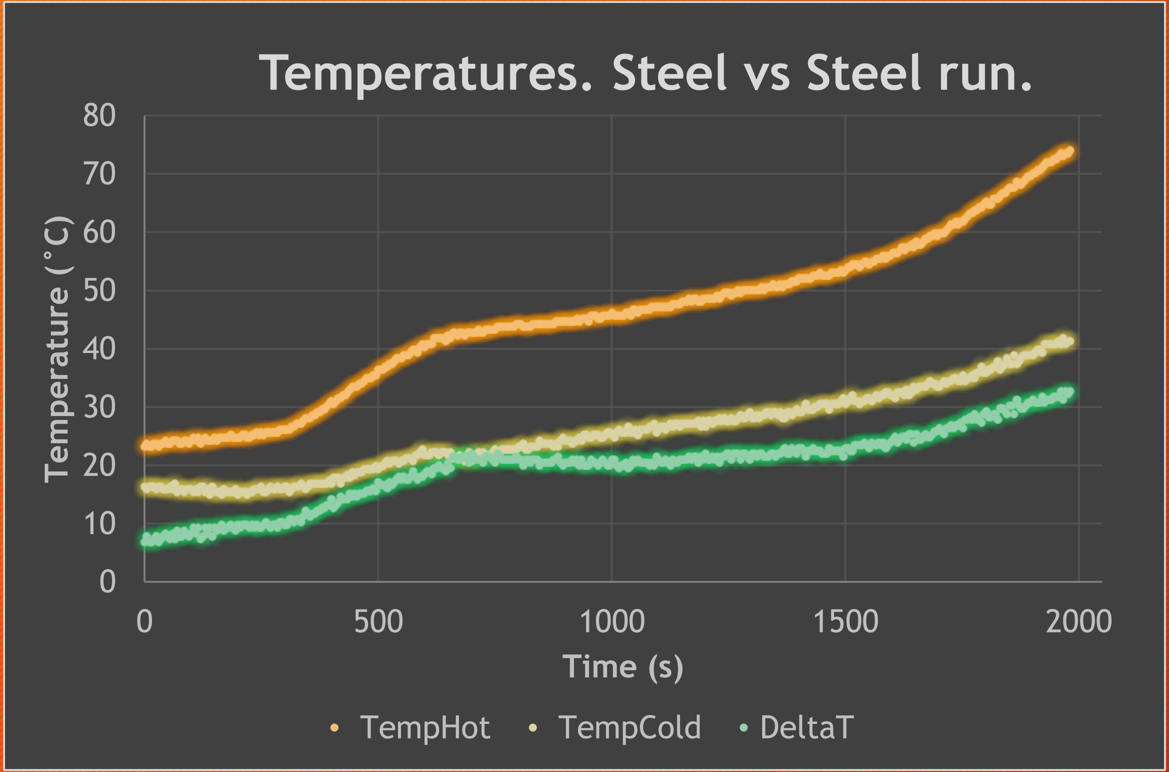
Heat convection effect is negligible

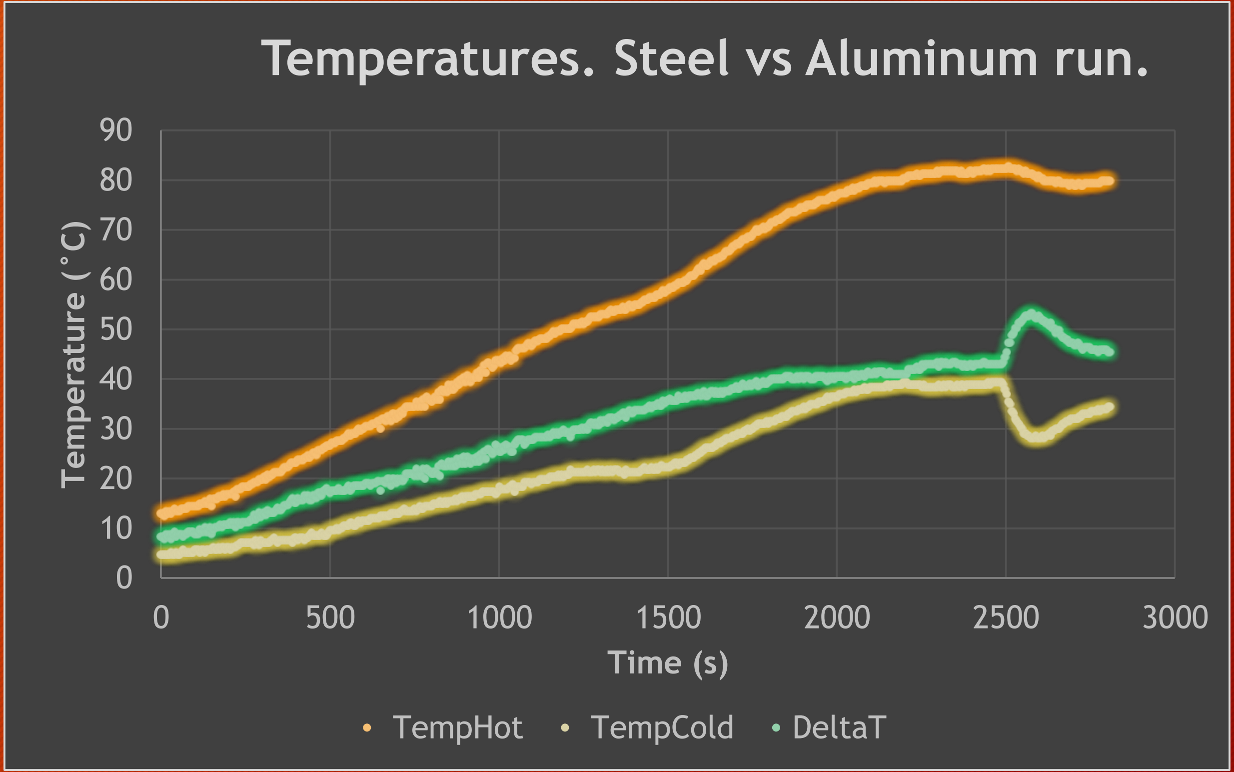


The convention heat loss rate: -1.8 W

Conduction heat transfer from hot to cold bar through TEG is -141 W.

Materials for the bars

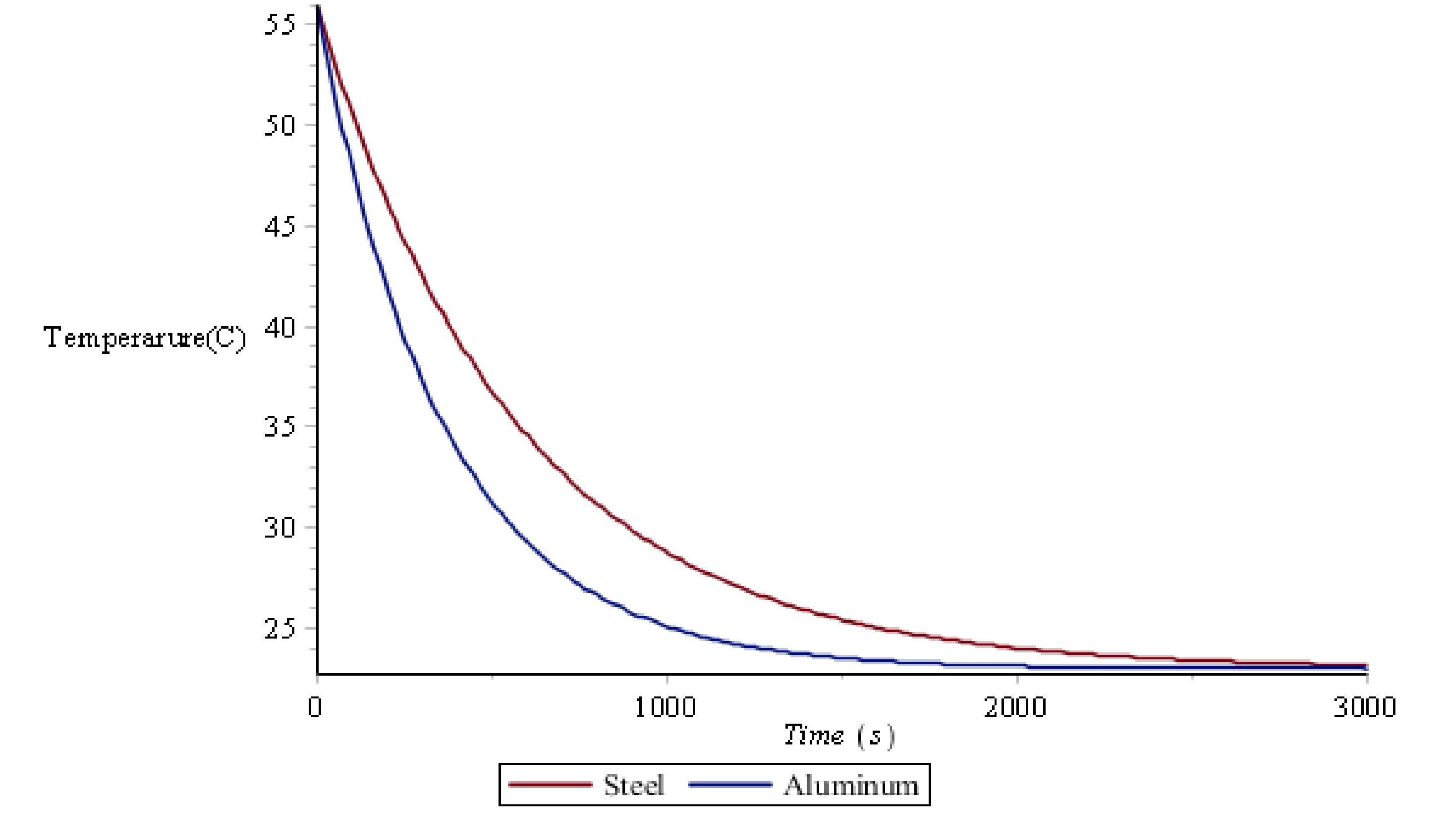




Theoretical Comparison of Steel and Alumimun

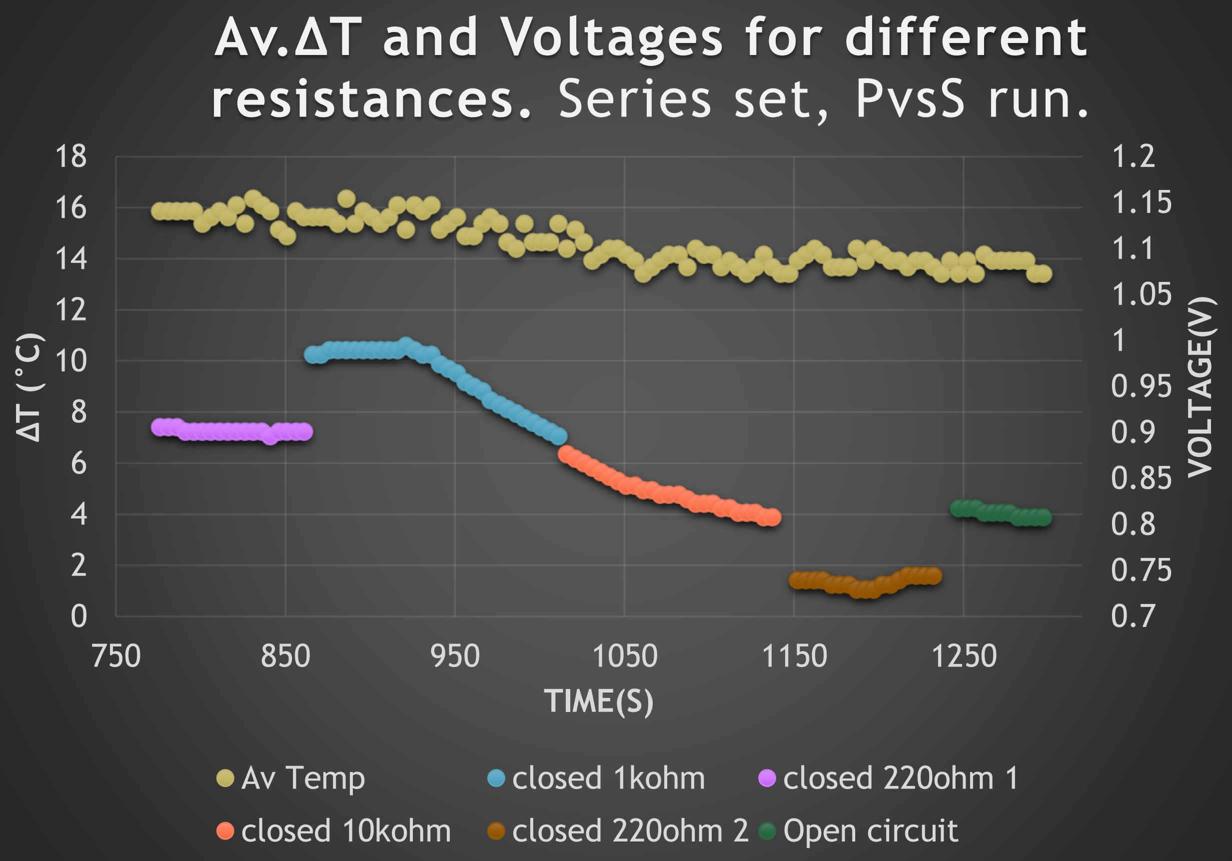
Aluminum bar transfers 12.8 times more heat energy per second then the steel bar

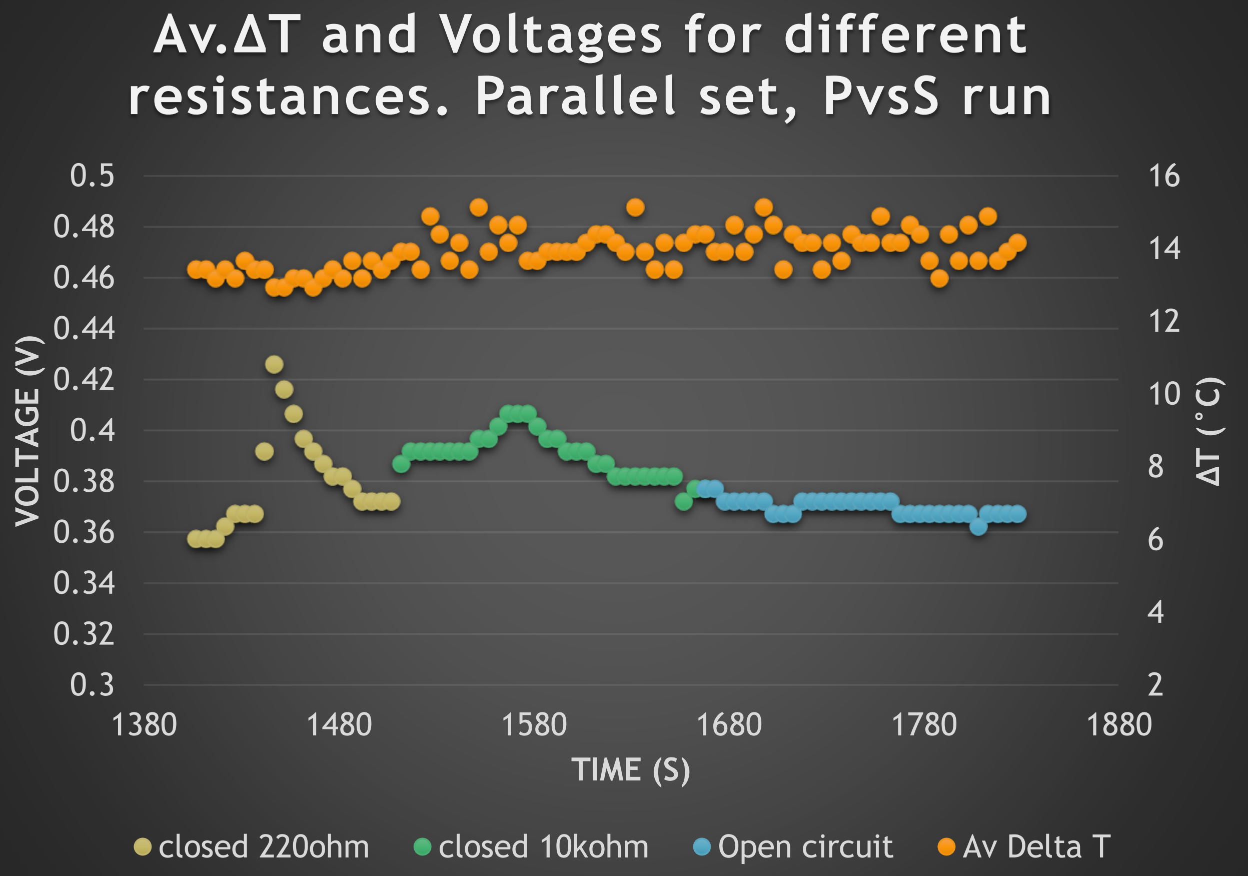
The difference in the cooling of the two materials is not as big as the difference in the heat transfer rate.



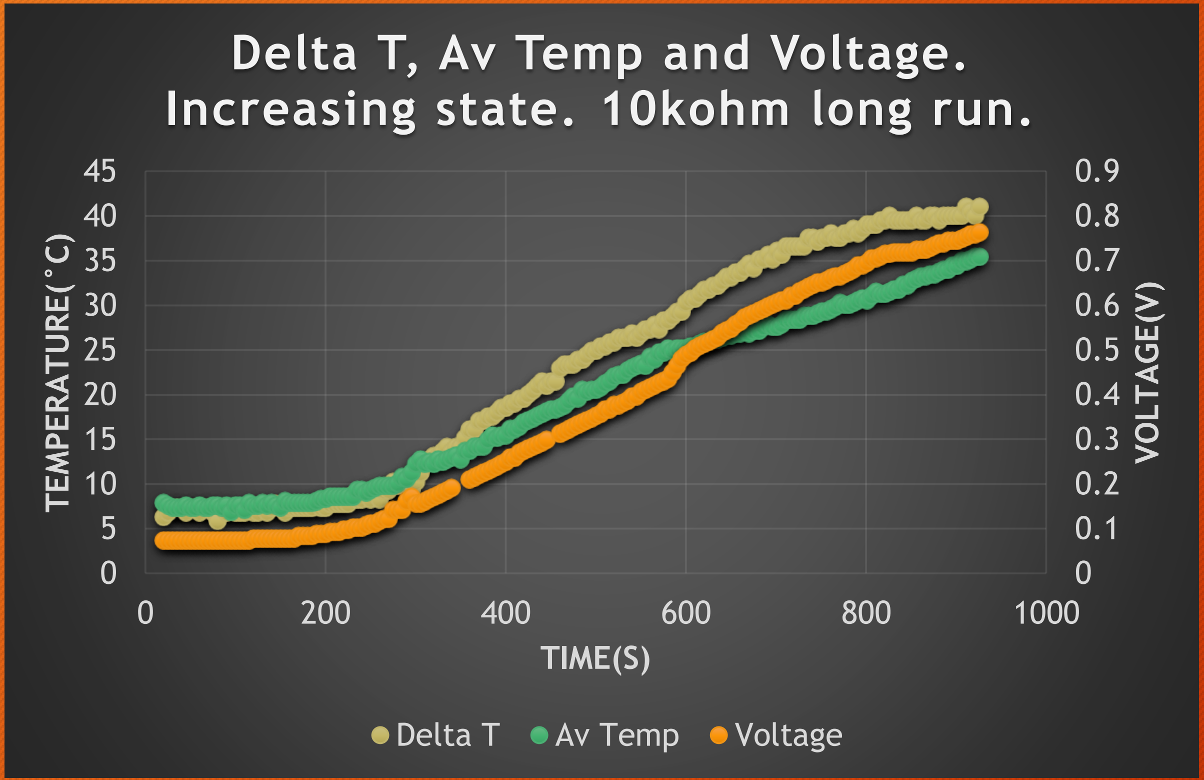
Newton's Law of Cooling

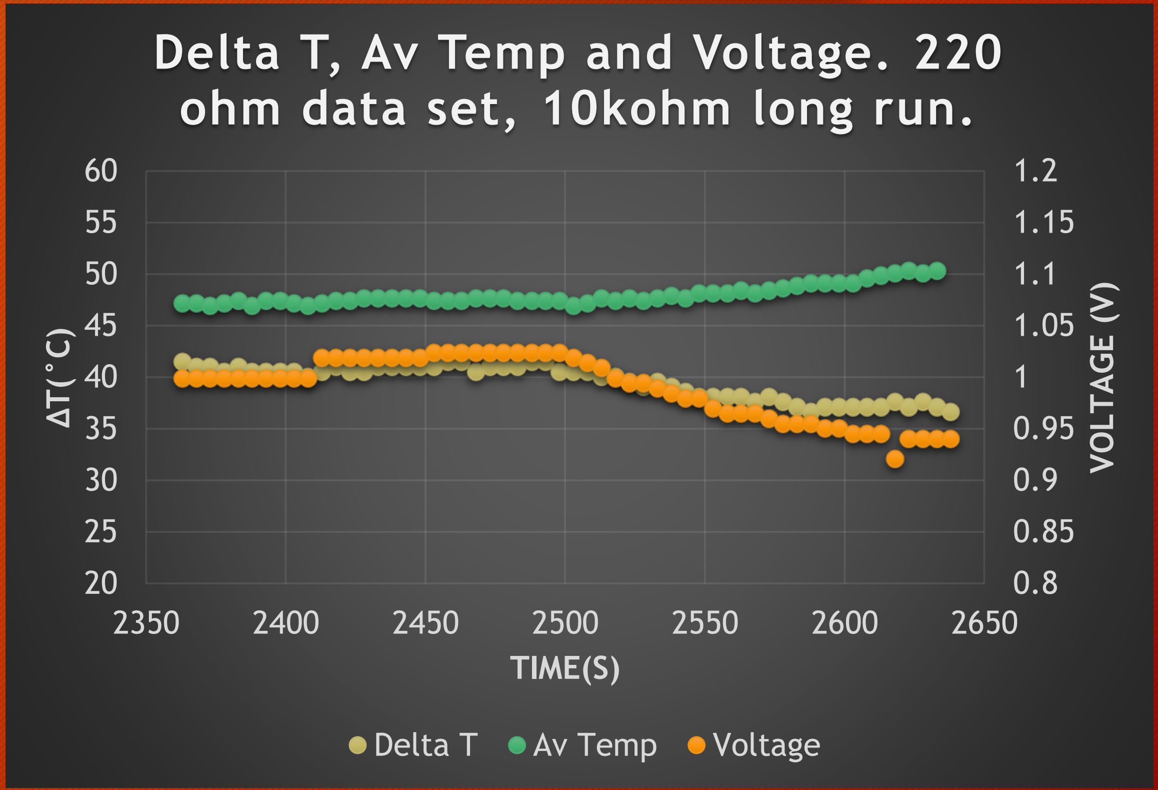
Different loads and TEG arrangements.





TEG Average Temperature Effect on Generated Voltage





ΔT determines the shape of the voltage graph, while average temperature acts as a scaling factor on the voltage graph.

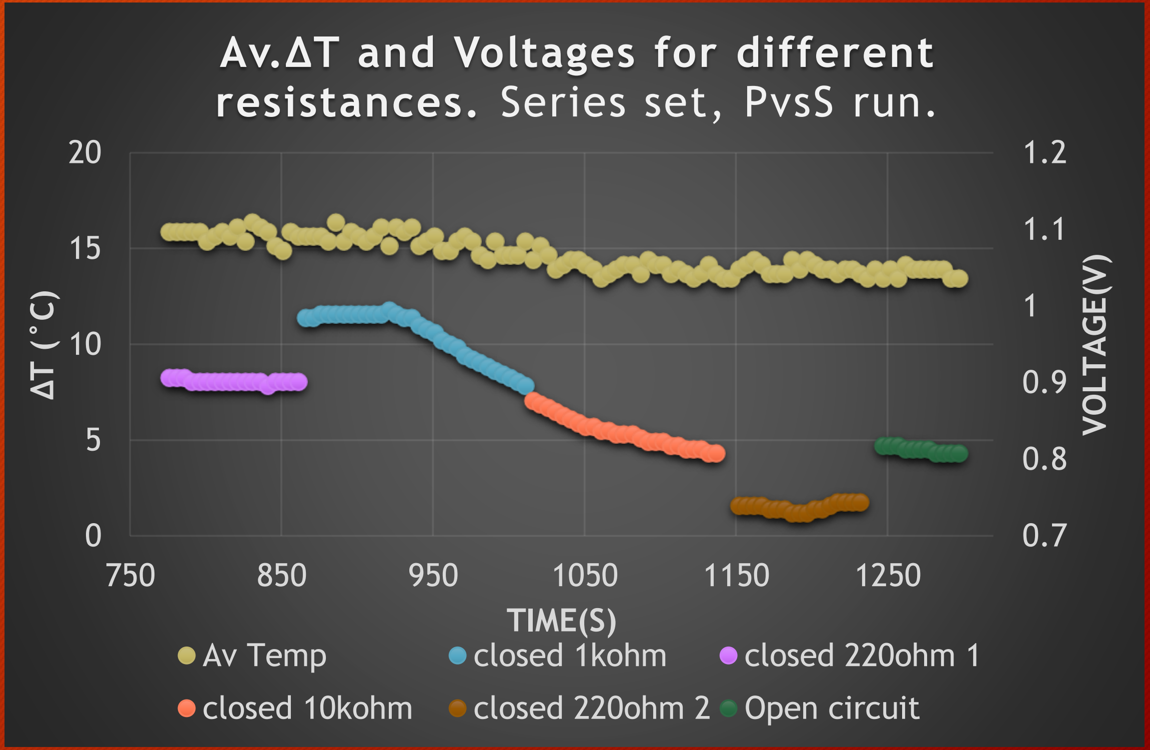
TEG Resistance

Can't measure resistance with multimeter, but we can calculate it from the data.

$$r = \frac{R * (V_{TEG} - V_R)}{V_R}$$

From PvsS run: 10.07 ohm
From 10k ohm long run: 8.06 ohm

The increased movement of the atoms increases the probability that electron will hit an atom on its way while going through the material -> increase of TEG internal resistance



Thank you