An Investigation of Thermoelectric Element Power Generation

Student Author: Isaac Raphael

Faculty Mentor: Dr. William Slaton

University of Central Arkansas

Department of Physics and Astronomy

Abstract

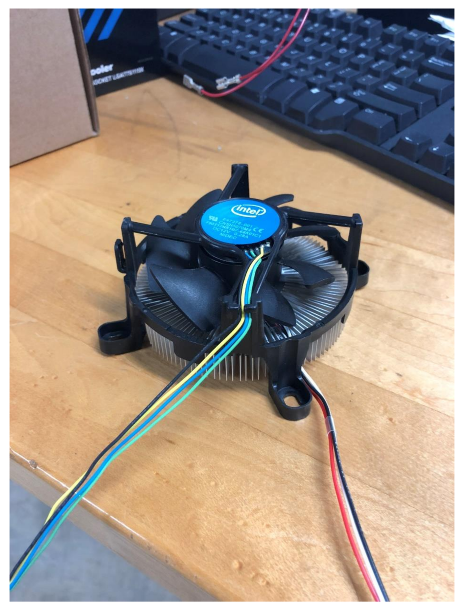
The purpose of this research project was two fold: to first quantify the cooling ability of two different CPU cooling units and then to characterize the power generation of a Peltier device in the context of a model CPU and CPU cooling unit. A Peltier device is a thermoelectric device that can act as a power supply when the two sides of the device are at different temperatures. Along with that, the goal of the research project was to automate the data collection processes. This was accomplished with prototyped circuits on a breadboard that were controlled by a Raspberry Pi 3. Python was the language used for the automation programs. This included for data acquisition as well as data analysis. Studying the cooling ability of the CPU cooling units resulted in Temperature vs. Time plots that showed how the well the cooling units could stabilize temperature when an aluminum block (model CPU) was heated over a range of power levels. Then, using the ability to develop stable temperature differences between the metal block and cooling unit and placing a Peltier device in between the two allowed I-V curves of the Peltier device to be produced.

Experimental Design

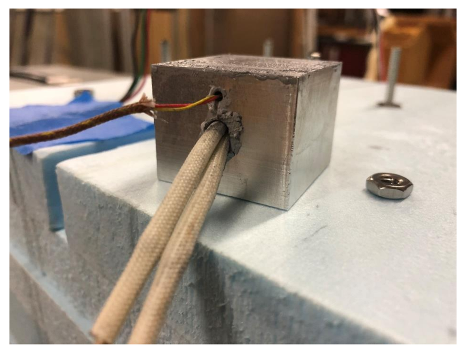
In this experiment, a CPU is simulated with an aluminum block that has a 100W thermoelectric heater inside of it. In order to simulate a CPU, this heater needed to be ran at varying power levels. This was accomplished with Pulse-Width-Modulation (PWM) to control the voltage supplied to the heater in time. For example, if the 100W heater is only on 40% of the time in a given period, then over times much greater than the given period, the heater "looks like" a 40W heater. In order to ensure that all heat generated from the heater flows up to the cooling unit, the heater was surrounded on all sides by an insulating foam. This was necessary for quantifying the cooling ability of the cooling units because then we knew that once thermal equilibrium was established, the energy in must equal the energy out. To measure temperatures of the system, a K-type thermoelectric temperature sensor was placed directly in the aluminum block and another temperature sensor was placed on the cooling unit. With these measurements, the difference in temperature was found and could be used to calculate the cooling ability of the cooling units. When the thermoelectric power device or Peltier device was introduced to the system, it was placed in between the heater and the cooling unit. The Hyper unit was chosen to be the dedicated cooling unit because it was the best. When different resistive loads were placed across the leads of the Peltier device and the voltage across the load was measured, an I-V curve describing the power output was attained. Initial data on this power generation data was collected using a hot plate and manually changing the resistors and measuring the voltage across them in order to have a feel for what kind of power output these devices are capable of. Moving forward, the goal is to have a working programmable variable resistor that allows for measurements to made automatically.

Setup

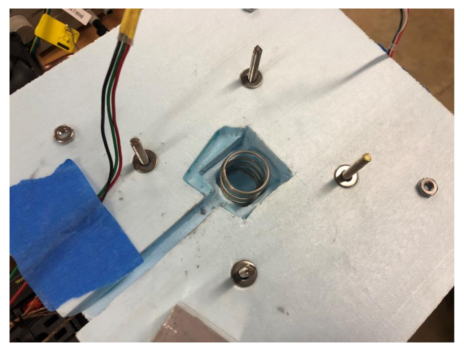
Hyper CPU Cooling Unit



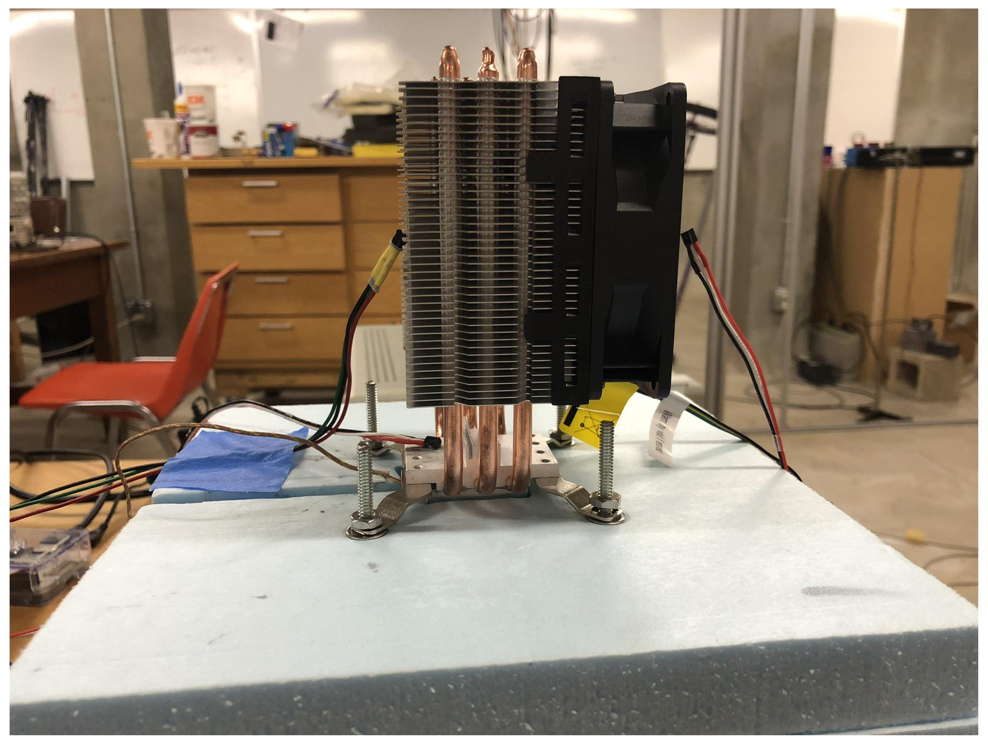
Intel CPU Cooling Unit



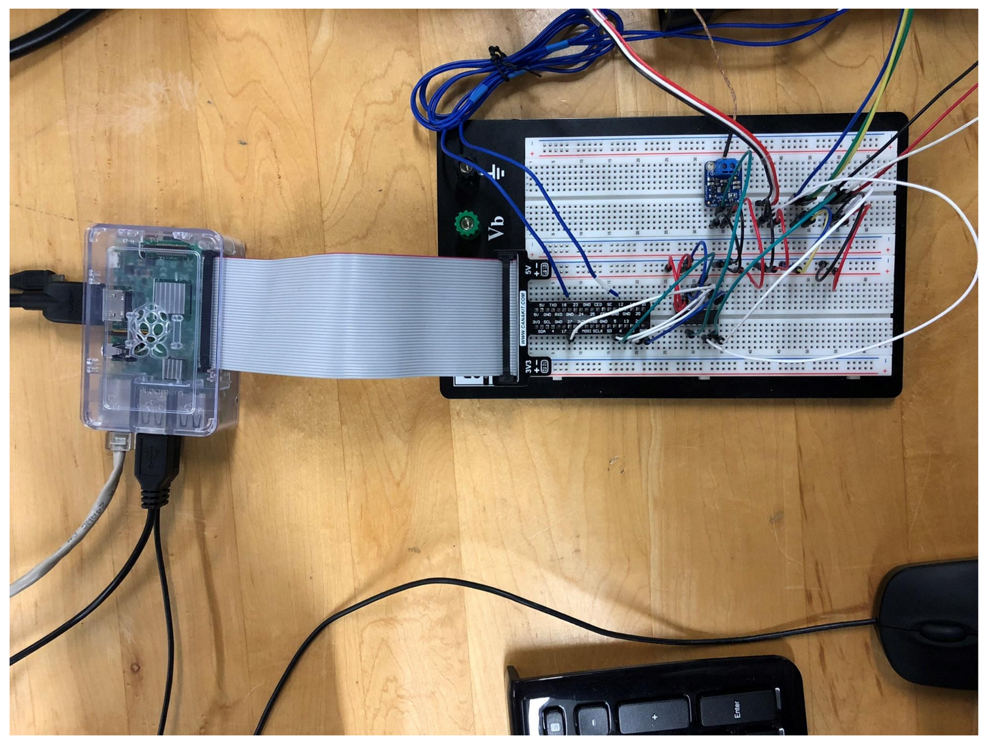
Model CPU



Insulating Foam/Model CPU Housing



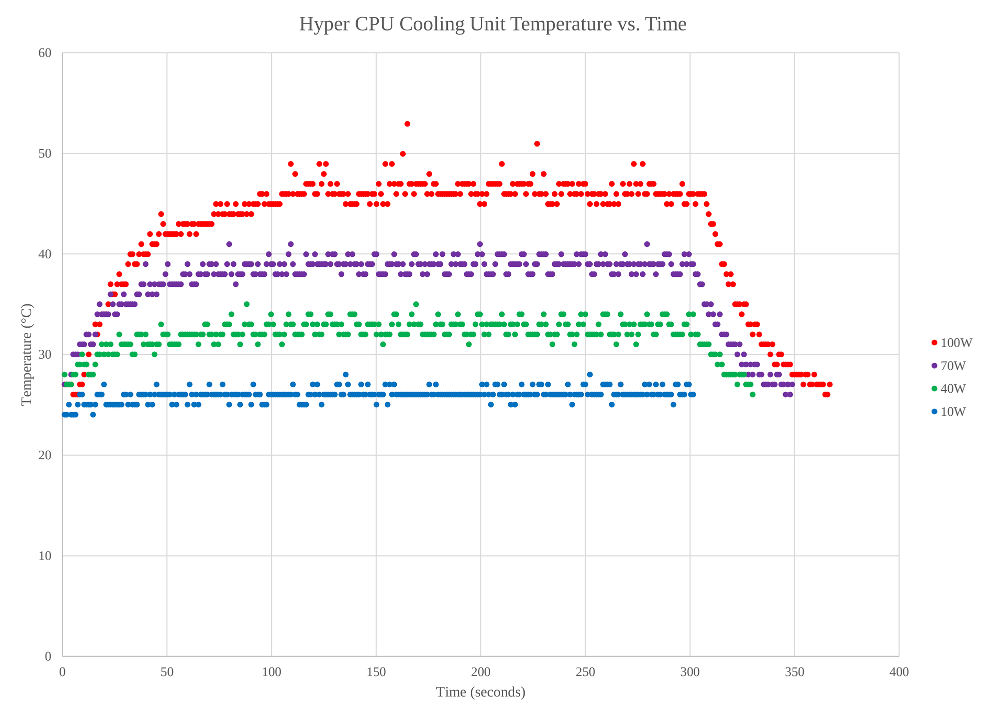
Cooling Unit with Sensors Setup



Raspberry Pi and Breadboard Circuitry

Characterizing the Cooling Units

The data below is temperature data versus time for each cooler at different power levels.



stable ΔT = 12.1897 C at 70W
stable ΔT = 16.82709 C at 100W
By conservation of thermal energy

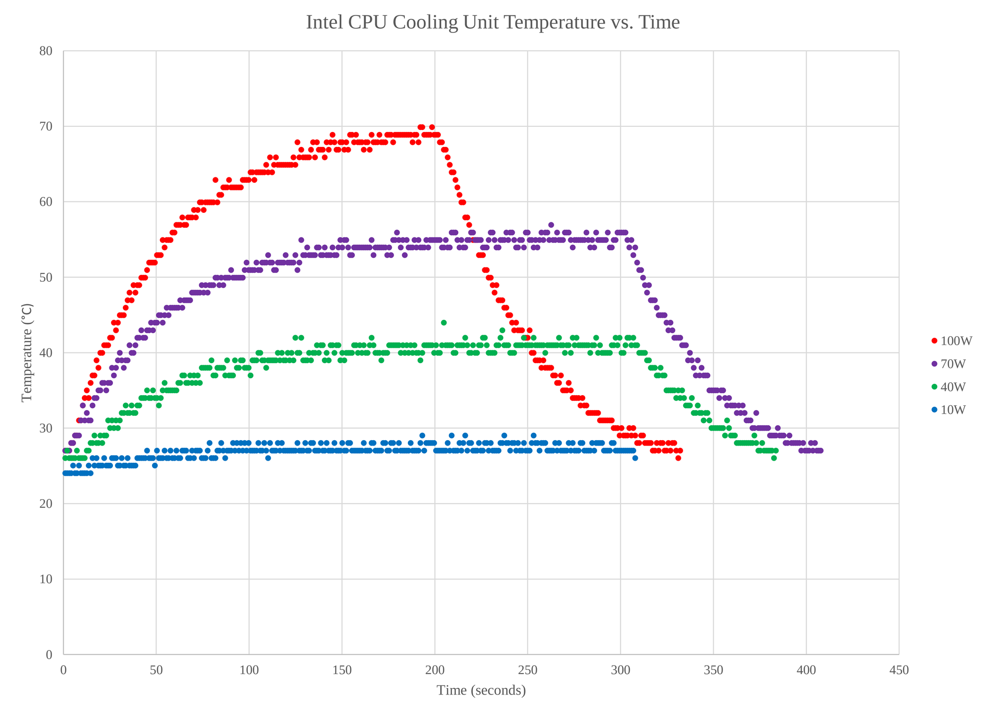
$$Power_{in} = Power_{out}$$

Once the temperature has stabilized, the above equation can be equated to the following equation where G is a proportionality constant.

$$Power = G * \Delta T$$

Based on the two measurements above, the proportionality constant for the Hyper Cooling Unit averages out to be

$$G_{Hyper} = 5.8 \frac{W}{°C}$$



Stable ΔT = 21.5 C at 70W
Stable ΔT = 13.5 C at 40W
Based on these measurements, the proportionality constant for the Intel Cooling Unit averages out to be

$$G_{Intel} = 3.1 \frac{W}{°C}$$

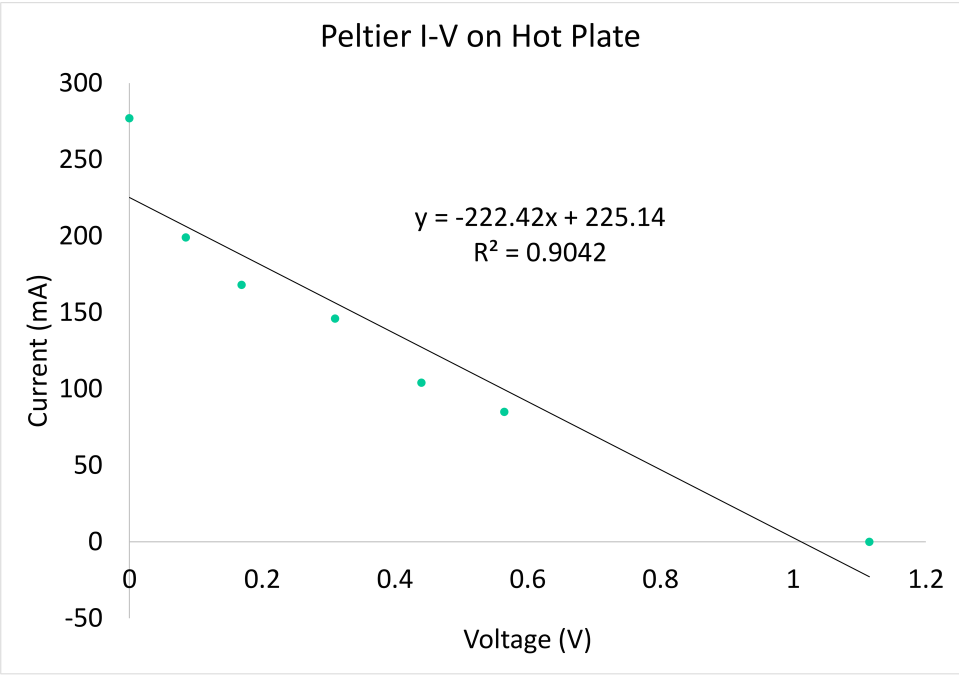
A higher proportionality constant means that the cooling unit can cool better. This is consistent with the data since $G_{Hyper} > G_{Intel}$

Characterizing the Pelier Device

The following is initial data collected on the Peltier device to get a feel for what a good range of resistive loads are to put across the leads and to have a feel for what kind of power output it is capable of.

T_hot	150 – 155 (F)	68.3333333	C	dT
T_cold	67.5 (F)	19.7222222	C	48.61111111

R (Ohms)	I (A)	V (V)
4.4	104	0.44
6.6	85	0.565
1.11E+07	0.01	1.115
2.2	146	0.31
1.1	168	0.169
0.6	199	0.085
0.2	277	0



The data was fitted to a linear trend assuming that the Peltier device is Ohmic. The fit is not the best model; however, it was fitted to data taken by hand, and the voltage measured was not absolutely steady because of the nature of the hot plate's heating ability. With the measuring process automated, more resistive loads can be measured at the high and low ends and measured over longer ranges of time to get a more accurate voltage measurement. This will verify if the data truly has a linear trend or not.

ACKNOWLEDGEMENTS

University of Central Arkansas
Department of Physics and Astronomy