Cap n’ Cool

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Introduction

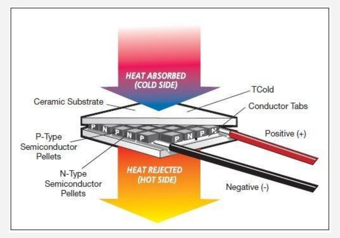
Mission
Design, test, and build a product that accelerates the cooling of liquids to create a comfortable drinking experience.

Requirements
The device needs to be...
- Easy to use
- Easy to clean
- Able to cool water by 20 degrees
- Food safe

Key concepts

Peltiers
The peltier effect generates a temperature difference when current is passed from one metal to another. By choosing specific metals, we can achieve a significant temperature difference between the materials. One side of the peltier device gets hot and one side gets cold.
Pros:
- *Cost effective*
- *Large temperature difference*
- *Compact/easy to integrate*

Cons:
- *Low Coefficient of Performance (COP)*
- *High power needed*

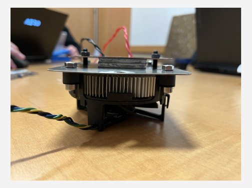


Food safety
Food safe materials must be used on all components that contact the liquid. This includes the materials in the cooling chamber, the straw, the thermal probe, and the adhesives used. In many cases, we were prevented from using the optimal materials, like copper due to food safety concerns. Additionally, we had to select non-toxic adhesive products, which resulted in the use of less optimal adhesives and sealants.

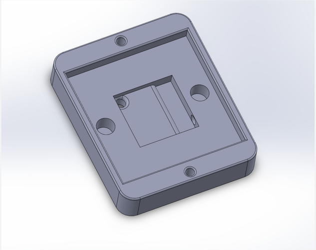
Heat Pipes
Heat pipes are used to conduct heat rapidly and often have thermal conductivities in the range of 100x that of copper. We decided to try and make one using a copper pipe and water by removing the air from the tube creating a strong vacuum. This would force the water to be in constant vapour-liquid equilibrium. However from our pressure calculations, we found that we need an 98% vacuum in order for the heat pipes to work. This proved to much for our seals and we could not achieve the pressures required.

Design

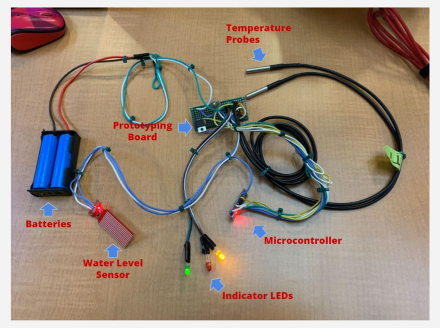
Assembly of Thermal Components
- The thermal assembly is made out of pieces of sheet metal and screws
- The peltiers are sandwiched tightly between two metal plates to maximize contact
- Thermal paste is used to improve thermal contact



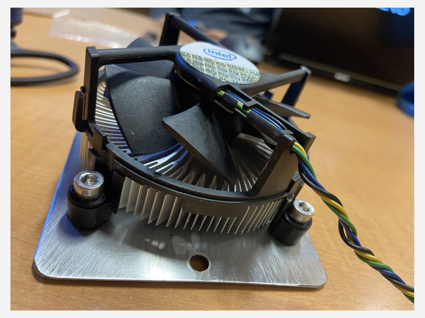
Cooling Chamber
- The cooling chamber is a 3D printed cavity that forces water past the surface of the Peltiers
- We attempted to make the cooling chamber as thin as possible to improve the thermal contact
- By removing the thermal assembly, the cooling chamber can be accessed for cleaning purposes



Electronics
- Uses temperature probes and a water level sensor to gather data
- The device is controlled by an ATmega32u4 microcontroller
- Powered by two 18650 lithium ion batteries
- An LED interface communicates to the user the current temperature



Heat Sinks
- After struggling to design a suitable heat sink, we selected a CPU fan + Heatsink
- Heat conducts through sheets of metal into the fins of the heat sink where it can be dissipated to the environment



Iterations
- Initial design was to cool the drink as it sat in the cup rather than cool as it was passed through the straw
- Heat pipes were envisioned to conduct the heat from peltier to atmosphere. Later changed to a purchased computer radiator

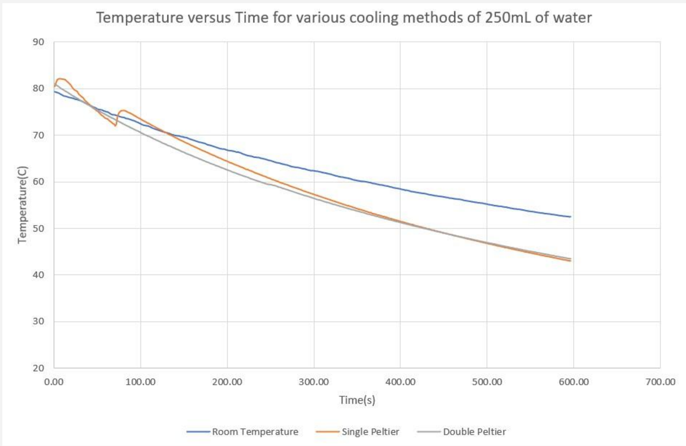
Manufacturing
- Machined metal parts including the stainless steel sheets were fabricated
- Cooling chamber and device housing was designed in Solidworks & printed on an *Ender 3*

Testing/Results

Individual Component Testing

<u>Thermal System</u>

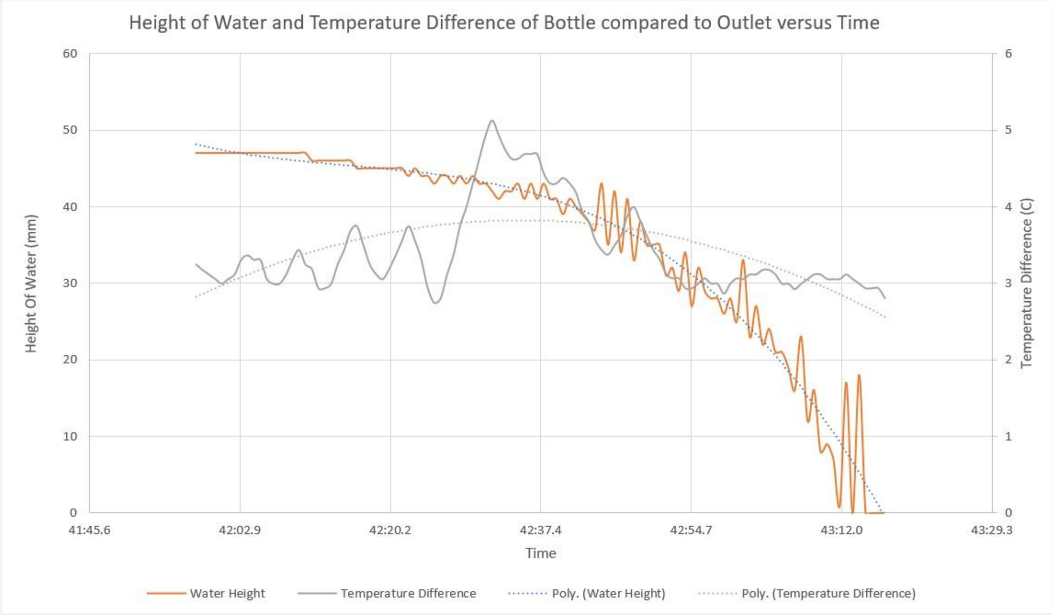
Peltier test
We ran a test to determine the cooling rate of our peltier set up. We placed a cup of hot water on top of our peltier and monitored the water’s temperature. We noticed that using the peltier cooled the liquid quickly. After this test, we decided to increase the number of peltiers used to increase the cooling rate of our device.



First Cooling Chamber Test
- Using our first iteration of the cooling chamber, we tried drinking through the device
- Tested volumetric and heat flow rate with initial cooling chamber design to influence final cooling chamber design

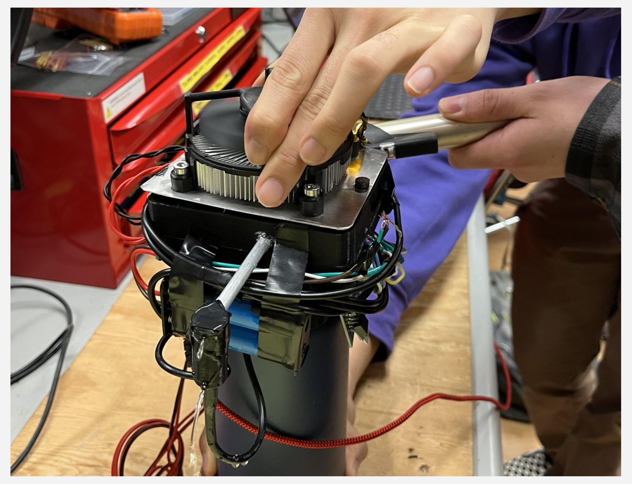
Full System Testing
- For ease of testing a bike pump valve was added to the main housing
- Cooling test was conducted by increasing the pressure in the bottle forcing water through the cooling chamber and out the straw
- Thermal sensors were strategically placed to read water temperature in the bottle and as it exits
- A water high sensor was used to measure the flow rate

Results
- Measured a 3 degree difference between inlet and outlet
- Achieved a cooling rate of 42 watts



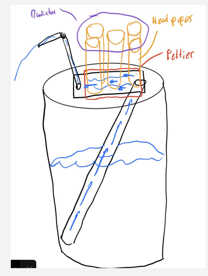
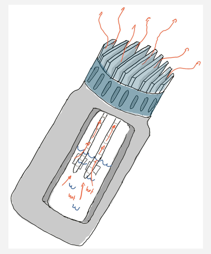
Conclusions

Future Considerations
There are a few way that we could improve the project:
- Further development of heat pipes to increase the effectiveness of the heat sink
- Upgrade steel sheets to copper for better thermal conduction
- Create custom PCB for a more compact and organised product (reduce wiring)
- Implement threading on the bottom of the device to easily attach and detach from the bottle

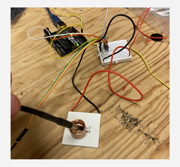


Summary

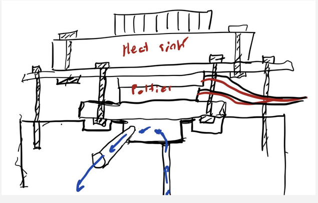
1) Initial sketch

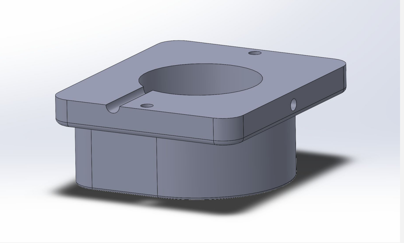
2) Testing



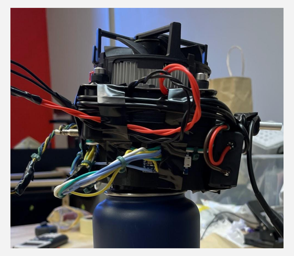

3) Concept generation



4) Modeling



5) Final Assembly



Closing Remarks
While we didn’t achieve the cooling rate we desired, our device demonstrates the engineering challenges such a device would face. We produced a functional prototype and got real world data, learning about many engineering designs and principles along the process.