The Solar Cooler

Team#7

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1. Introduction

1.1 Objective

During the summer, people usually bring a cooler for long drives or picnics to make their drinks stay cool, but the functionality of the cooler is highly depended on how often you can replace the ice. When the ice melts, the cooler just becomes a box filled with water. People has to lift their cooler, despite the weight of the water, box and drink, pour the warm water out and replace with ice. The situation might be worse if you are going for a picnic. The sun just melts the ice much more quickly and even worse, it is very likely that you can't find a store to buy more ice, and you are forced to have a hot coke in the summer.

The project goal is to develop a cooler that actively cools the items within via solar power, also, store energy to be able to cool the interior without sunlight presence.

The idea and need for a solar powered cooler is simple: we reduce the weight of the typical cooler and ice, and can increase the amount of time the objects within the cooler are cooled for and increasing space within the cooler. Using a solar panel to power the system is the most optimal way to do so, since they are lightweight and can charge the battery (or power the system) so long as there is incident light onto the panel's surface. With this design we achieve the basic requirements of a cooler, that are to be portable and more importantly to cool the items within.

1.2 Background

There are very few items similar on the market at the moment, however, these items are either integrated with other systems (such as a phone charger) increasing the price and complicating the system, or do not cool the interior very well. With that being said, this project will tackle the issue head on and aim to provide the user with a simple yet effective solution to heavy or ineffective coolers.

1.3 High-level requirement list

- Must cool at least 20 degrees Celsius below ambient temperature.
- Battery life must be able to power the system independently for at least 2 hours.
- The weight of the system must not exceed 15kg, the lighter the better!

2. Design

2.1 Block Diagram

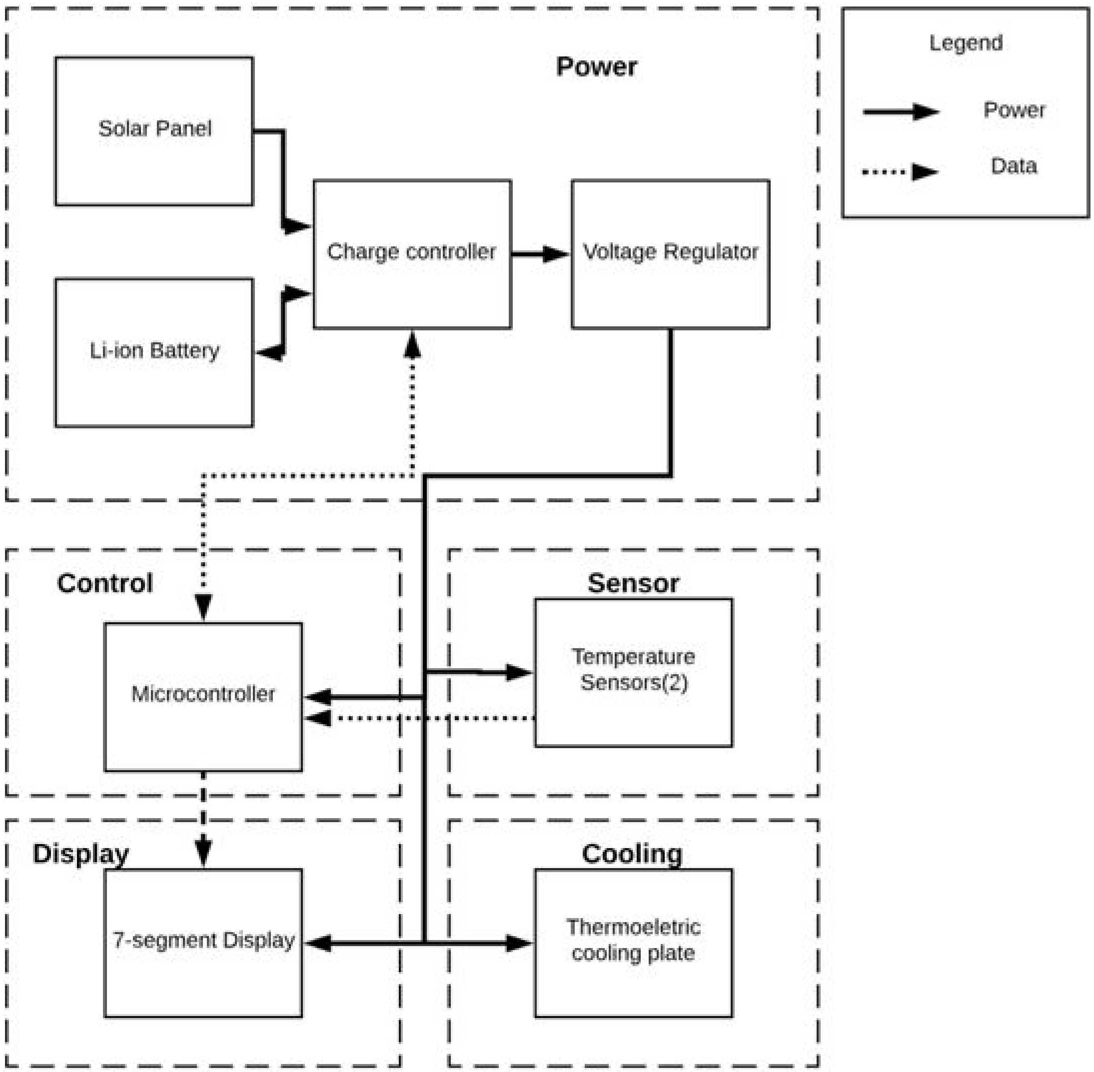

Figure 1: High Level Diagram

As the Figure 1 shows, the microcontroller will control the thermoelectric cooling plate according to the temperature sensors placed inside the cooler. The charge controller will manage the power flow of the system. When power is available from the solar panel, it will power the system and any excess power will charge the Li-ion battery. If there is no sunlight, the charge controller will switch to battery power. The power will go into voltage regulator and power the rest of the system. The exact operation of charge controller will be monitored and managed by microcontroller via sensing signals.

2.2 Physical Design

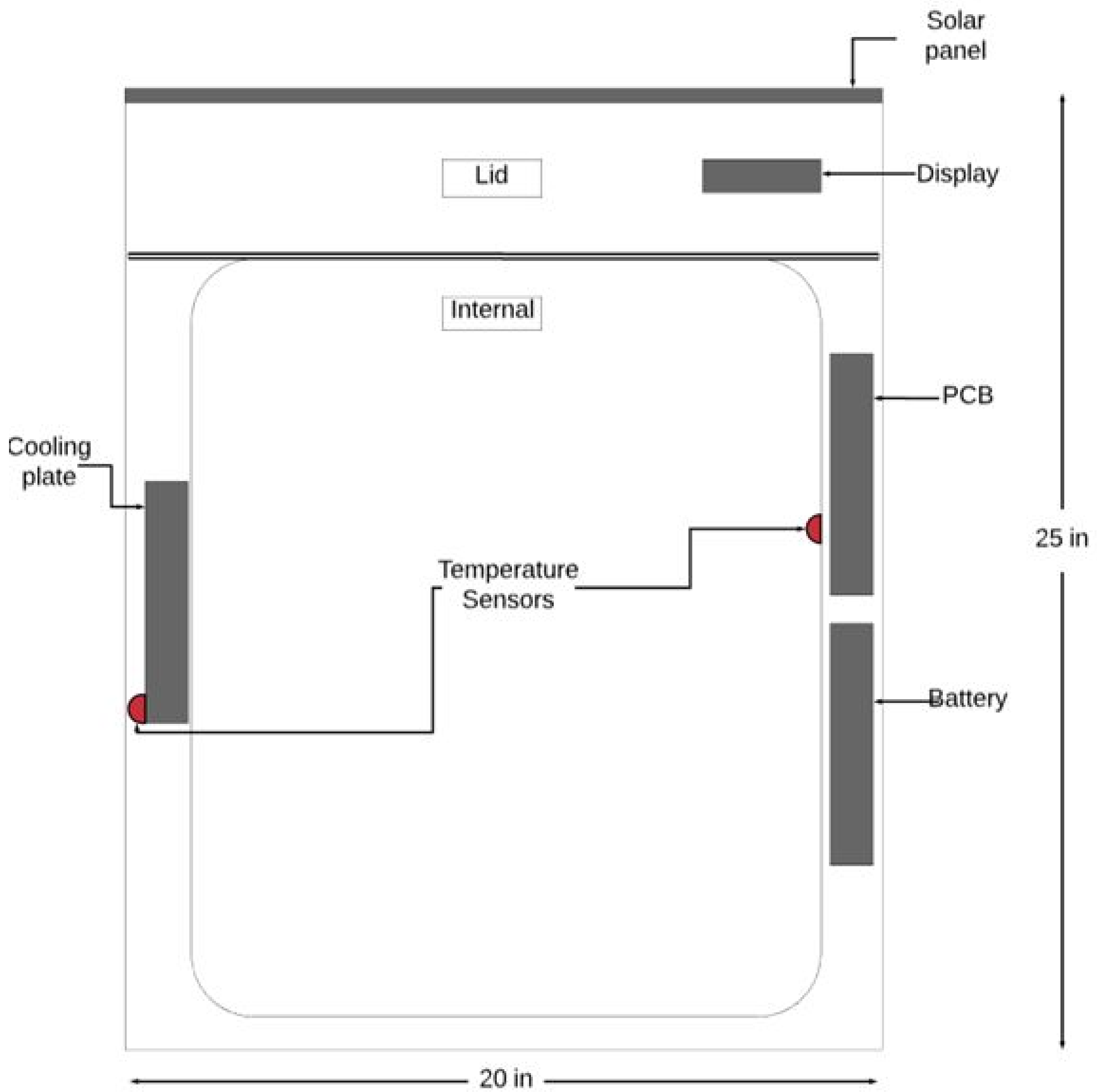

Figure 2: Physical Design Diagram

The dimensions of the cooler will be 25” x 20” x 25”. The inner casing must be waterproof so that no water leaks out of the case onto the battery or solar panel. The battery and PCB will be on either side of the walls of the cooler and the solar panel will be placed on the lid of the cooler for maximum sunlight. The solar panel will be 23” x 14”.

2.3 Functional Overview and Block Requirements

2.3.1:Power Unit

2.3.1.1 Solar Panel:

Solar panel will charge the system by converting light energy to electrical energy. We have selected a monocrystalline silicon panel module for a lightweight and robust component [1].

Since one of our requirements is to charge the 120Wh battery in under 7h, we have selected a 25W solar panel such that this is feasible even under mildly cloudy conditions. The calculation is as follows :

$$120Wh/25W = 4.8h$$

Requirements	Verification
1) The panel can provide up to 25W, at 18V and 1.4A under maximum power delivery conditions. 2) The solar panel charge the battery 120Wh (10Ah) fully in one day, or in other words, under 7 hours of sunlight.	1) Obtain Solar panel I-V curve and find maximum power point. 2) Verify maximum power point will fully charge battery in under 7 hours.

2.3.1.2 Charge Controller:

The charge controller is responsible for controlling the flow of charge into the battery from the solar panel. This will component will be responsible for regulating input voltage into the battery and prevent overcharging and damaging of the battery. The simplest way of doing so would be through a switched-mode power supply converter, more specifically a buck converter, whose main component is a MOSFET. Also, this component will have a 3A fuse to prevent short-circuit damage to the circuitry of the device

Requirements	Verification
1) Must provide battery with 12V, when battery is not fully charged. 2) Stop charging battery when battery is fully charged. 3) Disconnect power from rest of the circuit if 3A is exceeded.	1) Measure input/output voltage using voltmeter 2) Measure power output (to battery) when a fully charged battery is connected 3) Measure current using ammeter with an increasing current (up tp 5A).

2.3.1.3 Li-ion Battery:

The Li-ion battery will supply the power to the system when sunlight is not available. It will store the excess power from the solar panel when sunlight is available[4]. We use a 12V Lithium battery with capacity of 10 AH. If the cooling plate operate at current 3A, then with a fully charged battery it can run for:

10 AH/ 3A = 3.33 Hours

Requirements	Verification
1) Fully charged battery should power the system for at least 2 hours with voltage of 12V∓ 5%. 2) Battery should be operate in temperature range of 0 to 40 Celsius.	1) Measure the output voltage of the battery with a multimeter while the system is running. The multimeter should read 12V ∓ 5%. 2) Attach a 2A load and ensure the load is supplied for at least 2 hours via a voltmeter/ammeter. 3) While the system is running check the temperature at the center of the battery with a heat gun every 1 minute until temperature stabilize.

2.3.1.4 Voltage Regulator:

The voltage regulator will regulate voltage from battery to the control, sensor, and cooling units. The role of this component is to supply a constant operating voltage of each component. The voltage regulator will output a constant voltage of 5V with the input form the battery.

Requirements	Verification
1) Accept input of 12V. 2) Output 2 voltages: constant 5V ∓ 5% for microcontroller & 0-4.95V ∓ 5% for thermoelectric cooling plate[5].	1) Measure input/output voltages using voltmeter.

2.3.2 Control Unit

2.3.2.1 Microcontroller:

We will use ATMEGA328-PU The microcontroller will serve to provide control voltages to the surrounding units. It will need to tell the charge controller when to stop charging the battery. It will also input data from the temperature sensor and display the corresponding information to the 7 segment display. Lastly, will output the amount of remaining battery capacity through to the user via colored LED.

Requirements	Verification
1) Must appropriately send sensing voltages (0-5V) to charging, sensing and display units.	1) Send pseudo-signals and measure output signals.

2.3.2.2 7-Segment Display:

The 7-Segment Display[6] will be the monitor for our solar cooler. The internal temperature will be displayed in Fahrenheit. It will be a 4-character 7-segment display, where three will be used to show the temperature value to accuracy in tenth place, the fourth character will be use to show the sign of the value.

Requirements	Verification
1) The 7-segment takes will operate at 5V ∓ 5%.	1) Measure the voltage with a multimeter. The multimeter should read 5V∓ 5%.

2.3.3 Sensor Unit

2.3.3.1Temperature Sensor:

There will be two sensors, one will detect the internal temperature of the cooler, another will detect the temperature on the hot side of the cooling plate to prevent overheating. The sensors will provide feedback to the microcontroller which will control the cooling plate.

Requirements	Verification
1) The sensor should detect temperature with accuracy of at least 0.5 Celsius in the range -5 to 30 Celsius.	1) A thermometer will be place inside of the cooler and the outer temperature of cooling plate can be monitor with a heat gun. The measurement will be compare to the value output by the temperature sensors. The difference should be below 0.5 Celsius.

2.3.4 Cooling Unit

2.3.4.1Thermoelectric Cooling Plate:

The cooling plate will cool and maintain the internal temperature of the cooler which will be control by the microcontroller. It will achieve this by transferring the heat from the cold side of the plate(internal) to hot side of the plate(external). Heatsink will be attached to the hot side of the plate so that heat can escape properly to outside of the cooler. Temperature sensor will also be placed near hot side of the plate to monitor for risk of overheating.

Here we will calculate the amount of heat need to extract by the cooling plate to cool the internal temperature of the cooler by 20 Celcius. We will operate the cooling plate at 3A, 2V and assume dT = 20 Celsius, which is the difference in temperature between the inside(0 Celsius) and outside(20 Celsius) of the cooler. At these conditions, Qc = 7.5 W and Qh = 10W according to the data sheet [5], where Qc is the heat absorbed by the cold side and Qh is the heat expelled on the hot side. Assume the internal dimension of the cooler is 25'' x 20'' x 25'', note that this is a overestimate of the actual cooler. We also assume there's nothing inside of the cooler so we only have to worry about heat in the air. Thus the density of air at 0 Celsius is d = 0.000021 Kg/in^3 and heat capacity of air is c = 0.716 kJ/kg*C. Thus we have internal volume of the cooler:

V = 25*20*25 = 12500 in^3

Energy lost from cooling 20 Celsius is:

E = d*V*c* 20 C = 3759 J

The time cool with be 3759/7.5 = 501.2 sec = 8.35 minutes. So assume there's no heat introduce into the system, we can safely assume that we can cool the system to our desire temperature.

Requirements	Verification
1) Should cool the internal to 20 Celsius below the ambient temperature. 2) The hot side of the plate should not exceed 120 Celsius[5].	1) Supply power to plate and monitor temperature changes via temperature sensor (or thermometer) on cold and hot side of plate.

2.4 Risk Analysis

Since the device will be portable and designed to be taken to picnics, we must consider the potential risks of all the component. Firstly, we must consider that the overall rig may be dropped. With that being said, this can cause leakages in the battery and cause damage to the circuitry. Secondly, we must consider potential leaks from the packages or food stored within the cooling compartment; the liquids, if exposed to any of the electrical circuits can cause the subsystems to behave differently that intended, leading to undesired results or total loss of functionality; also this can cause shocks. Thirdly, we need to monitor the temperature on the cooling plate, there is possibility that overheating could occur during the operation as heat might not escape the system fast enough. The solutions to these risks will be addressed in the following safety section.

3. Ethics & Safety

There are two main safety concerns we have to worry about. First, due to the nature of the device, the system must be robust. The circuitry and items inside the cooler must be contained separately. The system must be waterproof to avoid shocks and the battery, incase of any leakages, has been chosen as lithium ion and not SLA (sealed lead acid) due to the toxicity of SLA. Second, we have to make sure the cooler door and parts are robust so that not sharp edges can be formed by wear and tear of cooler use. Third , the temperature sensor placed on the cooling plate will make sure there is no overheating during operation.

We have to make sure we don’t violate IEEE Code of Ethics[3] and ACM Code of Ethics[2] by avoiding injuring others. Through the use of our cooler, there is a chance that the cooler will malfunction, we will try to minimize the chance and mitigate the harm as much as possible. When release the product, we will follow the IEEE Code of Ethics[3] code number one by disclose promptly factors that might endanger the public or the environment.

Our project will very likely to accept help from many people, including TA, professor, friends, and people who have done similar projects in the past, we will follow IEEE Code of Ethics[3], “seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others”.

References

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