Solar Powered Doghouse

ECE 445 Design Review, Spring 2013

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1 Introduction

1.1 Statement of Purpose

This project was chosen keeping in mind dog-owners who live in places with an extreme climate – hot during summer and cold during the winter months. Our aim is to provide these dog-owners with a convenient means to house their dog, while the owners are away for the weekend. In winter months the temperature can be set to make sure the doghouse is warm. In the summer months there is an automatic fan system to ensure air circulation. There are no commercially available doghouses that provide this service while being powered by solar energy. Our group is excited about delivering a product that is safe, economically viable, and environmentally sustainable. We will focus on making the doghouse safe and easy to use.

1.2 Objectives

The goal of this project is to build a doghouse which controls its own temperature and is powered by solar energy. We will begin by developing a heated floor which will function in extreme weather conditions and will successfully heat a doghouse with inner dimensions of 44’’x 23.5’’x 26’’. We will be using a Morningstar SunGuard Solar Controller to efficiently harness the power from the solar panels and also help protect the battery. We have a component that protects the battery from being over drained. There is a temperature control component which will receive feedback from temperature sensors that will serve to regulate the temperature of the doghouse. Two small fans will also be installed to provide relief from the heat during the summer. The fan speeds will be automatically varied depending on the current temperature in the house. Finally, the solar panels are installed on the roof of the doghouse to provide power to the various electrical components. The result is fully functional doghouse which is sturdy, safe, easy to use, assemble, and maintain.

Functions

- Designed to keep the dog warm in the winter, and cool in the summer.
- The temperature range specified by the owner is maintained.
- Sensors send feedback to the circuit that determines whether to turn the heating on or off.
- Generates its own power via solar panels.
- Battery for storage of energy.
- Heating element underneath the floor to provide heat, and fans to cool the interior during summer.

Benefits

- No extra electricity cost.
- During winter, once temperature range is set, no need to monitor regularly.
- During summer, fan speeds are automatically changed depending on internal temperature.
- Tiled floor is easy to clean.

- Owner can leave dogs in a convenient temperature-controlled shelter while away.
- Well insulated to minimize heat loss.
- Safe for the dog as there are no exposed electrical components

Features

- 80 Watt solar panels on roof to generate power.
- Voltage threshold detector to ensure the battery is not over drained.
- Thermistors to monitor temperature range preset by the owner.
- Nichrome wire pattern underneath a tiled floor serve as heating element.
- R-10 insulation in walls.
- Radiant barrier on ceiling, walls, and below the heating element, to minimize heat loss.

2 Design

2.1 Block Diagram

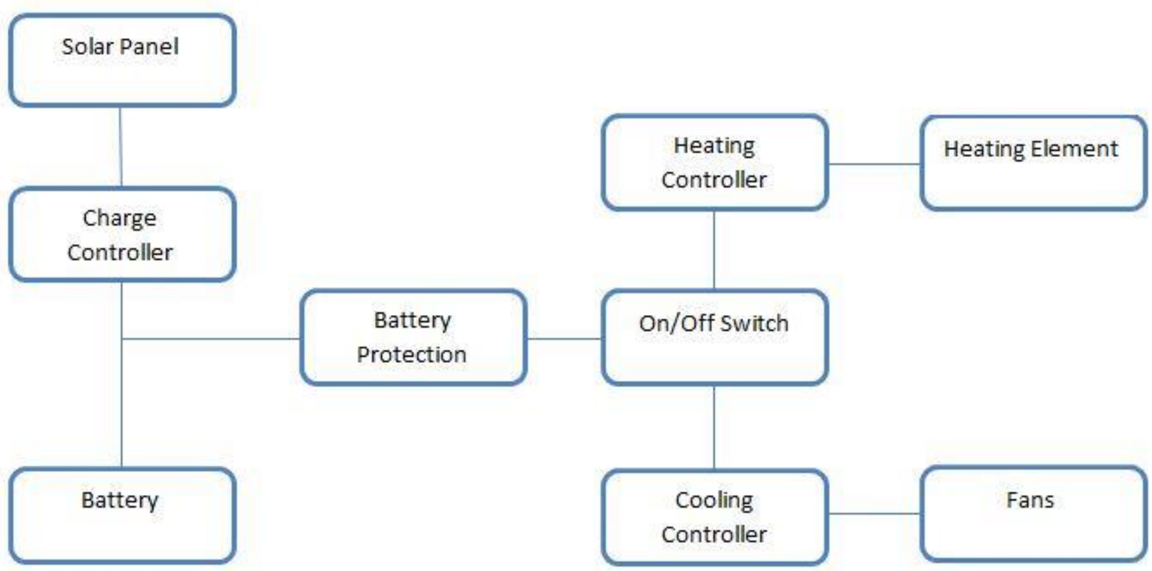


Figure 1: Block Diagram for the Entire Doghouse System

2.2 Block Descriptions

Solar Panel: The solar panel will be used to collect the energy from the sun throughout the day. The power from the panel will be controlled by the power controller and used to either charge the battery or to power the heating or cooling system. The panel is one 80W panel.

Battery: The battery will be used to power the heating or cooling system when the solar panel is not able to, due to of a lack of sunlight. The battery will be charged by the solar panel through the charge controller when daylight is available and the battery is not fully charged. The battery will be protected from overdischarge or overcurrent by the battery protection circuit. The battery will be a 12V battery with a 75Ah rating. The large Ah rating is required in order to ensure the system can be powered over a specified amount of time without charge from the panel.

Charge Controller: The charge controller will be used to charge the battery using the power from the solar panel. The charge controller will step down the higher voltage from the panel (~18V) to the voltage used to charge the battery (~12V). It also will ensure the battery is not overcharged. This module will be bought from SunGuard in order to maximize the efficiency of charging the battery.

Battery Protection: The battery protection circuitry will protect the battery from overcurrent and overdischarge by the load. The overcurrent protection will prevent the battery from outputting a high current above 5A, which would most likely occur in the event of a fault. In the event of the overcurrent protection being needed, the load will be disconnected and will not be powered until the reset button is hit by the user to indicate the problem is fixed. The overdischarge current protection will prevent the battery from being over discharged to the point that the battery voltage is below 80% rated voltage, or 10.5V. A lead acid battery can be permanently damaged if discharged below 10.5V. In the event of the overdischarge protection being needed, the load will be disconnected and will not be powered until the battery voltage is once again above 10.5V and then the load will automatically be reconnected. In the case of the panel providing power to the system, the battery will not be used as it is being charged, but the battery protection circuit should not negatively affect this operation. (See schematic below)

On/Off Switch-: This switch will be a simple SPST switch that will be controlled by the user. When On, the switch provide the panel or battery power to either the heating system or the cooling system depending on the house temperature. There is also an off position if the user does not want the system to run, but still wants to allow the battery to be charged by the panel.

Heating Controller: The heating controller will take the temperature set by the user and begin regulating the house temperature to that setting. The controller will use a thermistor to monitor the temperature of the house. If the temperature is too low with respect to the set temperature, the power controller will start powering the heating element from either the solar panel or the battery. If the temperature is too high with respect to the set temperature, the temperature controller will stop powering the heating element until the temperature drops. The heating controller will also have two other subcomponents incorporated into it. For the protection and comfort of the dog, the heating controller will also have a thermistor used to sense the temperature of the floor and prevent it from overheating. If the floor heats up above a maximum temperature (~102F), the controller will stop powering the heating element and let the heat dissipate before continuing to regulate the overall house temperature to the set value. (See schematic below)

Heating Element: The heating element will consist of a 13.5 feet of nichrome wire laid into the floor. The wire will be arranged into a spread out pattern used to heat approximately half of the floor of the doghouse. Only the back half of the house is being powered due to the high power requirements of the wire and the fact that most heat provided to the floor near the front would be wasted through the door anyway. This is also convenient for the dog since it now can get off the heated portion of the floor, but still be in the warm house. The tile paste will be laid directly onto the wire and the tile floor placed on top to be heated. The heating element will have a voltage applied across it by the temperature controller whenever the temperature in the house is low with respect to the temperature set by the user when the system is set to heating mode. (See element pattern below)

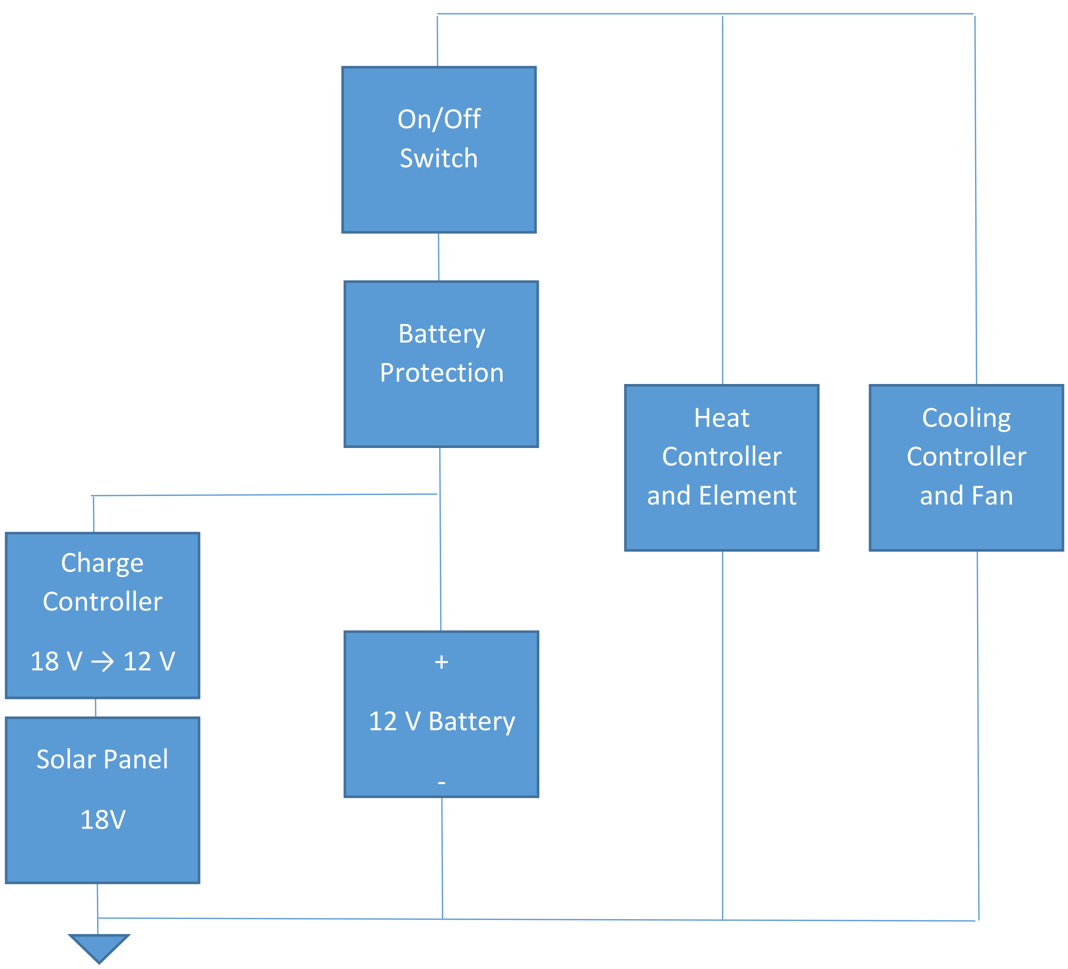
Cooling Controller: The cooling controller will be used to power the fan depending on the inside temperature of the doghouse. The controller will also use a thermistor the same way as the heating controller to sense the house temperature. The cooling controller will have a set range of temperatures in which the fan will not run, run at low speed, or run at high speed. These ranges will be preset rather than decided by the user. If the house is at a temperature below about 65F, the fan will not run. If the temperature is within about 65-80 degrees the fan will run at a low speed and above 80 degrees it will fun at a high speed. The controller will provide different voltages to the fan in order to run it at the two different speeds. (See schematic below)

Fans: There are two fans will be installed into the back wall of the house. The fans will be simple exhaust fans run on a dc voltage. If the system is set to cooling mode, the temperature controller will apply a certain voltage to the fan depending on the speed desired due to the house temperature.

(Optional) Occupancy Detector: This will allow the controller to heat the doghouse if it senses that the dog is in the house. This will help save energy and allow the system to run longer when needed since it will not waste power heating the house when it is not being used.

2.3 Schematics

Top Level Schematic



Heat Controller Schematic

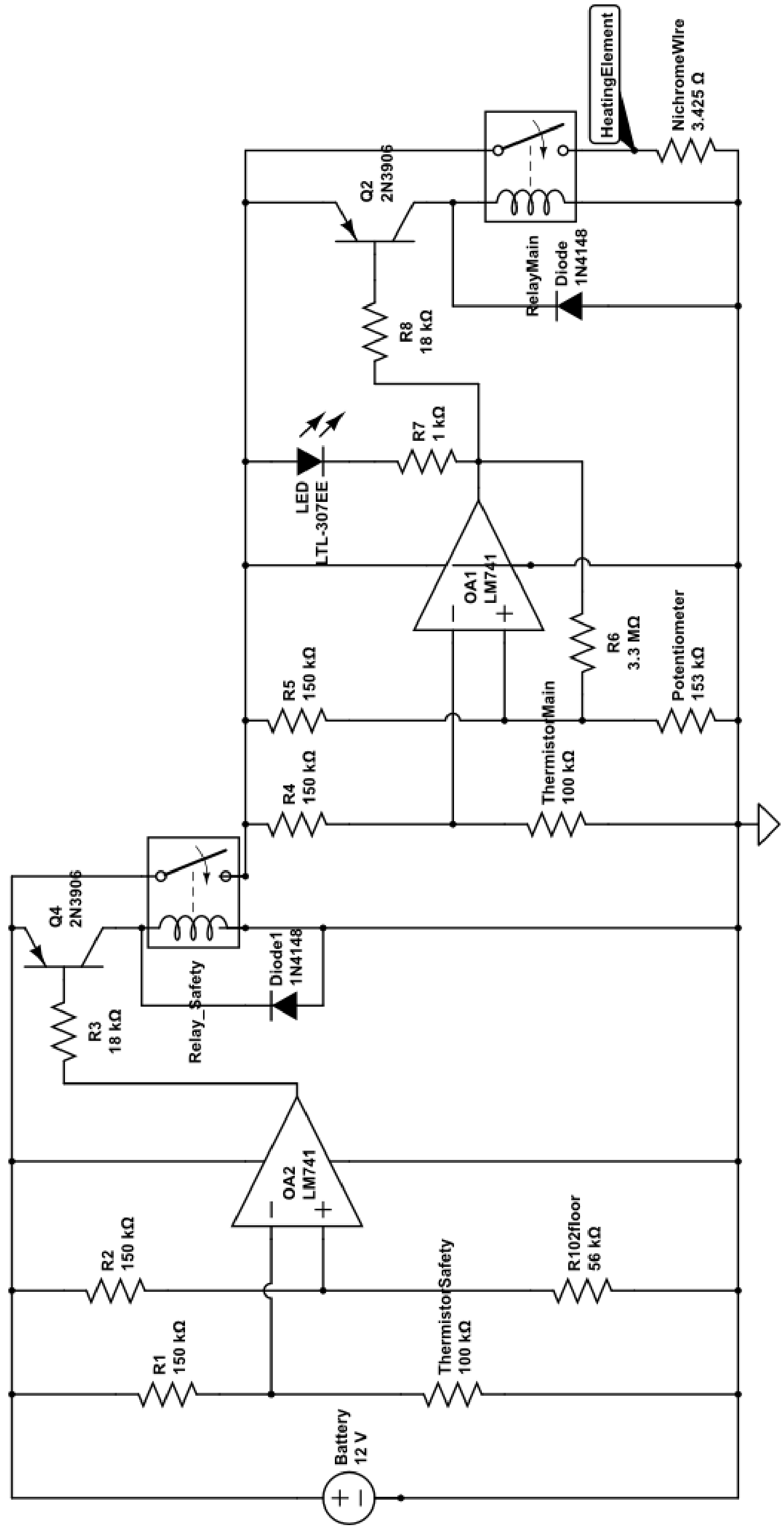


Figure 2: Electrical Schematic for Heat Controller

Cooling Controller Schematic

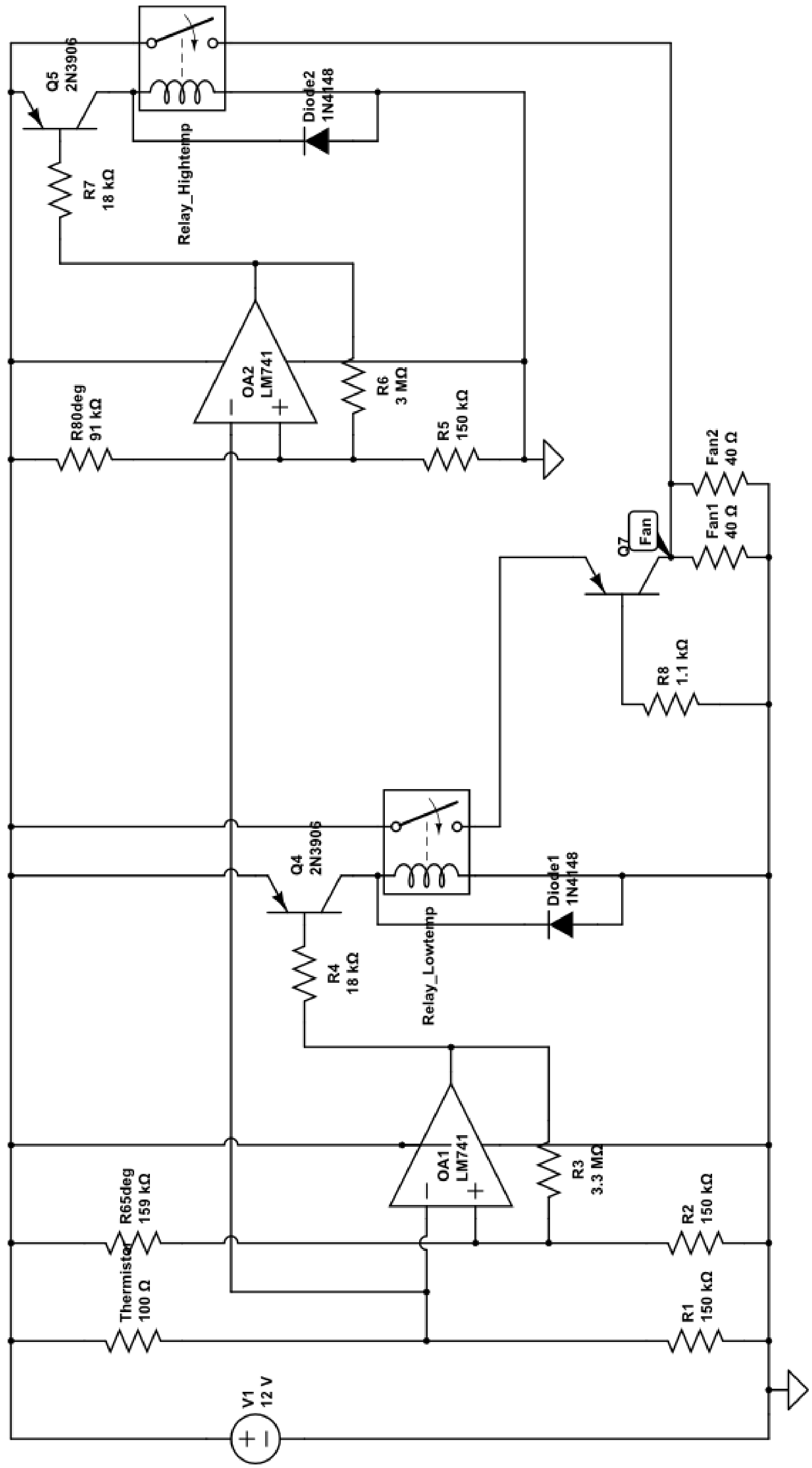


Figure 3: Electrical Schematic for Cooling Controller

Battery Protection Schematic

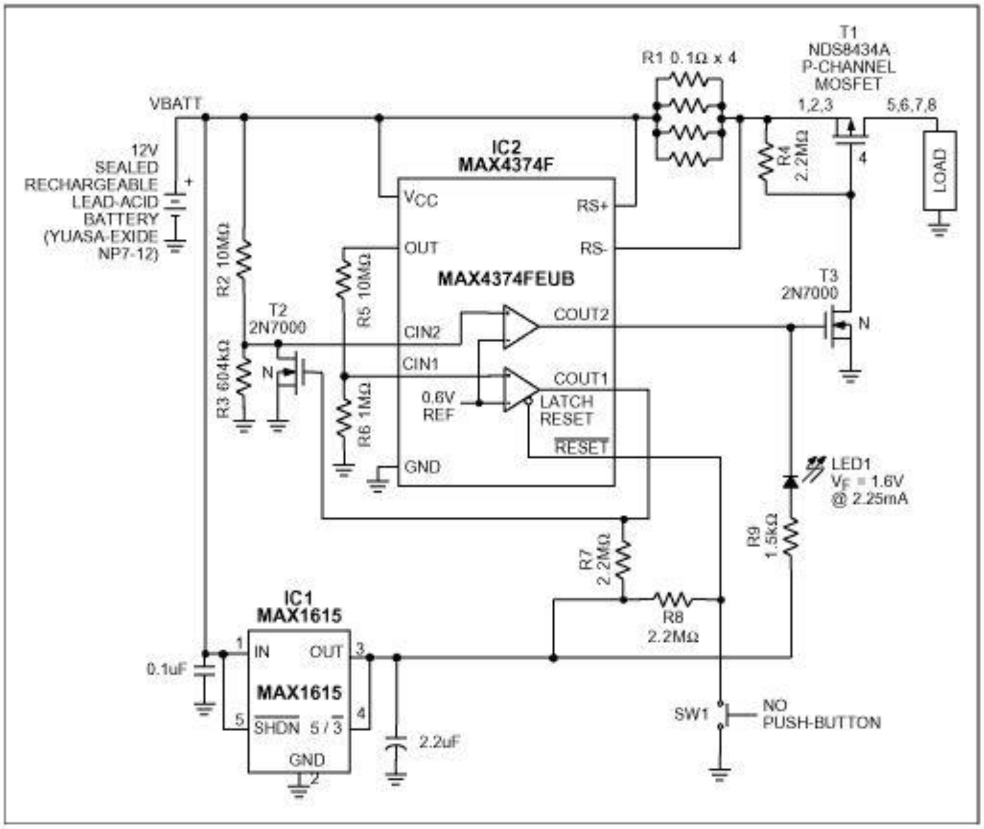


Figure 4: Electrical schematic for the battery protection circuit taken from Maxim Integrated [1].

Note: The Pchannel MOSFET (T1) will be replaced with FDS6375 since that particular part is obsolete.

Nichrome Wire Pattern

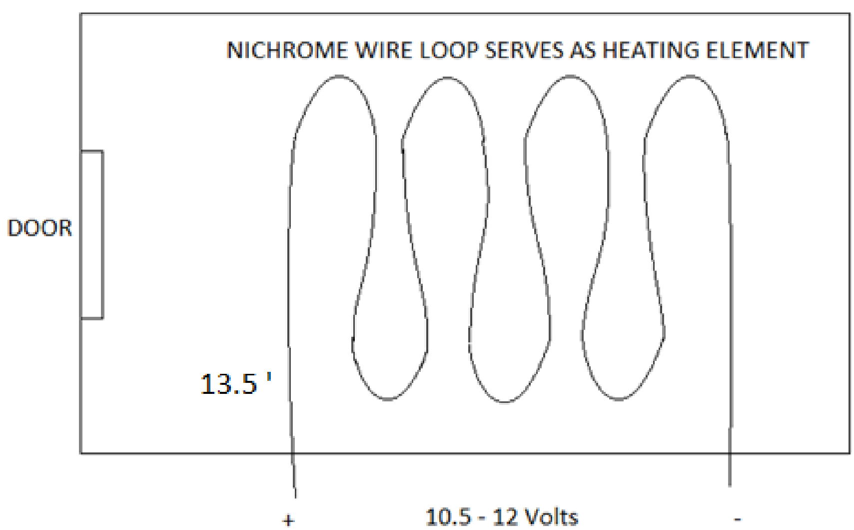


Figure 5: Displays the location of the heating element on floor of the doghouse.

Doghouse Dimensions

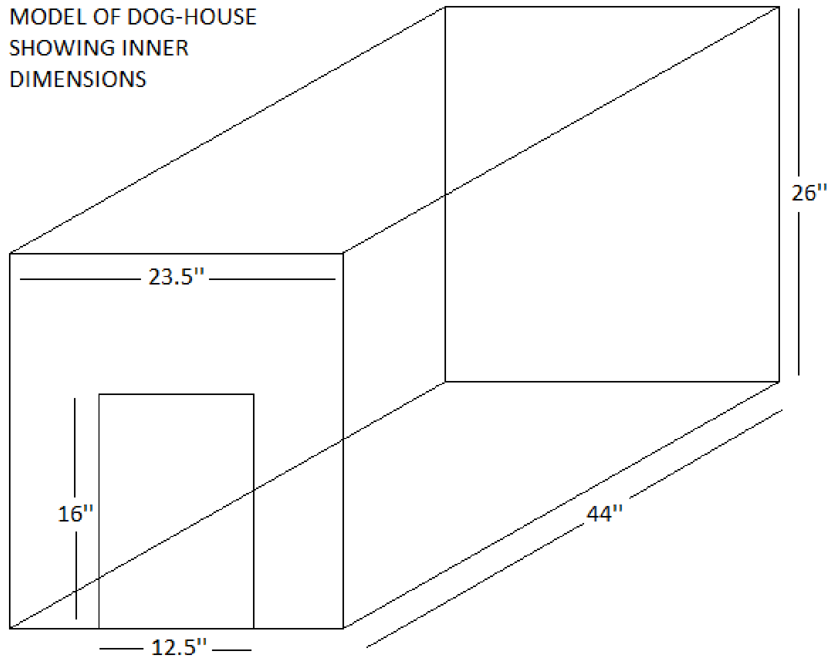


Figure 6: Shows the interior dimensions of the doghouse.

User Control Panel

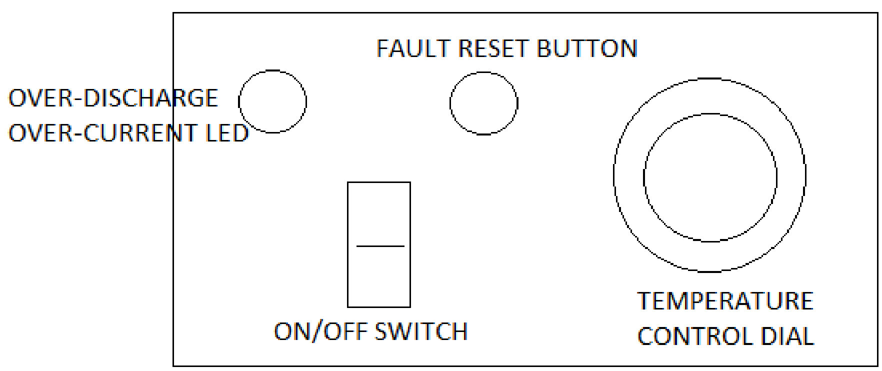


Figure 7: Shows the user input panel.

3 Calculations

3.1 Heating Requirements

Final doghouse inner dimensions: 44”x23.5”x26”

$$2(44in)(23.5\text{in}) = 2068\ in^2$$
$$2(44in)(26in) = 2288in^2$$
$$2(23.5in)(26in) = 1223in^2$$
Total surface area = $5578in^2 = 38.74ft^2$

Power requirement to raise the inner house temperature 35°F with R-10 insulation (R-5 per in):

$$power\ required = \frac{surface\ area * change\ in\ temperature}{insulation\ rating}$$

$$\frac{38.74(35)}{10} = .24307BTU = \mathbf{39.73W}$$

3.2 Power Dissipated in Heating Element

$$P = VI$$
$$P = (12V)(3.42A) = \mathbf{41W}$$

This indicates that the heating element should provide enough power to heat the inside of the doghouse.

3.3 Solar Panel Power:

Power rating: 80W
Average hours of sunlight a day: 5 hours
Efficiency with optimum panel angle: 75.2%

Power produced by panel per day: $80W * 5hours * .752 = \mathbf{300.8W\ per\ day}$

This power produced indicates that the panel should provide enough power to heat the doghouse over the course of a day, as well as charge the battery

3.4 Battery Calculations

Battery Voltage: 12V
Reserve Capacity Rating: 182 minutes at 25A
Expected Load Current for Heating System: 3.42A
(Heating system current used since cooling system current will be much smaller)

<u>Discharge Time:</u>

$$\frac{182min * 25A}{3.42A} = 1330.4\,\mathrm{min} = 22.2hours$$

If the battery was constantly being discharged (the floor is constantly heated) the battery should last about 22.2 hours without charge, but the system will not actually run constantly. It is expected that it will only need to run for about 20minutes of every hour in order to keep the house temperature at the set temperature. With this expectation factored in, the battery should last 3 times as long, **about 66.6 hours**, without any charging from the panel.

3.5 Heating Element Calculations:

Nichrome Wire Rating: .26Ω/ft
Length of Heating Element: 13.5 ft
Battery Voltage: 12V

$$total\ resistance\ of\ the\ coil = .26\Omega/ft * 13.5ft \quad = 3.51\Omega$$

$$current\ used\ by\ coil = \frac{12V}{3.51\Omega} = \mathbf{3.42A}$$

This current is the load current that will be provided to the heating element by either the battery or the panel when the heating system is on and running.

3.6 Solar Panel Angle

In order to maximize the efficiency of the system, it is required to adjust the angle of the solar panel twice a year. If the owner lives in the northern hemisphere, the panels need to be moved on March 30th and September 12th. For the Southern hemisphere, the panels should be moved on September 29th and March 14th.

A formula was found from MacsLab [2] in order to get the optimum angle. The formulas below are valid for latitudes between 25 and 50 degrees. The angle shown is the angle that the panels need to be tilted towards the equator. The graph below shows the optimum angle for the solar panels.

$$Summer: \quad angle = (latitude \cdot 0.930) - 21.0°$$

$$Winter: \quad angle = (latitude \cdot 0.875) + 19.2°$$

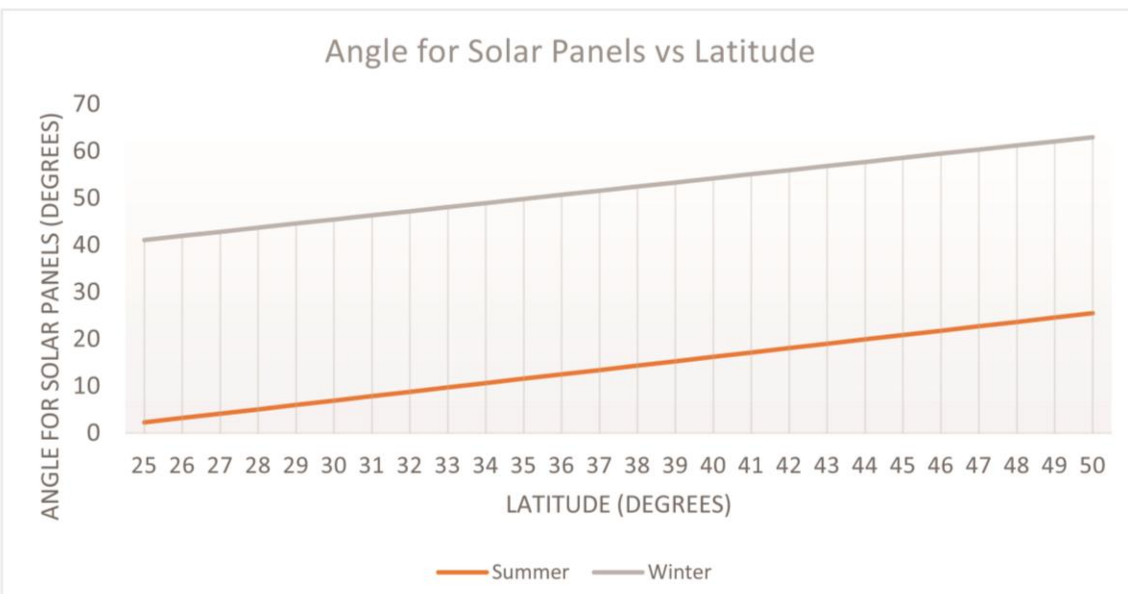


Figure 8: Solar Panel Angle Reference Plot- Shows the angle the solar panels need to be directed towards the equator during the respective season.

3.7 Schematic Values

Heat Controller

R1, R2, R3, R4 – Are chosen at 150KΩ to basically make a voltage comparator. 150 KΩ was selected because if the maximum temperature that the doghouse is heated to is 60°F, this corresponds to a thermistor resistance of 150 KΩ

R102Floor- This value is set to 56 KΩ because this is the corresponding resistance for the thermistor when the temperature is 102°F. This is a simply a safety setting. The floor must not get hotter than this temperature for the safety of the dog.

Potentiometer- The potentiometer used can go from 500Ω to 1 MΩ. However, since the house will most likely be operated in the range of 32°F to 60°F, the values of this potentiometer will fall in the range of 330 KΩ to 150 KΩ

Thermistors- The thermistor resistance values depend on the temperature. From the datasheet, the resistance of the thermistors should fall into the range of 830 KΩ to 37 KΩ. This corresponds to temperatures within the range of 0°F to 120°F. The hotter the temperature, the lower the resistance across the thermistor.

R8, R3- Has a value of 18 KΩ. The required current that is needed to switch the relay is 30mA. The beta value of transistor Q2 and Q4 is 100. The base current going into Q2 = 30mA/100 = .3mA. The voltage drop is 12-.7. So then from V=IR, 11.3/.3mA = 38 KΩ. However, just to be safe and make sure the relay will switch, this value is divided by 2, so 18 KΩ.

Diode1, Diode2- Serve to protect current from flowing into the transistor and blowing it.

LED- Lights up with the heating element is on, off when the heating element is off.

Transistors Q1, Q4- Amplify the base current in order for the relay to switch.

OpAmps OA1, OA2- Is a voltage comparator. If the voltage across the thermistor is greater than the voltage across the potentiometer or R102floor, then low voltage is outputted and the heater then turns on. If the voltage is greater across the potentiometer or R102floor, 12 V is outputted and heater turns off.

Relay_Safety- This relay serves as a switch that determines if the floor is too hot, past 102°F. If the floor becomes too hot, the switch is opened and the heating element will be turned off. A relay was chosen over a transistor because the voltage drop is minimal and therefore power is not wasted.

RelayMain This relay serves as a switch that determines if the temperature in the doghouse is cooler than what was set by the user. If it becomes too cold, the relay is enabled and current flows through the heating element.

R6- Is chosen to set the hysteresis point. The heating cannot be turning on every time it drops the slightest amount below the heat setting. The hysteresis point was set to be five degrees below the user input, centered around 37°F. Since the circuit is not linear, the points will vary depending on the operating temperature. The resistance of the thermistor at 32°F (when the heater must kick back on) is

330 KΩ while the resistance of the thermistor at 37°F (when the heater will turn off) is 283K. The critical points of the circuit are when the heater is off and about to turn on, at 32.1°F, which gives a V- of 8.25V, and the other critical point is when the heater is on and about to turn off, at 37.1°F, which gives a voltage of 7.84V. When the heater is off, the feedback resistor, R6, is in parallel with R5. V- must then be equal to V+ since this is a turning point. This leaves the equation below:

$$8.25\,V = \frac{12 \cdot R_{potentiometer}}{R5||R6 + R_{potentiometer}}$$

Then there is the equation for the other critical point, when the heater is on, and about to turn off. The output of the OpAmp is 0V when the heater is on, so the potentiometer is in parallel with R6. Once again, V- is set to equal V+:

$$7.84\,V = \frac{R6||\,R_{potentiometer}}{R6||\,R_{potentiometer} + R5}$$

This system of equations is solved and the values below are found:

$$R_{potentiometer} = 313.718\,K\Omega$$

$$R6 = 2.9\,M\Omega$$

The value that was actually chosen was 3.3 MΩ because that resistance was easily available.

Cooling Controller

R1, R2, R5 – Are chosen at 150KΩ to basically make a voltage comparator. 150 KΩ was selected because a lot of power is not being dissipated through these resistors, however, it is sufficient enough to build a voltage comparator.

R65deg- This value is set to 159 KΩ because this is the corresponding resistance needed across the thermistor when the fan needs to turn on at 65°F. This is calculated below under R3.

R80deg- This value is set to 91 KΩ because this is the corresponding resistance for the thermistor when the temperature is 80°F. This is the second threshold value. If the temperature is greater than 65°F, it then needs to be determined if it is less than or greater than 80°F.

Thermistor- The thermistor resistance values depend on the temperature. From the datasheet, the resistance of the thermistors should fall into the range of 830 KΩ to 37 KΩ. This corresponds to temperatures within the range of 0°F to 120°F. The hotter the temperature, the lower the resistance across the thermistor.

R4, R7- Has a value of 18 KΩ. The required current that is needed to switch the relay is 30mA. The beta value of transistor Q5 and Q4 is 100. The base current going into Q2 = 30mA/100 = .3mA. The voltage drop is 12-.7. So then from V=IR, 11.3/.3mA = 38 KΩ. However, just to be safe and make sure the relay will switch, this value is divided by 2, so 18 KΩ.

Diode1, Diode2- Serve to protect current from flowing into the transistor and blowing it.

Transistors Q4, Q5- Amplify the base current in order for the relay to switch.

Transistor Q7- This transistor is used to regulate the current that flows to the fan if the temperature in the doghouse is between 65°F and 80°F, in order for the fan to not be full speed. This is a power transistor because there is a large amount of current flowing through it.

OpAmps OA1, OA2- Is a voltage comparator. If the voltage across R65deg or R80deg is greater than the voltage across the thermistor, this means that it is warmer than the thresholds of 65°F or 80°F. Because it is a voltage comparator, each respective OpAmp will then output 12V, which is the signal that drives the fan.

Relay_Lowtemp- This relay serves as a switch that determines if the temperature in the doghouse is greater than 65°F. If this is true, the switch is opened and then it has to still be determined if it is less than or greater than 80°F. If the temperature is less 65°F, the switch remains open and no current flows through the fan, which means it is off.

Relay_Hightemp- This relay serves as a switch that determines if the temperature in the doghouse is less than or greater than 80°F. If it is greater than 80°F, the relay is closed and 12V is directly delivered to the fan. If it is less than 80°F, this relay remains open.

R8- This resistor regulates the current going through the fans. Both fans require 12 volts, and .3A of current to operator at full speed. In order to have the fans operate at half power, there needs to be .707· .6A = .424A flowing from the collector. Since the beta of Q7 = 40, the base current of the transistor needs to be .424/40 = 10.6mA. The voltage at the base of the transistor is 12-.7 = 11.3V. To find the resistance value, 11.3V/10.6mA = 1.1 KΩ.

R3, R6- Is chosen to set the hysteresis point since the relays must not chatter. The fans and the relays cannot be switching on or off every time the temperature drops the smallest bit beneath the threshold voltage. The hysteresis point was set to be five degrees below the user input, centered around 65°F. Since the circuit is not linear, the points will vary depending on the operating temperature. The resistance of the thermistor at 65°F (when the fan must kick on) is 135 KΩ while the resistance of the thermistor at 60°F (when the fan will turn back off) is 152K. The critical points of the circuit are when the fan is on and about to turn off, at 60.1°F, which gives a V- of 5.960V, and the other critical point is when the fan is off and about to turn on, at 64.9°F, which gives a voltage of 5.706V. When the fan is off, the feedback resistor, R3, is in parallel with R2. V- must then be equal to V+ since this is a turning point. This leaves the equation below:

$$5.706\,V = \frac{R2||R3}{R2||R3 + R65deg}$$

Then there is the equation for the other critical point, when the fan is on, and about to turn off. The output of the OpAmp is 12V when the fan is on, so R65deg is in parallel with R3. Once again, V- is set to equal V+:

$$5.960\,V = \frac{R2}{R3||R65deg + R2}$$

This system of equations is solved and the values below are found:

$$R65deg = 158.76\,K\Omega$$

$$R3 = \ 3.56\,M\Omega$$

The value that was actually chosen was 3.3 MΩ because that resistance was easily available. R6 was chosen to have the same value, seeing as a shifting to a higher temperature will not change the hysteresis point by too much. This is not critical.

4 Simulations

4.1 Heating Controller Simulation

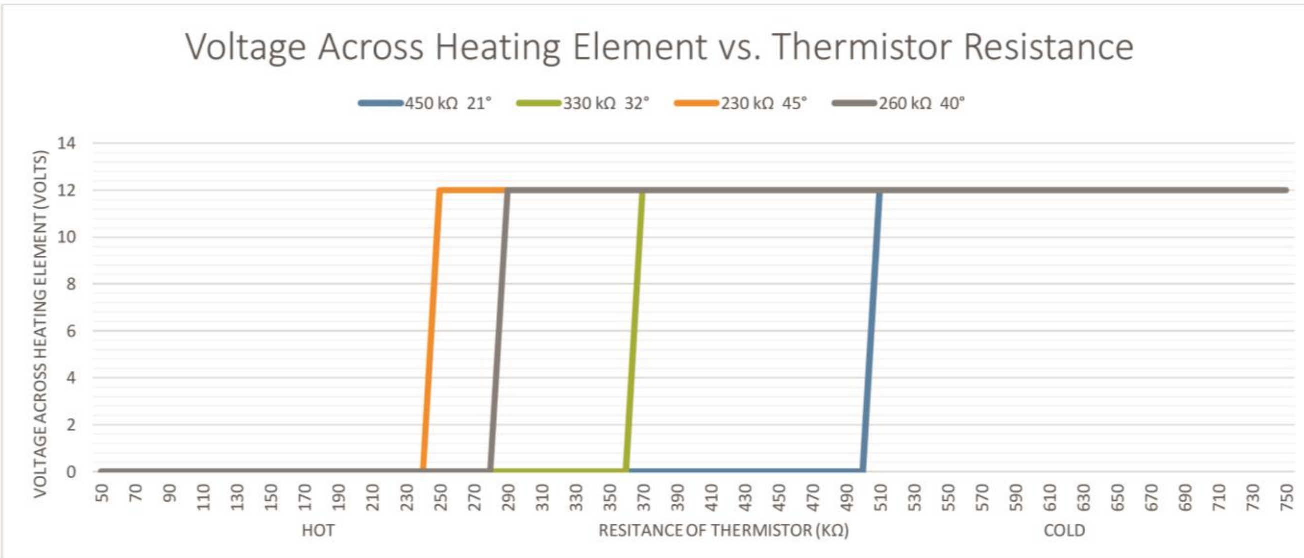


Figure 9: Simulation of Heating Controller Output- Shows the voltage across the heating element when the potentiometer is adjusted to various resistances shown.

4.2 Cooling Controller Simulation

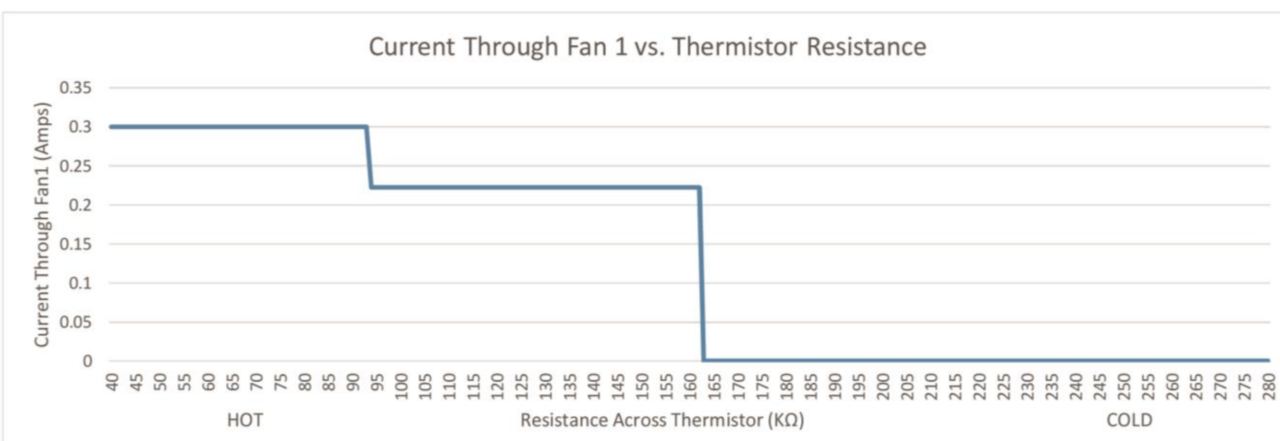


Figure 10: Simulation of Cooling Controller- Shows the output current at various thermistor resistances that correspond to various temperatures.

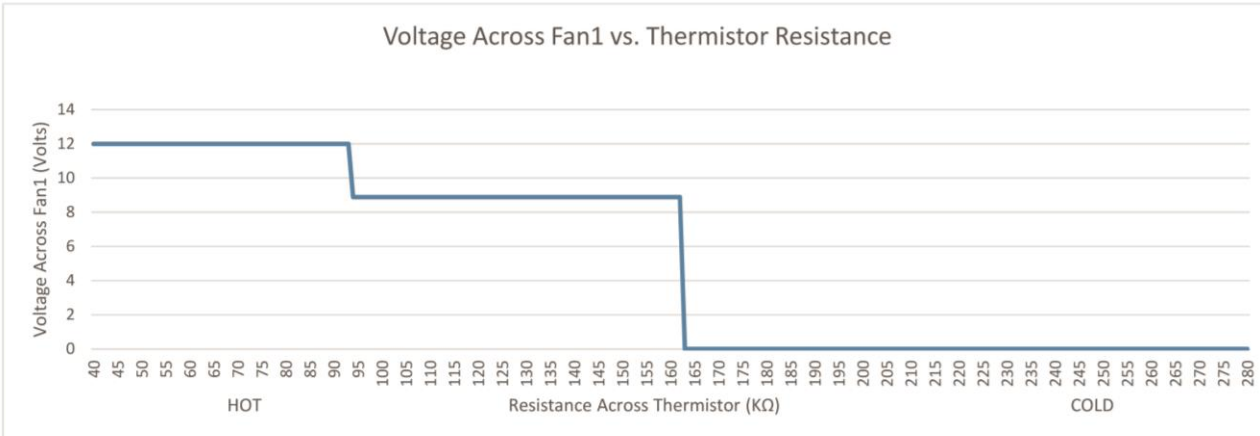


Figure 11: Simulation of Cooling Controller- Shows the output voltage at various thermistor resistances that correspond to various temperatures.

4.3 Voltage Threshold Detector Simulation

Due to the fact that the battery protection circuit will require building the given schematic with the specified chips, the following simulations are the expected waveforms rather than the actual simulated waveforms from the circuit. The waveforms are based on the expected behavior of the protection circuit in the event of overdischarge and overcurrent. For the overdischarge simulation, it can be seen that when the battery voltage drops below 10.5V the load current will be shut off, but if the battery is charged back above 10.5V, the load current will turn back on automatically. For the overcurrent simulation, it can be seen that when the load current exceeds 5A in the event of a fault or other error, it will immediately be cut off and will not be turned back on until the reset button is hit by the user (represented by the pulse in the button status waveform).

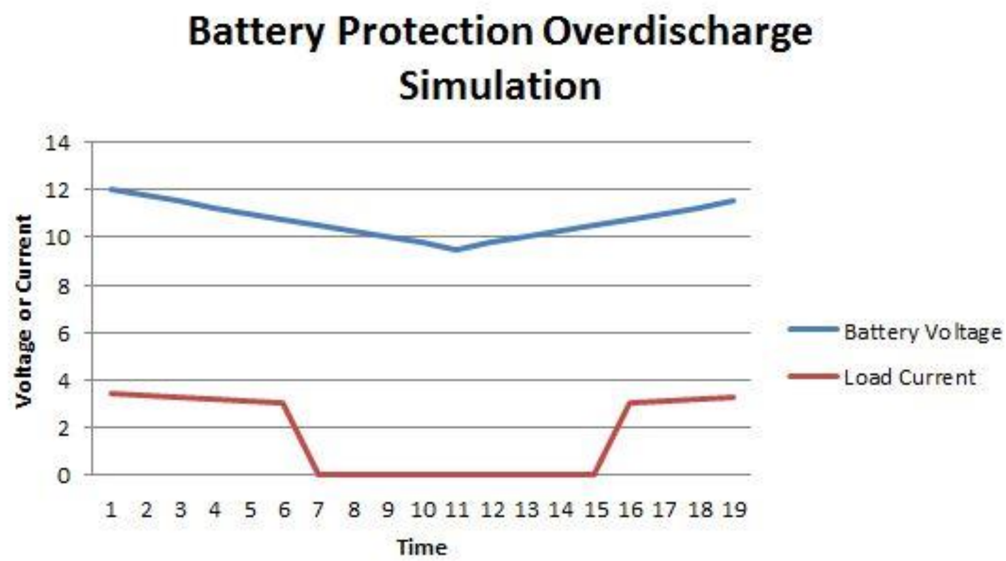


Figure 12: Theoretical Simulation of the Event of Overdischarging the Battery

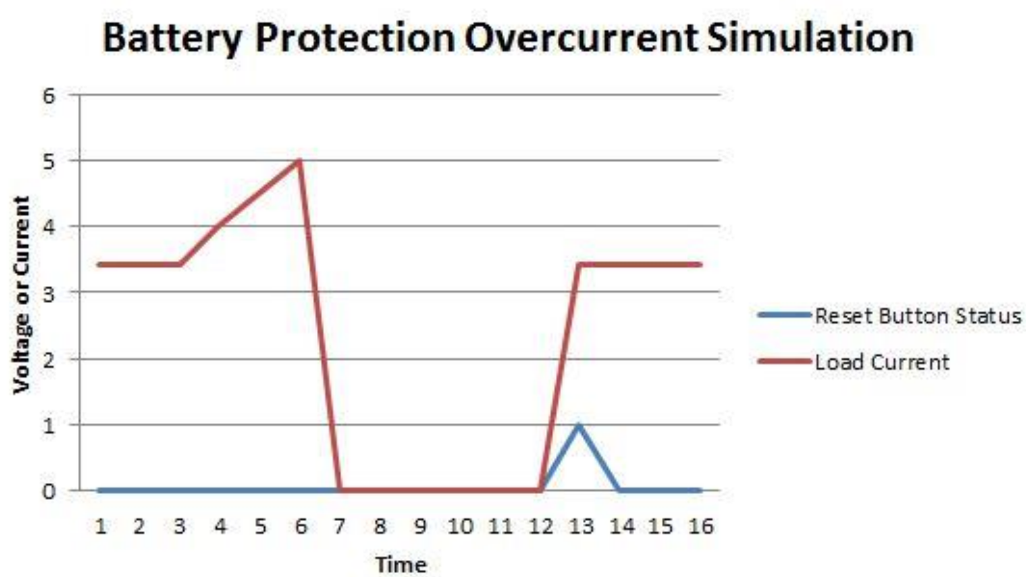


Figure 13: Theoretical Simulation of the Event of Overcurrent

5 Requirements and Verification

5.1 Requirements and Verification

Requirements	Verification
1. Solar Panel	

a. Solar panel should output a maximum current of 4.4 A when exposed full sunlight at noon in Champaign on an April day. b. Solar panel efficiency should be at least 75.2%	a. The panel will be brought outside on a sunny April day in Champaign tilted 50 degrees toward the equator. The output current will be measured and must be a max of 4.4A. b. The panel will be exposed to the same conditions as a, and the output voltage will be measured and must be between 13.5V and 18V.
2. Charge Controller a. Controller should convert the panel voltage to within 60mV of 12V b. Controller should stop charging the battery when it is charged to a full 12V	 a. The panel will be connected to the controller and exposed to daylight. The output voltage of the controller will be read and should be within 11.94V to 12.06V. b. The controller will be connected to either a fully charged battery or a 12V source and the fully charged LED on the controller should go on.
3. Battery a. Battery discharge time to depletion should be about 22 hours	 a. The battery will be attached directly to the 13.5 feet of nichrome wire. The battery voltage will be monitored every hour until the battery voltage drops to 10.5V. The result will be extrapolated to predict whether the battery will last the expected amount of time.
4. Battery Protection Circuit a. Protection circuit should turn off the load current if the battery voltage is depleted to 10.5V +/-1.5%. The load current should turn back on when the battery is charged back above 10.5V +/- 1.5%. b. Protection circuit should turn off the load current if the battery output current exceeds 5A +/-1.5%. The load current should stay at zero until the reset button is hit by the user indicating the fault has been corrected.	 a. The protection circuit will be connected to a DC source and the input voltage decreased from 12V. The load current will be monitored and when the input voltage reaches within 10.34V to 10.65V, the current should go to zero. When the voltage is increased above 10.34V to 10.65V, the current should go back above zero amps. b. The protection will be connected to a 12V source and the load will be changed to a load requiring at least a 5A current. The load current will be measured and should go to zero when the current falls within the range of 4.925A to 5.075A which corresponds to the tolerance of the 5A rated load. A load requiring less current will be connected and the reset button pressed to verify the current turns back on.
5. On/Off Switch a. The switch must route the input power to the heating and cooling systems if the switch is in the "on" position.	 a. The switch with be set to "on." The input voltage into the heating and cooling systems will be measured and must be within 10.5- 12V

b. The switch must have both systems off if it is in the "off" position	b. The switch should be set to "off." The input current for both the heating and cooling systems will be measured and must be zero.
6. Heating Controller a. When the floor temperature is exceeding 102 degrees, the voltage of the OpAmp (OA2) will increase to the source voltage (10.5-12V) and the heating element current should drop to zero. b. When the house temperature is below the set temperature on the dial, the heating element current should be 3.06-3.42 A and the voltage should be equal to the source voltage (10.5-12V). c. When the house temperature reaches the set dial temperature, the heating element current should drop to zero.	 a. A hair dryer will be directed at the floor thermistor, the temperature will be measured with a thermometer. The output voltage of OA2 will be monitored and when the temperature exceeds 102F, the voltage should jump to the source voltage (10.5-12V). The output current to the heating element will also be monitored and should drop to zero. b. A temperature above the current house temperature, checked with a thermometer, will be set on the dial. The heating element current will be monitored and should be within 3.06-3.42A as the element heats up and the voltage across the element should be equal to the source voltage. c. The house temperature will be read with a thermometer and the heating element current will be monitored. When the thermometer temperature matches the set dial temperature, the heating element current should drop to zero.
7. Heating Element a. The nichrome wire must be able to heat the floor tiles when being powered.	 a. A voltage of 10.5- 12V will be applied across the nichrome wire heating element. An infra-red thermometer will be used to continuously check the temperature of the porcelain tiles. The temperature should increase steadily from room temperature till the time the voltage is turned off. The test will be run until the temperature reaches 102 degrees Fahrenheit.
8. Cooling Controller a. When the temperature in the room is less than 65 degrees, the fans should both be off. b. When the temperature is between 65-80 degrees, the fans should be on low speed.	 a. An ice cube will be place directly next to the doghouse thermistor. The output of OpAmp OA1 will be measured and will be 0V. The voltage across the fans will also be measured and should also be 0V. b. The room will be made to fall within this range. If needed, a hairdryer or ice cubes can be used on the thermistor. The temperature of the doghouse will be confirmed with the infra-red thermometer. The voltage will be measured and OpAmp OA1 will have a voltage of 10.5-12V. The voltage of OpAmp OA2 will be 0V. This will result in the voltage across the fan terminals to be within the range of 7-9V.

c. When the temperature is greater than 80 degrees, the fan should be on high speed.	c. A hair dryer will be directed at the thermistor until the infra-red thermometer confirms the temperature. The voltage will be measured and OpAmp OA1 will have a voltage of 10.5-12V. The voltage of OpAmp OA2 will be 10.5-12. This will result in the voltage across the fan terminals to be within the range of 10.5-12V.
9. Fan a. The fan must have three different speeds. When 0V is applied, the fan must be off. b. When 8.48 V is applied, the fan must be at medium speed. c. When 12 V is applied the fan must be at full speed.	 a. 0V is applied to the fan terminals. The fan should not rotate. This should be checked with both fans. b. 8.48 V is applied, the fan must be rotating. This should be checked with both fans. c. 12 V is now applied to the fan. It should be rotating faster than the step above. This should be checked with both fans.

5.2 Tolerance Analysis

One of the most integral part of the doghouse is the system that regulates the temperature. If the house becomes too hot, the heating elements need to turn off. If the house becomes too cold, there must be a voltage applied to the heating elements. Also, the fan goes on automatically, depending on the temperature in the doghouse. If the doghouse cannot interpret the temperature at a decently accurate level, this comfortable doghouse turns into just a very expensive arrangement of wood. Another reason that temperature accuracy is important is that the floor temperature must not go over 105°F for safety of the dog. If the doghouse floor is hotter than this and the thermistors detect a temperature lower than this, the safety feature will not enable and the dog could be seriously injured.

The thermistors must have the proper resistance that corresponds to the temperature indicated on the data sheet. The thermistor data sheet says that the resistance is measured within 1% accuracy. However, for this application, a range of 2.5% will be enough to protect the dog and ensure a habitable doghouse. This will be checked by measuring the resistance of the thermistor at various temperatures. A wide range of temperature will be tested. A hair blower will be directed at the house and the temperature will be measured right next to the thermistor with the infrared thermometer. The resistance will then be measured and recorded. It will then be compared to the corresponding temperature on the data sheet to see if it falls in range. By placing an ice cube near the thermistor, cooler temperatures can be simulated. Twenty different data points will be measured that fall within the range of 32°F - 100°F. Once all of the resistances and temperature measurements are taken, it will be determined if all of these points fall within 2.5% of the data sheet specification.

6. Cost Analysis and Schedule

6.1 Cost Analysis

Labor Costs

We conducted a simplified cost analysis for our project to estimate the total cost of building a solar powered doghouse. We assumed an Hourly salary of $35.00 per person, and 150 total working hours per person.

Name	Hourly Rate	Total Hours Invested	Total Labor Cost
Krista Giacobazzi	$35.00	150	$13, 125.00
Lynn Deasey	$35.00	150	$13, 125.00
Gurbaaz Singh Sidhu	$35.00	150	$13, 125.00
Total		450	$39, 375.00

The total labor costs were calculated as shown,

$$Labor\ Costs = 35.00\ \cdot 2.5\ \cdot 150 = \$13{,}125.00$$

Component Status and Costs

Component	Part Number	Quantity	Status	Cost ($)
Wooden Doghouse	N/A	1	Constructed	150.00
80 W LaVie Solar panel	SABO 36/72	1	Borrowed	100.00
12 V Basement Watchdog Battery	Model # 30HDC140S	1	Borrowed	140.00
Morningstar SunGuard Power Controller	MS-SG-4-12	1	Ordered	31.74
Nichrome wire	16 Gauge 30 Feet	162 inches	Received	16.50
Thermistor	ATH100K1R25	2	Received	3.74
Small Fan	UTCB12	2	Will be ordered	20.00
Insulation	N/A	2’’X48’’X8’	Received	24.68
Tiles	N/A	8 (1 sq. foot each)	Received	30.00
Tile Paste and Grout	N/A	-	Received	14.43
SPST Switch	Model # 275-701	1	Available	3.19
Battery Protection Op Amp Chips	MAX4374F, MAX1615	2	Ordered	5.51
MOSFETS	2N7000	2	Borrowed	.84
PChannel MOSFET	FDS6375	1	Ordered	.84
OpAmp	NTE 941M	4	Borrowed	3.88
PNP Power BJT	NTE391	1	Borrowed	2.89
PNP BJT	2N3906	3	Borrowed	.80
Relay	86-112	4	Borrowed	12.00

Resistors, Capacitors, etc.	N/A	-	Available	5.00
Flyback Diode	1N4148	4	Will be ordered	2.00

Total Costs

Section	Total
Labor	$39, 375.00
Components	$566.04
Total	**$39,943.04**

6.2 Schedule

	Lynn Deasey	Gurbaaz Sidhu	Krista Giacobazzi
2/25 Design Review	Work on design review Get parts for Battery Protection Circuit, begin designing PCB for Battery Protection	Work on Design Review. Find ideas for motion detection/ occupancy sensors.	Work on design review make heat and fan controller schematic and make simulation
3/4	Get Battery Protection circuit PCB made and begin assembling/soldering parts	Make PCB for Fan controller circuit. Ensure all parts for this have been acquired.	Make PCB for Heat controller Make sure parts ordered that go on board
3/11	Finish assembly/soldering of Battery Protection Circuit. Verify circuit works.	Solder components on PCB designed earlier.	Solder components to heat controller board and make sure heat controller operates as expected. Begin assembly.
3/18 Spring Break			
3/25 Mock Up Demo	Assemble power components: Solar panel, charge controller, battery, battery protection circuit.	Connect the fan controller circuit to all associated blocks.	Finish the heating system. Attach heat component to the floor and also the PCB.
4/1	Integrate power system into doghouse, get any necessary enclosures made.	Integrate the finished block with the rest of the project.	Integrate the heat controller with the entire doghouse and assemble components as a team.
4/8	Testing/Debugging power system	Testing/Debugging	Testing/Debugging heating system.
4/15	Finish testing and debugging, Tile the floor of the house	Attach Solar Panel to the roof using adjustable metal frame.	Testing/Debugging. Paint the doghouse, make it look good.
4/22 Demo	Demo	Demo	Demo

4/29 Presentation/Papers	Presentation and Papers	Presentation and Papers	Presentation and Papers

7 Ethics

As engineers developing a product for use by the larger community we have an obligation to uphold the IEEE Code of Ethics [3] and Academic Honesty. Though all the points mentioned in the Code are of utmost importance, certain statutes of the Code are of pertinence to our project. Specifically,

- "to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;"

  We will take all necessary precautions in ensuring that our project is safe to use, both for the dog and the owner, and that it does not in any way cause harm to its immediate surroundings or the environment.

- "to be honest and realistic in stating claims or estimates based on available data;"

  We will present all our data, simulations and schematics honestly and will not distort our findings.

- "to improve the understanding of technology, its appropriate application, and potential consequences;"

  We will endeavor to build a good understanding of the various components of our project in the user's mind, and we will also elaborate upon the consequences of improper usage. This will help encourage the appropriate application of our project.

A thorough understanding of this Code as well as exercising good sense will ensure that our project is safe to use and environmentally sustainable.

8 Safety

Safety is one of the highest priorities for our group as our project has high current and voltage values associated with it. Consequently, we need to keep in mind the user's safety, the dog's safety as well as our own safety.

8.1 Safety of Dog

As we are developing a product which operates without manual supervision, it is vital that our dog-house is safe for the dog. To this end we will ensure that there are no exposed electrical components inside the dog-house. Our temperature control mechanism is another safety feature to ensure that the temperature of the dog-house is maintained at a level comfortable for the dog. We also have a battery protection component which helps mitigate the chances of a disaster due to faulty battery operation – over-discharge or over-drawing. Porcelain tiles form the floor of our dog-house, with grout in between. This ensures that out heating element is sealed off from water.

8.2 Safety of Owner

We also need the dog-house to be safe for the owner. The battery protection unit helps in this regard too. It ensures that untoward events, like fires or release of poisonous gases, do not occur. The user, too, should be protected from the high voltage and current associated with our project. We will ensure that no exposed electrical parts exist in our final project. Proper insulation and good planning will help us achieve this. Our project will also be easy to assemble and maintain so as to minimize injury from any repair or transportation.

8.3 Safety of Designer

We also need to keep in mind that our project does not harm us or our colleagues in any way during the development phase. Since our group is working with a 12 Volt lead-acid battery it is absolutely imperative that we exercise caution while connecting it to other components. Correct interpretation of data sheets and a good comprehension of the rated parameter values of each of our components will hold us in good stead while dealing with high voltages and currents. A thorough knowledge of the functioning of each part will also be paramount to maintaining a safe work environment. Fundamental aspects like correct safety gear, common sense and uncluttered workspace will go a long way in ensuring the safety of everyone.

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