BME Design-Fall 2023 - Caelen Nickel
Complete Notebook

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Caelen Nickel

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Team contact Information

Caelen Nickel - Dec 13, 2023, 8:49 PM CST

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Maysack-Landry	Charles	Communicator	maysacklandr@wisc.edu	(608) 381-3081	GreenBush
Heaton	Bryan	BSAC	bmheaton@wisc.edu	(952) 367-6597	Campus Village
Carlson	Tayler	BWIG	tacarlson3@wisc.edu	(920) 841-3986	Near Camp Randall
Binger	Caden	BWIG	crbinger@wisc.edu	(612) 413-4451	Near Camp Randall
Syslack	Annika	BPAG	asyslack@wisc.edu	(262) 336-0016	W. Washington Ave

Project description

Caelen Nickel - Dec 13, 2023, 8:48 PM CST

Course Number: BME 200/300

Project Name: Analysis of insulating properties of skin (rodent)

Short Name: Bioinstrument for Skin Insulation Research

Project description/problem statement:

In order to collect quantitative data necessary for the research of rodent skin thermodynamics and its effects, a biomedical device which can measure thermal insulation of a patch of ex-vivo mouse skin is required. An easy to use, reusable device is necessary to detect differences in temperature across the skin samples when under periodic pulsations of heat. Eliminating evaporative cooling on the skin improves the accuracy of the temperature measurements necessary to quantify insulation. The temperature data, taken within a specific accuracy and sensitivity, will be displayed graphically for ease of interpretation and exportable to MATLAB for analysis. Overall, this device will improve efficiency and accuracy in the thermodynamic testing of rodent skin in a cost effective manner.

About the client:

The client Dr. Caroline Alexander is a Professor of Oncology and principal investigator in the Mcardle Laboratory for Cancer Research, which is in the UW Carbone Cancer Center Developmental Therapeutics program. Her research on the relationship between rodents' metabolism and the heat permeability of their skin has opened new possibilities in improving health as there are implications in cancer, along with factors that could be replicated in humans.

9/11/2023 Client Meeting Notes

Caelen Nickel - Dec 13, 2023, 8:29 PM CST

Title: 9/11/2023 Client Meeting Notes

Date: 9/14/2023

Content by: Caelen Nickel

Present: BME 200/330 project team

Goals: Learn more about the relevant project background and client requirements/expectations

Content:

- A number of genetic studies show that metabolism is related to the skin tissue rather than other more commonly thought ones

- Skin is not just a dead, inert thing on the body, but can change with temperature changes

- There are current methods available to determine the surface temperature and heat loss of the rodent. However, cost of these systems is a barrier especially considering the relatively simple nature of the task required.

- Ex vivo is preferred, the rat will be newly unalive and thus non-invasiveness is not a concern. A postage stamp size patch of skin is surgically removed and used for all testing.

- The bottom surface of the skin is to be exposed to a heating element, preferably in pulses. 37 degree control test for the bottom of the skin is intended.

- The client and team agreed the heat pulses would be helpful in determining a graphical result of the heat insulative properties of the skin. The temperature on the dorsal (top) side of the skin can be measured and compared to the time/temperature of the heat pulse.

- The measure of evaporative cooling should be avoiding, specifically looking at conduction and convection.

- patches of skin will be no more than 2x4cm and .5mm thick

-must measure heat transfer while ignoring evaporative cooling

- precision to .1 degree, client uses a thermal gun with this precision already

Conclusions/action items:

As a result of the client meeting, the team has a better idea of what the problem statement should be. The preexisting problem statement must be refined, and background research and design idea brainstorming should be commenced.

11/17/2023 Client Meeting Notes

BRYAN HEATON - Nov 17, 2023, 1:32 PM CST

Title: Client Meeting Notes 11/17/2023

Date: 11/17/2023

Content by: Bryan Heaton

Present: All group members

Goals:

1. Discuss testing procedures
2. Discuss fabrication procedure

Content:

- Measure sensitivity of the temperature sensors
    - IF acetone wiped on skin cannot be detected (HIGHER temp), not sensitive enough
    - This process will continue to decrease the insulation of the skin with successive acetone wiping.
- Take a series of pulses of different temperatures to see how much heat will get through skin
- We can use the heat gun for testing
- Make pulse times adjustable for lab technicians (probably will have to do testing to find when pulses are not affected by hydration)
- Many lipids have different properties upon heating and cooling (different temperatures = different properties)

Conclusions/action items:

Testing for pretty much any data seems valuable to her.

12/01/2023 Client Meeting Notes

Caelen Nickel - Dec 13, 2023, 8:35 PM CST

Title: 12/01/2023 Client Meeting Notes

Date: 12/01/2023

Content by: Caelen Nickel

Present: Caelen Nickel and Charles Maysack-Landry

Goals: Introduce the client to the device prototype and begin testing said prototype.

Content:

- A simple walkthrough and demonstration on how to use the device was performed.

- Testing was performed, such as verification of the heating element and thermistor accuracy. See Testing and Results folder for details.

- As a result of testing and the heating element providing issues in its heating, future work and action items pending project continuation were discussed. See future work ideas in the Design Ideas folder in Caelen Nickel personal folder for more details.

Conclusions/action items:

This client meeting was vital in collecting data for the final presentation and final report. As a result of this meeting, the Heating Element Verification was performed and ready to analyze. In addition, client feedback regarding the design in general was helpful, such as ways to alter the design in the future. Also, we were provided with Tegaderm for continued testing.

2023/9/8 Advisor Meeting

Caelen Nickel - Oct 11, 2023, 1:29 AM CDT

Title: 2023/9/8 Advisor Meeting

Date: 9/8/2023

Content by: Caelen Nickel

Present: BME 200/300 Design Team

Goals: Receive the design project and meet with the advisor

Content:

- The design team met Dr. Williams and had a brief introduction into project details, expectations, etc.

- Much of this meeting was the team assigning roles and completing the first day tasks as outlined by Dr. P. and the design curriculum.

Conclusions/action items:

The design team will begin working on preliminary research, designs, and organize a client meeting.

2023/9/15 Advisor Meeting

Caelen Nickel - Oct 11, 2023, 1:30 AM CDT

Title: 2023/9/15 Advisor Meeting

Date: 9/15/2023

Content by: Caelen Nickel

Present: BME 200/300 Design Team

Goals: Go over preliminary research, design ideas, and the first week of assignments.

Content:

- The design team received instruction from Dr. Williams regarding the assignments that were due week one.

    - Dr. Williams made it clear that all activities mentioned and discussed in the weekly progress reports must have corresponding documentation in LabArchives

- Loose design ideas were discussed, especially regarding the method of temperature measurement and device power.

- Discussed the results from the client meeting and more specific requirements.

Conclusions/action items:

The design team will continue working on preliminary research and designs, making sure to update LabArchives in accordance with the progress reports.

2023/9/22 Advisor Meeting

Caelen Nickel - Oct 11, 2023, 1:30 AM CDT

Title: 2023/9/22 Advisor Meeting

Date: 9/22/2023

Content by: Caelen Nickel

Present: BME 200/300 Design Team

Goals: Go over the PDS and begin talking about the design matrix.

Content:

- The design team met with Dr. Williams to go over the past week's PDS

- Using the PDS criteria as a basis for constructing the matrix, the design team and advisor discussed expectations for the design matrix and what to include in design brainstorming.

Conclusions/action items:

Use advice from this meeting to draft the preliminary design matrix.

2023/09/29 Advisor Meeting

TAYLER CARLSON - Oct 11, 2023, 4:54 PM CDT

Title: Advisor Meeting

Date: 9/29/23

Content by: Tayler Carlson

Present: All group members

Goals: As a group, we are trying to figure out expectations for the presentation happening next Friday.

Content:

-Talked with Dr. Williams about what he expects for the presentation (well rehearsed, slides are easy to follow, etc.)

-Discussed our design matrix and how he would like that incorporated into our presentation

---Dr. Williams believes it would be smart to talk about both of our matrixes separately

---Wants us to double-check our math on the matrixes to make sure that it is done correctly

---The designs at the top should be easy to read

Conclusions/action items: We concluded that we need to triple-check our math and have a good layout for the design matrix. This is because it will be the main portion of the presentation that explains how we are going to move forward.

2023/11/17 Advisor Meeting

BRYAN HEATON - Nov 17, 2023, 12:55 PM CST

Title: 2023/11/17 Advisor Meeting Notes

Date: 11/17/2023

Content by: Bryan Heaton

Present: All group members

Goals:

1. Update Prof. Williams on our progress for the project
2. Discuss difficulties of the project
3. Run by testing procedure and discuss further testing

Content:

- Prepare for poster presentation by printing EARLY, making reservation provides soft deadline for project
- Feedback for poster possible if we send poster to Prof. Williams (LATEST Wednesday before)
- Prepare very specific testing procedure ASAP.
- Get working on specific sketches for the final product
- Setup date for testing in different environments (by ourself w/ tegaderm, and in lab)

Conclusions/action items:

Begin testing as soon as possible

2023/12/01 Advisor Meeting

TAYLER CARLSON - Dec 13, 2023, 9:17 AM CST

Title: Advisor Meeting Before Testing Carried Out

Date: 12/1/2023

Content by: Tayler Carlson

Present: All other team members: Charles, Caelen, Annika, Caden, Bryan

Goals: Update Prof. Williams on how our testing is coming and get his advice on how we should illustrate how our design works.

Content:

- We described our testing protocols to him and got his opinion on how the statistics tests should be run.

---- He seemed to approve of our methods of deriving the statistics.

- We also discussed our plans to test with our client later that day.

- When we discussed the poster, we inquired about how to properly show how our device was going to work. We found that it might be easier to make a diagram that was going to completely encompass the heat transfer going on in our design rather than trying to make diagrams that went piece by piece.

Conclusions/action items: The deadline for getting feedback on our poster is the the Wednesday before the poster presentation.

2023/09/24 Preliminary Design Idea Summary

Caelen Nickel - Sep 24, 2023, 7:35 PM CDT

Title: 2023/09/24 Preliminary Design Idea Summary

Date: 9/24/2023

Content by: Caelen Nickel

Goals: Layout a summary of design components and what differences various preliminary designs could have.

Content:

See attached document below

Conclusions/action items:

This summary is important in brainstorming both design components and how separate designs could be differentiated. The 3-4 preliminary designs will come from this brainstorming.

Caelen Nickel - Sep 24, 2023, 7:35 PM CDT

Temperature Measurement

- Thermistor, thermocouple, or thermopile are effective methods of temperature measurement.
  - One such component would be part of an electronic circuit paired with a microcontroller and code.
  - The temperature sensing component would alter the output voltage of the circuit, and temperature controlled testing and a calibration curve would equate this output voltage to a numerical temperature value.
  - Arduino code from a microcontroller would convert this output voltage into a temperature in ℃ and send this information to the researcher graphically.

Heating Element

- The use of wall power heating elements as used in BME 201 would be effective.
  - Beefcake relay
- Battery power is a safer and more flexible alternative. Specifications, incorporation into an electronic circuit, and operation must be explored.

- Regardless of the power source, a feedback loop must be implemented in order to maintain proper temperature and safety
  - A thermistor/thermocouple circuit measuring the temperature of the hot plate will be necessary.
  - The temperature sensor must be calibrated to know what resistance and corresponding output voltage indicates that the hot plate is at 37℃.
  - The Arduino microcontroller and code will read this output voltage level threshold and provide a signal to turn the hot plate on/off.
  - A manual switch will also be available to turn the hot plate on/off when the researcher wants to heat a sample or when the device is not in use.

Download

BME_300_Design_Idea.pdf (106 kB)

2023/10/10- Heating Materials

TAYLER CARLSON - Oct 11, 2023, 5:05 PM CDT

Title: Heating Materials

Date: 10/10/2023

Content by: Tayler Carlson

Goals: The goal is to research heat-conductive materials that will hopefully help reduce the evaporative cooling and heat loss that will occur with the pulsation of heat.

Content:

1. copper is the MOST conductive with a thermal conductivity of 223

2. aluminum is next with a conductivity of 118

3. then brass at a thermal conductivity of 64

4. next steel with a thermal conductivity of 17

5. lastly bronze with a thermal conductivity of 15

- good heat conductors that it doesn't allow for heat to be trapped

- whereas bad heat conductors will not allow heat to pass through causing the temperature they are working with to increase tremendously

- an example of good conductors could be the material that is found at the bottom of the pan whereas the material found in a thermis would be a bad conductor as it traps heat

Source:

[1] “Which Metals Conduct Heat Best?,” Metal Supermarkets, Feb. 17, 2016. https://www.metalsupermarkets.com/which-metals-conduct-heat-best/ (accessed Oct. 10, 2023).

Conclusions/action items: It is good to have a lot of options for good heat conductors which can be seen above. It is important that know we evaluate the cost of these conductors in order to figure out which one will be the most cost efficient for our project.

2023/10/11 Cost of Materials

TAYLER CARLSON - Oct 11, 2023, 5:14 PM CDT

Title: Cost of Materials

Date: 10/11/23

Content by: Tayler Carlson

Goals: The cost is going to begin to be evaluated through a comparison of 12x12 in sheets of the material of good conductive materials

Content:

- The top two conductors of focus are going to be copper and aluminum

- Most copper sheets are about $24.99

-Most aluminum sheets are about $12.19

- With that being said though, it is important to consider the thickness of the sheets---> good conductors are thicker

Source: "Copper Sheet, #30 Gauge, 12" x 12"." https://www.flinnsci.com/copper-sheet-30-gauge-12-x-12/c0080/ (accessed Oct. 11, 2023).

Conclusions/action items: Even though it seems that copper is more expensive, due to the vast ranges of thicknesses that can be purchased and its overall higher conductivity, we believe it will definitely be work paying up for.

Purchasing Record Spreadsheet- Last Updated 12-11-23

ANNIKA SYSLACK - Dec 11, 2023, 1:50 PM CST

Title: Material Purchasing Record Spreadsheet

Date: 11-1-23

Content by: Annika Syslack

Present: N/A

Goals: Keep a running account of all materials purchased throughout the semester.

Content:

Date	Material Purchased	Price	Means of Purchase
10-30	Thermistors (2)	$8.93	Caelen
10-30	General Amplifier	$7.84	Caelen
12-4	3D Printer -Box	$52.16	WisCard- Tayler
12-6	3D Printer -Lid	$12.08	WisCard- Tayler

Conclusions/action items:

Update table as needed to keep an accurate total of expenses.

2023/10/19 Thermistor Circuit Prototype with Pulsing LED

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:44 PM CDT

Title: Thermistor Circuit prototype with pulsing LED

Date: 10/19/23

Content by: Charles Maysack-Landry

Goals: Create a working prototype with a tester thermistor and prove pulsing capability of Arduino.

Content:

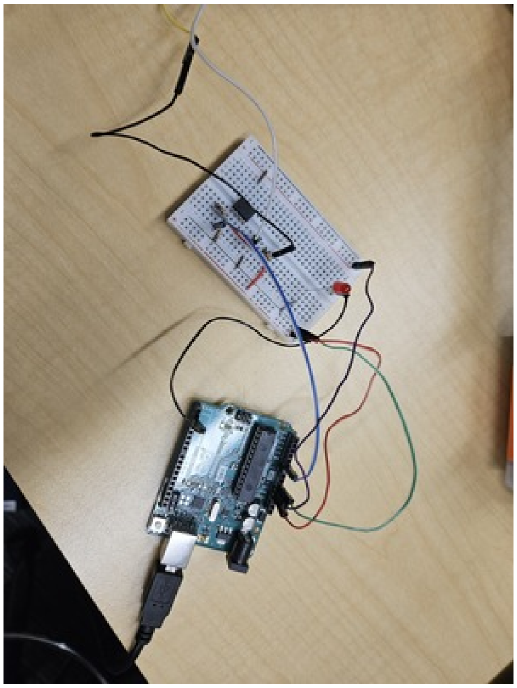
See attachments.

They are pictures of a voltage divider with a resistor and thermistor connected to a non-inverting amplifier circuit with a known gain. The Arduino sends 3.5 volts through both parts of the circuit and that output to an analog pin that will read the incoming voltage. This voltage can than be used to calculate the resistance of the thermistor which can be used to find the temperature. Added an LED in place of the heating element to be pulsed by the Arduino.

Conclusions/action items:

Purchase the final thermistor, measure the actual resistance of each resistor and create equations to determine the temperature measured by the circuit.

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:39 PM CDT



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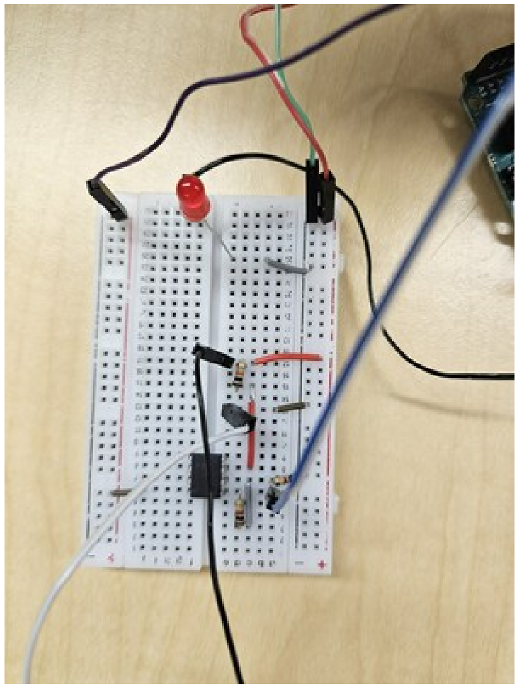
FullCircuit.jpg (2.53 MB)

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:39 PM CDT



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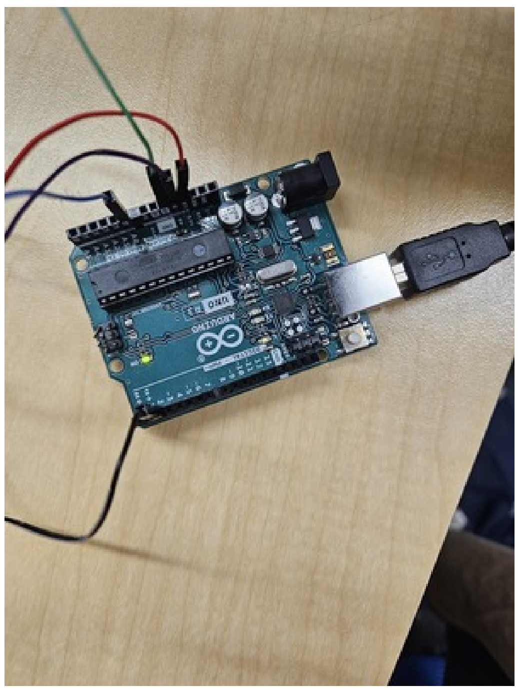
BreadBoard.jpg (1.94 MB)

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:39 PM CDT



Download

ArduinoUno.jpg (3.15 MB)

2023/11/09 Thermistor Datasheet, Calibration

Caelen Nickel - Nov 09, 2023, 11:14 PM CST

Title: 2023/11/09 Thermistor Datasheet, Calibration

Date: 11/09/2023

Content by: Caelen Nickel

Goals: Identify key specifications of the thermistor in order to make circuit calculations and calibration protocols

Content:

- For full thermistor datasheet, see Project Files folder or attachment below

- A thermistor is a type of variable resistor that changes resistance due to surrounding temperature. This will be used in the design of the temperature sensor and heating element because the change in resistance will cause a change in output voltage of the thermistor circuit, which can be read by an Arduino microcontroller.

- The thermistors used for the heating element modulation and temperature are identical. The said thermistor is a PTC, meaning that there is a positive correlation between temperature and resistance. As temperature increases, so does thermistor resistance.

- According to the datasheet, the PTC relationship between resistance and temperature is linear and can be modeled as such. This is especially true within the intended temperature range. As a result, the calibration curve fit will be linear, and the equation to convert output voltage received by the Arduino into a temperature reading will be of the form temperature = m*Vout + b.

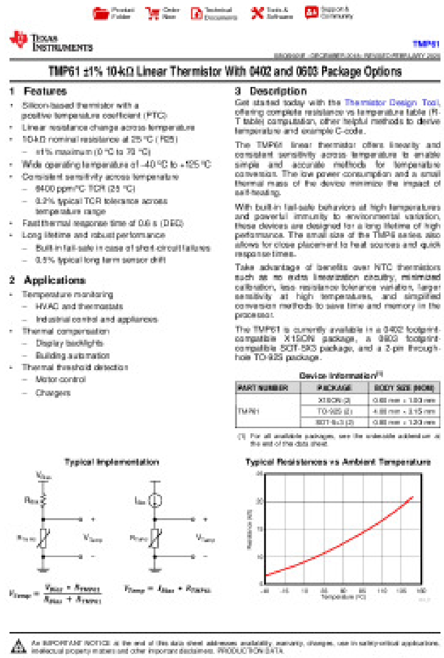
- In order to derive such equation, calibration testing of the thermistors is necessary, which will be documented following its completion in the Fabrication folder with a protocol in the Testing and Results folder.

- The thermistor datasheet outlines one data point on the calibration curve already, which is a resistance of 10 kOhm at room temperature (25 degrees C)

Conclusions/action items:

Using the information provided in this thermistor datasheet, the linear fit for the calibration curve can be completed as the intended relationship between temperature and resistance is known to be linear. Also, a data point on this relationship is provided, which allows for verification of proper thermistor functioning and to ensure the tolerance is small enough that accurate and reliable temperature measurement will be made. This is necessary for the client's research, and should be considered when completing the calibration curve and equation sensitivity. The more data points in addition to the provided room temperature one will give the most accurate equation with the best linear fit relative to the actual thermistor equation.

Caelen Nickel - Nov 09, 2023, 11:15 PM CST



TMP61

TMP61 ±1% 10-kΩ Linear Thermistor With 0402 and 0603 Package Options

1 Features

- Silicon-based thermistor with a positive temperature coefficient (PTC)
- Linear resistance change across temperature
- 10-kΩ nominal resistance at 25 °C (R25)
  - ±1% maximum (0 °C to 70 °C)
- Wide operating temperature of –40 °C to +125 °C
- Consistent sensitivity across temperature
  - 6400 ppm/°C TCR (25 °C)
  - 0.2% typical TCR tolerance across temperature range
- Fast thermal response time of 0.6 s (DEC)
- Long lifetime and robust performance
  - Built-in fail-safe in case of short-circuit failures
  - 0.5% typical long term sensor drift

2 Applications

- Temperature monitoring
  - HVAC and thermostats
  - Industrial control and appliances
- Thermal compensation
  - Display backlights
  - Building automation
- Thermal threshold detection
  - Motor control
  - Chargers

3 Description

Get started today with the Thermistor Design Tool, offering complete resistance vs temperature table (R-T table) computation, other helpful methods to derive temperature and example C-code.

The TMP61 linear thermistor offers linearity and consistent sensitivity across temperature to enable simple and accurate methods for temperature conversion. The low power consumption and a small thermal mass of the device minimize the impact of self-heating.

With built-in fail-safe behaviors at high temperatures and powerful immunity to environmental variation, these devices are designed for a long lifetime of high performance. The small size of the TMP6 series also allows for close placement to heat sources and quick response times.

Take advantage of benefits over NTC thermistors such as no extra linearization circuitry, minimized calibration, less resistance tolerance variation, larger sensitivity at high temperatures, and simplified conversion methods to save time and memory in the processor.

The TMP61 is currently available in a 0402 footprint-compatible X1SON package, a 0603 footprint-compatible SOT-5X3 package, and a 2-pin through-hole TO-92S package.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TMP61	X1SON (2)	0.60 mm × 1.00 mm
	TO-92S (2)	4.00 mm × 3.15 mm
	SOT-5X3 (2)	0.80 mm × 1.20 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Implementation

Typical Resistances vs Ambient Temperature

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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tmp61_Thermistor.pdf (1.28 MB)

2023/11/09 Operation Amplifier Datasheet, Pinout

Caelen Nickel - Nov 09, 2023, 11:31 PM CST

Title: 2023/11/09 Operation Amplifier Datasheet, Pinout

Date: 11/09/2023

Content by: Caelen Nickel

Goals: Identify key specifications of the operational amplifier, specifically the pinout, in order to fabricate the circuit.

Content:

- For full op-amp datasheet, see Project Files folder or attachment below

- An operational amplifier, or op-amp, is an electronic component capable of amplifying the electric potential (V) of an incoming signal. The amplification is only as large as the power provided to the op-amp, and no current (assumption) flows into the op-amp.

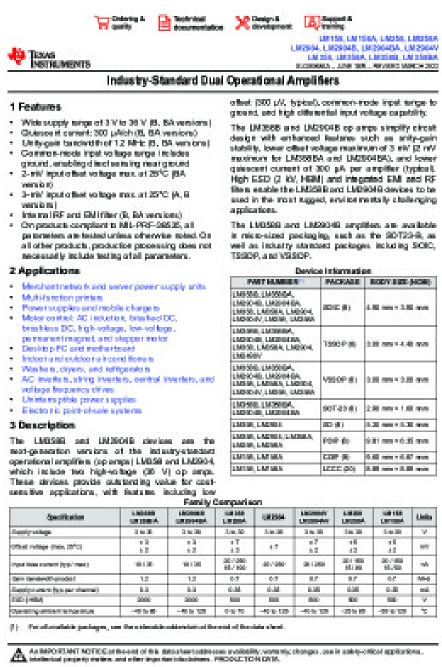
- From this, the gain G of an operational amplifier can be calculated based on the resistor values in series with specific pins of the op-amp. The calculations for resistor choices, calculation for overall gain, and reference to Arduino resolution against the client's desired sensitivity will be outlined in the Fabrication folder.

- As mentioned, the type and magnitude of gain an op-amp can provide is determined by what resistors are in series with what pins of the op-amp. The crucial information that the datasheet provides is what pin numbers and positions correspond to what function of the op-amp (V+ power source, input+, input-, GND/V- power source, etc.). This is outlined in the data sheet

Conclusions/action items:

Using the information provided in this operational amplifier datasheet, the pinout of the op-amp is known and thus the location of what wires/resistors can be determined in order to achieve a proper functioning circuit with the desired gain.

Caelen Nickel - Nov 09, 2023, 11:32 PM CST


LM158, LM158A, LM258, LM258A, LM2904, LM2904B, LM2904BA, LM2904V, LM358, LM358A, LM358B, LM358BA

Industry-Standard Dual Operational Amplifiers

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lm358_Op-Amp.pdf (4.1 MB)

2023/11/10 Thermistor Calibration

Caelen Nickel - Dec 01, 2023, 12:08 PM CST

Title: 2023/11/10 Thermistor Calibration

Date: 11/10/2023

Content by: Caelen Nickel

Goals: Derive an equation relating temperature to thermistor resistance

Content:

- As the thermistor datasheet outlines and as described in the corresponding LabArchives entry in the fabrication folder, the thermistors in use are PTC thermistors with a linear relationship between temperature and resistance.

    - As a result, the modeling of this relationship is simple, meaning that fewer data points are needed in comparison to an exponential relationship.

- In order to collect said data points, the thermistor resistance and the temperature of its environment must be simultaneously recorded and plotted.

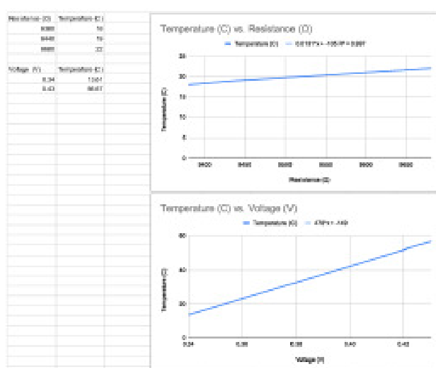
    - In order to do this, a digital multimeter was used to measure the resistance across the thermistor with alligator clips and + and GND probes in their respective ports in the multimeter.

    - Directly proceeding or following the resistance measurement, the ambient temperature of the thermistor surroundings was taken using a k-type thermocouple adapted to plug into the + and GND ports of the digital multimeter. The temperature setting would give a digital reading of temperature with this setting.

Conclusions/action items:

Using the thermistor calibration curve, an equation comparing resistance to temperature is generated, which using circuit calculations can yield an equation relating the analogRead of the Arduino to a temperature, which can be displayed or used in the modulation of the heating element.

Caelen Nickel - Dec 01, 2023, 12:09 PM CST



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Thermistor_calibration_curve_F23_-_Sheet1.pdf (95.7 kB)

2023/11/30 Arduino Code

Caelen Nickel - Dec 01, 2023, 1:12 AM CST

Title: 2023/11/30 Arduino Code

Date: 11/30/2023

Content by: Caelen Nickel

Goals: Create the Arduino code for the temperature sensor and heating element modulation

Content:

- See code in attachment below

- The premise behind the Arduino code is to convert the output voltage being received in the analog A0 and A1 pins from the breadboard circuit to temperature. First, the code converts the ADC values from the analogRead of the analog pins to a voltage value using the voltage range of the Arduino pins (5.0) divided by the resolution (1023). Then, this voltage is converted into a temperature value using the equation sourced from the calibration curve.

- For the temperature sensor, this temperature value is simply displayed on the serial plotter using the Serial.print function

- For the heating element, this temperature is compared to the desired temperature value of the heating element (34.0), and if it is lower the digital pin controlling the beefcake relay is powered, allowing the heating element to receive power through the relay.

Conclusions/action items:

Using this code, the circuit can be controlled to achieve its proper functioning. It is essential that the heating element be modulated correctly, and that temperature is displayed obviously. In order to ensure the circuit and accompanying code work properly, verifications have to be done using a waveform generator, multimeter, and Arduino serial plotter. Testing will also be done with the client to both verify the circuit and code work, but the interface between the device and the lab conditions, samples, and researcher.

Caelen Nickel - Dec 01, 2023, 1:12 AM CST

```
int rpin = 2;

int bpin = 11;


float slope = 400.99;

float yint = -107.906;


void setup() {

  // put your setup code here, to run once:

Serial.begin(9600);

pinMode(rpin, INPUT);

pinMode(bpin, OUTPUT);

}


void loop() {

  // put your main code here, to run repeatedly:

int sensorValue = analogRead(A0);

int heatValue = analogRead(A1);


float voltageValue0 = sensorValue * (5.0 / 1023.0);

float temp_reading = (slope * (voltageValue0)) + yint;

float voltageValue1 = heatValue * (5.0 / 1023.0);

float heat_temp = (slope * (voltageValue1)) + yint;


//Serial.println(voltageValue1);

Serial.println(temp_reading);

delay(1);


int rOutput = digitalRead(rpin);
```

```
if (rOutput = 1) {
    //Serial.println("on");
    //float heat_temp = 22.0;
    if (heat_temp < 34.0) {
      digitalWrite(bpin, HIGH);
    } else {
      digitalWrite(bpin, LOW);
    }
  } else {}
    //Serial.println("off");
    digitalWrite(bpin, LOW);
}
```

Caelen Nickel - Dec 03, 2023, 3:19 PM CST

Edited:

```
int rpin = 2;

int bpin = 11;


float slope = 487.0;

float yint = -149.0;


void setup() {

  // put your setup code here, to run once:

Serial.begin(9600);

pinMode(rpin, INPUT);

pinMode(bpin, OUTPUT);

}


void loop() {

  // put your main code here, to run repeatedly:

int sensorValue = analogRead(A1);

int heatValue = analogRead(A5);


float voltageValue1 = sensorValue * (5.0 / 1023.0);

float temp_reading = (slope * (voltageValue1)) + yint;

float voltageValue5 = heatValue * (5.0 / 1023.0);

float heat_temp = (slope * (voltageValue5)) + yint;


//Serial.println(heatValue);

//Serial.println(voltageValue0);

Serial.print("temp_reading");

Serial.println(temp_reading);
```

```
Serial.print("heat_temp");

Serial.println(heat_temp);

delay(1000);


int rOutput = digitalRead(rpin);

//Serial.println("on");

//float heat_temp = 22.0;

if (heat_temp > 34.0) {

  digitalWrite(bpin, LOW);

    }

if (heat_temp < 30.0) {

  digitalWrite(bpin, HIGH);

    }

}
```

2023/12/13 Project Box Fabrication

Caelen Nickel - Dec 13, 2023, 7:45 PM CST

Title: Project Box Fabrication

Date: 12/13/23

Content by: Tayler and Annika

Present: Tayler and Annika

Goals: Create a project box that will be able to hold the circuit once it is assembled. It needs to have a slidable lid to have easy access to the circuit. We also need to make sure that the box is thick enough that holes can be drilled in the box.

Content:

- We downloaded resources that allowed us to make the box.

- It did take us multiple attempts during the sketch process in order to make sure that both the box and lid components were done correctly.

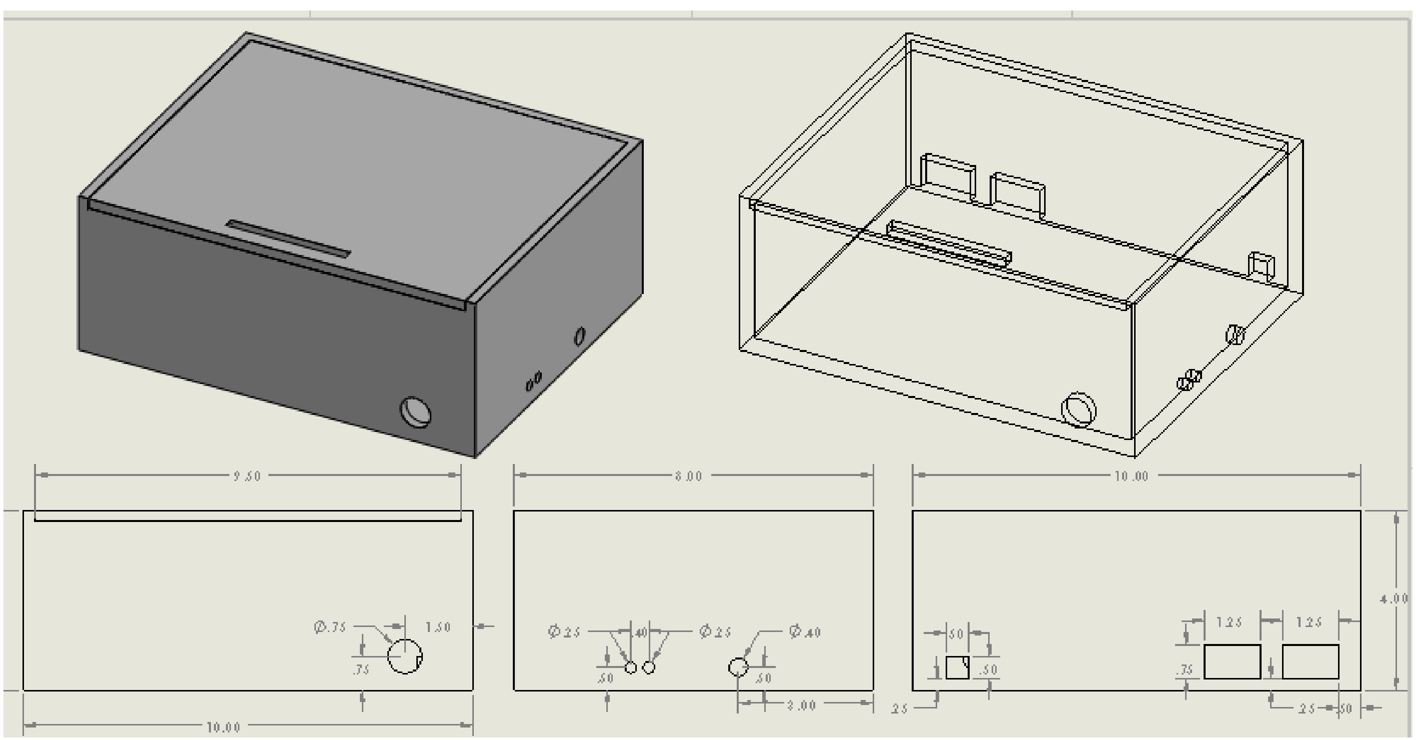
- We went to the Makerspace and were able to print with PLA

--- The box component took 20 hours to create and the lid component took 8 hours.

- Dimensions: 10 in length, 8 in width, 4 in height

- Thickness: 0.25 in

- Cost of the Box and Lid respectively: $52.16 + $12.08 = $64.24



Conclusions/action items: The box turned out well and was adequate in performing its necessary task. We found that it was even bigger than we needed to hold the circuit, which can be refined in future iterations of the design.

2023/12/13 Machining Holes into 3D Printed Box

Caelen Nickel - Dec 13, 2023, 7:45 PM CST

Title: Machining Holes into 3D Printed Box

Date: 12/13/2023

Content by: Charles Maysack-Landry

Goals: Drill holes into the 3D printed box to allow wires to pass in and out.

Content:

Used a hand drill with a 1 inch Forster bit to drill two holes, one in the front for the heating element and one in the back for the wall plugs. These holes were sanded down with an orbital sander.

A 3/8ths inch drill bit was used to drill three holes. One of the holes was for the thermistors and the other two were used to create a rectangular hole to connect the heating element to the wall power. The holes were the opposite corners over the diagonal of the rectangle and a coping saw was used to carve out the rectangle. The orbital sander was also used to sand down the holes.

Conclusions/action items:

PLA is a challenge to machine as it melts with any friction. However, the holes allowed for the circuit to function and connections with the outside to be made.

2023/11/23 - Determination of Ordering of Testing Protocols

BRYAN HEATON - Nov 23, 2023, 6:07 PM CST

Title: Determination of Ordering of Testing Protocols

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Determine which testing protocols are dependent on certain aspects of our device being functional
2. Order the testing protocols accordingly so as to have valid testing for all aspects of device

Content:

I have determined that this order should work so as to ensure each necessary part is functional for each test:

1. **Validating Arduino Program for the Collection of Temperature Data**
2. **Ensuring the Functionality of the Thermistors**
3. **Ensuring Sufficient Sensitivity in the Implemented Thermistors**
4. **Ensuring Sufficient Sensitivity in Thermistors via Acetone Catalyzed Lipid Breakdown**
5. **Validating Arduino Program for the Control of the Heating Element**
6. **Determining Significant Difference in the Measurement of Thermodynamic Data**

Conclusions/action items:

This order of tests should work for making sure each necessary part is functional for each test.

2023/11/23 - 1) Validating Arduino Program for the Collection of Temperature Data

BRYAN HEATON - Nov 23, 2023, 6:10 PM CST

Title: Validating Arduino Program for the Collection of Temperature Data

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Test for correct thermistor data interpretation and output.

Content: The protocol is below. Alternatively, the document containing the protocol can be found here.

Validating Arduino Program for the Collection of Temperature Data

This test is important to ensure that the data collected by the thermistors is correctly interpreted and turned into an output of temperatures. This test involves checking the arduino program for the correct transformation of thermistor data into temperature data while cross checking with the heat gun.

For this test,

1. Collect the heat gun and assembled device.
2. Ensure that the heating element is at room temperature with nothing on it.
3. Place the heat gun so that it is directed at the surface of the heating element.
4. Begin heating the heating element.
5. Simultaneously monitor the temperature measured by the heat gun and the thermistor in the heating element.
6. Turn off the heating element once the heating element has reached 34° Celsius.
7. If the thermistor has been verified to be functional, you can conclude the functionality of the arduino program for the collection of temperature data with the following:
    a. If the temperature measurements from the heat gun align with that of the arduino program temperature output, the arduino program is functional in collecting temperature data.
    b. If the temperature measurements from the heat gun do not align with that of the arduino program temperature output, the arduino program is not functional in collecting temperature data.

Conclusions/action items:

This testing protocol should be sufficient in testing the arduino for the correct interpretation of the thermistor data.

2023/11/23 - 2) Ensuring the Functionality of the Thermistors

BRYAN HEATON - Nov 23, 2023, 6:14 PM CST

Title: Ensuring the Functionality of the Thermistors

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Test for functionality and accuracy of the thermistors.

Content: The protocol is below. Alternatively, the document containing the protocol can be found here.

Ensuring the Functionality of the Thermistors

Making sure that the thermistors located in the assembled device are functional is paramount to accurate thermodynamic data collection.

For this test,

1. Obtain a heating element identical to the one used in the assembled device.
2. Ensure that the arduino program for the transformation of the thermistor data into temperature is functional.
3. Obtain the heating gun to use as a valid source of thermodynamic data collection.
4. Ensure that the heating element is at room temperature with nothing on its surface.
5. Handle the heat gun so as to record the surface temperature of the heating element.
6. Begin heating the heating element.
7. Begin recording the temperature of the heating element with the heat gun.
8. Simultaneously monitor the thermodynamic data output from the arduino gathered by the thermistor.
9. Ensure that the measurements from the heat gun and the thermistor are equivalent throughout the whole heating process.
10. Once the heating element has reached 34° Celsius, stop data collection and turn off the heating element.
    a. If the temperature readings from the heat gun and thermistor are equivalent throughout the heating process, the thermistor is functional.
    b. If the temperature readings from the heat gun and thermistor are not equivalent throughout the heating process, the thermistor is not functional.

Conclusions/action items:

This testing protocol should be sufficient in testing the functionality of the thermistors.

2023/11/23 - 3) Ensuring Sufficient Sensitivity in the Implemented Thermistors

BRYAN HEATON - Nov 23, 2023, 6:17 PM CST

Title: Ensuring Sufficient Sensitivity in the Implemented Thermistors

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Test for increments of measurement of temperature at a minimum sensitivity of 0.1° Celsius.

Content: The protocol is below. Alternatively, the document containing the protocol can be found here.

Ensuring Sufficient Sensitivity in the Implemented Thermistors

This test involves ensuring that the implemented thermistors on both the heating element and the heat measurement plate are sufficiently sensitive for the collection of thermodynamic data. The test will be repeated for each of the implemented thermistors.

For the test,

1. Ensure that the device is assembled correctly. You may want to complete the tests ensuring the functionality of the heating element and heat measuring plate before this test.
2. Begin with the thermistor on the heating element.
3. For this thermistor, locate the output from which you can see the recorded temperature.
4. Ensure that the heating element is at room temperature.
5. While observing the output for the recorded temperature from the thermistor on the heating element, begin heating the heating element to 34° Celsius.
6. Ensure that the thermistor includes readings to the tenth of a degree Celsius or smaller.
    a. If the temperature readings are in increments of 0.1° Celsius or smaller, the thermistor is sufficiently sensitive in its readings of thermodynamic data.
    b. If the temperature readings are in increments larger than 0.1° Celsius, the thermistor is **not** sufficiently sensitive in its readings of thermodynamic data.
7. Repeat this process with the thermistor located on the heat measurement plate.
    a. For the purposes of this test, there does not need to be a sample in the device.

Conclusions/action items:

This testing protocol should be sufficient in ensuring a minimum measuring increment of 0.1° Celsius.

2023/11/23 - 4) Ensuring Sufficient Sensitivity in Thermistors via Acetone Catalyzed Lipid Breakdown

BRYAN HEATON - Nov 23, 2023, 6:26 PM CST

Title: Ensuring Sufficient Sensitivity in Thermistors via Acetone Catalyzed Lipid Breakdown

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Create a test for ensuring the thermistors can monitor small changes in insulation

Content: The protocol is below. Alternatively, the document containing the protocol can be found here.

Ensuring Sufficient Sensitivity in Thermistors via Acetone Catalyzed Lipid Breakdown

In addition to ensuring that the thermistors can record temperature changes of a tenth of a degree Celsius or smaller, ensuring that the thermistors can detect these small changes is equally important. By breaking down the lipids of the skin sample, a decrease in the insulative properties of the sample is observed. The thermistors in the assembled device should be sensitive enough to detect this change.

For this test,

1. Gather the assembled device, a sample of ex vivo rodent skin, and an acetone wipe.
2. Locate the temperature output from the thermistors.
3. Ensure the heating element on the assembled device is at room temperature.
4. Place the sample of skin on the heating element, such that the dorsal side is face up.
5. Record the initial temperature of the dorsal side of the skin from the heat measurement plate.
6. Begin heating the skin until the heating element reaches 34° Celsius.
7. Record the change in temperature from the final temperature measured by the heat measurement plate and the initial temperature recorded previously.
8. Remove the sample from the heating element. Let the skin and the heating element cool to room temperature.
9. Retrieve the acetone wipe.
10. Wipe the dorsal surface of the sample of rodent skin. Do ***one pass*** with the acetone wipe.
11. Repeat steps 2-8 with the wiped sample. Ensure that you have recorded the change in temperature of this sample.
12. Again, wipe the dorsal surface of the sample of rodent skin. Only do ***one more pass*** with the acetone wipe.
13. Repeat steps 2-8 with this doubly wiped sample. Ensure that you have recorded the change in temperature of this sample.
14. Ensure that the temperatures measured with 0, 1, and 2 passes of the acetone wipe are significantly different from one another.
    a. If the measurements are significantly different, the thermistors are sufficiently sensitive.
    b. If the measurements are not significantly different, the thermistors are NOT sufficiently sensitive.

Conclusions/action items:

This test should be sufficient in ensuring the thermistors are capable of monitoring small changes in skin insulation.

2023/11/23 - 5) Validating Arduino Program for the Control of the Heating Element

BRYAN HEATON - Nov 23, 2023, 6:27 PM CST

Title: Validating Arduino Program for the Control of the Heating Element

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Create a test for validation of the arduino program in controlling the heating element upon reaching a desired temperature in the heating element.

Content: The protocol is below. Alternatively, the document containing the protocol can be found here.

Validating Arduino Program for the Control of the Heating Element

This test is important for the pulsing behavior of the assembled device. It will test the ability of the arduino program to monitor and control the heating element.

For this test,

1. Gather the assembled device and ensure it is connected to the arduino program.
2. Ensure that the heating element is at room temperature with nothing on it.
3. Set the arduino program to turn off the heating element upon reaching a temperature of 34° Celsius.
4. Obtain a heating gun as a valid source of thermodynamic data collection.
5. Place the heating gun so as to point at the surface of the heating element.
6. Set the arduino program to turn on the heating element.
7. Monitor the heating gun until the surface temperature of the heating element reaches 34° Celsius.
8. If the heating element turns off upon reaching 34° Celsius as monitored by the heat gun, the arduino program is functional for the control of the heating element.

Conclusions/action items:

This test should be sufficient in validating the arduino program for controlling the heating element upon reaching a desired temperature.

2023/12/4 - 6) Determining Significant Difference of Thermodynamic Data

BRYAN HEATON - Dec 04, 2023, 2:46 PM CST

Title: Determining Significant Difference of Thermodynamic Data

Date: 12/4/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Create a test to statistically determine the ignorance of evaporative cooling in our design
2. Explain the validity of the t-test in this case

Content:

Determining Significant Difference in the Measurement of Thermodynamic Data

The first part of this test involves gathering thermodynamic data for human skin. To achieve this, use both of the different methods of recording the dorsal surface's change in temperature upon heating. To increase the quality of the hypothesis test, we will collect a large quantity of samples for each method of thermodynamic data collection.

For the procedural test,

1. Obtain a heating element capable of producing heat pulses of 34° Celsius.
2. Upon completion of setting up the heating plate and ensuring it is functioning properly, begin measuring the temperature of your hand with the heat gun before any external heating has been applied. Record this initial value. *
3. Place your hand on the heating element, ensuring the element is still turned off.
4. Upon placing your hand on the heating element, begin heating the element to 34° Celsius.
5. Once your hand has been heating for ten seconds, record the temperature of the heated side of your hand using the heat gun. Record this value. *
6. Subtract the final temperature observed from the initial temperature. Record this value. *
7. Repeat steps 4 through 9 many times, ensuring a large sample size of data collected.
8. After heating each sample and recording temperatures using the heat gun, repeat steps 4 through 10. The only difference in this iteration is that recording the temperatures of the skin will be with the assembled device.
9. Ensure that the change in temperature values are noticeably different from zero before analyzing the data. If they are close to zero or no heat was perceived in the testing process, something may be nonfunctional in the device or the heat gun.

	Trial #1	Trial #2	Trial #3	Trial #4
Initial Temp.				
Final Temp.				
Change in Temp.				

**sample table provided for the procedural test detailed above*

To determine whether or not our device is sufficient in the avoidance of measuring the temperature altering effects of evaporative cooling, run a two-sample hypothesis test for the difference in means between skin measured with the heat gun versus skin measured with the assembled device. Use a t-test in this protocol. This is a great option as normality of the sample data can be assumed with relatively large sample sizes (>30).

The hypothesis test will be run with the following hypotheses:

$$H_0: \mu_{gun} - \mu_{assembled} = 0$$

$$H_A: \mu_{gun} - \mu_{assembled} \neq 0$$

The samples of rodent skin come from a random sample of a much larger population of skin samples. For this hypothesis test, Use an value of 0.05.

For the hypothesis test,

1. If not installed already, ensure that R and RStudio are installed on your computer. These are necessary tools for running hypothesis tests.
2. Provided here is a code skeleton for this testing case.
3. Once copied into RStudio, find the second chunk (bits of code denoted by the triple apostrophe and curly brackets).
4. The numbers entered into the code are sample values and are meant to be changed. Interpretation of the variable names should be done as follows:
    a. **heat_gun_mean**: the mean final temperature of the heat gun measurements
    b. **Assembled_device_mean**: the mean final temperature of the assembled device's measurements
    c. **heat_gun_sd**: the standard deviation of the final temperature measurements gathered from the heat gun.
    d. **assembled_device_sd**: The standard deviation of the final temperature measurements from the assembled device.
    e. **n_heat_gun**: the number of trials done for thermodynamic data collection with the heat gun
    f. **n_assembled_device**: the number of trials done for thermodynamic data collection with the assembled device.
5. Once the data has been entered into this chunk, run the chunk by pressing the green check mark in the top right corner of the area denoted as described previously.
6. After running this chunk, the t-test has been run. The decimal value outputted into the terminal is the p-value for the experiment.

Interpretation of the p-value:

If the p-value is greater than the value, we fail to reject the null hypothesis that the mean measurements of changes in temperature of the dorsal side of rodent skin samples is not different when measured with a heat gun versus the assembled device.

If the p-value is less than the value, we reject the null hypothesis that the mean measurements of changes in temperature of the dorsal side of rodent skin samples is not different when measured with a heat gun versus the assembled device.

Conclusions/action items:

This test should be sufficient in determining significant difference of our thermodynamic data collection.

2023/12/1 Client Device Testing

Caelen Nickel - Dec 03, 2023, 4:39 PM CST

Title: 2023/12/1 Client Device Testing

Date: 12/1/2023

Content by: Caelen Nickel

Present: Caelen Nickel, Charles Maysack-Landry

Goals: Collect data for in the testing, results, and conclusions sections of the final presentation and final report, as well as perform necessary device verifications for proper functioning compared to the PDS

Content:

- Caelen and Charles went to the McCardle lab in the UW-Madison Carbone Cancer Center in the WIMR building in order to meet with the client in her lab space.

- The assembled device was turned on and used. The heating element pulsing and temperature was observed, as well as the thermistor temperature sensor.

  - The intended operation of the heating element was not fully known as the client requirements for this component were not given. The client was unsure how the relationships she was exploring would translate to what's required of the heating element. Temperature was provided (34 degrees C) and a pulsing nature was stated, but no specifics regarding this aspect of the heating element were given.

  - As a result, we explored this functioning with the client to identify how best to code the heating element operation. Amendments were made to the Arduino code as can be seen in the project files folder and Arduino code entry to alter the pulsation timing and temperature control.

- The accuracy of the thermistors and corresponding circuits was then measured by using a piece of lab equipment which has a heating surface and can be set to a specific, accurate (presumably) temperature. The thermistors were compared to this temperature, as well as each other.

  - As a result, it was observed that there are component errors caused by the +/- 5% tolerance values of the resistors. In order to refine calculations, resistor resistance must be measured rather than using the design specifications. Also, the resolution of the Arduino microcontroller provided some issues in data, and this can be corrected by increasing input voltage in order to cause greater voltage discrepancies between different temperatures.

- We also talked to the client about ideas for future work and project continuation.

Conclusions/action items:

As a result of this testing, necessary conclusions can be made about the project. First, it was determined how the heating element code should be written in order to cause intended functioning per the client. The adjustments have been implemented and tested, however it was determined that a heating element of higher quality would give a better result, and if the project continues budget will be given to purchase one. As mentioned, circuit calculations must be redone. In order to refine calculations and yield better accuracy, resistor resistance must be measured rather than using the design specifications. Resistor values must also be altered to give a higher input voltage, yielding greater resolution. These changes should be made in the device before more testing.

2023/12/3 Tegaderm Testing

Caelen Nickel - Dec 03, 2023, 5:06 PM CST

Title: 2023/12/3 Tegaderm Testing

Date: 12/3/2023

Content by: Caelen Nickel

Present: Caelen Nickel

Goals: Collect data for in the testing, results, and conclusions sections of the final presentation and final report, specifically how Tegaderm layers influence dorsal temperature measurement, providing a device verification along the way.

Content:

- Using Tegaderm from the client and from previous wound care, testing was done measuring the dorsal temperature after heating the Tegaderm. The heating element was turned on heating the bottom of the Tegaderm and allowing its insulative properties that resemble skin to yield a different dorsal temperature.

- 10 seconds of data collection were done with a control group (no Tegaderm), then 1, 2, 4, 8 Tegaderm layers. The Arduino serial monitor data was exported to MATLAB, where the data was processed and trimmed to 10 seconds.

- Using MATLAB, statistical measures were calculated and a bar graph was made comparing the average temperature of the dorsal side of the Tegaderm over the different layer tests.

Conclusions/action items:

The Tegaderm testing shows that there is ample sensitivity in the thermistor circuit to differentiate between Tegaderm layers, and the expected result was achieved, with more Tegaderm layers yielding a lower dorsal temperature due to insulation. This data and its corresponding graph will be instrumental in the poster presentation and final report, as well as verifying the device is sensitive. Additional sensitivity testing must be done (see testing protocol 4).

Caelen Nickel - Dec 03, 2023, 5:11 PM CST

```
time = linspace(0, 10, 1000);

% Display the values
% disp(dataset(1:1000));
% figure(1)
% plot(time, therm_control);
% figure(2)
% plot(time, therm_teg1);
% figure(3)
% plot(time, therm_teg2);
% figure(4)
% plot(time, therm_teg4);
% figure(5)
% plot(time, therm_teg8);

% Teg test data visualization
tests = {'0', '1', '2', '4', '8'};
means = [35.56, 35.32, 35.17, 34.46, 33.52];
stdDev = [0.2386, 0.3150, 0.3302, 0.2884, 0.3287];

barColors = ['r', 'g', 'c', 'b', 'm'];

figure;
hold on;
for i = 1:numel(tests)
    bar(i, means(i), 'FaceColor', barColors(i));
end
errorbar(1:numel(tests), means, stdDev, '.', 'Color', 'k', 'LineWidth', 1.0);
```

```
hold off;


title('Dorsal Temperature for Differing Layers of Tegaderm', 'FontSize', 18);

ylim([30,38]);

xticklabels('');

xlabel('Tegaderm Layer Tests', 'FontSize', 18);

ylabel('Temperature (Celcius)', 'FontSize', 18);

legend('show');
```

2023/12/12 Heating Element Verification Results

Caelen Nickel - Dec 13, 2023, 7:42 PM CST

Title: 2023/12/12 Heating Element Verification Results

Date: 12/1/2023

Content by: Caelen Nickel

Present: Caelen Nickel, Charles Maysack-Landry

Goals: Using the data collected during the client device testing from the heating element, perform statistical calculations and conclusions on the functioning of the heating element.

Content:.

- The functioning of the heating element was explored with the client to identify how best to code the heating element operation.

- The accuracy of the thermistors and corresponding circuits was then measured by using a piece of lab equipment which has a heating surface and can be set to a specific, accurate (presumably) temperature. The thermistors were compared to this temperature, as well as each other. Then, simulated use of the device was performed without a sample. The ventral thermistor was placed on the heating element while it ran. As proper running occurred, the Arduino modulated the heating element, turning it off and on to maintain temperature target. Data from the ventral thermistor is below.

- From this data, visual observations were made:

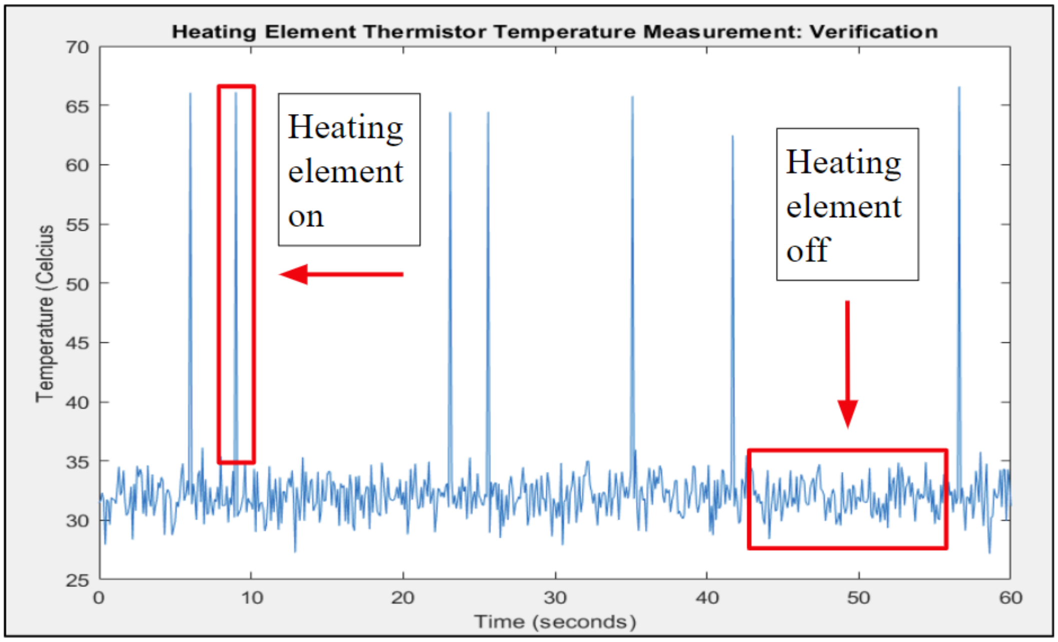
There were periods of the heating element being active (powered) and inactive (see attachment below). The spikes in temperature show the heating element in the active state. The periods in activity and inactivity show proper functioning of the ventral thermistor circuit, relay, and wall power DC adapter,

The temperature spikes during the active state of the heating element are large in amplitude but small in period.. The heating element heats up rapidly and to high temperatures above what is necessary.

Conclusions/action items:

As a result of this testing and its analysis, necessary conclusions can be made about the project. It was determined that the Arduino modulates the heating element as intended. However, the heating element heats too rapidly and to an overly hot temperature. As a result, damage to the sample can be done, and this creates a risk in both testing and to the researcher. As a result, future work should include a new, higher quality heating element.

Caelen Nickel - Dec 13, 2023, 7:43 PM CST



2023/12/12 Tegaderm Testing Results

Caelen Nickel - Dec 13, 2023, 8:21 PM CST

Title: 2023/12/12 Tegaderm Testing Results

Date: 12/12/2023

Content by: Caelen Nickel

Present: Caelen Nickel

Goals: Analyze data for the results and conclusions sections of the final presentation and final report, specifically how Tegaderm layers influence dorsal temperature measurement, providing a device verification along the way. Perform statistical analysis.

Content:

- Using Tegaderm from the client and from previous wound care, testing was done measuring the dorsal temperature after heating the Tegaderm. The heating element was turned on heating the bottom of the Tegaderm and allowing its insulative properties that resemble skin to yield a different dorsal temperature.

- 10 seconds of data collection were done with a control group (no Tegaderm), then 1, 2, 4, 8 Tegaderm layers. The Arduino serial monitor data was exported to MATLAB, where the data was processed and trimmed to 10 seconds.

- Using MATLAB, statistical measures were calculated and a bar graph was made comparing the average temperature of the dorsal side of the Tegaderm over the different layer tests.

- A multiple comparison test was performed using the anova() function in MATLAB. The data files from testing were transferred from Arduino serial monitor to MATLAB and processed as arrays. Then, these arrays for each experimental group were analyzed using ANOVA and the code attached below.

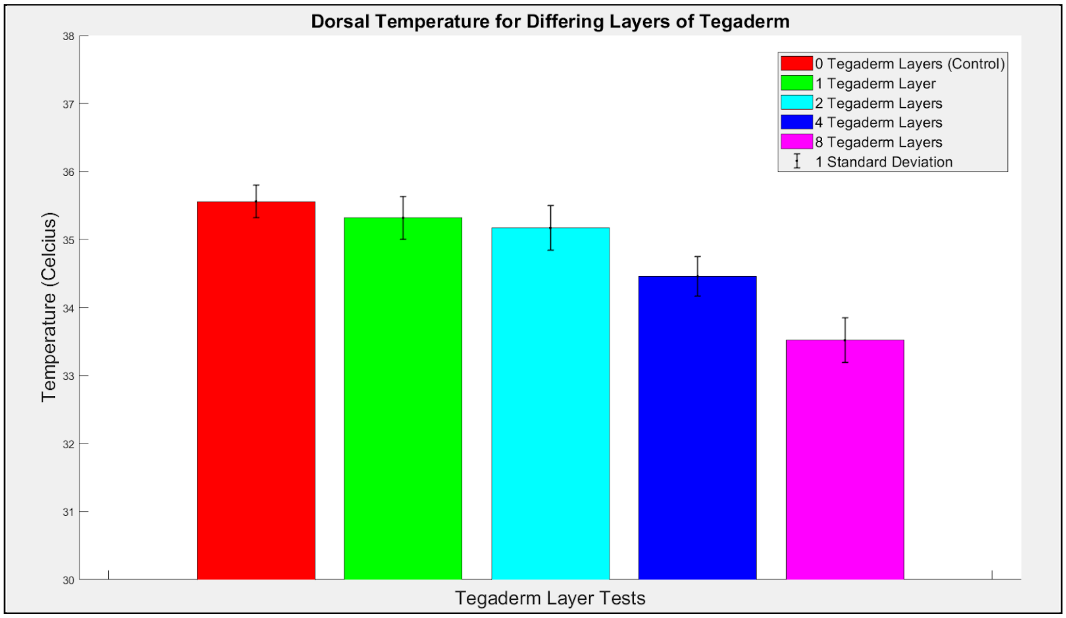
- The results of the data were visualized via a bar graph comparing each experimental group on the basis of temperature.

- The final ANOVA table was generated by MATLAB and referenced in the final report and presentation.

Conclusions/action items:

The Tegaderm testing shows that there is ample sensitivity in the thermistor circuit to differentiate between Tegaderm layers, and the expected result was achieved, with more Tegaderm layers yielding a lower dorsal temperature due to insulation. This data and its corresponding graph will be instrumental in the poster presentation and final report, as well as verifying the device is sensitive. Additional sensitivity testing must be done (see testing protocol 4). Since the p-value was calculated to be below the corrected alpha value of 0.01, the null hypothesis that at least two of the experimental groups are not significantly different is rejected.

Caelen Nickel - Dec 13, 2023, 7:51 PM CST



Caelen Nickel - Dec 13, 2023, 8:04 PM CST

```
% Perform a multiple comparison test
group ={'Control', '1 Tegaderm Layer', '2 Tegaderm Layers', '4 Tegaderm Layers', '8 Tegaderm Layers'};
data = [therm_control, therm_teg1, therm_teg2, therm_teg4, therm_teg8];
% Example data
group = {'GroupA', 'GroupB', 'GroupC', 'GroupD', 'GroupE'};
% Perform one-way ANOVA
[p, tbl, stats] = anova1(data, group, 'off');
% Display results
disp('ANOVA p-value:');
disp(p);
disp('ANOVA table:');
disp(tbl);
```

ANOVA p-value:

0.00001

ANOVA table:

```
{'Source' }    {'SS'        }    {'df'  }    {'MS'      }    {'F'         }    {'Prob>F'  }
{'Columns'}    {[2.7040e+03]}    {[   4]}    {[676.0017]}    {[7.6460e+03]}    {[       0]}
{'Error'  }    {[  441.6204]}    {[4995]}    {[  0.0884]}    {0×0 double  }    {0×0 double}
{'Total'  }    {[3.1456e+03]}    {[4999]}    {0×0 double}    {0×0 double  }    {0×0 double}
```

2023/12/13 Skin Temperature Testing and Results

Caelen Nickel - Dec 13, 2023, 8:18 PM CST

Title: 2023/12/13 Skin Temperature Testing and Results

Date: 12/13/2023

Content by: Caelen Nickel and Bryan Heaton

Present: Caelen Nickel

Goals: Outline and perform testing to determine if the device likely ignores the effects of evaporative cooling.

Content:

Determining Significant Difference in the Measurement of Thermodynamic Data

Materials:

1. Infrared gun
2. Assembled device
3. Hand or other exposed skin
4. Computer (for running Arduino IDE, thermistor data interpretation, and statistical analysis)

Procedure:

1. Upon completion of setting up the full thermistor circuit and ensuring it is functioning properly, begin measuring the temperature of the surface of your hand with the infrared thermometer and thermistor simultaneously.
2. Collect data for 10 seconds, taking a video of the digital display of the infrared thermometer in order to collect its data.
3. Export the Arduino serial monitor into MATLAB and enter the data points from the infrared thermometer into an array in MATLAB

To determine whether or not our device is sufficient in the avoidance of measuring the temperature altering effects of evaporative cooling, run a two-sample hypothesis test for the difference in means between skin measured with the heat gun versus skin measured with the assembled device. Use a one sided student t-test in this protocol. This is a great option as normality of the sample data can be assumed with relatively large sample sizes (>30).

The hypothesis test will be run with the following hypotheses:

$H0$: μ*infrared* - μ*thermistor* = 0

HA: μ*infrared* - μ*thermistor* ≠ 0

The samples of rodent skin come from a random sample of a much larger population of skin samples. For this hypothesis test, Use an alpha value of 0.05.

Conclusions/action items:

As a result of the one sided student t-test, a p-value of 1.24E-7 was calculated. This value is much lower than the alpha value of 0.05, thus indicating that the null hypothesis is rejected. meaning that the thermistor sensor mean is significantly greater than that of the infrared thermometer. As a result, the null hypothesis that there was no difference in the means between each of the 2 groups was rejected, and the alternative hypothesis that the device is sufficient in ignoring the effects of evaporative cooling was accepted. This information was vital for discussion and conclusions in the final report and presentation.

Caelen Nickel - Dec 13, 2023, 8:19 PM CST

	Mean (℃)	**Standard Deviation (℃)**
Thermistor	34.91	0.3520
Infrared	33.2	0.2938

2023/09/24 LTSpice Thermistor Circuit File

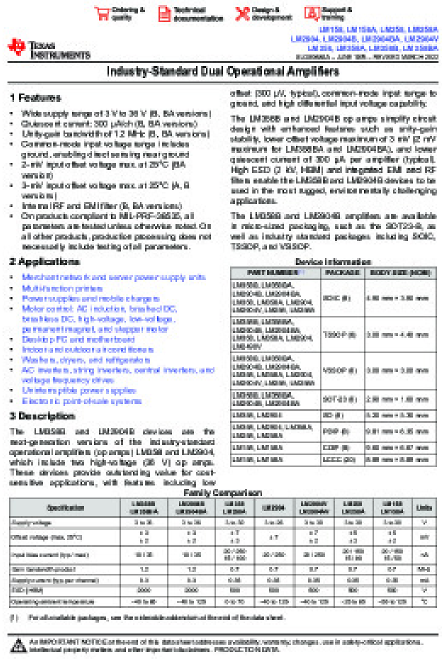
Caelen Nickel - Sep 24, 2023, 7:36 PM CDT

Download

BME_300_Temp.asc (880 B)

2023/11/09 Operational Amplifier Datasheet

Caelen Nickel - Nov 09, 2023, 10:58 PM CST


Industry-Standard Dual Operational Amplifiers

1 Features

2 Applications

3 Description

Device Information

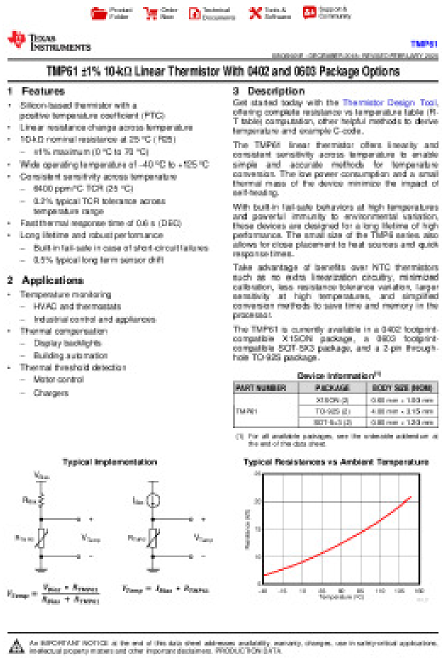
Family Comparison

Download

lm358_Op-Amp.pdf (4.1 MB)

2023/11/09 Thermistor Datasheet

Caelen Nickel - Nov 09, 2023, 10:59 PM CST



Texas Instruments — TMP61

TMP61 ±1% 10-kΩ Linear Thermistor With 0402 and 0603 Package Options

1 Features

- Silicon-based thermistor with a positive temperature coefficient (PTC)
- Linear resistance change across temperature
- 10-kΩ nominal resistance at 25 °C (R25)
  - ±1% maximum (0 °C to 70 °C)
- Wide operating temperature of –40 °C to +125 °C
- Consistent sensitivity across temperature
  - 6400 ppm/°C TCR (25 °C)
  - 0.2% typical TCR tolerance across temperature range
- Fast thermal response time of 0.6 s (DEC)
- Long lifetime and robust performance
  - Built-in fail-safe in case of short-circuit failures
  - 0.5% typical long term sensor drift

2 Applications

- Temperature monitoring
  - HVAC and thermostats
  - Industrial control and appliances
- Thermal compensation
  - Display backlights
  - Building automation
- Thermal threshold detection
  - Motor control
  - Chargers

3 Description

Get started today with the Thermistor Design Tool, offering complete resistance vs temperature table (R-T table) computation, other helpful methods to derive temperature and example C-code.

The TMP61 linear thermistor offers linearity and consistent sensitivity across temperature to enable simple and accurate methods for temperature conversion. The low power consumption and a small thermal mass of the device minimize the impact of self-heating.

With built-in fail-safe behaviors at high temperatures and powerful immunity to environmental variation, these devices are designed for a long lifetime of high performance. The small size of the TMP6 series also allows for close placement to heat sources and quick response times.

Take advantage of benefits over NTC thermistors such as no extra linearization circuitry, minimized calibration, less resistance tolerance variation, larger sensitivity at high temperatures, and simplified conversion methods to save time and memory in the processor.

The TMP61 is currently available in a 0402 footprint-compatible X1SON package, a 0603 footprint-compatible SOT-5X3 package, and a 2-pin through-hole TO-92S package.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TMP61	X1SON (2)	0.60 mm × 1.00 mm
	TO-92S (2)	4.00 mm × 3.15 mm
	SOT-5X3 (2)	0.80 mm × 1.20 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Implementation

Typical Resistances vs Ambient Temperature

Download

tmp61_Thermistor.pdf (1.28 MB)

2023/11/30 Arduino Code

Caelen Nickel - Dec 01, 2023, 12:58 AM CST

```
int rpin = 2;

int bpin = 11;


float slope = 400.99;

float yint = -107.906;


void setup() {

  // put your setup code here, to run once:

Serial.begin(9600);

pinMode(rpin, INPUT);

pinMode(bpin, OUTPUT);

}


void loop() {

  // put your main code here, to run repeatedly:

int sensorValue = analogRead(A0);

int heatValue = analogRead(A1);


float voltageValue0 = sensorValue * (5.0 / 1023.0);

float temp_reading = (slope * (voltageValue0)) + yint;

float voltageValue1 = heatValue * (5.0 / 1023.0);

float heat_temp = (slope * (voltageValue1)) + yint;


//Serial.println(voltageValue1);

Serial.println(temp_reading);

delay(1);


int rOutput = digitalRead(rpin);
```

```
 if (rOutput = 1) {

   //Serial.println("on");

   //float heat_temp = 22.0;

   if (heat_temp < 34.0) {

     digitalWrite(bpin, HIGH);

   } else {

     digitalWrite(bpin, LOW);

   }

  } else {}

   //Serial.println("off");

   digitalWrite(bpin, LOW);

 }
```

Caelen Nickel - Dec 03, 2023, 3:18 PM CST

Edited:

```
int rpin = 2;

int bpin = 11;


float slope = 487.0;

float yint = -149.0;


void setup() {

  // put your setup code here, to run once:

Serial.begin(9600);

pinMode(rpin, INPUT);

pinMode(bpin, OUTPUT);

}


void loop() {

  // put your main code here, to run repeatedly:

int sensorValue = analogRead(A1);

int heatValue = analogRead(A5);


float voltageValue1 = sensorValue * (5.0 / 1023.0);

float temp_reading = (slope * (voltageValue1)) + yint;

float voltageValue5 = heatValue * (5.0 / 1023.0);

float heat_temp = (slope * (voltageValue5)) + yint;


//Serial.println(heatValue);

//Serial.println(voltageValue0);

Serial.print("temp_reading");

Serial.println(temp_reading);
```

```
Serial.print("heat_temp");

Serial.println(heat_temp);

delay(1000);


int rOutput = digitalRead(rpin);

//Serial.println("on");

//float heat_temp = 22.0;

if (heat_temp > 34.0) {

  digitalWrite(bpin, LOW);

    }

if (heat_temp < 30.0) {

  digitalWrite(bpin, HIGH);

    }

}
```

2023/12/13 MATLAB Code

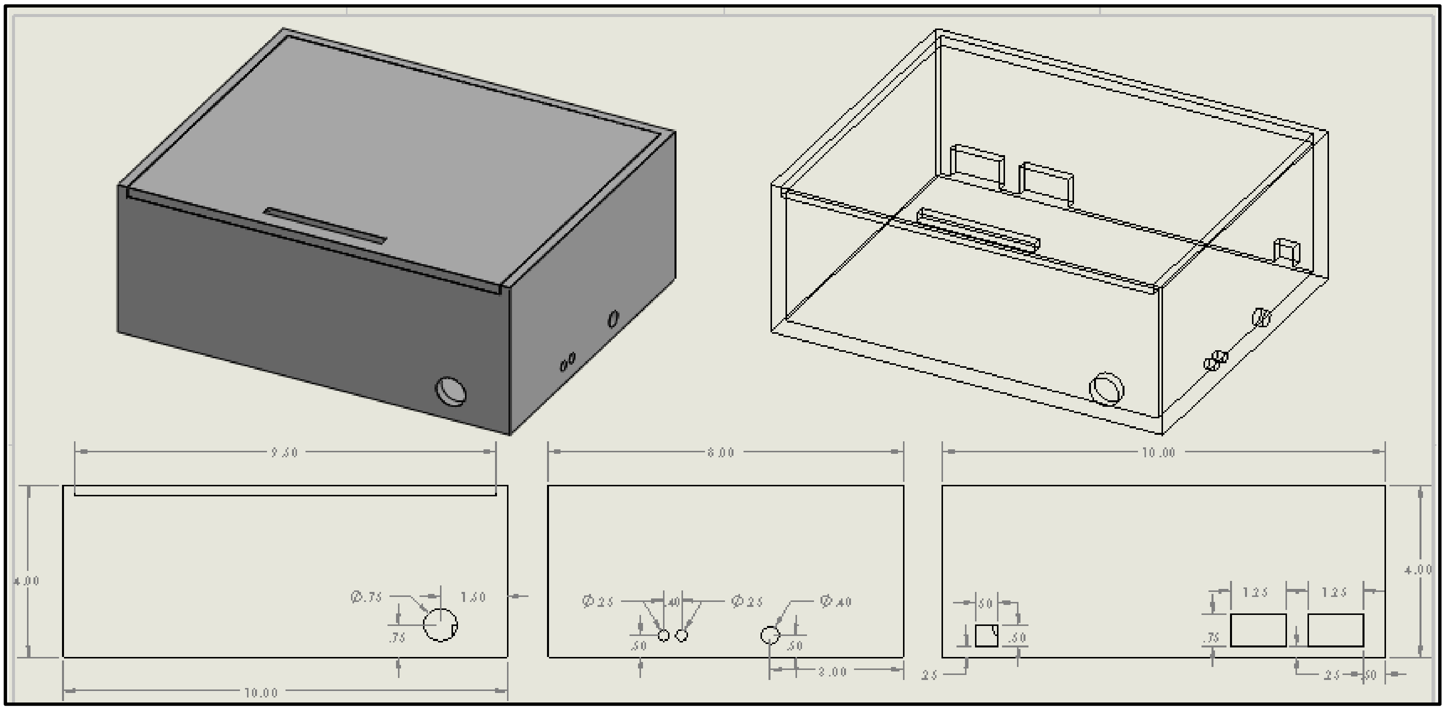
Caelen Nickel - Dec 13, 2023, 8:23 PM CST

```
% Perform a one-sided t-test (less than)
[h_less, p_less, ci_less, stats_less] = ttest2(group1, group2, 'Tail', 'left');
% Display results for less than alternative
fprintf('One-sided t-test (less than) result:\n');
fprintf('   t-statistic: %.4f\n', stats_less.tstat);
fprintf('   p-value: %.4f\n', p_less);
fprintf('   Confidence interval: [%.4f, %.4f]\n', ci_less(1), ci_less(2));
% Determine if the null hypothesis can be rejected
if h_less
   fprintf('The null hypothesis (mu1 <= mu2) can be rejected at the 5%% significance level.\n');
else
   fprintf('The null hypothesis (mu1 <= mu2) cannot be rejected at the 5%% significance level.\n');
end
% Perform a one-sided t-test (greater than)
[h_greater, p_greater, ci_greater, stats_greater] = ttest2(group1, group2, 'Tail', 'right');
% Display results for greater than alternative
fprintf('\nOne-sided t-test (greater than) result:\n');
fprintf('   t-statistic: %.4f\n', stats_greater.tstat);
fprintf('   p-value: %.4f\n', p_greater);
fprintf('   Confidence interval: [%.4f, %.4f]\n', ci_greater(1), ci_greater(2));
% Determine if the null hypothesis can be rejected
if h_greater
   fprintf('The null hypothesis (mu1 >= mu2) can be rejected at the 5%% significance level.\n');
else
   fprintf('The null hypothesis (mu1 >= mu2) cannot be rejected at the 5%% significance level.\n');
end




% Perform a multiple comparison test
group ={'Control', '1 Tegaderm Layer', '2 Tegaderm Layers', '4 Tegaderm Layers', '8 Tegaderm Layers'};
data = [therm_control, therm_teg1, therm_teg2, therm_teg4, therm_teg8];
% Example data
group = {'GroupA', 'GroupB', 'GroupC', 'GroupD', 'GroupE'};
% Perform one-way ANOVA
[p, tbl, stats] = anova1(data, group, 'off');
% Display results
disp('ANOVA p-value:');
```

```
disp(p);
disp('ANOVA table:');
disp(tbl);
```

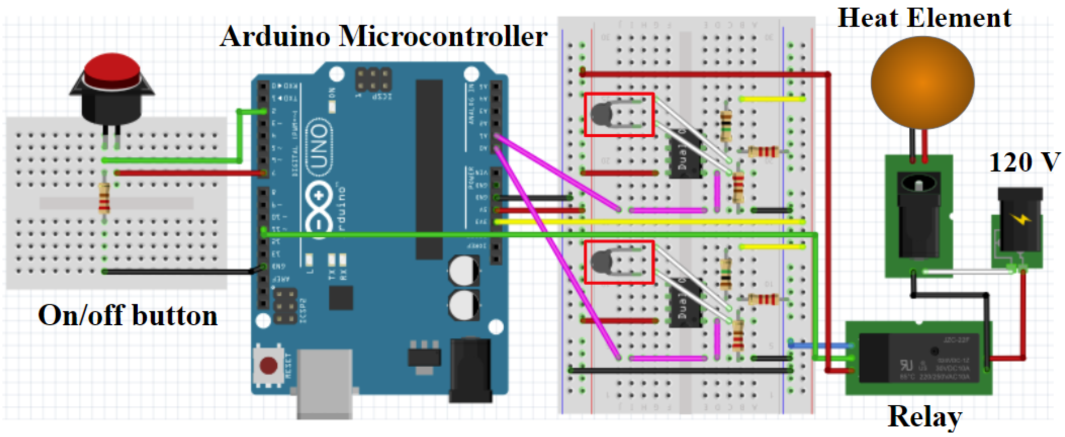
2023/12/13 SOLIDWORKS Drawing

Caelen Nickel - Dec 13, 2023, 8:24 PM CST



2023/12/13 Final Design Fritzing Diagram

Caelen Nickel - Dec 13, 2023, 8:25 PM CST



Product Design Specifications

Caelen Nickel - Sep 29, 2023, 3:30 PM CDT

THE UNIVERSITY of WISCONSIN MADISON

PRODUCT DESIGN SPECIFICATIONS: ANALYSIS OF INSULATING PROPERTIES OF SKIN (RODENT)

Date: 09/15/2023

BME 200/300

Client: Dr. Caroline M. Alexander

Team Members:

Team Leader: Caelen Nickel

Communicator: Charles Maysack-Landry

BWIG: Taylor Carlson

BWIG: Caden Binger

BSAC: Bryan Heaton

BPAG: Annika Syslack

Download

Product_Design_Specifications.pdf (341 kB)

Preliminary Design Matrix

Caelen Nickel - Sep 29, 2023, 3:29 PM CDT

Analysis of Insulating Properties of Skin (Rodent) Design Matrices

Heating Element Design Matrix

Table 1: Design Matrix for evaluation of heating element preliminary designs according to a set of five weighted criteria. Highlights indicate the highest score(s) of each section.

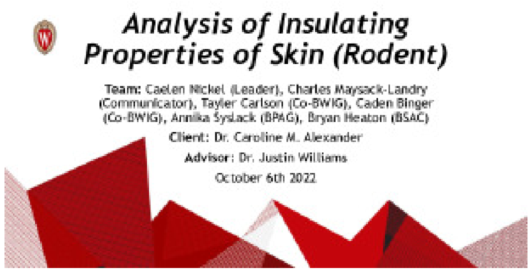
Design Categories (Weight)	Wall Power Heating Element 		Battery Power Heating Element 	
Safety (30)	2/5	12	4/5	24
Accuracy (25)	4/5	20	3/5	15
Ergonomics (20)	3/5	12	3/5	12
Cost (15)	4/5	12	1/5	3
Ease of Fabrication (10)	4/5	8	2/5	4
Total (100)	64		58	

Download

Design_Matrix_1_.pdf (1.45 MB)

Preliminary Design Presentation

Caelen Nickel - Oct 06, 2023, 12:29 PM CDT



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Preliminary_Presentation_2_.pdf (2.21 MB)

Preliminary Report

Caelen Nickel - Oct 11, 2023, 10:56 PM CDT

THE UNIVERSITY of WISCONSIN MADISON

ANALYSIS OF INSULATING PROPERTIES OF SKIN (RODENT)

BME 200/300

Client: Dr Caroline M. Alexander

Advisor: Dr. Justin Williams

Team Members:

Team Leader: Caelen Nickel

Communicator: Charles Maysack-Landry

BWIG: Taylor Carlson

BWIG: Caden Binger

BPAG: Annika Syslack

BSAC: Bryan Heaton

Date: 10/11/2023

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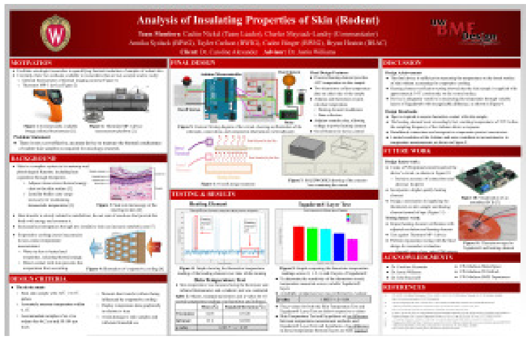
Preliminary_Report_1_.pdf (2.17 MB)

Final Poster Presentation

TAYLER CARLSON - Dec 13, 2023, 9:02 AM CST

TAYLER CARLSON - Dec 13, 2023, 9:01 AM CST



Download

Final_Poster_Presentation_copy.pdf (1.75 MB)

Final Report

TAYLER CARLSON - Dec 13, 2023, 9:22 AM CST

Caelen Nickel - Dec 13, 2023, 8:43 PM CST

ANALYSIS OF INSULATING PROPERTIES OF SKIN (RODENT)

BME 200/300

Client: Dr. Caroline M. Alexander

Advisor: Dr. Justin Williams

Team Members:

Team Leader: Caelen Nickel

Communicator: Charles Maynack-Landry

BWIG: Tayler Carlson

BWIG: Caden Binger

BPAG: Annika Syslack

BSAC: Bryan Heaton

Date: 10/11/2023

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Final_Report_2_.pdf (3.66 MB)

2023/12/06 Initial Final Deliverables Meeting

TAYLER CARLSON - Dec 13, 2023, 9:15 AM CST

Title: Inital Final Deliverables Meeting

Date: 12/6/2023

Content by: Tayler Carlson

Present: All group members able to attend

Goals: The goal was to discuss the presentation and assign parts while also going over the feedback given in order to make our poster even better

Content:

- Assigned Parts:

-- Tayler: Motivation

-- Caden: Background and Design Criteria

-- Bryan: Testing and Statistics

-- Charles: Final Design

-- Annika: Discussionn

-- Caelen: Future Work

- We also discussed the things that we needed to highlight on the poster in order to make the presentation engaging

--- reference to figures and diagrams---> make sure to use these as signposts throughout the presentation

Conclusions/action items: We are going to practice our parts and make a script for ourselves that we will be able to go over a couple of times the next day. People needed to practice their parts thoroughly in order to make sure that we could have a smooth practice before the symposium.

2023/12/07 Final Team Meeting Before Poster Session

TAYLER CARLSON - Dec 13, 2023, 9:22 AM CST

Title: Final Team Meeting Before Poster Session

Date: 12/07/2023

Content by: Tayler Carlson

Present: All group members

Goals: The goal was to run through the presentation a couple of times to ensure that everyone was well-versed in what they were going to say.

Content:

- The first time around, everyone was able to have their script in front of them

-- We finished in about 11 minutes and 20 seconds.

- The second time around we practiced without scripts in front of us.

--- This went a little slower and took about 11 minutes and 40 seconds.

- We decided that we would have at least one group member where a watch to alert the last person speaking that we were in the 11-12 minute range and they should begin to wrap up the presentation.

Conclusions/action items: The people who would be wearing watches would be Tayler and Annika to ensure that we had people checking the time on both sides so that people would know if they were on track for their speaking parts or not.

2023/09/19 Evaporative Cooling Research

Caelen Nickel - Sep 19, 2023, 5:03 PM CDT

Title: Evaporative Cooling Research

Date: 9/19/2023

Content by: Caelen Nickel

Goals: Gain an increased understanding of how evaporative cooling works and how to prevent it from being measured.

Link: https://baltimoreaircoil.com/evaporative-cooling#:~:text=Cooling%20through%20evaporation%20is%20a,a%20liquid%20to%20a%20vapor.

Reference:

[1 “What is Evaporative Cooling | Baltimore Aircoil.” https://baltimoreaircoil.com/evaporative-cooling (accessed Sep. 19, 2023).

Content:

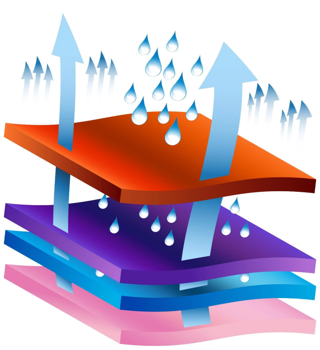
- Evaporative cooling is, as the name suggests, cooling via evaporation. Liquid fluids are naturally at a lower physical energy than gaseous fluids. The conversion of liquid to gas via evaporation takes energy and obtains it from the surface that it is on. Thus, that surface experiences a decrease in energy.

- One of the most known examples of this is perspiration. The body releases sweat onto the surface of the skin, where it eventually evaporates. When the sweat evaporates, it takes energy from the skin in the form of heat to become a gas, thus decreasing the energy on the skin and removing thermal energy (heat) from the body.

Conclusions/action items:

Evaporative cooling is a result of liquid fluid heating up and evaporating, and this understanding of how it occurs will be helpful in preventing the measurement of it..

Caelen Nickel - Oct 06, 2023, 12:41 PM CDT



This figure illustrates how evaporative cooling interacts with the different layers of skin. Moisture is expelled onto the surface of the skin (sweating), or in our case heated internally.

2023/10/4 Skin Physiology

Caelen Nickel - Oct 06, 2023, 1:16 PM CDT

Title: Skin Physiology Research

Date: 10/4/2023

Content by: Caelen Nickel

Goals: Gain an increased understanding of the physiology of skin relative to the design project.

Reference:

W. Tang, S. Liu, H. Zhu, and S. Ge, "Microtribological and micromechanical properties of the skin stratum corneum," *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, vol. 226, no. 10, pp. 880–886, Oct. 2012, doi: 10.1177/1350650112450395.

Content:

- Skin is comprised of multiple layers that have anatomical structure and function. Skin is far from inert, having sensory neurons and many examples of gene regulation and expression within it.

- As Dr. Alexander works with, skin has metabolic control that is a genetic factor, meaning that gene expression can control metabolism at the skin.

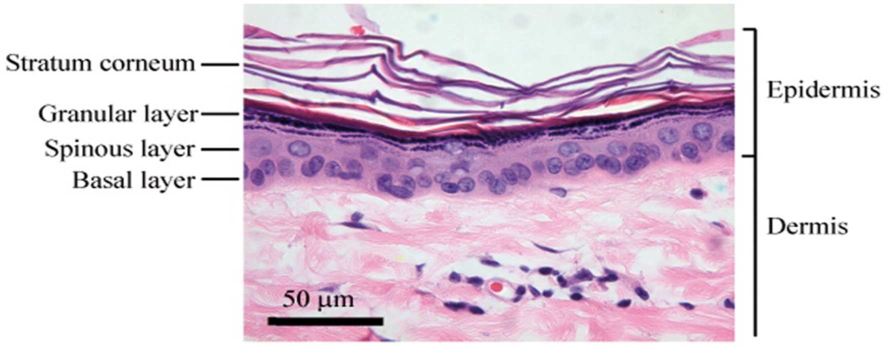
- Within the cells of skin and between tissue layers, there is moisture that can affect temperature measurement via evaporative cooling

- Heating the skin as is done in the research could cause liquid water to evaporate and cause thermal energy to escape.

Conclusions/action items:

The knowledge of skin anatomy and physiology is important in understanding how evaporative cooling could occur and must be prevented.

Caelen Nickel - Oct 06, 2023, 1:17 PM CDT



This figure illustrates anatomy and scale, highlighting the layered nature.

2023/10/11 Metabolism Research

Caelen Nickel - Oct 11, 2023, 3:22 PM CDT

Title: 2023/10/11 Metabolism Research

Date: 10/11/2023

Content by: Caelen Nickel

Goals: Gain an increased understanding of how metabolism impacts other health factors necessary to complete the motivation and background sections of the preliminary report.

Link: https://www.mayoclinic.org/healthy-lifestyle/weight-loss/in-depth/metabolism/art-20046508.

Reference:

[1] "Can you boost your metabolism?," Mayo Clinic. Accessed: Oct. 11, 2023. [Online]. Available: https://www.mayoclinic.org/healthy-lifestyle/weight-loss/in-depth/metabolism/art-20046508

Content:

- Metabolism is a very broad aspect of health that is the result of many different and separate processes.

- Metabolism is described as the means of converting nutrients in food to energy. As mentioned, there are many processes that are capable of doing this and affecting the overall consumption of nutrients and production of energy.

- Consumption of nutrients most directly refers to cellular respiration, where glucose is converted into energy. Because glucose that remains unused is converted to lipids, the consumption of glucose is important in fat production, or the lack thereof.

    - With consuming nutrients, this affects weight gain and shows how metabolism relates to diet-induced obesity that is examined in the client's research.

- In addition to pertaining to weight, metabolism is a broad process that affects many parts of the body and health, including sleep, energy, functioning, etc.

- From this research, the following sentence was paraphrased in the preliminary report:

Metabolism is a factor that directly relates to energy, sleep, and overall health with implications in preventing diet-induced obesity.

Conclusions/action items:

Metabolism is a very general term, and refers to the collection, or sum, of many processes. That being said, it is vital to functioning as a person and its regulation affects weight and more. As a result of this understanding, the preliminary report can be written, especially the motivation and background sections.

2023/09/19 PDS Materials Research---Plastics

Caelen Nickel - Sep 19, 2023, 5:02 PM CDT

Title: PDS Materials Research---Plastics

Date: 9/19/2023

Content by: Caelen Nickel

Goals: Understand material properties and determine if plastics can be used for the project application, using this information to complete the PDS.

Link: https://www.ensingerplastics.com/en-us/shapes/plastic-material-selection/low-temperature

Reference:

[1] "Low temperature plastics | Ensinger." https://www.ensingerplastics.com/en-us/shapes/plastic-material-selection/low-temperature (accessed Sep. 19, 2023).

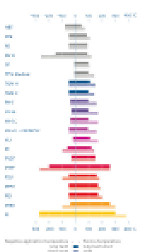
Content:

- This source provides a graphic illustrating the temperatures in degrees C at which different variety of plastics can be servicable both short term and long term. This figures is attached. The majority of materials can withstand physiological body temperature, as regarding material science, 37 degrees C is not high.

Conclusions/action items:

The use of plastics in the design, especially in proximity to the heating element, is feasible and can be included in design considerations.

Caelen Nickel - Sep 19, 2023, 5:09 PM CDT



2023/09/19 PDS Materials Research---Heat Transfer

Title: PDS Materials Research---Heat Transfer

Date: 9/19/2023

Content by: Caelen Nickel

Goals: Understand material properties and determine how the use of different materials will impact the heating element functioning, using this information to complete the PDS.

Link: https://www.google.com/url?q=https://www.metalsupermarkets.com/which-metals-conduct-heat-best/%23:~:text%3DWhich%2520Metals%2520Conduct%2520Heat%2520The%2520Best%253F%26text%3DAs%2520you%2520can%2520see%252C%2520out,use%2520for%2520a%252

Reference:

[1] btiernay, “Which Metals Conduct Heat Best?,” *Metal Supermarkets*, Feb. 17, 2016. https://www.metalsupermarkets.com/which-metals-conduct-heat-best/ (accessed Sep. 19, 2023).

Content:

- Varying materials, this resource focusing on metals, have different abilities to transfer heat through them.

- In the project application, the plate which rests on the top of the skin sample should be fabricated of a material that does not impair the measuring device. Similarly, the surface of the heating efficient.

- This resource provides a table of a type of metal and its ability to transfer heat in the units BTU/(hr*ft*degree F)

- Copper and aluminum were notably the highest performing metals in this regard, with steel being rather low.

Conclusions/action items:

The use of metal in the design, especially in proximity to the heating element and temperature probe, is a possibility and thus later designs should incorporate these heat transfer findings..

2023/09/21 Electronic Components Cost Research

Caelen Nickel - Sep 21, 2023, 11:00 PM CDT

Title: Electronic Components Cost Research

Date: 09/21/2023

Content by: Caelen Nickel

Goals: Gain an approximative understanding of how much the main electronics will count that are needed in the design for budgeting and PDS purposes.

Link: https://www.sparkfun.com/categories

Reference:

[1] "Product Categories - SparkFun Electronics." https://www.sparkfun.com/categories (accessed Sep. 21, 2023).

Content:

- A firm budget has not yet been provided. However, the total cost of the device should be affordable as the prices of current commercial alternatives was cited as a hurdle by the client.
    - The necessary variation of microprocessors to operate the electronic circuit range from $20-$30 [13].
    - For the measurement of heat, K-type thermocouples cost $5.50, and thermopiles can be purchased for under $40 [13].
    - Wires, resistors, and other minor electronic items cost under $1.00 per unit [13].
    - All stock metal and plastic for the final design of the product cost under $35 [3]. However, prototypes can be constructed using scrap material available in the UW-Madison TeamLab.

Conclusions/action items:

This research was instrumental in completing the PDS, and understanding the cost of essential electrical components will be important in formulating a budget.

2023/10/11 Client Research

Caelen Nickel - Oct 11, 2023, 11:05 PM CDT

Title: 2023/10/11 Client Research

Date: 10/11/2023

Content by: Caelen Nickel

Goals: Learn more about the client in order to complete the preliminary report.

Link: https://mcardle.wisc.edu/faculty/caroline-alexander/

Reference:

[2] “Caroline Alexander,” McArdle Laboratory for Cancer Research. Accessed: Oct. 11, 2023. [Online]. Available: https://mcardle.wisc.edu/faculty/caroline-alexander/

Content:

- The client Dr. Caroline Alexander is a Professor of Oncology in the UW Carbone Cancer Center Developmental Therapeutics program. Her research on the relationship between rodents’ metabolism and the heat permeability of their skin has opened new possibilities in improving health as there are implications in cancer, along with factors that could be replicated in humans

Conclusions/action items:

This research was instrumental in completing the preliminary report, and understanding the background of the client..

2023/09/24 Surface Thermocouple

Caelen Nickel - Sep 24, 2023, 7:01 PM CDT

Title: 2023/09/24 Surface Thermocouple

Date: 9/24/2023

Content by: Caelen Nickel

Goals: Learn more about thermocouple designs and how to incorporate them into the product design.

Content:

https://www.iothrifty.com/products/tc-sa-k-type-surface-thermocouple?variant=14364329574442&gclid=Cj0KCQjwvL-oBhCxARIsAHkOiu0U_X8zUgWed-3tPWCj5bwURlebc1BPV9sw_7X0OiUwqE5yT8Ol5QcaAgKzEALw_wcB

- Above is a link for the TC-Sa type K/T thermocouple with adhesive backing. To avoid measuring evaporative cooling, a dorsal plate should be in contact with the skin sample. Ideally, temperature measurement through this component would be done, and the adhesive thermocouple would be optimal to place on the backing of this plate.

Conclusions/action items:

This commercially available thermocouple model would be helpful in product design and should be considered in the design ideas.

2023/09/24 Thermocouple Components

Caelen Nickel - Sep 24, 2023, 7:23 PM CDT

Title: 2023/09/24 Thermocouple Components

Date: 9/24/2023

Content by: Caelen Nickel

Goals: Detail what components a thermocouple design would require.

Content:

- From BME 201 and 310, a K-type thermocouple is already possessed.

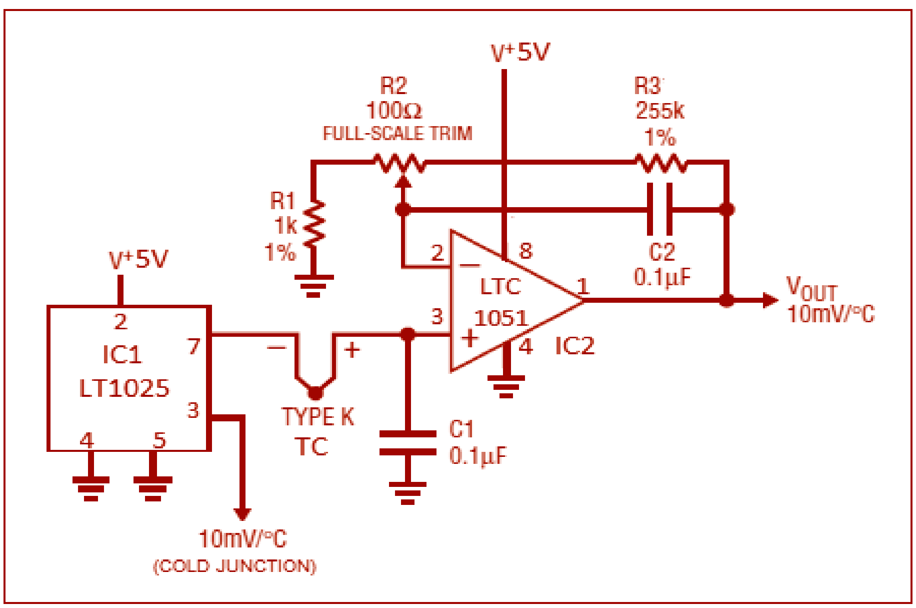
- In order to incorporate a K-type thermocouple into a circuit, an LT 1025 is necessary. This device provides a connection to the negative terminal of the thermocouple.

- The positive terminal of the thermocouple is treated as the Vout for determining the temperature. However, in order for greater precision and resolution, a non-inverting op-amp circuit with gain > 1 should be used. Thus, a non-inverting op-amp circuit (op-amp, 2 resistors, 5 V power) is necessary

Conclusions/action items:

This detail will be important in design matrix considerations, especially relating to cost and ease of fabrication..

Caelen Nickel - Oct 11, 2023, 1:09 AM CDT



Circuit schematic for the use of a K-type thermocouple

2023/09/24 Preliminary Design Idea Summary

Caelen Nickel - Sep 24, 2023, 7:26 PM CDT

Title: 2023/09/24 Preliminary Design Idea Summary

Date: 9/24/2023

Content by: Caelen Nickel

Goals: Layout a summary of design components and what differences various preliminary designs could have.

Content:

See attached document below

Conclusions/action items:

This summary is important in brainstorming both design components and how separate designs could be differentiated. The 3-4 preliminary designs will come from this brainstorming.

Caelen Nickel - Sep 24, 2023, 7:26 PM CDT

Temperature Measurement

- Thermistor, thermocouple, or thermopile are effective methods of temperature measurement.
  - One such component would be part of an electronic circuit paired with a microcontroller and code.
  - The temperature sensing component would alter the output voltage of the circuit, and temperature controlled testing and a calibration curve would equate this output voltage to a numerical temperature value.
  - Arduino code from a microcontroller would convert this output voltage into a temperature in ℃ and send this information to the researcher graphically.

Heating Element

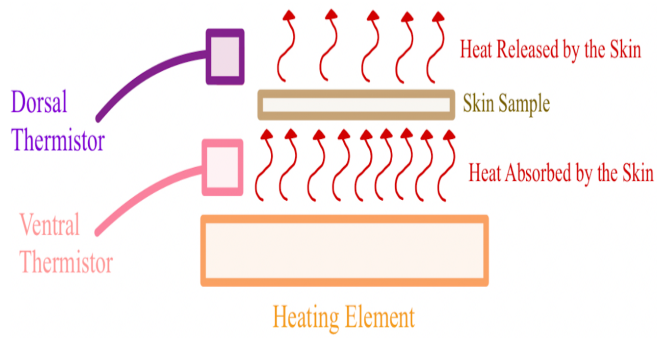
- The use of wall power heating elements as used in BME 201 would be effective.
  - Beefcake relay
- Battery power is a safer and more flexible alternative. Specifications, incorporation into an electronic circuit, and operation must be explored.

- Regardless of the power source, a feedback loop must be implemented in order to maintain proper temperature and safety
  - A thermistor/thermocouple circuit measuring the temperature of the hot plate will be necessary.
  - The temperature sensor must be calibrated to know what resistance and corresponding output voltage indicates that the hot plate is at 37℃.
  - The Arduino microcontroller and code will read this output voltage level threshold and provide a signal to turn the hot plate on/off.
  - A manual switch will also be available to turn the hot plate on/off when the researcher wants to heat a sample or when the device is not in use.

Download

BME_300_Design_Idea.pdf (106 kB)

Caelen Nickel - Dec 13, 2023, 8:27 PM CST



This image provides an illustration of the overall idea of the design and how the thermistors and heating element interact with the skin sample.

2023/10/10 Wall Power Heating Element

Caelen Nickel - Oct 11, 2023, 1:24 AM CDT

Title: 2023/10/10 Wall Power Heating Element

Date: 10/10/2023

Content by: Caelen Nickel

Goals: Detail a design for the heating element that uses wall power and has heating element regulation.

Content:

- For the use of wall power in a circuit, the 120 V from the outlet must be processed and allocated correctly to components.

    - The heating element can be powered directly with 120 V wall power. However, the breadboard and Arduino microcontroller require at most +5 V power. Therefore, power from the computer via a USB or USB-C can provide the power to these components, or an alternative method similar to a beefcake relay.

- Regardless, a beefcake relay (BME 201) is necessary to process the 120 V wall power.

- The Arduino can have direct control over the beefcake relay, turning it on and off to direct power to the heating elements or not.

- The Arduino would have code downloaded that reads the value of output voltage from a thermistor circuit to determine where the heating element is relative to 37 degrees C as intended. Depending on this Analog reading, the Arduino would then power or not power the beefcake relay.

    - There would be a corresponding LED that would indicate beefcake relay power, and show the user whether the heating element is on or off,

- A thermistor circuit is a circuit that can read temperature with the use of Arduino code. It makes use of a thermistor, which is a variable resistor dependent on temperature. Thus, temperature affects the Vout of the circuit which can be read by the Arduino.

    - For more information on thermistor circuit, see Thermistor Temperature Sensor under Design Ideas.

- A rocker switch would provide a manual way to turn on or off the beefcake relay regardless of if the thermistor circuit indicates the temperature in respect to 37 degrees C. This would be an alternative to unplugging the device.

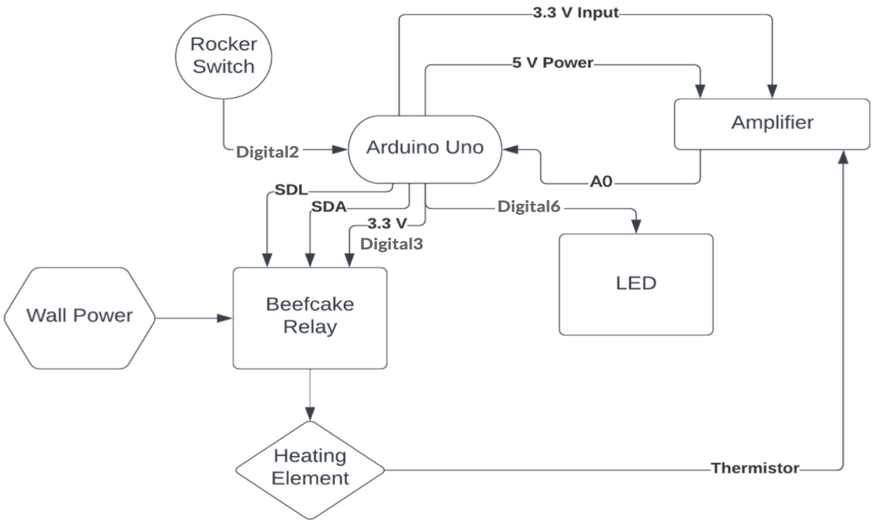
- As outlined in the Design Matrix:

A heating element design centered on wall power being the primary power source would be constructed in a way represented by the block diagram (below). A beefcake relay would be incorporated in order to process the wall power and send it to the heating element, pending power from the Arduino microcontroller. A rocker switch and thermistor circuit both control the Arduino. If the rocker switch is in the off position and/or the thermistor circuit detects a temperature greater than 37 ℃, the Arduino microcontroller and downloaded code would instruct the beefcake relay to not send wall power to the heating element, thus turning it off.

Conclusions/action items:

This design has many favorable components and should be considered in the heating element design matrix. The design team has experience working with these components and has many of the components already for prototyping and fabrication purposes. Moving forward, this design will be considered in the design matrix. Favorable scoring will indicate that this design is to be continued, thus fabrication and attaining the materials is the next step.

Caelen Nickel - Oct 11, 2023, 1:25 AM CDT



A hardware block diagram of the proposed thermistor circuit

2023/10/10 Thermistor Temperature Sensor

Caelen Nickel - Oct 11, 2023, 10:53 PM CDT

Title: 2023/10/10 Wall Power Heating Element

Date: 10/10/2023

Content by: Caelen Nickel

Goals: Detail a design for the temperature sensor that uses a thermistor in a circuit.

Content:

- A thermistor circuit is a circuit that can read temperature with the use of Arduino code. It makes use of a thermistor, which is a variable resistor dependent on temperature. Thus, temperature affects the Vout of the circuit which can be read by the Arduino.- The Arduino would have code downloaded that reads the value of output voltage from the thermistor circuit.

- The code responsible for reading the Vout and converting voltage to temperature is derived from a calibration curve. A calibration curve uses known temperature values that the thermistor is exposed to, while observing what the experimental resistance of the thermistor is. Using circuit calculations, the Vout can be calculated and plotted relative to temperature.

    - In a spreadsheet application such as MS Excel, the line of best fit can be determined, and this serves as the equation that the Arduino uses to convert Vout to temperature.

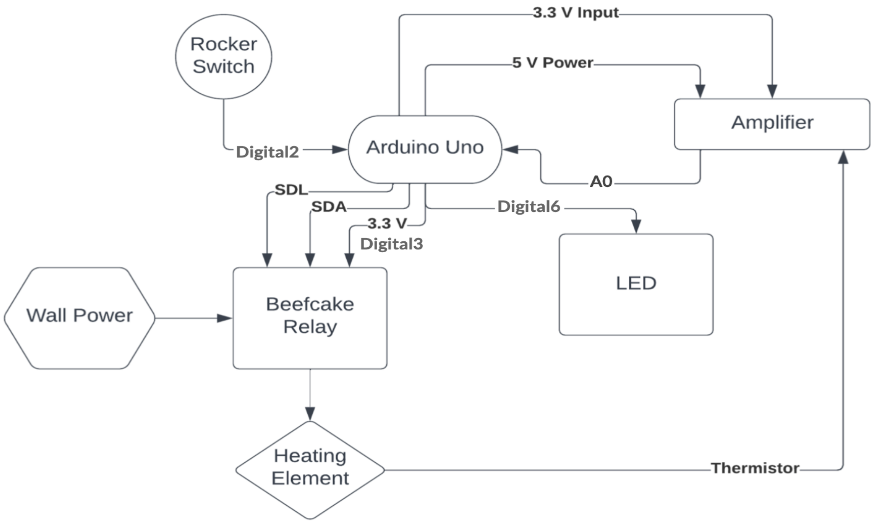
- As outlined in the Design Matrix:

The thermistor is a variable resistor that responds to changes in temperature with corresponding changes in temperature exhibiting a linear relationship. In the shown conformation, the thermistor resistance would dictate the gain of the circuit, directly influencing the output voltage received by the Arduino microcontroller. This circuit design is that of a voltage divider into a non-inverting amplifier, thus Gain = 1 + ($R_{Thermistor}$ / R3).

Conclusions/action items:

This design has many favorable components and should be considered in the temperature sensor design matrix. The design team has experience working with these components and has many of the components already for prototyping and fabrication purposes. Moving forward, this design will be considered in the design matrix. Favorable scoring will indicate that this design is to be continued, thus fabrication and attaining the materials is the next step. Next, the calibration curve with the thermistor must be made in order to program the Arduino.

Caelen Nickel - Oct 11, 2023, 10:12 PM CDT



A hardware block diagram of the proposed thermistor circuit

2023/12/7 Future Work Ideas

Caelen Nickel - Dec 13, 2023, 7:22 PM CST

Title: 2023/12/7 Future Work Ideas

Date: 12/7/2023

Content by: Caelen Nickel

Goals: Based on testing and the status of the final design, identify ways in which the design requires modifications and where improvements can be made.

Content:

- Redo circuit calculations to account for component tolerances
  - As mentioned in the Sources of Error section above and discussed in the Electrical Background, many electrical components, namely resistors, have tolerances. These deviations of experimental resistance from posted product specifications cause error.
  - Measure experimental resistance using a digital multimeter and substitute these resistance values into circuit calculations where posted resistance values were.
  - The addition of a filter would help eliminate noise, which Figure 14 displays.
- Create a printed circuit board (PCB) of the final breadboard circuit
  - Breadboards are useful for electrical circuit fabrication, but they are intended to be for temporary designs, proof of concept, testing, etc.
  - PCB connections are soldered, making them more stable and decreasing the likelihood of errors in circuit function and accuracy as a result of connections being interrupted, which has happened through the verification and testing process.
  - Compared to a breadboard, a PCB is much more condensed, allowing for the device electronics to be smaller and thus have a product with a smaller footprint. This is expected to increase the device's ease of use as it is better able to fit in the lab space.
- Purchase and incorporate a higher quality heating element into the next design iteration
  - Replace the current, low-cost heating element which experiences rapid heating that is too severe for use on skin samples.
- Implement a mechanism for applying the thermistors and heating element to the skin sample
  - The design process focused on the instrumentation aspect of the design; however, after testing and client feedback, a design process for the interface between the device and skin samples is necessary.
  - A conductive metal plate design with embedded thermistor(s) would firmly hold the sample to the heat source and thermistors, while ensuring that evaporative cooling cannot occur.
  - This would increase ease of use and provide a more consistent contact for heating element and thermistors on the sample.

Conclusions/action items:

Identifying what is necessary to do should the project be continued is important. In discussion with the client, many of these possibilities were brainstormed, as well as what direction should be taken if the project is continued. This bulleted list will be directly used in the final report, and a summary of this will be used in the final poster presentation.

Caelen Nickel - Dec 13, 2023, 7:24 PM CST

Due to amendments made in the final report as a result of feedback received during the poster presentation and after the presentation online, items have been added to the future work as reflected above.

Training Documentation Summary

Caelen Nickel - Sep 25, 2023, 5:04 PM CDT

My Memberships

Membership Type	Start Date	Expiry Date	Renew	Card Info
Lab Membership	Mon, May 22 2023	Sun, Dec 31 2023	Not Renewable	N/A
Lab Orientation	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Intro to Machining	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Intro to Shop Tools	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A

Download

Training_Documentation.png (46.9 kB)

10/19/2023 Evaporative Cooling Clarification Research

BRYAN HEATON - Oct 19, 2023, 12:56 PM CDT

Title: Evaporative Cooling Clarification

Date: 10/19/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Gain a better understanding of what evaporative cooling is and how to avoid measuring it in our prototype.

Content:

1. Evaporative cooling can be measured separately from other methods of heat transfer
2. Measuring evaporative cooling can be done by having a change in heat and a change in mass measurement to estimate the amount of water loss on the sample
3. Avoiding measurement of evaporative cooling is beneficial to limit design complications and maximize reliability.

[1] G. Havenith *et al.*, “Evaporative cooling: Effective latent heat of evaporation in relation to evaporation distance from the skin,” *Journal of Applied Physiology*, vol. 114, no. 6, pp. 778–785, 2013. doi:10.1152/japplphysiol.01271.2012

Conclusions/action items:

Evaporative cooling is the process by which the skin releases heat from sweating. Measuring it in relation to total heat loss is possible, but avoiding circumstances altogether in which evaporative cooling is present is certainly better for our design.

2023/11/15 - Specific Heat Capacity Research

BRYAN HEATON - Nov 17, 2023, 11:15 AM CST

Title: Specific Heat Capacity Research

Date: 11/15/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Attempt to find a value for the specific heat capacity of rodent skin
2. Attempt to find numerical values necessary for the usage of the heat energy transfer equation

Content:

Different animals skins' specific heat capacities (J/Kg * K) [1]

Human: 3.39

Rabbit: 3.47

Pig (epidermis): 3.53, 3.71

Pig (dermis): 3.15, 3.28

Mice are considered excellent models for humans in terms of experimentation on heat and temperature [2]. This is due to their very similar core and preferred temperatures [3]. This could mean that modeling mouse skin as having a similar specific heat capacity could be plausible. Human skin's specific heat capacity is close to representative of an average between the observes animals skin's specific heat capacity as well, which also suggests the human value may be a good estimate for rodent skin.

Conclusions/action items:

The specific heat capacity of rodent skin is likely very similar to that of humans. More in-depth research on studies in this field may be necessary to determine for sure.

References:

[1] https://www.researchgate.net/publication/247609956_Specific_heat_capacities_of_human_and_animal_tissues

[2] https://www.jax.org/why-the-mouse/excellent-models

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6196327/

2023/11/17 - Mice Thermal Conductance Research

BRYAN HEATON - Nov 17, 2023, 11:33 AM CST

Title: Mice Thermal Conductance

Date: 11/17/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Gather quantitative data to relate mice thermodynamic data with metabolic rate
2. Better understand the definitions of metabolic rate, how it's calculated, and what factors are important in building our design in terms of temperatures.

Content:

Whole Body Thermal Conductance is a measure of a rodent's thermal conductance as a function of ambient temperature:

$$WBTC = MR/(T_c - T_a)$$

where MR = Metabolic Rate, Tc is core temperature, and Ta is the ambient temperature.

At its' core, WBTC is a measure of the ease of heat transfer between a being and its environment in W/degrees C.

WBTC does not account for evaporative cooling, so it is usually only used at temperatures where evaporative cooling is negligible.

- This works great for our project as evaporative cooling is not a factor due to our design.

For laboratory mice: WBTC = 1.0 - 1.5 W/kg/degree C.

Conclusions/action items:

If we can apply these findings to samples of skin somehow, we can use this to calculate metabolic rate of the mice (the desired data!!) from our device.

References:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6196327/ (GREAT RESOURCE FOR US!!!)

10/19/2023 Competing Design in Humans

BRYAN HEATON - Oct 19, 2023, 1:02 PM CDT

Title: Bryan Heaton

Date: Competing Temperature Sensor Design in Humans

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Evaluate the effectiveness and differences in our proposed design and this design on humans.

Content:

There already exists a device very similar to the one we must produce. This device is for use on living humans, and works in a similar fashion. A 2cm x 2cm sensor is stuck to the skin, on which an internal thermostat measures the temperature transfer from a person of normal body heat to the outside.

[1] P. J. Rodríguez de Rivera, M. Rodríguez de Rivera, F. Socorro, M. Rodríguez de Rivera, and G. M. Callicó, “A method to determine human skin heat capacity using a non-invasive calorimetric sensor,” *Sensors*, vol. 20, no. 12, p. 3431, 2020. doi:10.3390/s20123431

Conclusions/action items:

1. Making our design specifically for rat skin may set us apart
2. Alternatively, creating a programmable device for use on a variety of different animal skins could be beneficial

2014/11/03 - Heat Transfer Equation Research

BRYAN HEATON - Nov 15, 2023, 10:38 AM CST

Title: Heat Transfer Equation Research

Date: 11/15/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Obtain an equation we can use for heat transfer
2. Obtain an equation we can use for RATE of heat transfer, as the time in which it takes for the insulative properties of the skin to work is important to our current problem

Content:

1. Thermal energy is given as $Q = mc\Delta T$ [1].
2. Heat flux (Φ) is the rate of heat transfer, and will likely be useful for developing our product [1].
    1. Heat flux vector points in the direction of lower temperature [2]
    2. Heat flux gives the rate of heat transfer through a given surface (W) [2]
    3. Heat flux density (φ) is the heat flux per unit Area [2]
    4. Thermal conductivity (k) is the measure of a material to conduct / transfer heat energy [1].
        1. This will likely be important in picking a material for heating element

$JH_c = \lambda dTdZ$ gives the equation for heat flux, where JHc is the conductive heat flux, lambda is a thermal conductivity constant for the material, and T is temperature.

Heat flux can be measured in two different ways:

1. Measuring the temperature on both sides of a material with known thermal conductivity (less reliable) [3]
2. Using a heat flux sensor (a thermopile / thermocouple!!) [3]

Conclusions/action items:

1. Using simply the heat energy equation may be simpler for our level of comfort in thermodynamics
2. These equations could likely help us determine another quantitative measure of the insulating properties of rodent skin

References:

[1]https://whatsinsight.org/thermal-energy-equation/

[2]https://whatsinsight.org/heat-flux/

[3]https://byjus.com/heat-flux-formula/

9/29/2023 Thermometer Component Research

BRYAN HEATON - Sep 29, 2023, 12:41 PM CDT

Title: Thermometer Component Research

Date: 9/29/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Gain a better understanding of the competing thermometer designs possible for our product.

Content:

To better understand the competing thermometers that we can use in our design, I researched the basics of thermistors, thermocouples, and thermopiles.

Thermistors are simply resistors which can add quickly and easily to another circuit, very efficient space-wise [1].

Thermocouples consist of multiple wires which are kept at different temperatures to measure the temperature of an element. Thermocouples are more inherently larger than thermistors and require more maintenance in usage [2].

Thermopiles consist of a thermocouple with a few added components. In this way, thermopiles are the least space efficient and require more room to manage and maintain [3].

[1] "Thermistor: What Is It? How Does It Work? Types Of, Uses," *www.iqsdirectory.com*.

https://www.iqsdirectory.com/articles/thermocouple/thermistors.html

[2] "Thermocouple," Encyclopædia Britannica, https://www.britannica.com/technology/thermocouple (accessed Sep. 29, 2023).

[3] Electrical4U, "Thermopile: A device that converts heat into electricity," Electrical4U, https://www.electrical4u.com/thermopile/ (accessed Sep. 29, 2023).

Conclusions/action items:

Thermistors are likely the best option for a heating element

9/22/2023 Heat Conductive Metals Research

BRYAN HEATON - Sep 22, 2023, 12:32 PM CDT

Title: Heat Conductive Metals Research

Date: 9/22/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Find metals which will use the least amount of energy in transferring heat to rodent skin
2. Gain knowledge on how to maximize efficiency in heat transfer

Content:

Silver, copper, and aluminum are all very conductive options for heat transfer. Steel seems to be a very poor heat conducting option. Aluminum is cheaper, lighter, and easier to work with than copper in most scenarios. Copper is corrosion resistant and resists "biofouling", which may be beneficial for our design.

References:

[1] “Best Heat Conductive Metals,” Best heat conductive metals, https://www.industrialmetalsupply.com/blog/best-metals-conducting-heat (accessed Sep. 22, 2023).

Conclusions:

Looking into copper and aluminum seem like the best options for our design. Further research into conductivity at different temperatures may be necessary for this choice.

Action items:

Continue more in-depth research on material usage for the heat plates.

11/9/2023 Heat Transfer Equations Research

BRYAN HEATON - Nov 09, 2023, 12:45 PM CST

Title: Heat Transfer Equations Research

Date: 11/9/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals: Gain a better understanding of the mathematics and physics behind the heat transfer in our project.

Content:

This equation seems to be the heat transfer equation for one-dimensional variable conductivity of the element being heated. This should be applicable as we are unsure if the insulating properties of the skin are uniform throughout.

Noting that the area A is constant for a plane wall, the one-dimensional transient heat conduction equation in a plane wall becomes

Variable conductivity:
$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \dot{e}_{\text{gen}} = \rho c\frac{\partial T}{\partial t} \qquad \textbf{(2–13)}$$

Conclusions/action items:

Further research on what this equation means for our project is necessary.

2023/11/19 - Initial Work on First Testing Protocol

BRYAN HEATON - Nov 19, 2023, 10:50 PM CST

Title: Testing Protocol Progress: Testing for Significant Difference in the Measurement of Thermodynamic Data

Date: 11/19/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Create a bootstrap hypothesis test skeleton
2. Detail the steps required to test for significant difference in the measurement of thermodynamic data
3. Educate the reader on the process of the bootstrap hypothesis test
4. Effectively utilize a tool for inference without the assumption of a normally distributed population of data

Content:

The link to the testing protocol can be found here. It is not yet finished, but provides a great initial framework for the test.

Conclusions/action items:

Continue the detailing of the testing protocol with attention to detail. The goal is to have someone who has never heard of our project or hypothesis testing to be able to follow along and effectively complete the test.

2023/11/20 - First Testing Protocol Complete

BRYAN HEATON - Nov 20, 2023, 11:21 AM CST

Title: First Testing Protocol Complete

Date: 11/20/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Create a visually appealing way to show the hypotheses for the hypothesis test
2. Complete the details of the first testing protocol.

Content:

The link to the final protocol can be found here. The protocol includes:

1. A descriptive procedure for the data collection process
2. A short description of the necessity of the bootstrap method of hypothesis testing
3. Resources to run bootstrap hypothesis tests
4. A code skeleton for the bootstrap hypothesis test described in the document
5. A step-by-step procedure for running the hypothesis test in RStudio, easily followed even without coding experience

Conclusions/action items:

Will tweak this procedure as necessary, however I believe this is close to done. Statistics can be a very valuable tool for determining the functionality of projects upon their completion.

2023/11/23 - Second Testing Protocol Complete

BRYAN HEATON - Nov 23, 2023, 3:41 PM CST

Title: Second Testing Protocol Complete

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Create an easy-to-follow testing protocol for ensuring the thermistors measurements are in small enough increments.
2. Practice writing procedures for real world testing on engineered devices

Content:

The link to the completed testing protocol can be found here.

Conclusions/action items:

Testing protocols should be written for even the smallest of tests to ensure replication of the production of the device is possible.

Continue writing the testing protocols for our device.

2023/11/23 - Third Testing Protocol Complete

BRYAN HEATON - Nov 23, 2023, 3:43 PM CST

Title: Third Testing Protocol Complete

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Write a detailed procedure to ensure that the thermistors are gathering sufficiently sensitive thermodynamic data
2. Practice writing easily replicable testing protocols.

Content:

The finished testing protocol can be found here.

Conclusions/action items:

Testing the thermistors for sensitivity is immensely important for the functionality of our device.

2023/11/23 - Fourth Testing Protocol Complete

BRYAN HEATON - Nov 23, 2023, 4:02 PM CST

Title: Fourth Testing Protocol Complete

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Write a detailed procedure to ensure that the thermistors are functional
2. Practice writing easily replicable testing protocols.

Content:

The finished testing protocol can be found here.

Conclusions/action items:

Testing the thermistors for functionality is paramount for our device to work.

2023/11/23 - Fifth Testing Protocol Complete

BRYAN HEATON - Nov 23, 2023, 4:20 PM CST

Title: Fifth Testing Protocol Complete

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Write a detailed procedure to ensure that the arduino program is correctly interpreting thermistor data.
2. Practice writing easily replicable testing protocols.

Content:

The finished testing protocol can be found here.

Conclusions/action items:

Testing the arduino program for correctly interpreting thermistor output is paramount for our device to work.

2023/11/23 - Sixth Testing Protocol Complete

BRYAN HEATON - Nov 23, 2023, 4:44 PM CST

Title: Sixth Testing Protocol Complete

Date: 11/23/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Write a detailed procedure to ensure that the arduino program is correctly monitoring and controlling the heating element.
2. Practice writing easily replicable testing protocols.

Content:

The finished testing protocol can be found here.

Conclusions/action items:

Testing the arduino program for correctly monitoring the heating element is paramount for our device to work.

2023/12/4 - Remaking Old Protocol

BRYAN HEATON - Dec 04, 2023, 2:42 PM CST

Title: Remaking Old Protocol

Date: 12/4/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Recreate the testing protocol relating to hypothesis testing to better represent the data we were able to collect in testing
2. Show that a t-test is now reasonable to run given the much larger sample sizes than anticipated

Content:

A link to the new testing protocol can be found here.

Conclusions/action items:

Although annoying, redoing protocols to better represent the process we were able to do is the right thing to do for the design process.

12/11/2023 - Remaking Old Protocol for Final Report

BRYAN HEATON - Dec 11, 2023, 3:24 PM CST

Title: Remaking Old Protocol for Final Report

Date: 12/11/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Remake the fourth protocol detailing the testing for sensitivity in thermistors to better show what was done in the laboratory
2. Increase accuracy of final report in the design process

Content:

NEW Protocol 4: Ensuring Sufficient Sensitivity in Thermistors via Tegaderm Layer Testing

Materials:

1. Minimum 8 layers of Tegaderm
2. Assembled device
3. Computer (for running arduino program, thermistor data interpretation, and statistical analysis)

Procedure:

1. Gather Tegaderm and separate into individual sheets
2. Ensure the heating element is turned off and at room temperature
3. Begin testing with 0 layers of Tegaderm placed on the heating element (control)
4. Allow the heating element to heat for 10 seconds while gathering temperature data from the dorsal thermistor
5. Record the temperature data
6. Repeat steps 4-5 with 1, 2, 4, and 8 layers of Tegaderm placed on the heating element, stacked one on top of the other.
7. After data collection for each group is complete, run an ANOVA test for the data in MATLAB, with the null hypothesis being that the mean temperature for each group is the same and the alternative hypothesis being that at least one mean temperature is different.
8. Analyze the p-value in context of the test with an ã value of 0.01.

Conclusions/action items:

- Remaking protocols as the process continues is important for replication of the process

2023/11/30 - Work on Results and Analysis Section for Final Poster

BRYAN HEATON - Nov 30, 2023, 5:59 PM CST

Title: Work on Results and Analysis Section for Final Poster

Date: 11/30/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Create a skeleton for results and analysis on the final poster
2. Include relevant information to the hypothesis test conducted
3. Indicate the need for an alternative hypothesis test to the regular t-test.

Content:

Results and Analysis

- Samples of rodent skin were measured for their thermodynamic properties with the existing method and our assembled device to ensure a significant ignorance of evaporative cooling.
- The change in temperature was calculated for each sample of rodent skin with A) the heat gun and B) our device. A two sample bootstrap test was conducted for significant difference in the data:

	Mean	Standard Deviation
Heat Gun		
Assembled Device		
p-value		

Table 1: Summary of the collected data and the corresponding p-value for the conducted bootstrap test.

Null Hypothesis: There is no significant difference in the data collected for the two populations.

Alternative Hypothesis: There is significant difference in the data collected for the two populations.

- A two-sample bootstrap hypothesis test was conducted due to lack of certainty about normality of the population of data
- The null hypothesis is rejected as the p value is smaller compared to the α value of 0.05.
- Due to the results of the test, it is concluded that the assembled device effectively ignores the thermodynamic altering effects of evaporative cooling.

Conclusions/action items:

- **Need to update section accordingly once testing has concluded**

2023/12/4 - Final Results and Analysis Section Complete

BRYAN HEATON - Dec 04, 2023, 2:23 PM CST

Title: Final Results / Analysis Section Complete

Date: 12/4/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Update the section to better represent data that was able to be collected in the testing process
2. Explain the usage of t versus bootstrap test (very large sample sizes ensures approximate normality)

Content:

Results and Analysis

- Live skin was measured for it's thermodynamic properties with the existing method and our assembled device to ensure a significant ignorance of evaporative cooling.
- The change in temperature was calculated for the skin with A) the heat gun and B) our device. A two-sample t test was conducted for significant difference in the data:

	Mean	Standard Deviation
Heat Gun	33.2	0.2938
Assembled Device	34.9	0.3520
p-value	1.24e-90	

Table 1: Summary of the collected data and the corresponding p-value for the conducted t-test.

Null Hypothesis: There is no significant difference in the data collected for the two populations.

Alternative Hypothesis: There is significant difference in the data collected for the two populations.

- A t-test was performed as the quantity of data (100 and 1000 samples) was large enough to ensure normality
- The null hypothesis is rejected as the p value is much smaller compared to the α value of 0.05.
- Due to the results of the test, it is concluded that the assembled device effectively ignores the thermodynamic altering effects of evaporative cooling.

Conclusions/action items:

- This should be a sufficient section to explain the large testing process involved with our project.

12/11/2023 - Work on Testing Section of Final Report

BRYAN HEATON - Dec 11, 2023, 3:28 PM CST

Title: Work on Testing Section of Final Report

Date: 12/11/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Remake obsolete testing protocols to better reflect the completed design process
2. Summarize each testing protocol (Testing section of the report)
3. Detail each testing protocol (Appendix A of the report)

Content:

The link to the report can be found here. The work done on the testing section and appendix A was done in this session.

Conclusions/action items:

N/A. Possibly work on results section with Caelen.

12/12/2023 - Work on Conclusion Section of Final Report

BRYAN HEATON - Dec 12, 2023, 9:02 PM CST

Title: Work on Conclusion Section of Final Report

Date: 12/12/2023

Content by: Bryan Heaton

Present: Bryan Heaton

Goals:

1. Summarize the design process in a concise manner
2. Highlight events in the process that guided the creation of the device

Content:

The link to the final report can be found here. Any work on the conclusion section was done in this session.

Conclusions/action items:

1. Finalize the report

9/21/2023 ThermTest MP-V

CADEN BINGER - Sep 21, 2023, 1:00 PM CDT

Title: ThermTest MP-V

Date: 9/21/2023

Content by: Caden Binger

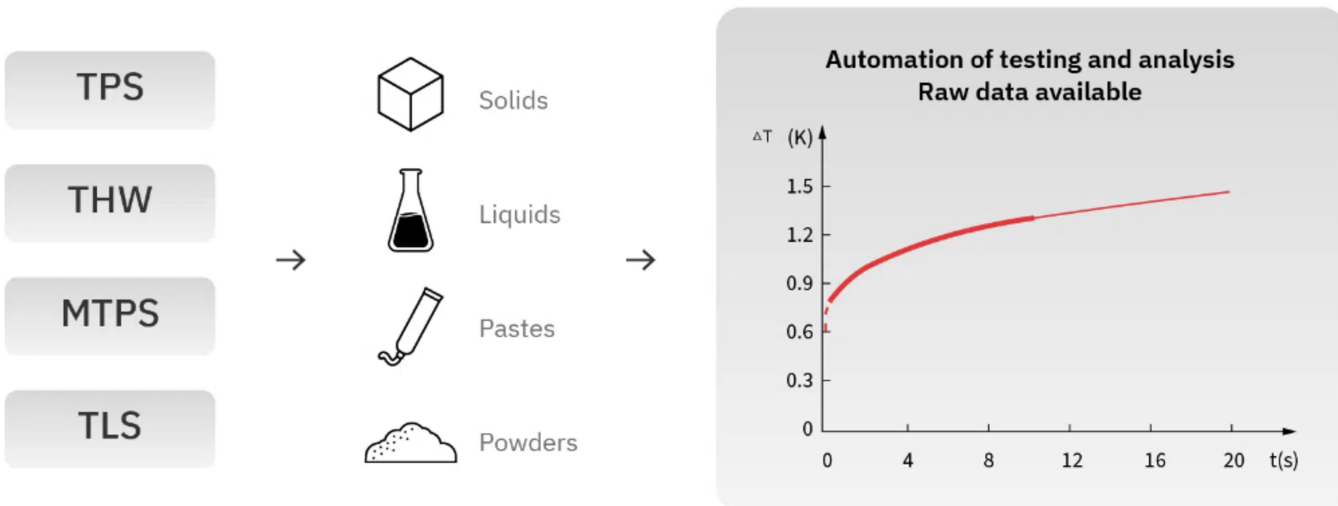
Present: Caden Binger

Goals: To research and understand how this competing design works and how we can use this to help us make a low-cost version that fits our clients needs.

Content: https://thermtest.com/mp-v

Our client sent us this link to this product to show us what she was looking into, but that it was far too expensive, and it does more than she needs it to do. It can measure the thermal conductivity, thermal diffusivity, specific heat and thermal effusivity of solids, liquids, pastes and powders. Currently, our client just needs to measure the temperature from the inside of the mice's skin and how it affects the outside of the temperature of the outside of the skin, not everything that this product can do.

It does give a good example of how we can represent our data.



This is what we were thinking anyways, by using a change in temperature over time, then taking that data and graphically analyzing it.

They also claimed that their sensors accuracy varied from 2%-5%, so that could be a good standard for our product to aim for. Also, their product can range from -75 to 300 degrees Celsius, when all we need is for it to be at 37 degrees Celsius.

Overall, the information on how their product was lacking on their website, and I couldn't find anything else on their website to help explain it, so I will just have to keep researching other products.

Conclusions/action items: Continue to research other competing products

The graph representation was useful in backing up our original idea on how to graphically analyze the data.

9/25/2023 Meeting Notes

CADEN BINGER - Sep 28, 2023, 7:52 PM CDT

Title: Group Meeting Notes

Date: 9/25/2023

Content by: Caden Binger

Present: Caden, Charles, Caelen, Annika, Bryan, Tayler

Goals: To evaluate and rank the categories for our design matrix and assign sections to individuals to fill out

Content: We made two separate design matrices to individually determine what power source and what temperature sensor to incorporate into our design. They are attached below.

Heating Element Design Matrix

Table 1: Design Matrix for evaluation of heating element preliminary designs according to a set of five weighted criteria. Highlights indicate the highest score(s) of each section.

Design Categories (Weight)	Wall Power Heating Element		Battery Power Heating Element	
Safety (30)	2/5	12	4/5	24
Accuracy (25)	4/5	20	3/5	15
Ergonomics (20)	3/5	12	3/5	12
Cost (15)	4/5	12	1/5	3
Ease of Fabrication (10)	4/5	8	2/5	4
Total (100)	**64**		**58**	

Temperature Sensor Design Matrix

Table 2: Design Matrix for evaluation of temperature sensor preliminary designs according to a set of five weighted criteria. Highlights indicate the highest score(s) of each section.

Design Categories (Weight)	Thermistor Temperature Sensor		Thermocouple Temperature Sensor		Thermopile Temperature Sensor	
Accuracy (35)	4/5	28	5/5	35	1/5	7
Ease of Fabrication (20)	4/5	16	3/5	12	2/5	8
Cost (20)	4/5	16	3/5	12	2/5	8
Size (15)	5/5	15	4/5	12	3/5	9
Safety (10)	4/5	8	3/5	6	3/5	6
Total (100)	**83**		**77**		**38**	

Then we established who would write each section in the design matrix document. We re-ranked the categories for each matrix, as certain categories like accuracy were more important for one matrix than the other.

Conclusions/action items:

Complete the paragraphs describing the individual sections for the design matrix

Start work on the preliminary presentation and start practicing

9/28/2023 Thermocouple Notes

CADEN BINGER - Sep 28, 2023, 8:01 PM CDT

Title: Thermocouple Notes

Date: 9/28/2023

Content by: Caden Binger

Present: Caden Binger

Goals: To establish a baseline of knowledge on some of the potential temperature sensors we will be using

Content: https://www.omega.co.uk/prodinfo/thermocouples.htm

A thermocouple is a temperature sensor that consists of two different metal wires joined at one end that measures temperature. They are commonly used for measuring a wide range of temperatures, from extremely low (-200°C) to high (up to 2,500°C). They are known for their high sensitivity to temperature changes, making them suitable for precision temperature measurements.

The accuracy of a thermocouple depends on factors like the type of thermocouple, the materials used, and the calibration process. They can typically have accuracies ranging from ±0.5°C to ±5°C.

Thermocouples are versatile temperature sensors with a long history of use so they can also be useful to us in our design process.

Conclusions/action items: Continue to research possible temperature sensors for our design process

Start work on our preliminary design presentation

10/5/2023 Meeting Notes

CADEN BINGER - Oct 05, 2023, 9:07 PM CDT

Title: Preliminary Presentation Practice

Date: 10/5/2023

Content by: Caden Binger

Present: Caden, Charles, Caelen, Tayler, Annika

Goals: To practice our individual parts of the preliminary design presentation. And to also edit any parts that needed fixing or a tune up.

Content: We practiced our parts and everything went smoothly. We edited a couple of things but nothing too major. All there is left to do is to practice the script and then perform it all on Friday.

Conclusions/action items: Edit anything that needs to fixed

Practice the script

Present on friday

10/5/2023 Preliminary Presentation Script

CADEN BINGER - Oct 05, 2023, 9:15 PM CDT

Title: Preliminary Presentation Script

Date: 10/5/2023

Content by: Caden Binger

Present: Caden Binger

Goals: To create a script of things that I want to mention in my portion of the presentation, so I can study it and make sure that I am ready to present.

Content:

For the temperature sensor design criteria, we are focusing on five key categories, Accuracy, Ease of Fabrication, Cost, Size, and Safety.
Our product's main purpose is to monitor temperature, so the accuracy of these measurements are crucial in order to provide conclusive thermodynamic data, making it a priority in our design consideration.
Ease of fabrication is another important aspect of our product, as we want a solution that is highly accurate, but also one that is easy to incorporate and one that is well-known to our team.
Cost-effectiveness is always a consideration in the design process, and while we aim to create a high-quality product, we also want to keep it budget-friendly.
Next category is size. While the size of each temperature sensor is relatively similar, we are taking the overall size of the circuit into consideration as well.
Lastly is safety. While safety is an incredibly important aspect of any laboratory equipment, the safety concerns associated with each temperature sensor are relatively low.

Looking at the design matrix for each temperature sensor, the aspects of the thermistor
For accuracy, the thermocouple wins with a score of 5, followed closely by thermistors. This is because thermocouples directly alter the voltage output, leading to more precise temperature measurements. The thermopile temperature sensor design received a score of 1 in this category because thermopiles are capable of measuring evaporative cooling even when in direct contact with the samples, which would take thermodynamic factors into account that the researchers are attempting to avoid.
For ease of fabrication, thermistors scored the highest with a 4. Thermistors are well-known to our design team, making them the most practical choice. They don't require additional amplifiers or filters, which simplifies the circuit design and reduces components. This simplicity translates into ease of fabrication, ensuring a smooth development process.
For cost, thermistors win this category as well, as they are the least expensive option, which will allow us to keep our product low-cost. This affordability aligns with our goal of providing a cost-effective product for our client.
In the size category, the thermistor wins again due to its compact size and simple circuitry, making it a practical choice for a laboratory environment.
And lastly, safety. The thermistor wins again because of its simple circuit design, which means fewer components and lower risk, unlike thermocouple and thermopiles.

Conclusions/action items: Study the script so I can loosely follow it without having to look at it

Present it smoothly

10/13/2023 Advisor Meeting Notes

CADEN BINGER - Oct 19, 2023, 6:13 PM CDT

Title: Advisor Meeting Notes

Date: 10/13/2023

Content by: Caden Binger

Present: Caden, Charles, Caelen, Annika, Bryan, Tayler

Goals: To address issues with out preliminary presentation and how we can go about fixing them

Content: The problem statement was a little vague/short. A lot of white space on the slides. Maybe add some graphics or something. Said that there were many specs missing in the PDS. Said we made justifications without giving reasons for the design choices. Also said that the criteria was not specific enough. Also said that the preliminary designs for sensors and heaters were mixed and hard to follow.

Conclusions/action items: Discussed that we should meet with our client again to discuss our design idea.

Start ordering materials for design fabrication.

10/19/2023 Evaporative Cooling and Thermoregulatory Processes Notes

CADEN BINGER - Oct 19, 2023, 6:25 PM CDT

Title: Evaporative Cooling and Thermoregulatory Processes Notes

Date: 10/19/2023

Content by: Caden Binger

Present: Caden Binger

Goals: To expand my knowledge on the topics of evaporative cooling and it's affects of the skin's thermoregulatory processes

Content: I mainly researched one study that I will provide the link for. Other than that, the rest was just looking up definitions and general information.

https://pubmed.ncbi.nlm.nih.gov/31302039/

The study's primary aim is to address obesity by exploring the concept of converting food calories into heat. This is achieved by inducing thermogenesis in beige and brown adipose tissues. Thermogenesis refers to the process of heat production in the body. The study leverages the positive health benefits associated with β-adrenergic stimulation, a process that activates specific receptors to promote thermogenesis. Rather than concentrating solely on thermogenesis, the research introduces a unique strategy centered on the regulation of heat loss. Thermoregulation is the process of maintaining a stable internal body temperature. Inefficient heat conservation refers to the inability to retain heat effectively, which can result in the need for more thermogenesis (heat production) to maintain body temperature. To investigate these concepts, the researchers used a combination of surface temperature thermography, a technique to measure skin temperature, and rates of trans-epidermal water loss. Trans-epidermal water loss measures the rate at which water evaporates through the skin. These measurements were used to assess the total heat transfer in genetically-engineered and genetically diverse mice. This variation of how well a mouse's skin can retain heat can be attributed to either naturally occurring differences or genetic modifications. Of particular interest is the wide range of rates of evaporative cooling resulting from trans-epidermal water loss. Evaporative cooling is the process by which heat is removed from the body when water on the skin's surface evaporates. The researchers speculate that the physiological mechanism of increased evaporative cooling leading to a higher demand for thermogenesis (heat production) could be harnessed as an "energy sink." In this context, an "energy sink" refers to a mechanism for dissipating excess energy. This concept could have a role in developing strategies to address metabolic diseases, particularly obesity.

Conclusions/action items: Continue to research more to further my understanding on this topic.

10/19/2023 Advanced Thermistor Notes

CADEN BINGER - Oct 19, 2023, 6:37 PM CDT

Title: Advanced Thermistor Notes

Date: 10/19/2023

Content by: Caden Binger

Present: Caden Binger

Goals: To expand my knowledge on the circuitry and electronics that are going to be involved in our product.

Content:

The Steinhart-Hart Equation:

The Steinhart-Hart equation is a mathematical model used to convert thermistor resistance to temperature accurately.

1/T= A+BlnR + C(lnR)^3

$$\frac{1}{T} = A + B\ln R + C(\ln R)^3$$

In this equation,

A, B, and C are coefficients specific to the thermistor type and its temperature range.

R is the resistance of the thermistor at a given temperature.

T is the absolute temperature in Kelvin (K).

The equation allows for the accurate conversion of the resistance of a thermistor to its corresponding temperature in Kelvin. This is essential when precise temperature measurements are required.

Coefficient Determination:

To apply the Steinhart-Hart equation, you need to know the values of the coefficients A, B, and C for your specific thermistor.

Manufacturers typically provide datasheets that include these coefficients, making it straightforward to use the equation.

These are just some basic notes that I thought were useful in learning how to implement a thermistor into our design.

Conclusions/action items: I hate coding, but I will have to look into how to incorporate it into our actual design instead of just how it works. Also learn how to take the output data and turn it into graphical data that we can analyze.

10/26/2023 Questions for Client Meeting

CADEN BINGER - Oct 26, 2023, 4:28 PM CDT

Title: Questions for Client Meeting

Date: 10/26/2023

Content by: Caden Binger

Present: Caden Binger

Goals: Establish a set of questions for our client primarily based on design considerations to help give us insight for our prototyping process

Content:

1. Is there a specific size of the product that you are hoping for?
2. Do you anticipate performing any kind of sterilization process in between uses? If so, is there a material better suited for that process in terms of product longevity?
3. How do you plan on accessing the data?

Conclusions/action items: These are just some general questions to start off with and I'm sure that a lot more will be asked during the meeting. Other than that, just be prepared for the meeting and prepare for show and tell.

9/21/2023 Rough Design Sketch 1

CADEN BINGER - Sep 21, 2023, 12:45 PM CDT

Title: Rough Design Sketch 1

Date: 9/21/2023

Content by: Caden Binger

Present: Caden Binger

Goals: To create a rough sketch of a potential design option

Content: Will be an attached pdf below

Conclusions/action items: Create more sketches

Make this sketch more detailed with included dimensions when we decide on a heating element

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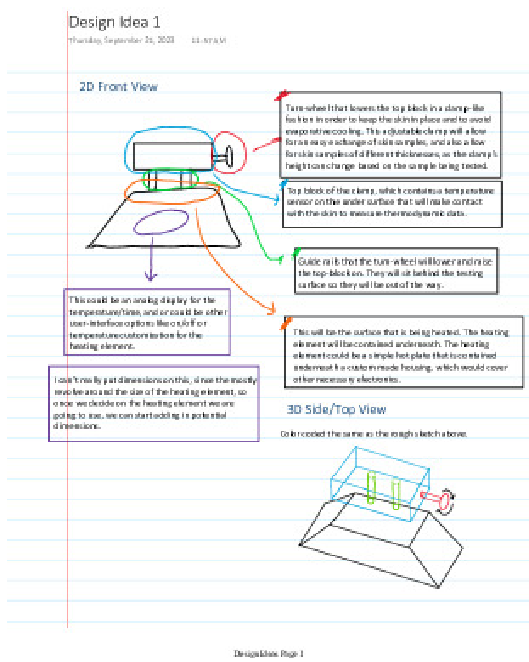
CADEN BINGER - Sep 21, 2023, 12:43 PM CDT



[Download](#)

Rough_Design_Idea_1.pdf (600 kB)

2023/09/24 Heat Measuring Research

ANNIKA SYSLACK - Sep 24, 2023, 10:18 PM CDT

Title: Heat Measuring Devices Research

Date: 9-24-23

Content by: Annika Syslack

Present: N/A

Goals: Gain an understanding of thermocouples versus thermopiles, as no experience has occurred with these devices in previous classes.

Content:

Thermocouple- device that measures temperature with two dissimilar metal wires formed at a junction; junction heated/cooled and small voltage is generated in circuit that can be measured

-relatively cheap (Amazon @ $12.00)

-poorer accuracy compared to thermopile

-oxidation can damage thermocouple

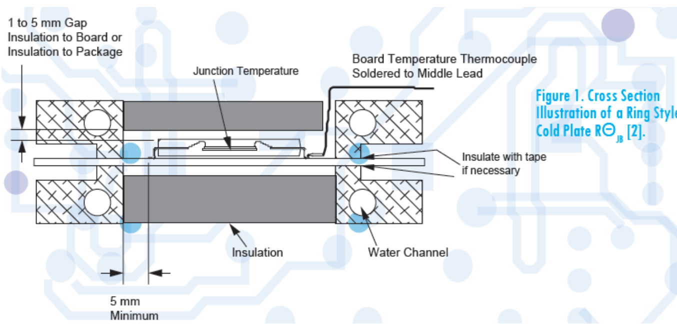


Figure 1. Cross Section Illustration of a Ring Style Cold Plate $R\Theta_{JB}$ [2].

Thermopile- made of thermocouples, can create more minivolts than a single thermocouple

-Highly sensitive

-more beneficial for creating electricity from heat versus measuring temperature

Sources:

"Difference Between Thermopile and Thermocouple: 2023 Practical Guide." *Linquip*, 10 October 2021, https://www.linquip.com/blog/difference-between-thermopile-and-thermocouple/. Accessed 24 September 2023.

"What is Device Thermal Coupling and How Does it Affect Thermal Management? | Advanced Thermal Solutions." *Advanced Thermal Solutions, Inc.*, 31 August 2011, https://www.qats.com/cms/2011/08/31/what-is-device-thermal-coupling-and-how-does-it-affect-thermal-management/. Accessed 24 September 2023.

Conclusions/action items: Utilize information in contributing to team meeting surrounding design ideas and design matrix as well as when design construction begins.

2023/10/18 Mouse Skin Research

ANNIKA SYSLACK - Oct 18, 2023, 10:54 PM CDT

Title: Mouse Skin Research

Date: 10-18-2023

Content by: Annika Syslack

Present: N/A

Goals: Gain a better understanding of how mouse skin works to be more knowledgable about the goal of the team's device.

Content:

- In a study from Harvard Medical School, research into the structure of mouse skin showed that the skin consists of a thin epidermal surface, thicker connective dermis tissue layer, and a large adipose layer. There is then a muscle tissue layer that separates the skin from bodily functions. They applied this structure to how tumor growth occurs in patients with the inactivation of mutated TSC1 and TSC2 genes. Results of the study showed the dermis layer of skin thickened with mast cells when mice had this inhibition of mutated genes. By creating the model of the skin, further information about those with this mutation could be applied to treatment

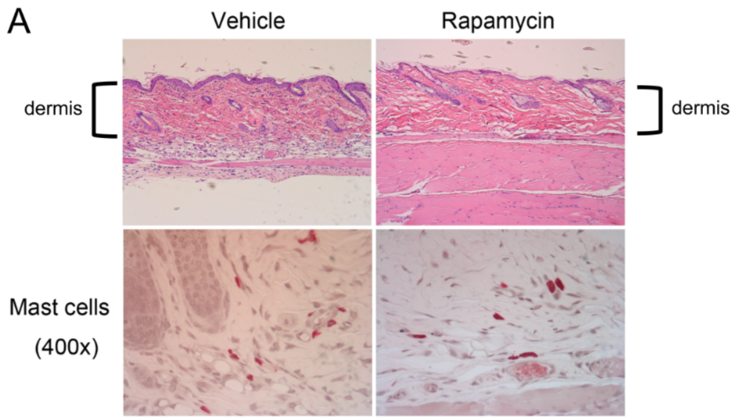


Figure 1: Results of mouse skin model surrounding genetic mutation.

-From a study from the University of Leiden, mouse skin was utilized to test how skin elasticity can increase the rate of penetration of drugs through vesicular systems; vesicular systems are complex assemblies of lipid bilayers within the skin, with liquid-state vesicles having a higher rate than gel state (more rigid systems). This allows for further information surrounding the structure and dynamics of skin to be understood.

Works Cited

"Analysis of a Mouse Skin Model of Tuberous Sclerosis Complex". *PLOS ONE*, December 2016, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0167384#:~:text=Normal%20mouse%20skin%20consists%20of,the%20skin%20from%20other%20structures. Accessed October 18, 2023.

"Elasticity of vesicles affects hairless mouse skin structure and permiability". *Journal of Controlled Release,* December 1996, https://www.sciencedirect.com/science/article/abs/pii/S0168365999001686?via%3Dihub. Accessed October 18 2023.

Conclusions/action items: Based on the two cited sources, this information can be applied to the research process and ideas surrounding the client's research, as well as what the device will be doing a lab setting.

2023/11/08 Thermistor Circuitry Research

ANNIKA SYSLACK - Nov 08, 2023, 10:11 PM CST

Title: Thermistor Circuitry and Equation Research

Date: 11-8-23

Content by: Annika Syslack

Present: N/A

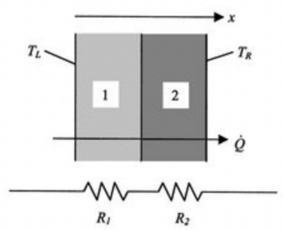
Goals: Gain a better understanding of circuitry research to better understand the process at which fabrication is completed.

Content:

-In problem solving, heat transfer- Current = temperature difference / thermal resistance

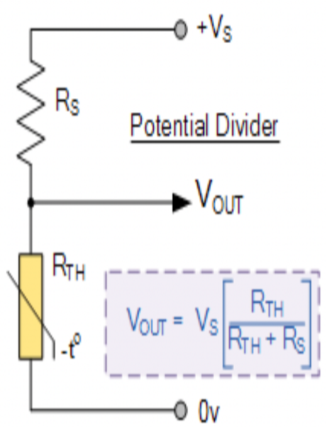
-thermal resistance = L/kA where L = thickness of sample; k = constant (thermal conductivity of sample); A = area of plane

- from this formula, it can be interpreted that as L increases, the heat transfer will decrease; as A increases, heat transfer will increase



-In thermistor solving, [(T2)(T1) / temperature difference] x ln(resistance at T1 / resistance at T2)

-thermistors require excitation signal; converts the temperature change to voltage change



- can be used in a potential divider circuit with an input of voltage to measure the temperature change

Works Cited

16.4 Thermal Resistance Circuits, https://web.mit.edu/16.unified/www/FALL/thermodynamics/notes/node118.html. Accessed 8 November 2023.

“Thermistors and NTC Thermistors.” *Electronics Tutorials*, https://www.electronics-tutorials.ws/io/thermistors.html. Accessed 8 November 2023.

Conclusions/action items:

Using this background research, can have a better understanding of the fabrication process despite not taking some of the classes that are helpful to understanding the circuitry being utilized in creating the temperature measuring device.

2023/11/27 General Background Research

ANNIKA SYSLACK - Nov 28, 2023, 10:34 PM CST

Title: Background Research for Poster

Date: 11-27-23

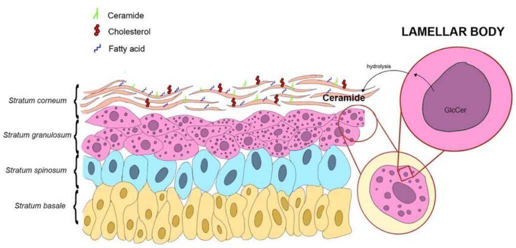
Content by: Annika Syslack

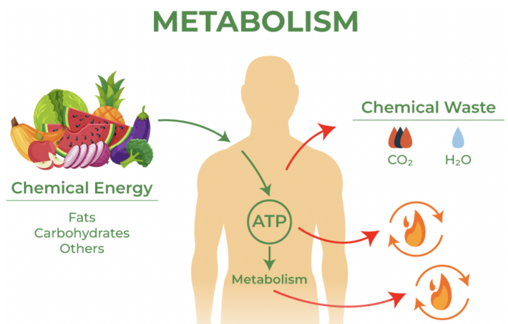
Present: N/A

Goals: Create a more cohesive version of previously completed research on skin and heat energy for the background section of the poster.

Content:

- Skin is a complex system in its anatomy and physiological processes, including heat regulation. The magnitude of heat dissipation from the body to its surroundings is facilitated by blood flow and layers of tissues, in the form of calories. However, the exact process of this caloric loss is largely unknown. [1]
- The anatomy of skin includes adipose tissue, which stores heat close to the skin surface [2]. Lamellar bodies are also present in the epidermal layer, which carry cargo required for maintaining homeostasis, or a constant body temperature [3].
- Heat transfer is closely related to metabolism, the net sum of reactions that provide the body with energy [4] This energy is required to dissipate heat, which applies to skin as the thermal properties of the skin can work to increase metabolic activity to produce thermal energy.
- By studying the connection between the skin anatomy and its impact on heat loss and the body's metabolism can provide important information into human health, including obesity.





Works Cited

[1] "The ability of the skin to absorb heat; The effect of repeated exposure and age." *NCBI*, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3524686/. Accessed 28 November 2023.

[2] "New Findings On Mechanisms For Body Temperature Regulation By Fat Tissue - Georgia State University News - University Research - Health & Wellness," Georgia State News Hub. Accessed: Oct. 11, 2023. [Online]. Available: https://news.gsu.edu/2017/10/05/new-findings -mechanisms-body-temperature-regulation-fat-tissue/

[3] "Physiology, Metabolism - StatPearls." *NCBI*, https://www.ncbi.nlm.nih.gov/books/NBK546690/. Accessed 28 November 2023.

[4] "Epidermal Lamellar Body Biogenesis: Insight Into the Roles of Golgi and Lysosomes." *Frontiers*, 9 July 2021, https://www.frontiersin.org/articles/10.3389/fcell.2021.701950/full. Accessed 28 November 2023.

Conclusions/action items: Implement information into poster, edit if needed.

2023/09/19 Standards and Specifications Research

ANNIKA SYSLACK - Sep 19, 2023, 12:07 PM CDT

Title: Standards and Specifications Research for PDS

Date: 09-19-23

Content by: Annika Syslack

Present: N/A

Goals: Gain in depth knowledge surrounding the safety and specifications that the device must follow in order to be utilized in the client's setting.

Content:

The National Safety Standard IEC 61010-031 Ed. 20 b: 2015 addresses specific safety standards surrounding constructed electrical equipment in order for it to be utilized. This standard will be necessary to follow in order for the device to be properly utilized in a laboratory setting. There is also a similar standard, IEC 61010-2-010 Ed. 4.0 b:2019, which is similar in the safety aspect but is specific for electrical equipment with a heating element. Various hazards that must be kept in mind when constructing the device include chemical burning and shock, excessive temperature, mechanical hazards, etc. Though the device itself should not present with any of these problems, it is important to understand these standards for reference.

Works Cited:

"IEC 61010-2-010 Ed. 4.0 b:2019 - Safety requirements for electrical equipment for measurement, control and laboratory use - Part 2-010: Particular requirements for laboratory equipment for the heating of materials." *ANSI Webstore*, https://webstore.ansi.org/standards/iec/iec61010010ed2019. Accessed 19 September 2023.

"IEC 61010 Overview - Standard for Safety Requirements for Electrical Equipment." *High Tech Design Safety*, 22 January 2020, https://hightechdesignsafety.com/iec-61010-overview-standard-for-safety-requirements-for-electrical-equipment/. Accessed 19 September 2023.

Conclusions/action items: Input research into PDS to share with team.

2023/12/11 Standards and Specifications Research

ANNIKA SYSLACK - Dec 11, 2023, 2:39 PM CST

Title: Further Research for Standards and Specifications for Final Report

Date: 12-11-23

Content by: Annika Syslack

Present: N/A

Goals: Add to and strengthen work surrounding standards and specifications of the final design.

Content:

-The National Electric Code and National Fire Protection Association have standards which provide guidance as to what electrical devices can and cannot do including voltage limitations of 1,200 amps

-Standard 1910.304(f)(2)(iii) states that the conductor, short circuit and protective device, which in this case would be the box, must have similar operating times for ease of use and to prevent damaging of the specified parts

Works Cited

"NFPA 70: National Electrical Code for Industrial Business Owners." *C3 Controls*, https://www.c3controls.com/white-paper/nfpa-70-an-overview/. Accessed 11 December 2023.

"1910.304 - Wiring design and protection. | Occupational Safety and Health Administration." *OSHA*, https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.304. Accessed 11 December 2023.

Conclusions/action items:

Implement synthesized research into final report.

2023/11/16 Circuitry Material Ideas

ANNIKA SYSLACK - Nov 16, 2023, 1:17 PM CST

Title: Design Based on Given Materials

Date: 11-16-2023

Content By: Annika Syslack

Present: N/A

Content:

-obtained various materials from the ECS including two cord, heating element, 2 prong plug and Qwic connec beefcake relay

-based on material type, soldering and heat shirking is best to connect the two cord to the heating element most effectively

-based on given wiring, circuitry shown will be utilized from BME 201 lab:

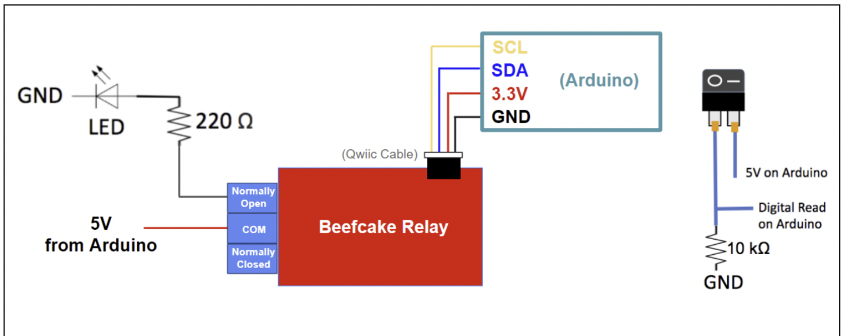


Figure 7: Controlling Beefcake Relay with an Arduino digital read pin

Action Items: Use various materials and instructions to create intended design.

2023/11/17 Fusion 360 Box Design

ANNIKA SYSLACK - Nov 18, 2023, 11:52 AM CST

Title: Outer Box Design

Date: 11-17-2023

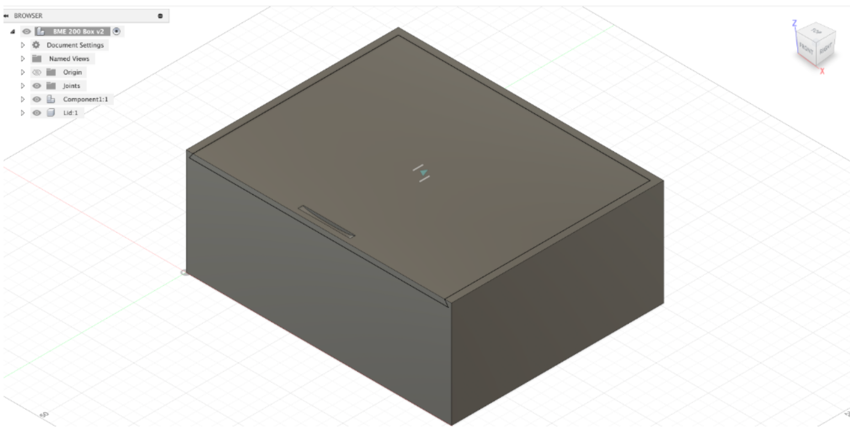
Content by: Annika Syslack

Present: Tayler Carlson

Goals: Create an applicable box to encase the circuit of the design.

Content:

Rectangular box with sliding lid and latch to allow for easy removal. Design is calibrated in order to easily adjust dimensions based on the finalized circuit.



Conclusions/action items: Adjust dimensions as needed, 3D print once correct.

2023/09/19 Preliminary Background Research Relating to the Skin

TAYLER CARLSON - Oct 11, 2023, 11:28 AM CDT

Title: Preliminary Background Research Relating to the Skin

Date: 9/19/23

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: Through background research, I am hoping to gain a better understanding of the layers of skin and how they influence metabolic processes. Additionally, I am planning to take a surface-level look at a competing product in order to gain a better understanding of how we might be able to improve and/or change it to better fit the client's needs.

Content:

Evaporative Cooling provides a Major Metabolic Energy Sink [1]

-talks about food calories as heat plays a large role in metabolic energy exhibited as obesity

-believe that stored in adipose tissue shows positive health improvements

---> What is thermogenesis? ---> process of heat production

-heat transfer/heat loss can happen through water loss

-mouse skin has good heat retention --> can add liquid lamellae(thin layer of tissue)

-evaporative cooling leads to increased demand for thermogenesis

----> What does energy sink mean? --> energy comes and goes

- based on graphs seems as though lipid layers and fur play a role in insulation properties

Source:

[1] I. Kasza et al., “Evaporative cooling provides a major metabolic energy sink,” Molecular metabolism, https://www.ncbi.nlm.nih.gov/pubmed/31302039 (accessed Sep. 19, 2023).

Thermtest Instruments- MP-V [2]

-accurate measurements for thermal conductivity, thermal diffusivity, specific heat, and thermal efficiency of solids, liquids, pastes, and powders

-record after an increase in temperature occurs and then diffused based on thermal transport properties

-uses many different sensors

Source: [2] "MP-V - Transient Plane Source - Modified Transient Plane Source,” *Thermtest*. https://thermtest.com/tps-2 (accessed Sept. 19, 2023).

Conclusions/action items: It is important to understand how the skin works because our device should be able to make it through all layers while eliminating the evaporative cooling which doesn't give the full picture. It would also be interesting to figure out the role that fur plays in insulation, and if that affects the evaporative cooling aspect.

2023/10/10 Biology and Physiology of the Skin- MORE IN DEPTH

TAYLER CARLSON - Oct 11, 2023, 12:34 PM CDT

Title: Biology and Physiology of the Skin

Date: 10/10/2023

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: I am hoping to understand why the skin is the reason for heat transfer. Is it because of the anatomical structures that it possesses or is it because of the proximity to the environment? I am also hoping that looking at the client's published literature will give me a better idea of what is known about the skin.

Content:

- skin plays a role in all things related to heat (retaining or dissipating) [1]

- there are many layers of the skin but our client has narrowed the lamellae and the adipose tissue down to being the main contributors to heat transfer [1]

- rodent skin is extremely adaptive which means that changing the diet, genes, or the environment has an impact on the composition of the skin---> heat transfer [1]

- adipose tissue is a layer of fatty tissue and is responsible for regulating temperature [2]

- lamellae is closer to the skin which means that its main function is to regulate the transfer of heat to the outside world or the internal world [3]

Sources:

[1] I. Kasza *et al.*, “Evaporative cooling provides a major metabolic energy sink,” *Molecular Metabolism*, vol. 27, pp. 47–61, Sep. 2019, doi: https://doi.org/10.1016/j.molmet.2019.06.023.

[2] “New Findings On Mechanisms For Body Temperature Regulation By Fat Tissue - Georgia State University News - University Research - Health & Wellness,” *Georgia State News Hub*, Oct. 05, 2017. https://news.gsu.edu/2017/10/05/new-findings-mechanisms-body-temperature-regulation-fat (accessed Oct. 11, 2023).

[3] A. Coskun and B. Demir, “Comparative analysis of different lamella geometries used in exhaust gas heat exchangers,” *Applied Thermal Engineering*, vol. 100, pp. 1–10, May 2016, doi: https://doi.org/10.1016/j.applthermaleng.2016.02.007.

Conclusions/action items: The skin is the main contributor to regulating heat transfer. The special tissues can be adapted to impact heat transfer positively or negatively. All in all, this device should be able to properly measure the temperature change in order to assess how the changes impact heat transfer.

2023/10/18-Adipose Tissue Growth

TAYLER CARLSON - Oct 18, 2023, 10:35 PM CDT

Title: Adipose Tissue Growth

Date: 10/18/23

Content by: Tayler Carlson

Goals: In learning about adipose tissue, it is possible to continue to understand the problem statement and why rodent skin research can continue to help with future human research.

Content:

-adipose tissue makes up quite a bit of men's and women's body mass

1) men is 10 to 20 percent of their body mass

2) women is 5 to 8 percent of their body mass

-elderly men and women see a different location increase in their adipose tissue---> in this case the adipose tissue decreases in the legs and increases in the central fat

-there is white and brown adipose tissue----> there is a severe increase in brown adipose tissue due to aging in humans but not in rodents

-research is still uncertain as to why rodent skin is so unlikely to succumb to the aging properties that humans do

-metabolic processes are greatly influenced by the aging properties of the skin

----> which is why it makes sense that rodents are unaffected by aging properties maintaining their skin adaptability whereas people succumb to adipose increase through aging creating a difference in metabolic processes

Source: X. Wang, M. Xu, and Y. Li, “Adipose Tissue Aging and Metabolic Disorder, and the Impact of Nutritional Interventions,” *Nutrients*, vol. 14, no. 15, p. 3134, Jul. 2022, doi: https://doi.org/10.3390/nu14153134.

Conclusions/action items: In conclusion, if adipose tissue could be changed as age increases, it may be possible that metabolic processes would be able to maintain healthy processes.

2023/10/11 Need for Biomedical Device

TAYLER CARLSON - Oct 11, 2023, 11:48 AM CDT

Title: Need for this Biomedical Device

Date: 10/10/2023

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: Through research, the overarching motivation for this project will become known. What type of issue is it targeting and how many people could be affected by a positive outcome?

Content:

- the main focus of this research deals with how effecting certain aspects of a rodent's living conditions can impact the adaptability of the skin [1]

---> This includes changing genes, environment, or diet which in turn affect the metabolic rates at which skin transfers heat [1]

- most rodents are susceptible to tumor prevention [1]

- with that being said, the obesity epidemic in humans has become more prominent and scary in recent years [2]

- more than one billion people are affected by the obesity crisis [2]

- of those one billion, four million are likely to die per year [2]

-it might be possible that skin adaptability in humans could lead to a decrease in the obesity crisis [2]

Sources:

[1] “Caroline Alexander,” *McArdle Laboratory for Cancer Research*. https://mcardle.wisc.edu/faculty/caroline-alexander/ (accessed Oct. 11, 2023).

[2] E. Laurence, “Obesity Statistics,” *Forbes Health*, Jan. 17, 2023. https://www.forbes.com/health/body/obesity-statistics/#:~:text=According%20to%20the%202022%20State (accessed Oct. 11, 2023).

Conclusions/action items: The effects of this device could be incredibly large. Although the research right now pertains to rodents, it is possible that the long term goal would be research on human skin and its adaptable characteristics. If human skin could be conditioned and modified it is possible that overall human health would be helped.

2023/10/05 Client Information

TAYLER CARLSON - Oct 11, 2023, 12:34 PM CDT

Title: Client Information

Date: 10/05/2023

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: To gain more information about the client in order to understand where the purpose of this biomedical device is coming from.

Content:

-specializes in oncology

-works in developmental therapeutics

- works at the UW Carbone Cancer Center

- most of the focus is on tumor prevention

- metabolism is a game changer when it comes to skin adaptiveness, especially in rodents

Sources:

[1] "Caroline Alexander," *McArdle Laboratory for Cancer Research*. https://mcardle.wisc.edu/faculty/caroline-alexander/ (accessed Oct. 11, 2023).

Conclusions/action items: Our client is a well-established researcher in oncology. Her passion is for tumor prevention. This at least hits home for me because my dad had melanoma which is skin cancer. Her research with rodents could eventually translate into human skin adaptive qualities.

2023/11/09- Thermal Energy Transfer Equation Research

TAYLER CARLSON - Nov 09, 2023, 3:56 PM CST

Title: Thermal Energy Transfer Equation Research

Date: 11/10/2023

Content by: Tayler Carlson

Goals: I am trying to understand the components of the thermal transfer heat equation. This will hopefully allow me to know what parts we are working against.

Content:

-thermal energy: energy that is in heat

---> cold temperatures do still have thermal energy, but they lack thermal energy

- thermal energy contains kinetic energy

- conduction: transfer of kinetic energy

- radiation is another form of heat transfer

- thermal equation = mass x specific heat transfer x change in temperature

- not sure how the specific heat would work in this case!!!

Source: *Study.com*, 2022. https://study.com/learn/lesson/thermal-energy-equation-examples.html#:~:text=Change%20in%20thermal%20energy%20is

Conclusions/action items: I think that we will be able to graph the thermal energy equation as long as we figure out the specific heat that should be used. I am going to continue to do research on specific heat in order to better understand how we can calculate that.

2023/11/09-Specific Heat Research

TAYLER CARLSON - Nov 09, 2023, 4:40 PM CST

Title: Specific Heat Research

Date: 11/9/23

Content by: Tayler Carlson

Goals: Trying to figure out more about specific heat in order to learn how it plays a role in the thermal equation. It is key in understanding thermal heat transfer? Will we be able to calculate by just knowing three variables?

Content:

- amount of energy to increase temperature one centigrade per 1 gram

- specific heat = thermal energy/(mass times temperature)

- units: calories or joules per gram

- specific heat for a human is 3.47 kJ/(kg x degrees celsius)

- the specific heat for humans can also different depending on the tissues that are associated with the areas measured

-with that being said, the ability to stabilize body temperature does create the possibility of even specific heat depending on size of the organism

----> does this translate to mouse skin????

Source: X. Xu, T. P. Rioux, and M. P. Castellani, “The specific heat of the human body is lower than previously believed: The Journal *Temperature* toolbox,” *Temperature*, pp. 1–5, Jul. 2022, doi: https://doi.org/10.1080/23328940.2022.2088034.

Conclusions/action items: In conclusion, it is definitely possible to find the specific heat of mouse skin. I think a good place to start would be to ask the client or go through her research in order to find this minute yet important detail. Especially if we are going to continue with this idea.

2023/11/16- Client Meeting Prep Questions

TAYLER CARLSON - Nov 16, 2023, 4:49 PM CST

Title: Client Meeting Prep Questions

Date: 11/16/23

Content by: Tayler Carlson

Goals: I am trying to come up with a list of questions based on possible testing protocols that we will run past the client.

Content:

1) Is it possible for the specific heat of mouse skin to be similar to the specific heat of human skin?

2) Will we have access to possible lab employees when it comes to testing?

3) Would we be able to have access to a lab space similar to one she will be working with in order to make sure our product works for her?

4) Do you know what the specific heat of the Tegaderm is?

Conclusions/action items: Based on the previous client meetings it seems that the client is very willing to lend us whatever we might need for testing. She also made it seem as though she would allow us into her laboratory if needed.

2023/09/20 Specifics for Product Design Shelf Life

TAYLER CARLSON - Oct 11, 2023, 12:33 PM CDT

Title: Specifics for Product Design

Date: 9/19/23

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: Through research, shelf life of the materials we will use should be found. Shelf life is important because it will be able to help in choosing which materials should be purchased for the creation of this device.

Content:

Shelf life:

Copper: [2] [3]

-corrosion resistant

-tough metal as it has a high melting point

-highly ductile so easy to mold into different shapes and sizes

-seems that a sheet of copper has an indefinite lifespan due to the fact that it can endure minimal heat increase without losing its shape

Heating element: [1]

-seems that most heating elements have a lifespan of about 10 years

--> due to resistive properties on the plate and corrosion protected electronics

Plastic/Resin: [1]

-most have a shelf life of about 3 years

---> after this though it is possible that corrosion may occur

Sources:

[1] “Shelf Life & Storage,” *PRO-SET Epoxies*. https://www.prosetepoxy.com/home/shelf-life-storage/#:~:text=Epoxy%20resin%20and%20hardener%20formulations (accessed Sept. 20, 2023).

[2] “Why Copper Is Good for Heat Transfer - Why Copper Is Good for Heat Transfer - Solar Water Heater,” *www.solarmate.com.my*. https://www.solarmate.com.my/blog/2021/why-copper-good-for-heat-transfer#:~:text=Have%20you%20ever%20wondered%20why (accessed Sept. 20, 2023).

[3] “Copper Sheet, #30 Gauge, 12" x 12",” *www.flinnsci.com*. https://www.flinnsci.com/copper-sheet-30-gauge-12-x-12/c0080/ (accessed Sept. 20, 2023).

Conclusions/action items: This type of research serves to give a better idea of the relative shelf life of the products we are planning to use. Based on the research done about the materials being considered, it is clear that there are no shelf life limitations as most of these materials have long shelf lives.

2023/09/20-Specifics for Product Design Ergonomics

TAYLER CARLSON - Oct 11, 2023, 12:32 PM CDT

Title: Specifics for Product Design - Erogonomics

Date: 09/20/2023

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: To get a better understanding of the working environment our device will be a part of. Important to research the dimensions of the average work environment in order to get a better idea of the constrictions that may occur.

Content:

Ergonomics: [1]

- there are many different sizes of laboratory workbenches as the difference in laboratory space varies dramatically from one space to the next.

---> most range from 24-36 inches broad, 30-120 inches deep, and 30-36 inches tall

- the device we are creating should be able to comfortably fit within even the smallest workbench which would be about 24 x 30 x 30 inches

-it is important to note that this device will need to be operated with care so as not to destroy the skin sample which is why it might be important to advise them to insert the skin sample onto the plate at a comfortable height

-due to the heating element it will be important for this laboratory work bench to be near an outlet as to be able to plug it in

Sources:

[1] “What Are The Right Dimensions For Your Laboratory Bench?,” *https://www.labtechsupplyco.com/*. https://www.labtechsupplyco.com/how-to-measure-the-right-laboratory-bench-dimensions-for-your-needs/#:~:text=Laboratory%20Workbenches&text=The%20majority%20of%20workbenches%20are (accessed Sep. 20, 2023).

Conclusions/action items: The device should be small enough to fit within the specified area. It should also be able to allow for little necessary adjusting of the work environment. Based on the average size of workspace, the device should easily fit within it.

2023/09/20-Specifics for Product Design Size

TAYLER CARLSON - Oct 11, 2023, 12:30 PM CDT

Title: Specifics for Product Design- Size

Date: 9/20/2023

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: To get a general idea of the size of the components we will be using: hot plate and possible metal sheets. Make sure that these materials can be cost-efficient as well.

Content:

Size:

-the type of hot plate needs to accommodate a skin sample of about 2x4 cm material on the plate which means a smaller plate with smaller dimensions would probably be easier to use

-overall hotplate dimensions including the controls range from 20.8 x 36 x 10 cm (moderate) to 28.8 x 43.8 x 20 cm (large) [1]

--->small, cost-efficient heating plates can range from 14x14x5 cm [1]

-copper sheets come in sizes of about 15x23x0.5 cm [2]

Sources:

[1] “Thermo Scientific Hotplates and Stirrers Benchtop equipment for every lab, every day.” Accessed: Sep. 20, 2023. [Online]. Available: https://assets.thermofisher.com/TFS-Assets/CMD/brochures/ELED%20Hotplates%20and%20Stirrers_Final%200919.pdf

[2] “Amazon.com: Eowpower 2 Pieces 99.9% Pure Copper Sheet Metal Plate, 6" x 6" x 18 Gauge(1mm) Thickness, No Scratches for DIY Projects : Industrial & Scientific,” *www.amazon.com*. https://www.amazon.com/Eowpower-Pieces-Thickness-Scratches-Projects/dp/B0B1TM5Y87?th=1 (accessed Sep. 20, 2023).

Conclusions/action items: The size of the components looked at seem to fit within the average work environment that I researched before. It also seems that there are many different sizes of these components available which is good because it allows for the materials purchased to flexible.

2023/09/20-Specifics for Product Design Weight

TAYLER CARLSON - Oct 11, 2023, 12:29 PM CD

Title: Specifics for Product Design - Weight

Date: 9/20/23

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: Figure out if there are any weight limits so that they can be properly followed. Also, make sure that materials planning to use will properly fit in the weight limit if there is one of them.

Content:

Weight:

- most sheets of copper weigh an average of 4 ounces per sheet [1]

- the heating element which is going to be the biggest weight of this project weighs about 21 ounces [2]

-the design should be rather light which means that we wouldn't want it to exceed 16 kg for females and 25 kg for males as they would be carrying the device close to their bodies at chest heig according to the legal limit [2]

Sources:

[1] “Copper Sheet, #30 Gauge, 12" x 12",” *www.flinnsci.com*. https://www.flinnsci.com/copper-sheet-30-gauge-12-x-12/c0080/ (accessed Sept. 20, 2023).

[2] “Multifunctional Electric Heating Plate for Melting Wax,Candle Making and Mor (white).” https://www.amazon.com/Multifunctional-Electric-Heating-Melting-More%EF%BC%88white/dp/B0C69CBGRQ/ref=asc_df_B0C69CBGRQ/?tag=hyprod-20&linkCode=df0&hvadid=663284298854&hvpos=&hvnetw=g&hvrand=9493848766634448232&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9018948&hvtargid=p 2216265748764&gclid=CjwKCAjwjaWoBhAmEiwAXz8DBZJUUdaTMpzjLghqmsJrr-ZKnK6dFfnoMqwNPpkU-NYaisQ0HgT7IxoCKW8QAvD_BwE&th=1 (accessed Sep. 20, 2023).

Conclusions/action items: The proper guidelines for weight need to be followed when we are creating our device. Right now though, it seems as though that should not be a problem.

2023/11/02- Breadboard Research

TAYLER CARLSON - Nov 02, 2023, 4:41 PM CDT

Title: Breadboard Research

Date: 11/02/20

Content by: Tayler Carlson

Goals: I am planning to do research on how a breadboard works in order to better understand the electrical components of our design.

Content:

- a breadboard makes connects electrical components

- the breadboards are divided into outer sections (2) and inner sections

---> based on the connections it is possible the different sections

- breadboards don't come with their own power supplies which means you have to come up with something that powers it

---> this could include an Arduino which in our case is something we are going to use

- there is normally an anode and cathode connection at some point Getting Started

Source: amandaghassaeiuh-man-duh-guss-eye-dot-comFollowMore, “Breadboard How To,” *Instructables*. https://www.instructables.com/Breadboard-How-To/ (accessed Nov. 02, 2023).

Conclusions/action items: Although I am not entirely familiar with the electrical elements we are using, I am hoping that my research and the learning process will better get me acquainted with these things. One of the questions I do have and will continue to do more research on is an Arduino. Based on the image above, it seems as though it may be connected to a computer but I am wondering if this can be done through wall power instead.

2023/12/06- Overall Design Specification Sketch

TAYLER CARLSON - Dec 06, 2023, 11:47 AM CST

Title: Overall Design Specification Sketch

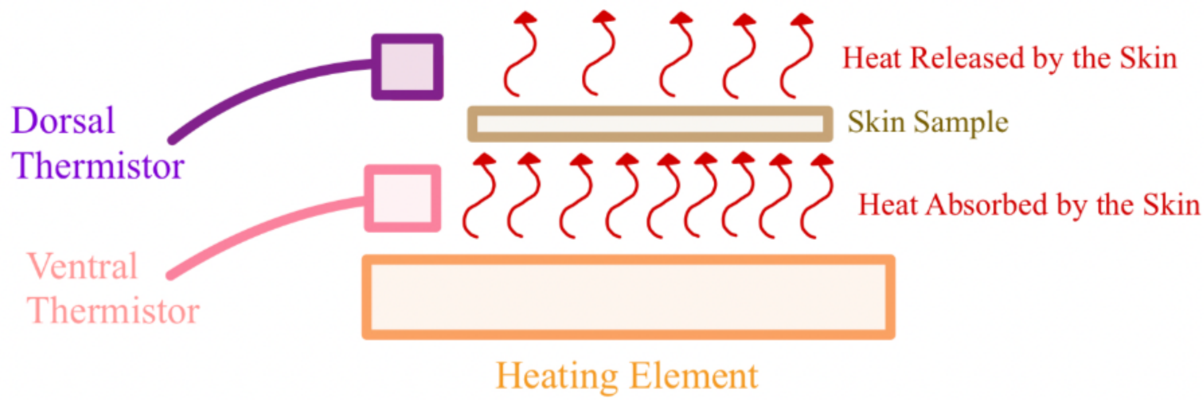
Date: 12/6/2023

Content by: Tayler Carlson

Present: Caelen Nickel

Goals: The goal of this sketch was to make it easy for the person looking at it to comprehend what our project was in a nutshell.

Content: Although it may appear to be relatively simple, it was important that we capture the essence of the project in something that was appealing and simple. This sketch does depict how the thermistors will be placed in relation to our skin sample; it should allow for the easy explanation during the poster presentation.



Conclusions/action items: In conclusion, this sketch will allow for easy talking points during the presentation. It also properly depicts the set up of project in an easy to understand way.

2023/12/12-Ethical Consideration Research-Animal Testing

TAYLER CARLSON - Dec 13, 2023, 7:49 PM CST

Title: Ethical Considerations

Date: 12/12/2023

Content by: Tayler Carlson

Present: None

Goals: Through this research, I will be able to learn more about the ethical concerns of animal testing that could be associated with this project. I am hoping by the end that I will be able to tie these ethical concerns into how our device needs to handle them.

Content:

Source: M. Ghasemi and A. R. Dehpour, “Ethical considerations in animal studies,” *Journal of medical ethics and history of medicine*, vol. 2, p. 12, 2009, Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3714121/

- the guidelines listed come from "Guidelines for Ethical Conduct in the Care and Use of Animals provided by the American Association of Psychologists"

- there was the increased popularity of animal testing due to the publication of the "Origin of Species"

- there needs to be a clear, clarifying statement of the scientific purpose

---- The purpose of the research must be reasonable and the experimental design should use the minimum number of animals

---There should be someone who oversees the animal's care before they are used for animal testing

- animals before and after surgery should maintain their integrity

Source: A. Fathi Hamouda, “Ethical to using rats in the scientific researches,” *Pharmacy & Pharmacology International Journal*, vol. Volume 6, no. Issue 1, Jan. 2018, doi: https://doi.org/10.15406/ppij.2018.06.00149.

- there is not enough scientific data or ethic respect for any ethical rules

- an Ethics Committee conducted a study that said that 10% of studies involved in animal research only use rats in an ethical way and with interest and noble purpose

- people using rats need to be better at the three R's (Replacement, Reduction, Refinement)

--- This particular article proposes that animals should not be used

--- With that being said, they are proposing that fewer animals be used and how they be used for animal testing be refined to ensure they are being treated respectfully pre and post-mortum

Source: National Library of Medicine, “Regulation of Animal Research,” *Nih.gov*, 2004. https://www.ncbi.nlm.nih.gov/books/NBK24650/

- the Animal Welfare Act was passed in order to gain more humane animal practices

- what was interesting about this act was the fact that it excluded most of the common animals used in testing (rats, mice, and birds) but these species are protected in the Public Health Service Policy

1. justification for animal use and how many will be used

2. the procedures and drugs that eliminate pain if they are put down

3. alternative methods instead of animal testing

4. make sure that this research isn't duplicated

Conclusions/action items: All in all, it is important to maintain integrity when it comes to the animals that people are working with whether they are alive or dead. It is also important that whatever is gained from these animals is treated respectfully. Due to the heating of the device, the skin must be placed securely without being torn from any part of our device in order to treat the animal involved in the testing respectfully.

2023/09/28 Size Requirements for Temp Sensors

TAYLER CARLSON - Oct 11, 2023, 12:28 PM CDT

Title: Size Requirements for Temp Sensors

Date: 2023/28/09

Content by: Tayler Carlson

Present: Tayler Carlson

Goals: I am working on figuring out the size requirements for our project to make it fit within the design matrix's criteria. The measurements for the temperature probes need to be small enough to fit on the very tiny skin sample. The heating element also needs to be small enough to fit underneath the heating plate which must also fit the skin sample.

Content:

Thermistor Temperature Sensor: [1]

-Bead Thermistors: the size of the probe 0.075 mm to 5 mm, in diameter made of certain metals, fragile

-Disk and Chip Thermistors: the size of the probe 0.25 mm to 25 mm in diameter, takes a little bit more to raise the temperature

-Glass Thermistor: the size of the probe 0.4 mm to 10 mm in diameter, very stable design

Source:

[1] “NTC thermistor | Resistor types | Resistor Guide,” *eepower.com*. https://eepower.com/resistor-guide/resistor-types/ntc-thermistor/# (accessed Sep. 28, 2023).

Thermocouple Temperature Sensor: [2]

-The sensors can change in sizes from 2mm to 6 mm in diameter

-There are many different types of conductors that come with these distinct diameters

---> Examples include solid and stranded conductors with different gage sizes

Source:

[2] “Metric Size Tube & Wire General Purpose Thermocouple - Thermocouple-Online.com,” *thermocouple-online.com*. https://thermocouple-online.com/thermocouple-C4.html (accessed Sep. 28, 2023).

Thermopile Temperature Sensor: [3]

-There are many different sensors that can be created for this type of sensor

-Most smaller chips have a surface area of 0.6x0.6 mm^2

----> The bigger chips can be as large as 2.1x2.1 mm^2

Source:

[3] “Thermopile Infrared Sensor Overview | Heimann Sensor,” *www.heimannsensor.com*. https://www.heimannsensor.com/thermopile-infrared-sensors#:~:text=Thermopile%20Sensors (accessed Sep. 28, 2023).

Conclusions/action items: All of these sensors fit the guidelines that were previously discussed by the design matrix. With that being said, it seems as though the thermistor was better than the competitors. It seems as though it has more options for sensors; all of the sensor options are small enough that they could easily be used for the the skin sample we would be using.

2023/10/18-Thermocouple Design Information

TAYLER CARLSON - Oct 18, 2023, 1:03 PM CDT

Title: Thermocouple Design Information

Date: 10/18/23

Content by: Tayler Carlson

Goals: I am going to try to learn more about thermocouple sensors and their role in appliances in hopes of figuring out a way to model them for our use.

Content:

-thermocouples can be found in lots of different kitchen appliances

-temperature sensor that has two metal wires that create voltage that mimics temperature difference

-it is connected to a hot and cold junction with two dissimilar pieces of wire

-there seem to be seven different kinds of thermocouples (K, J, T, B, E, N, R)

---> In our case, it seems that a T type of thermocouple would be the best due to the fact that involves copper wire and it measures a smaller range of temperature pulses (-200 Celsius to 300 Celsius)

-Most thermocouples are very safe and easy to replace if necessary

---> Most thermocouples last between one to five years

Sources: "A Comprehensive Guide to Thermocouples: Types, Uses & Installation," *partsfe.com*, Oct. 05, 2023. https://partsfe.com/blog/post/installation-and-cleaning-of-garland-thermocouple#:~:text=It%20serves%20to%20detect%20the (accessed Oct. 18, 2023).

Conclusions/Action Items: In conclusion, it seems that a thermocouple is a decent choice. Would be decently easy to implement but the larger temperature range means that it is a lot less accurate.

2023/10/18-Thermistor Design Information

TAYLER CARLSON - Oct 18, 2023, 10:12 PM CDT

Title: Thermistor Design Information

Date: 10/18/23

Content by: Tayler Carlson

Goals: I am trying to learn more about the thermistor in order to be able to incorporate it into our design. By learning the pros and the cons, I am hoping to better understand the thermistor temperature sensor.

Content:

- thermistors overall seem like some of the best options:

1) temperature-sensitive

2) accurate

3) cheap

---> they work the best over a small range which works perfectly for our design due to the fact that the temperature will pulse within a range of five degrees celcius

-they are smaller than a lot of other temperature sensors which makes it good match for the size of the skin sample

-one main place that temperature sensors are used is in healthcare and patient monitoring which is perfect for the specifications of our design

Source: “The Advantages of Thermistors,” *Variohm.com*, 2019. https://www.variohm.com/news-media/technical-blog-archive/the-advantages-of-thermistors

Conclusions/action items: This source has made it abundantly clear that the thermistor design is better suited for the specification of our project due to the fact that it covers a small temperature range and is extremely accurate due to that fact.

2023/10/26-Rough Design Sketches

TAYLER CARLSON - Oct 26, 2023, 1:59 PM CDT

Title: Rough Design Sketches

Date: 10/28/23

Content by: Tayler Carlson

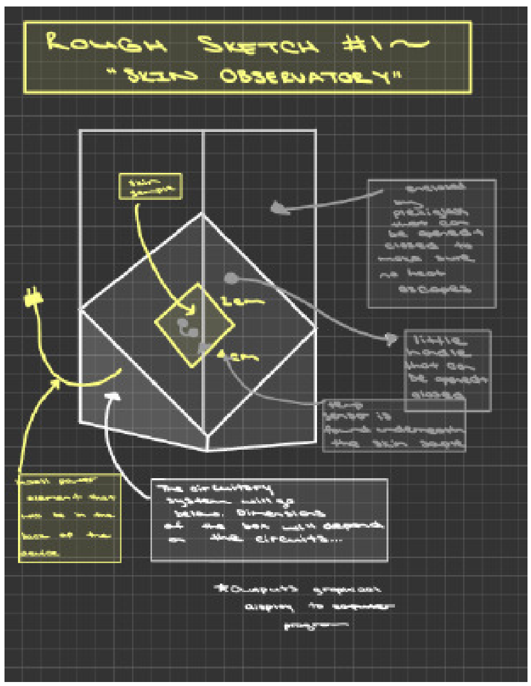
Goals: I am planning to make two sketches of what I believe our final design may look like as we continue into our prototype journey.

Content:

See below. I included the file to my three possible design sketches.

Conclusions/action items: I found that the hardest part was incorporating the temperature sensor. I am going to do further research about the easiest way to incorporate the temperature sensor manually.

TAYLER CARLSON - Oct 26, 2023, 1:58 PM CDT



Download

Rough_Design_Sketches.pdf (327 kB)

2023/10/26-Self Functioing Temperature Sensor Holders

TAYLER CARLSON - Oct 26, 2023, 2:34 PM CDT

Title: Self Functioning Temperature Sensor Holders

Date: 10/26/23

Content by: Tayler Carlson

Goals: I am hoping to research ways that the temperature sensor could be easily held without a person having to do it. If it is possible to build a temperature sensor holder I feel as though that would be the best option.

Content:

- I have found two different kinds of possible temperature sensor holders I feel would allow for minimal invasion of the heating space and would allow for ease of use.

-The first temperature sensor holder is from Grayline Medical.

--It has a clip that allows it to not only clip on the side but also to the temperature sensor.

-- It is made of steel which would make it a good conductor---> luckily our temperature shouldn't pulse up that high

-- It costs about $123.99 though.

Source: “Thermco Products Stainless Thermometer Holder with Clip - HOLDER, THERMOMETER WITH CLIP, SS, 5 PLACE - ACCTH10001 Each / Each,” *Grayline Medical*. https://www.graylinemedical.com/products/thermco-products-stainless-thermometer-holder-with-clip-holder-thermometer-with-clip-ss-5-place-accth1000?variant=31858182979641 (accessed Oct. 26, 2023).

-The second temperature sensor holder is much more affordable but may be a little more difficult to incorporate with our design.

-- It costs about $8.

-- It is originally used on a grill but it is possible that we cut slits into the top in order to hang this contraption upside down to be able to read the temperature on the skin sample.

Source: "Amazon.com: CAPPEC Universal Meat Grill Thermometer Probe Clip Holder - Works for Ambient Temperature Readings (Set of 4) : Patio, Lawn & Garden," *www.amazon.com*. https://www.amazon.com/CAPPEC-Universal-Grill-Thermometer-Holder/dp/B07CTKPN1R?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&smid=A3FJG8JN63YWQ3&th=1 (accessed Oct. 26, 2023).

Conclusions/action items: I think that the more affordable option would be better just do to the budget. It would also be good to have a little bit of versatility with the clips. I think creating a grill-like option in the top would also allow for the increase of heat to escape through the top and allow for the heat escape to be minimal yet safe.

2023/11/16-Temperature Probe Sketch Ideas

TAYLER CARLSON - Nov 16, 2023, 4:34 PM CST

Title: Temperature Sensor Probe Sketch Ideas

Date: 11/16/2023

Content by: Tayler Carlson

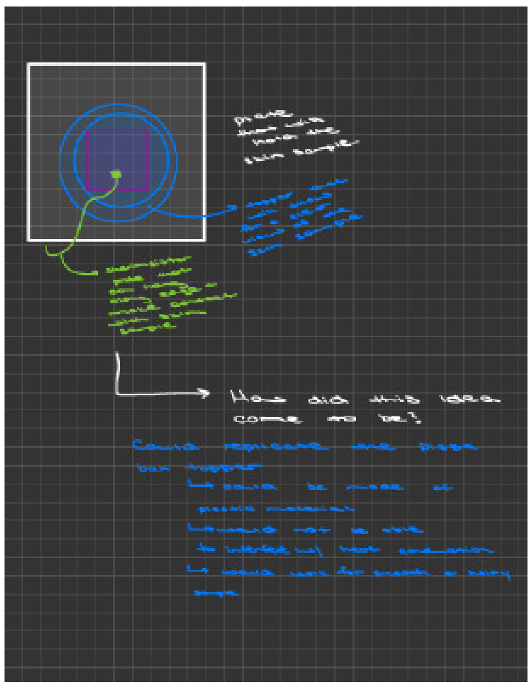
Goals: Begin to formulate a sketch idea of how we are going to allow the temperature sensor to stay on the skin sample without any interference.

Content: See the sketches below.

Conclusions/action items: There is one design choice in particular that sticks out to me because it allows for no intervention in the cooling process. It seems to be the most minimally invasive way to get an accurate temperature reading. The other design choice would work for skin samples with hair but would cause an interference without hair.

TAYLER CARLSON - Nov 16, 2023, 3:52 PM CST

TAYLER CARLSON - Nov 16, 2023, 3:52 PM CST



Download

Rough_Design_Sketches_for_Temp_Sensor.pdf (231 kB)

2023/11/23-Project Box

TAYLER CARLSON - Nov 23, 2023, 5:22 PM CST

Title: Project Box

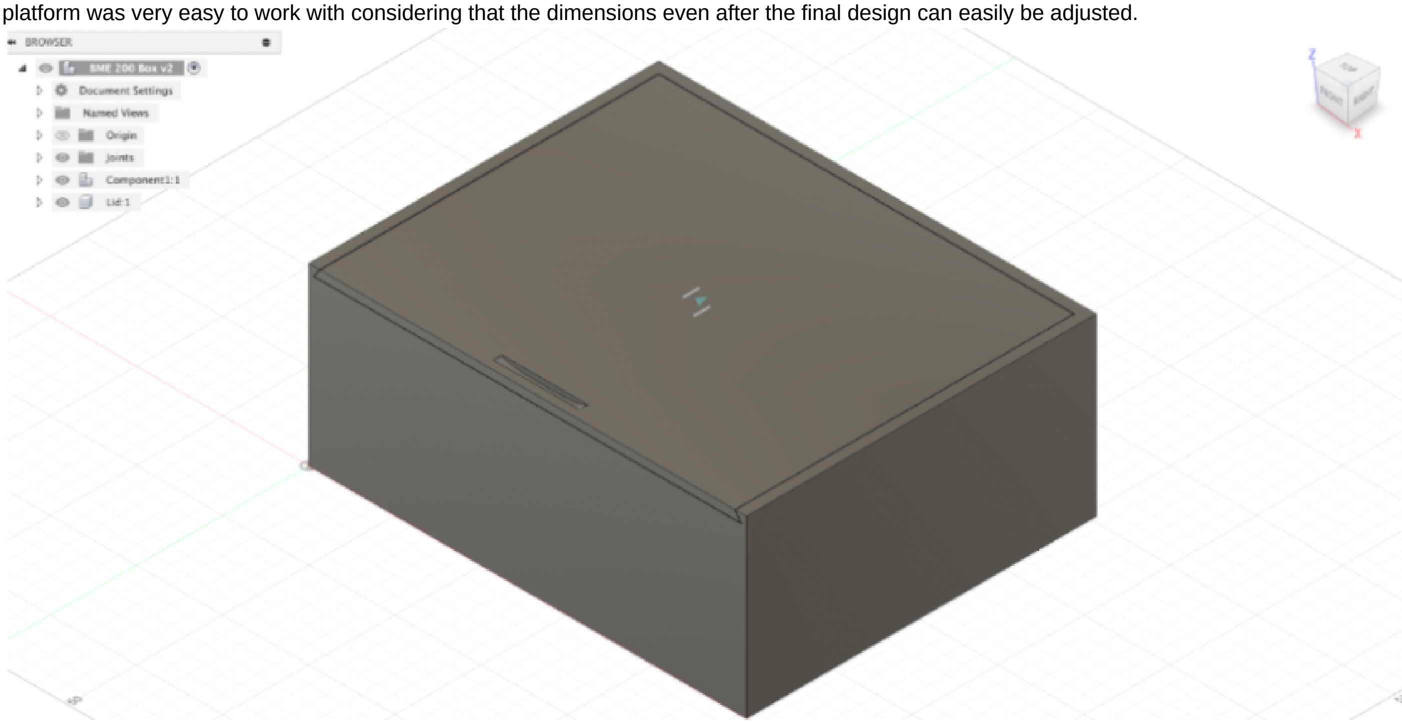
Date: 11/23/23

Content by: Tayler Carlson

Present: Annika Syslack

Goals: We are working on creating a project box that has a slide-shut top. We are planning to 3D print this box because we believe it will be the most cost-efficient way to make a box that will hold the circuits and the wires.

Content: We decided on a dovetail lid because we wanted to be able to slide it open and close without messing with the circuits that will be placed within. The thickness of the box may need to be adjusted if it cannot withstand the drilling. We used a 3D design platform called Fusion360. This platform was very easy to work with considering that the dimensions even after the final design can easily be adjusted.



Sources: Product Design Online, “Sliding Dovetail Lid for 3D Printed Box | Fusion 360 Tutorial,” *www.youtube.com*. https://www.youtube.com/watch?v=HMtLqm5TkGE (accessed Nov. 20, 2023).

Conclusions/action items: We have created a starting prototype for our box. We are not entirely sure if the dimensions will be good enough for the circuits yet as we created the rough outline first. Right now, we are planning on drilling holes through the sides of the box so that the wall power can be plugged in.

2023/11/30- Project Box Sketches

TAYLER CARLSON - Nov 30, 2023, 3:46 PM CST

Title: Project Box Sketches

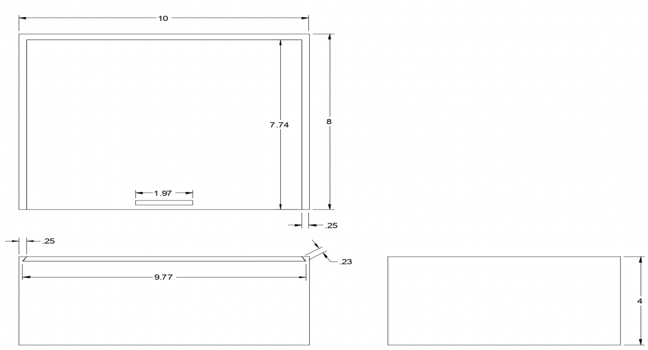
Date: 11/30/23

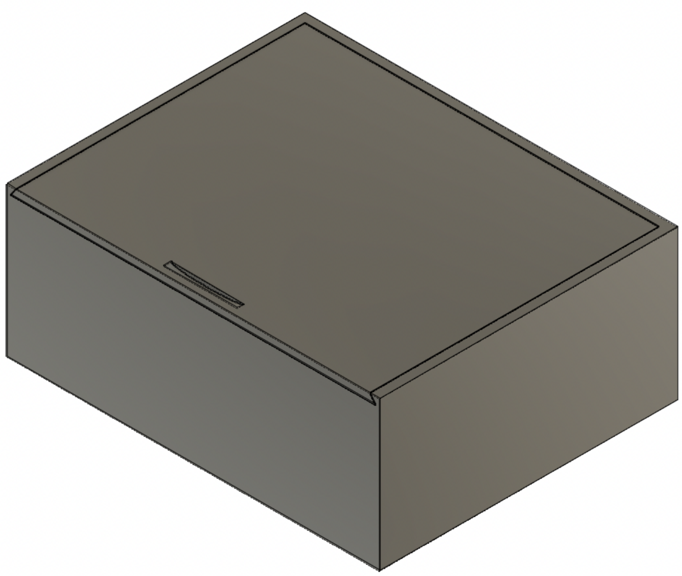
Content by: Tayler Carlson

Present: Annika Syslack

Goals: Try to depict the proper dimensions for the project box.

Content: We had to research how to properly change the dimensions within the Fusion360 program. Once we figured it out, we had to pick which sides of the box we were going to choose to highlight for the poster project.





Source: K. Gilham, “How to Edit a Sketch Dimension in Fusion 360 - Fusion 360 Blog,” *Fusion 360 Blog*, May 19, 2022. https://www.autodesk.com/products/fusion-360/blog/how-to-edit-a-sketch-dimension-in-fusion-360/#:~:text=You%20can%20also%20modify%20dimensions (accessed Nov. 30, 2023).

Conclusions/action items: I am hoping that these designs will be able be good for our poster as they properly showcase the skeletal construction.

Non-Fourier analysis of skin biothermomechanics

CHARLES MAYSACK-LANDRY - Sep 21, 2023, 1:19 AM CDT

Title: Non-Fourier analysis of skin biothermomechanics

Date: 9/20/2023

Content by: Charles Maysack-Landry

Goals: Learn more about skin and measuring temperature of it

Content:

https://www.sciencedirect.com/science/article/abs/pii/S0017931007006552?via%3Dihub

Epidermis, dermis, and subcutaneous are main parts of skin

Skin does many things for the body, a main one being temp control

Extreme thermo environments can be dangerous, but certain medical practices use extreme temps as treatment

This paper is wondering why extreme temps cause pain, what is happening to the human body at these temps and how to protect people in these situations. The last two questions are what our clients wants answered atm

Skin heat transfer is mainly conductive, things like blood, sweat, and hair or fur all play a role

Our client seems interested in mainly metabolic heat generation atm

This paper states that though Fourier's law is generally useful in practical applications it cannot be used to accurately calculate the heat conduction behavior shown in skin due to things like thermal wave phenomenon or hyperbolic heat conduction

This is more specific than what our client told us during our meeting and shows why they need specific temperature data and can't use the basic math we've learned to figure out the heat transfer

Skin tissue has "non-homogeneous inner structure" which has been documented to cause non-Fourier heat transfer in other materials and is being proved to be true of skin

Basically many researchers have hit different organic tissues with microwaves or lasers at different powers and have found odd reactions that aren't explained or modeled by Fourier's law

Some discussion and conflicting research on if tissues are Fourier or not

Rapid heating therapies will rely on a good understanding of thermomechanics in the body and around the area of treatment. A baseline is to know if the body acts as Fourier or not

It seems this paper concludes that non-Fourier models of skin heat transfer should at least be studied more thoroughly.

Conclusions/action items:

This paper gave me a better understanding of what our client is trying to figure out and what problems they have been facing and need help to solve

Thermal management of epidermal electronic devices/skin system considering insensible sweating

CHARLES MAYSACK-LANDRY - Sep 21, 2023, 11:25 AM CDT

Title: Thermal management of epidermal electronic devices/skin system considering insensible sweating

Date: 9/20/2023

Content by: Charles Maysack-Landry

Goals: Study the second paper written about our clients work to learn more recent info about their research

Content:

- epidermal electronic devices are sensors that stick to the skin
    - They have similar mechanical properties to skin, meaning they can stay on during deformation
    - Used in health monitoring
- LEDs and heaters on the EEDs can cause thermal discomfort to the skin if the heat isnt managed correctly
- Pennes bioheat transfer equation assumes Foureir properties of the skin, but accounts for things like blood flow and metabolism, but doesn't account for evaporative cooling
- Sweat can be sensible or insensible
    - Sensible is what i think of as sweat, where insensible evaporates before the skin becomes moist
- Modifying Pennes equation to account for sweating is a difficult process especially while including sensible sweating
- This paper wants to define a model for the temp distribution of skin

Conclusions/action items:

Insensible sweating is an important factor in the heat managment of the skin and must be taken into account by any model or researcher.

CHARLES MAYSACK-LANDRY - Sep 21, 2023, 11:25 AM CDT

Thermtest MP-1

CHARLES MAYSACK-LANDRY - Sep 20, 2023, 3:19 PM CDT

Title: ThermTest MP-1

Date: 9/20/2023

Content by: Charles Maysack-Landry

Goals: Learn more about existing competition for our design

Content:

https://thermtest.com/mp-1

- Can use different sensors for liquid or solid, etc
- Solid sensor is tps(Transient Plane Source)
- Pulses temperature using a small wire to generate heat
- Traditionally uses a two sided design but can measure with only one side
- Double spiral of nickel surrounded by insulation is placed between two piece of the sample material and then the sensor measures thermal conductivity, specific heat and thermal diffusion
- TPS calculator model
- Can measure very small samples. 5mm x 5mm and .01mm thick
- Can test for several minutes and produce up to 600 data points a second
- Accuracy within 3%
- Temperature is changeable
- Multiple test concurrently
- Perfect circle leads to better tps theory?

Conclusions/action items:

This product goes above and beyond what our client needs and is too expensive. The basic theory is useful, however, as we can use the idea of pulse temperature through the skin and not just having a continual flow of heat. I wonder why they usually use two sheets of the sample?

CHARLES MAYSACK-LANDRY - Sep 20, 2023, 3:18 PM CDT

[Download]

Thermtest-MP-1.pdf (5.86 MB)

Total-Range Traceable Thermometer

CHARLES MAYSACK-LANDRY - Sep 20, 2023, 3:

Title: Thermocouple based Competition

Date: 9/20/2023

Content by: Charles Maysack-Landry

Goals: Learn more about possible competition to our design

Content:

https://www.traceable.com/4015-traceable-total-range-thermometer.html#product_tabs_description_tabbed

https://thermocouple-online.com/thermocouple/?gclid=CjwKCAjwsKqoBhBPEiwALrrqiKc_B6giLGpDuo28R3jKywnmtmofuUUFZ1FfIko_OpXtoTgear_0IhoChgAQAvD_BwE

https://webstore.ansi.org/standards/astm/astme230e230m17

https://www.grainger.com/product/3KGN3?gucid=N%3AN%3APS%3APaid%3AGGL%3ACSM-2295%3A4P7A1P%3A20501231&gclid=Cj0KCQjwj7CZBhDHARIsAPPWv3fI0WFEyewtFrlEZVnDo5Au4rdLOpW6xgXgqmvdzUd7qTOvjLpmSlwaAgSmEALw_wcB&gcl

- Setting to indicate when a certain temperature is reached
  - Could use this in our design
- Type-K Beaded probe
- Logs max and min temps
- Useful over range of 40-250 degrees celsius
- Thermocouples are cheap but aren't usually accurate below a degree
- "Type K" or any other type of thermocouple is determined by a standards table
- Chromel and Alumel are used in many thermocouples, especially type K

https://www.omega.com/en-us/resources/k-type-thermocouples#:~:text=A%20Type%20K%20thermocouple%20refers,style%20of%20sensor%20or%20cable.

- Holds a table for general output voltage of thermal couples
- Thermocouples are usually used for fluid temp measurements

Conclusions/action items:

It seems to be more difficult to measure solids than liquids/gases in a way. It doesn't seem to me that thermocouples are going to be very useful. But the ideas from these thermometers, like settings to remember max temp and to look for when a certain temperature is reached maybe useful to implement.

ASTM D7340-07(2018)e1- Standard Practice for Thermal Conductivity of Leather

CHARLES MAYSACK-LANDRY - Nov 09, 2023, 2:25 PM CST

Title: **Standard Practice for Thermal Conductivity of Leather**

Date: 11/9/23

Content by: Charles Maysack-Landry

Goals: Find and research standards that may pertain to our project and design

Content:

Leather is a thicker material than the skin we will be using, but it originates from mammals so standards that pertain to the measurement of its thermal conductivity may be helpful to have. This method involves a constant heat source, which is different than our idea for a pulsing heat source. There are three short metal cylinders with high conductivity such as brass: 70/30 copper/zinc on both sides and separating the sample and heat source, like a double decker sandwich. The difference between the metal cylinders above and below the sample is measured. The top one is kept at a constant temp by the heat source, where the lower side is slowly heating up while being measured. The rate of change of the cylinder is assumed to be the rate of heat transfer through the sample if there is no heat lose. Using the rate of temp change, the dimensions of the cylinders and sample, and accounting for heat lose the thermal conductivity can be calculated. Equations are given in the standard. This method assumes a high thermal resistance as it is meant for shoe material. I expect rat skin to have less resistance, if just due to how thin it is. It was noted in the slandered that if a material typically contains air, it should always me measure under the same pressure. This is useful for testing samples with hair I think.

https://compass.astm.org/document/?contentcode=ASTM%7CD7340-07R18E01%7Cen-US

Conclusions/action items:

This standard doesn't completely pertain to what we are doing but it has some useful information inside.

Thermopiles research

CHARLES MAYSACK-LANDRY - Sep 28, 2023, 1:08 PM CDT

Title: Thermopile Research

Date: 9/28/2023

Content by: Charles Maysack-Landry

Goals: Learn the basics of what a thermopile is and what it does. What are it's strengths and weaknesses

Content:

Electrical4U. "Thermopile: What Are They (and How Do They Work?) | Electrical4U." *Https://Www.electrical4u.com/*, 18 June 2023, www.electrical4u.com/thermopile/. Accessed 28 Sept. 2023.

Thermopiles are many thermocouples in series or sometimes parallel. They use the same thermoelectric effect to generate a voltage when there is a temperate change in two different metal wires, but because there are many thermocouples there is more voltage. The voltage output can be measured and reverse engineered to find what the temperature must be to generate that voltage given prior data on the voltage to temp values of the thermocouples/thermopile. Seebeck coefficient depends on the type and combo in the thermocouples, and the overall proportion between temp and voltage of the thermopile depends on this coefficient and amount of thermocouples pairs. A thermoresistant layer is required to slow heat transfer between the hot and cold parts of the thermopile. If the thermocouples are in parallel then the current increases with more thermocouples instead of the voltage. Thermopile sensors are non-contact.

Conclusions/action items:

The non-contact use of thermopiles would not work to limit the effects of evaporative cooling, which is what our client wants our device to do while measure.

Thermistor Circuit prototype with pulsing LED

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:45 PM CDT

Title: Thermistor Circuit prototype with pulsing LED

Date: 10/19/23

Content by: Charles Maysack-Landry

Goals: Create a working prototype with a tester thermistor and prove pulsing capability of Arduino.

Content:

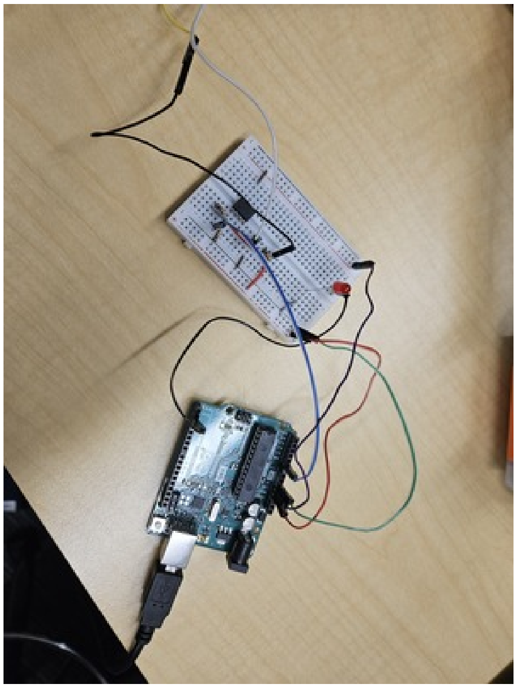
See attachments.

They are pictures of a voltage divider with a resistor and thermistor connected to a non-inverting amplifier circuit with a known gain. The Arduino sends 3.5 volts through both parts of the circuit and that output to an analog pin that will read the incoming voltage. This voltage can than be used to calculate the resistance of the thermistor which can be used to find the temperature. Added an LED in place of the heating element to be pulsed by the Arduino.

Conclusions/action items:

Purchase the final thermistor, measure the actual resistance of each resistor and create equations to determine the temperature measured by the circuit.

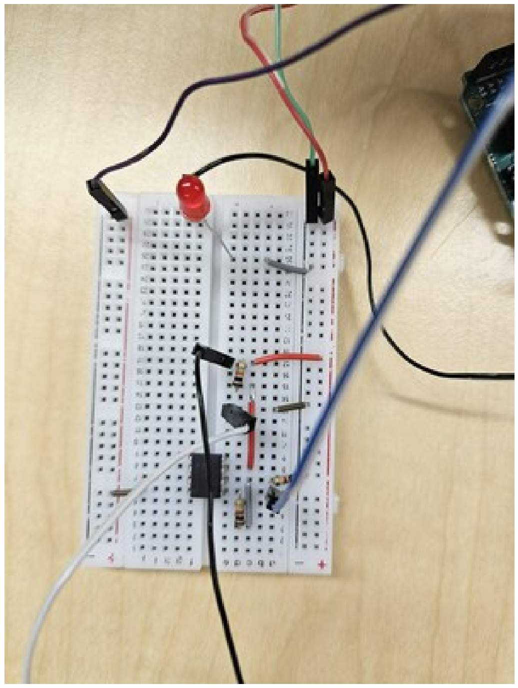
CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:37 PM CDT



Download

FullCircuit.jpg (2.53 MB)

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:38 PM CDT



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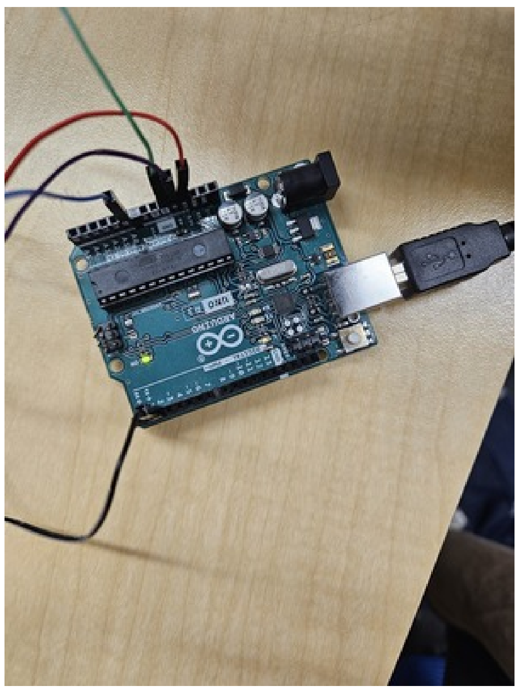
BreadBoard.jpg (1.94 MB)

CHARLES MAYSACK-LANDRY - Oct 19, 2023, 1:38 PM CDT



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ArduinoUno.jpg (3.15 MB)

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: