Team 1817:Electrical plug, connector, and receptacle temperature sensor (Hubbell)

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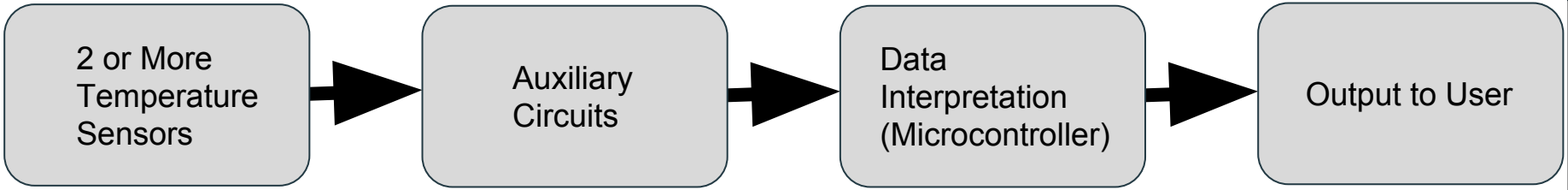
Project Statement

- The Task:
  - Research existing temperature sensing technologies
    - Accuracy
    - Temperature Range
    - Method
    - Problems
  - Look to utilize existing technology in miniaturization/optimization

Specifications/ Constraints

- Temperature sensing system:
  - Two or more sensors
  - **1 inch x 1 inch** component density
  - Temperature range: **-20°C to 80°C**
  - Minimum Accuracy: **±1°C**
  - Onboard Microcontroller for data interpretation
  - Final design cost $6-8

Setup


2 or More Temperature Sensors
Auxiliary Circuits
Data Interpretation (Microcontroller)
Output to User

Design Choices

Based on our research, the two optimal technologies are:

1. Resistance temperature detectors (RTDs)
    a. Requires minimal supplemental circuits
    b. Provides repeatability, stability, and are extremely accurate temperature sensors
2. Infrared devices (IR)
    a. Accurate, fast, and non-contact method of measurement

RTD

- Correlates resistance value to temperature value
- Close proximity/contact

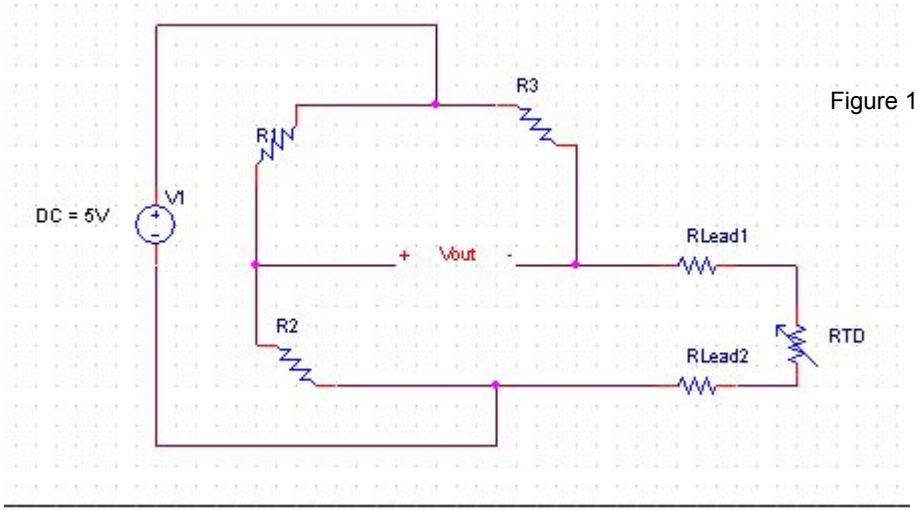


Figure 1: 2-wire RTD auxiliary circuit

Infrared

- **Non-Contact**
- IR Thermopile
  - Produces small voltage based off temperature difference
  - Requires: output voltage amplification and ambient temperature

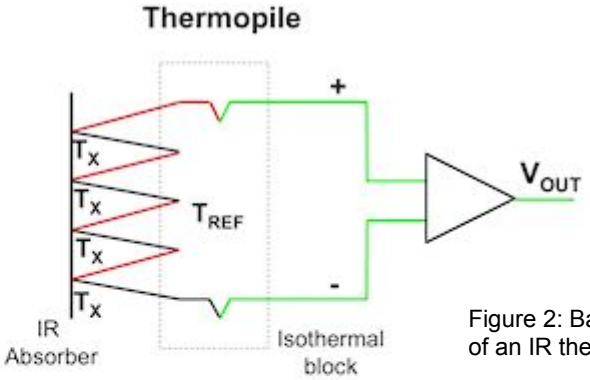
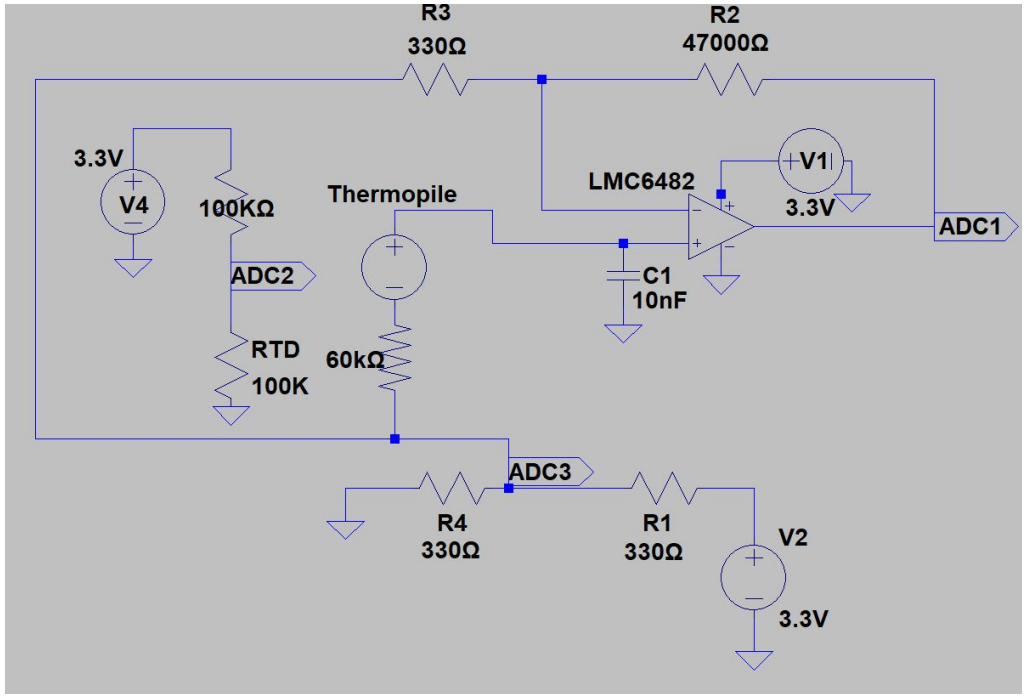


Figure 2: Basic design of an IR thermopile

Figure 3:Amphenol Advanced Sensors ZTP-135SR-Thermopile Sensor

Infrared Circuit Design



- Ztp-135SR
  - Output Voltage Range:-2mV to 11mV
- Amplifier output:

$$V_{Out} = 143.924 * V_{Therm} + V_{Bias}$$

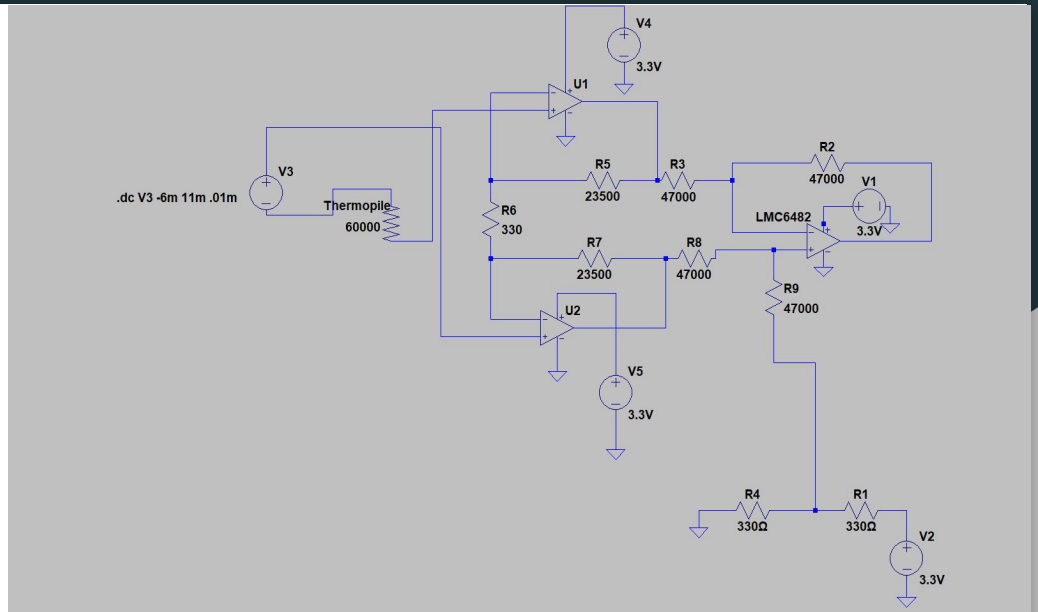
- Calculation for Temperature:

$$T_{Obj} = \sqrt[4]{\frac{V_{Therm}}{K} + T_{Ambient}^4}$$

Figure 4: IR thermopile test circuit

Simulation Testing

Instrumentation Amplifier Setup



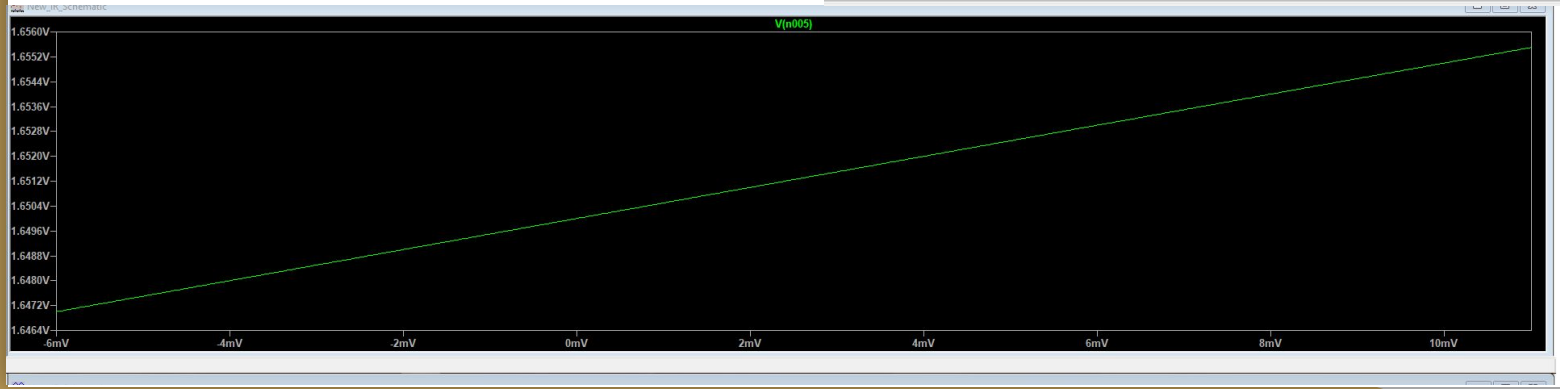


Figure 5: Thermopile Voltage Out

Simulation Results

Instrumentation Amplifier Setup

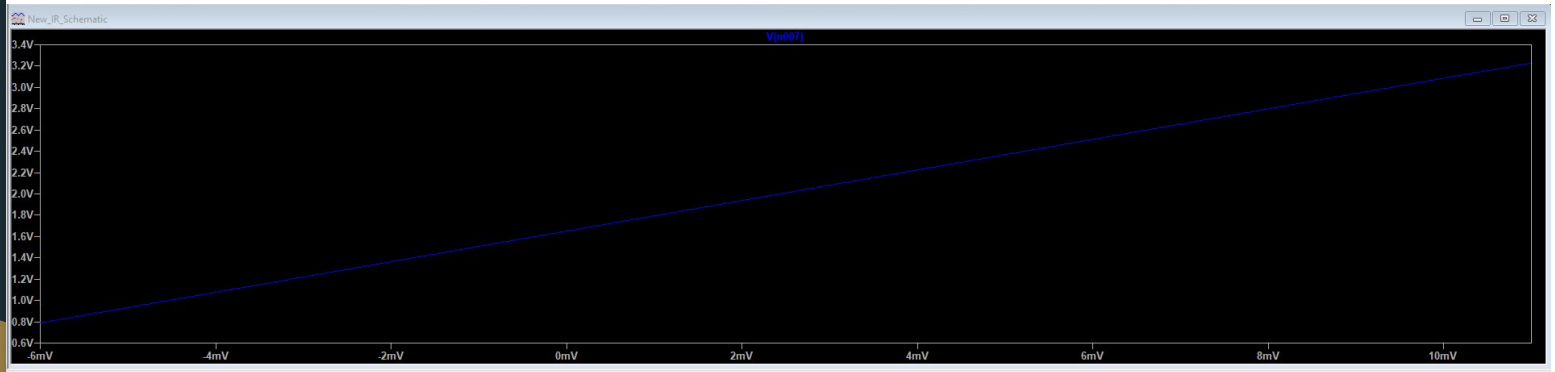
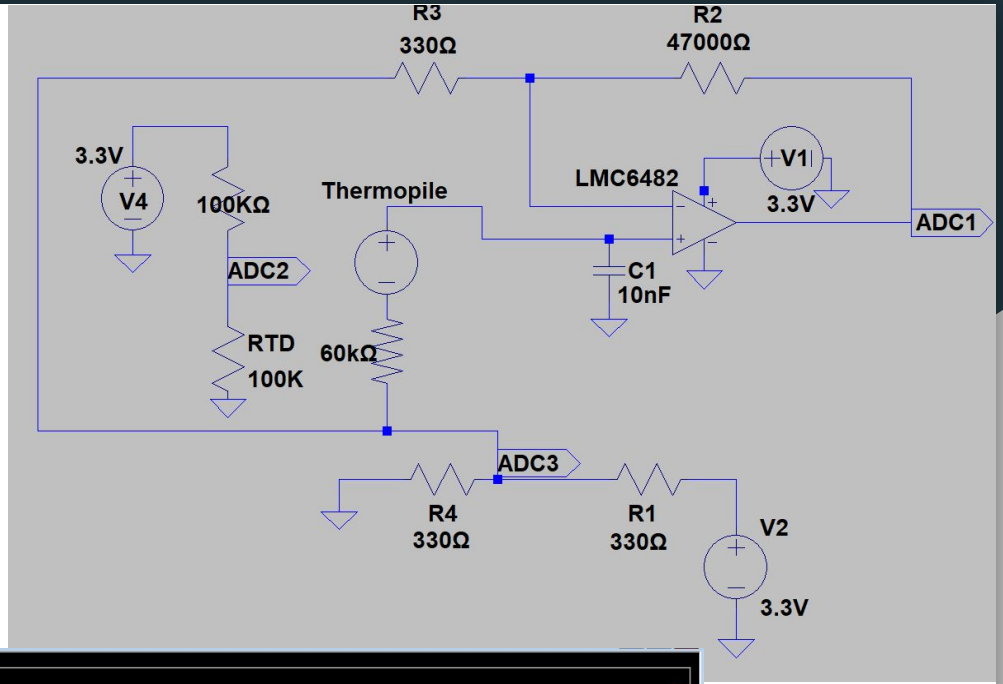


Figure 6: Overall Output Voltage

Figure 7: Reference Voltage

Simulation Testing

Single Amplifier Setup



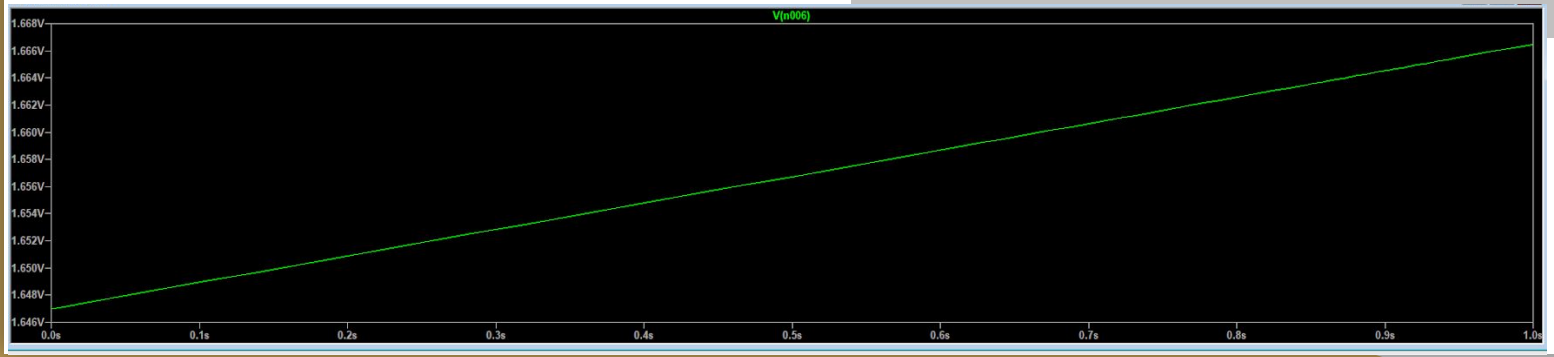


Figure 8: Thermopile node Output Voltage

Simulation Results

Single Amplifier Setup

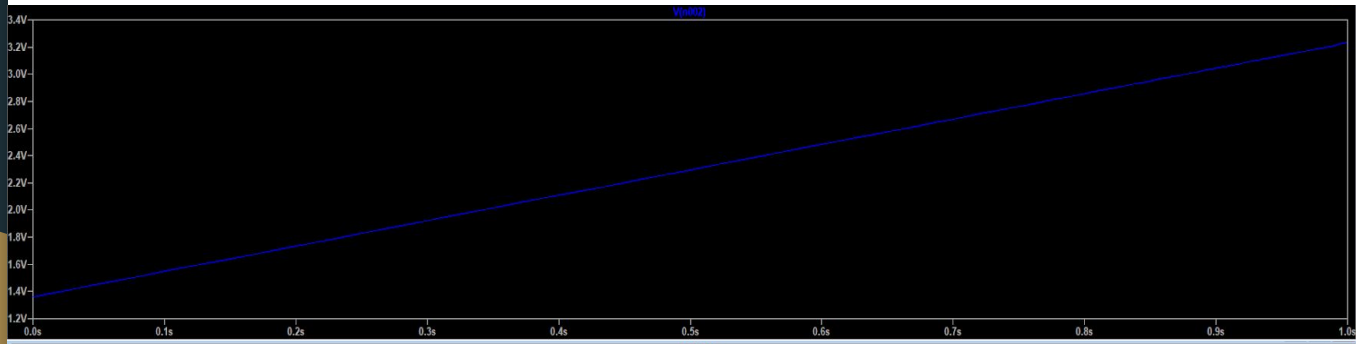


Figure 9: Overall Output Voltage

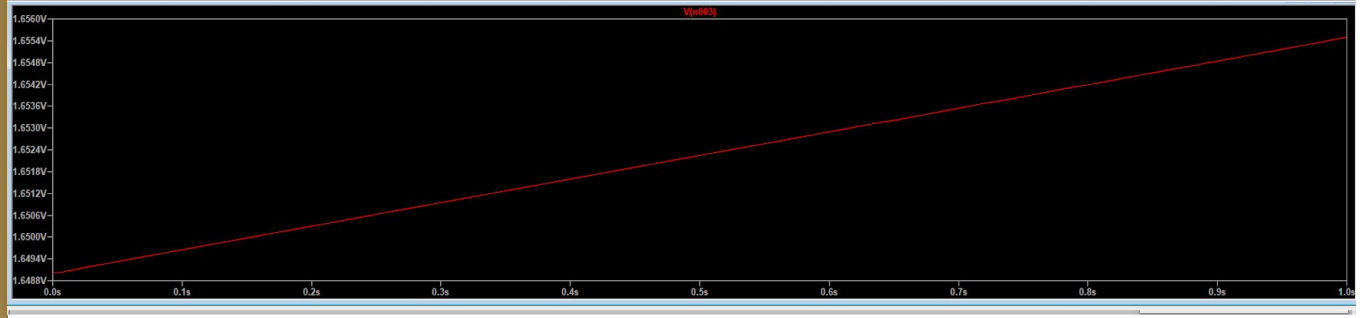
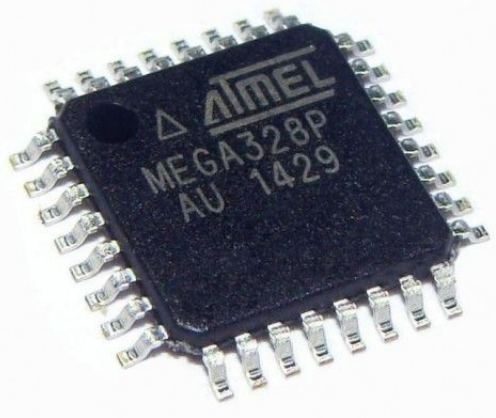


Figure 10: Reference Voltage

Microcontroller

- Requires multiple inputs from sensor array
- Small Size
- Atmega328P
  - **23** General purpose I/O connections
  - Offered on a development board (Testing)
  - Offered as a **standalone chip**
  - Operates within temperature sensing range
  - Onboard 10-bit ADC
  - QFN package

Figure 11: Atmel Atmega328p surface mount package



Testing

- Build auxiliary circuits on a breadboard
  - Compare components in the IR and RTD ranges
  - Different package sizes and manufacturers
  - Compare IR and RTD circuits at the same time
- Compare the temperature measurements of different materials
  - Copper, Brass, Aluminum
  - Range of temperatures from -20°C to 80°C and temperatures outside the range

Testing-Microcontroller

- UART interface
  - Displays as much data as possible
    - Raw input
    - Converted temperatures
  - Multiple sensors handled at once
- Utilize ADC for measurement

Figure 12: IDE used for producing the test code.

Testing Circuits

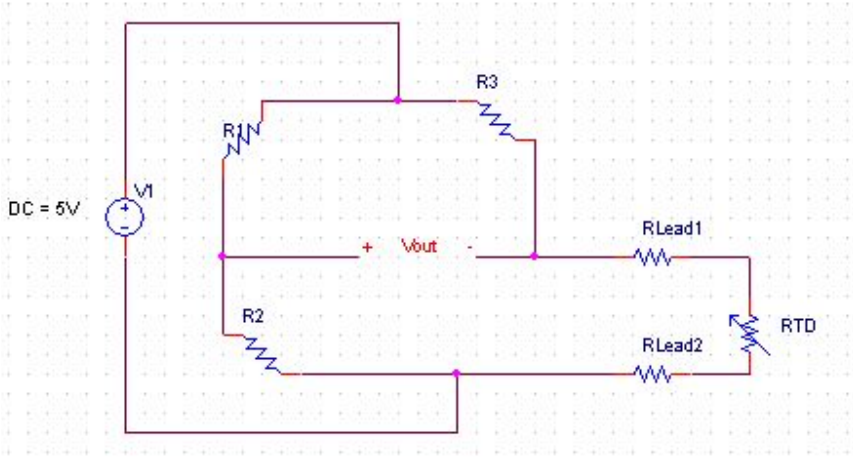


Figure 13:
RTD Circuit Implementation

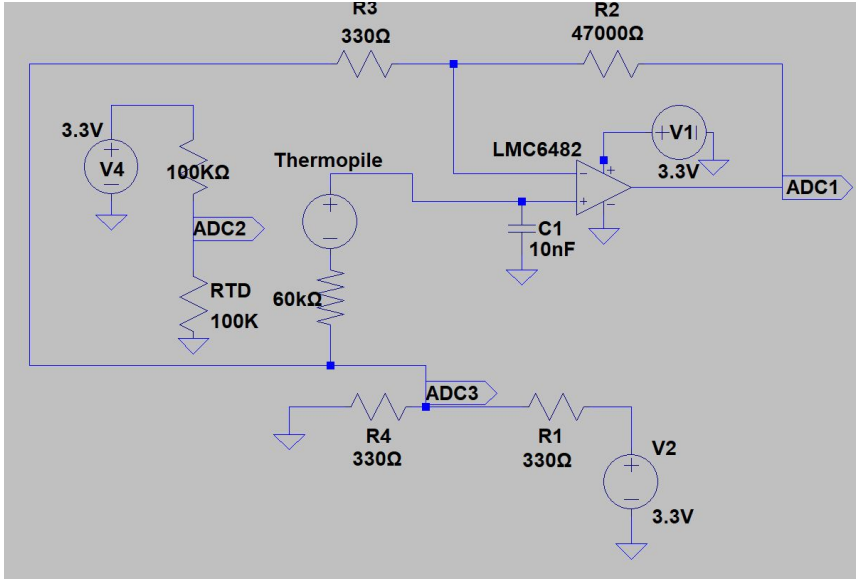


Figure 14:
IR Circuit Implementation

Testing Apparatus

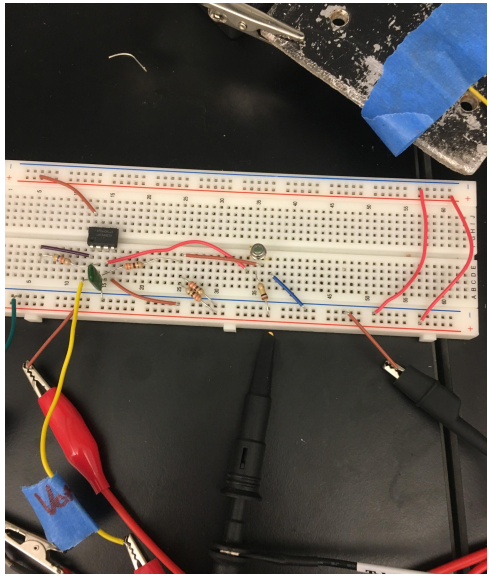


Figure 15: Thermopile testing circuit with supplementary components.

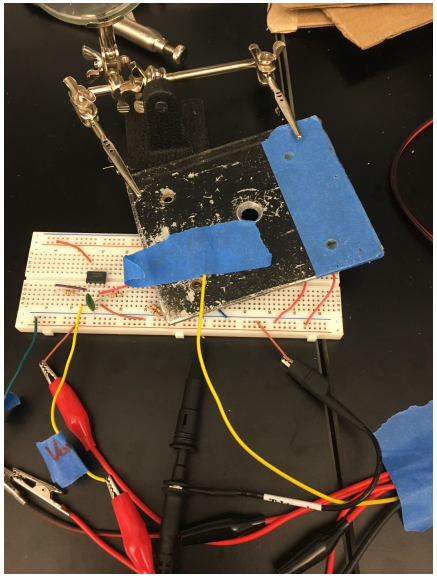


Figure 16: Thermopile testing circuit with aluminum plate as measurement target. A thermocouple is attached for reference temperature reading.

Testing Apparatus

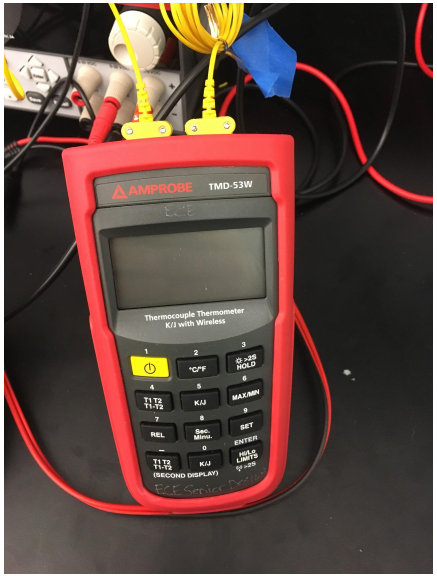


Figure 17:
Fluke with thermocouple used for reference temperature and comparison to calculated values.

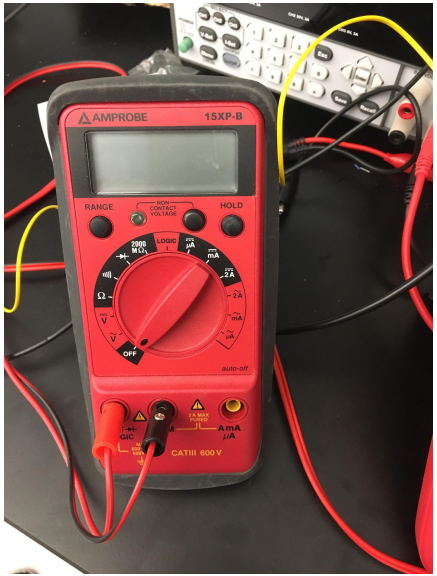
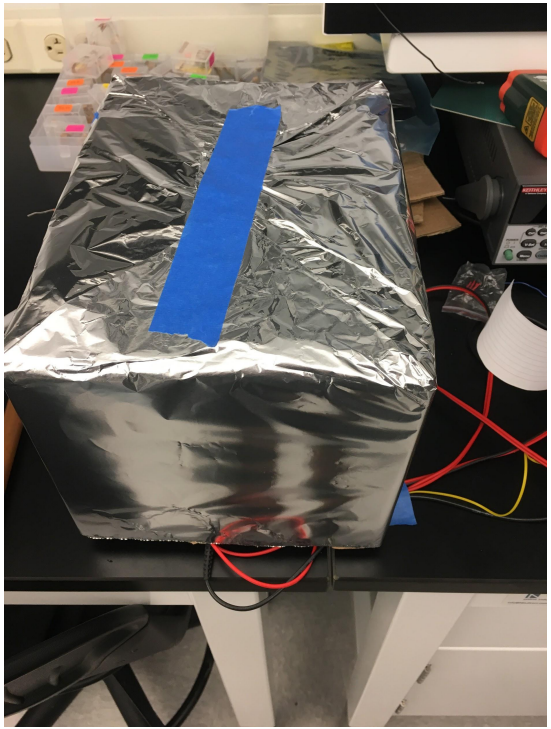


Figure 18:
Multimeter used to take voltage readings of specific points on our circuit for verification of microcontroller measurement.

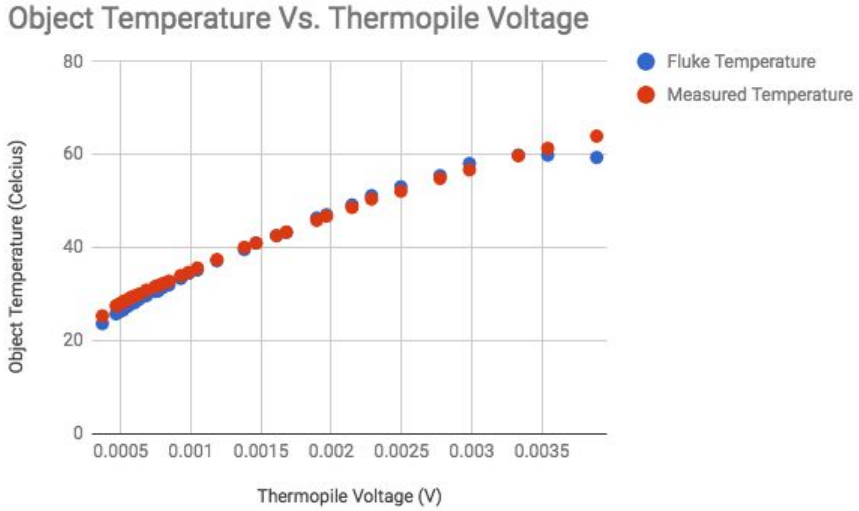
Testing Apparatus

Figure 19:
Circuit Isolation from electromagnetic interference (EMI). Utilizes cardboard to block external IR.



Experimental Findings

- Based on testing:
  - Thermopiles:
    - Fast Response
    - Accurate
    - Non-Contact
  - RTD:
    - Close proximity/contact
    - Accurate
    - Longer measurement time



PCB Considerations

- Grounding
- Error mitigation
  - Masking Color
- Part Placement
  - Single side or both sides
- Size
  - Surface mount vs. Through hole

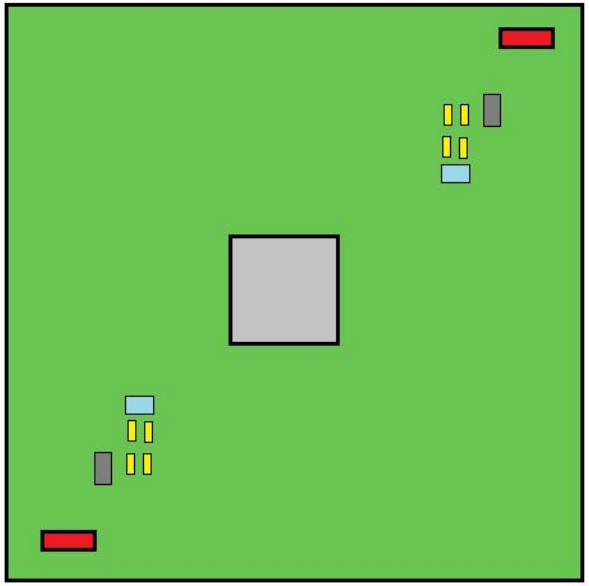
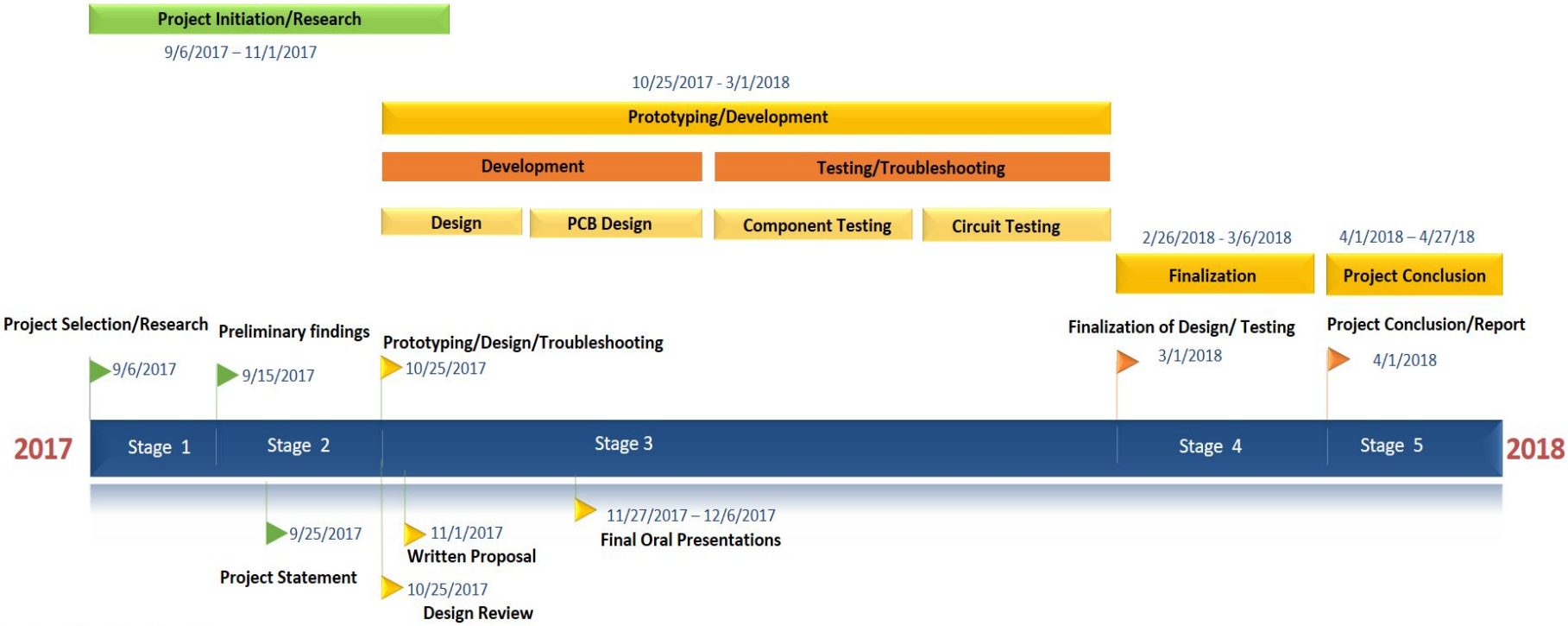


Figure 20:
General PCB layout

Timeline


Project Initiation/Research
9/6/2017 – 11/1/2017
10/25/2017 - 3/1/2018
Prototyping/Development
Development
Testing/Troubleshooting
Design
PCB Design
Component Testing
Circuit Testing
2/26/2018 - 3/6/2018
Finalization
4/1/2018 – 4/27/18
Project Conclusion
Project Selection/Research
9/6/2017
Preliminary findings
9/15/2017
Prototyping/Design/Troubleshooting
10/25/2017
Finalization of Design/ Testing
3/1/2018
Project Conclusion/Report
4/1/2018
2017
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
2018
9/25/2017
Project Statement
11/1/2017
Written Proposal
10/25/2017
Design Review
11/27/2017 – 12/6/2017
Final Oral Presentations

Next Steps

- Completed Schematics
- PCB design
- Troubleshooting

Questions?

Works cited

- Karaki, Habib. “Figure 2”, 27 February 2014, http://www.sensorsmag.com/components/demystifying-thermopile-ir-temp-sensors , Accessed: 23 October 2017
- “Figure 3”, https://www.digikey.com/product-detail/en/amphenol-advanced-sensors/ZTP-135SR/235-1330-ND/3974095 Accessed: 23 October 2017
- “Figure 11” https://www.smart-prototyping.com/image/cache/data/2_components/Chip/101785%20ATMEGA328P-AU/1-750x750.jpg
- “Figure 12” http://www.atmel.com/webdoc/atmelstudio/ Accessed: 22 November 2017