Design Review 5
Team 3: Self-Powered Wireless Sensor

Jacquelyn Burnham, Omar Rodriguez, Caleb Stallings

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Team 3

Jacquelyn Burnham:

Lead Controls and Programmer

Meghan Busch:

Financial Advisor and Quality Control

Thomas Dodamead:

Team Leader

Omar Rodriguez:

Webmaster and Lead EE

Caleb Stallings:

Lead CAD Designer

Caleb Stallings

Agenda

- Introduction
- Design Analysis
- Testing & Validation
- Conclusion

Introduction

Project Background

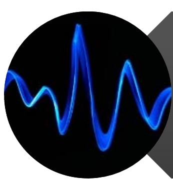
Design, build, and demonstrate a method to power a sensor that will transmit data of a specific variable wirelessly to the Engine Control Module (ECM) in a Cummins' diesel engine.

Important Objectives

Remain in stand-by condition up to 36 hours

Could measure one specific parameter (pressure, temperature, velocity, etc.) in the engine

Wireless communication at least 5 meter range

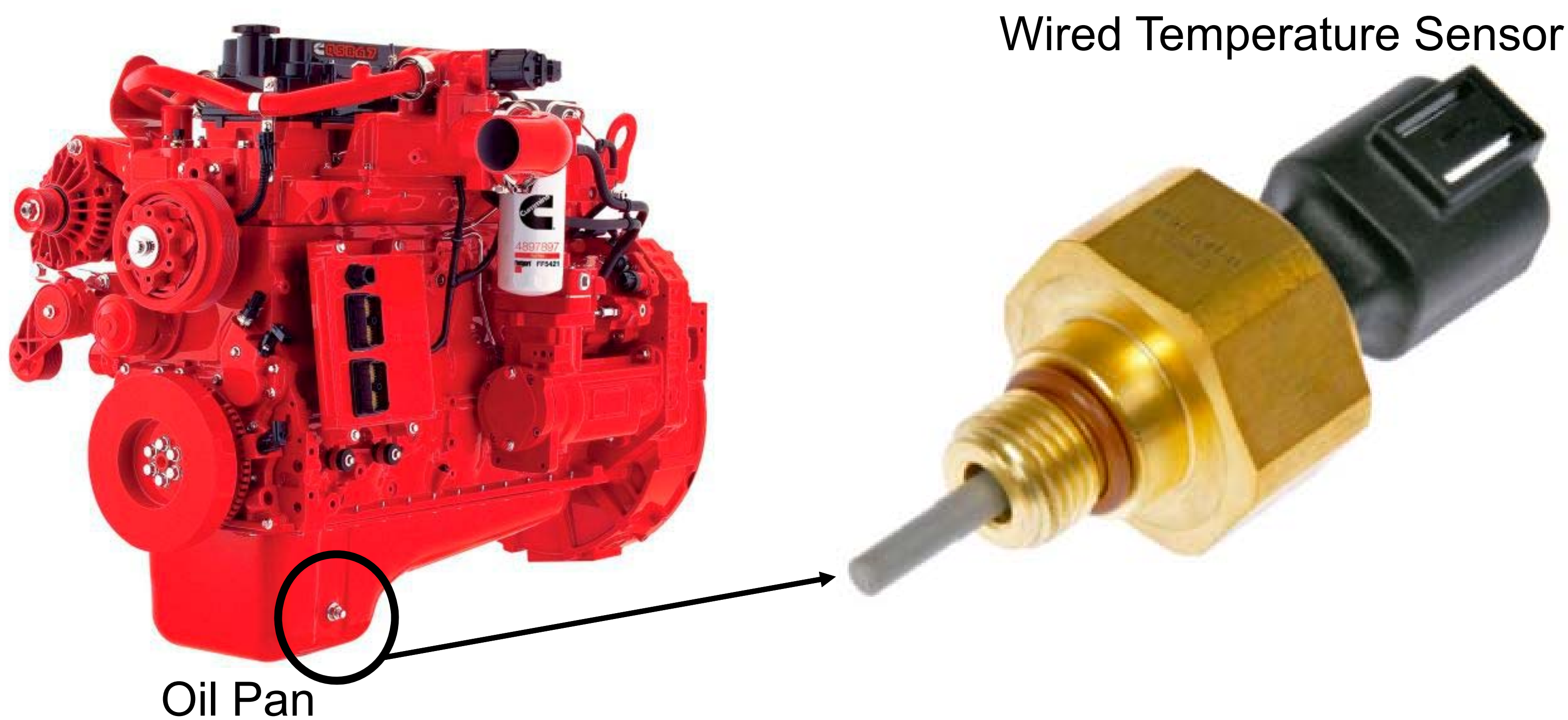


Minimum sampling frequency of 1 Hz

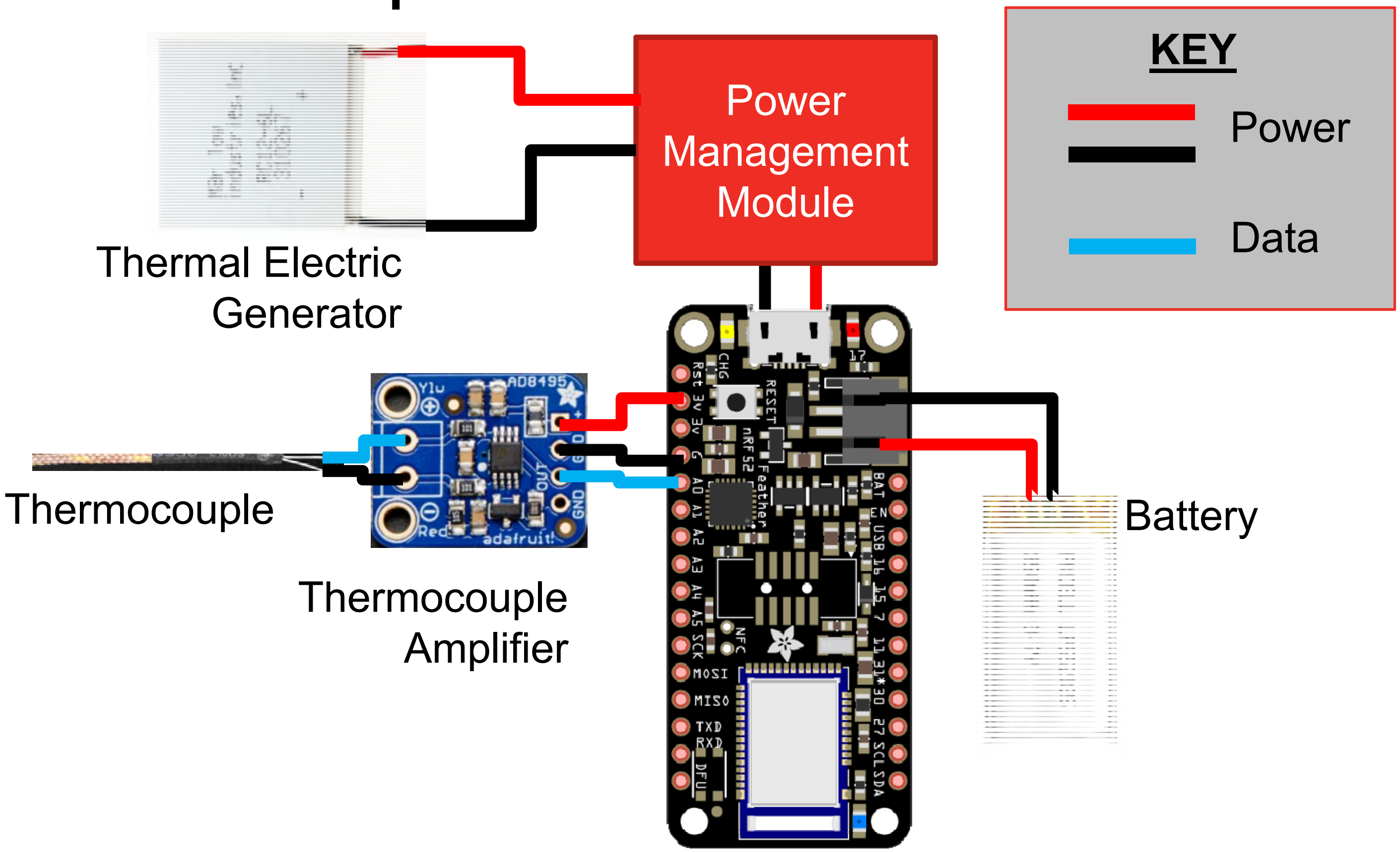
Design Concept Revisions

Sensor	Wireless Communication	Microcontroller	Power Generation
Thermocouple	BLE	Arduino Uno Rev 3	Thermoelectric Generator
Thermistor	CAN Bus	Teensy 2.0	Piezoelectric
MAP Sensor	ZigBee	Adafruit Bluefruit Feather	Pyroelectric
Hot-Wire Sensor	RFID		Induction
Oxygen Sensor			Micro-turbine

Traditional Wired Temperature Sensor



Wireless Temperature Sensor



Design Assumptions

- ECM compatible with receiving temperature data in ˚C using Bluetooth5
- ECM will send wake-up signal on engine start (t=0)
- Sensor is engine oil temperature sensor
- Oil pan has necessary hardware for assembly

Design Analysis

Current Design

Baseplate

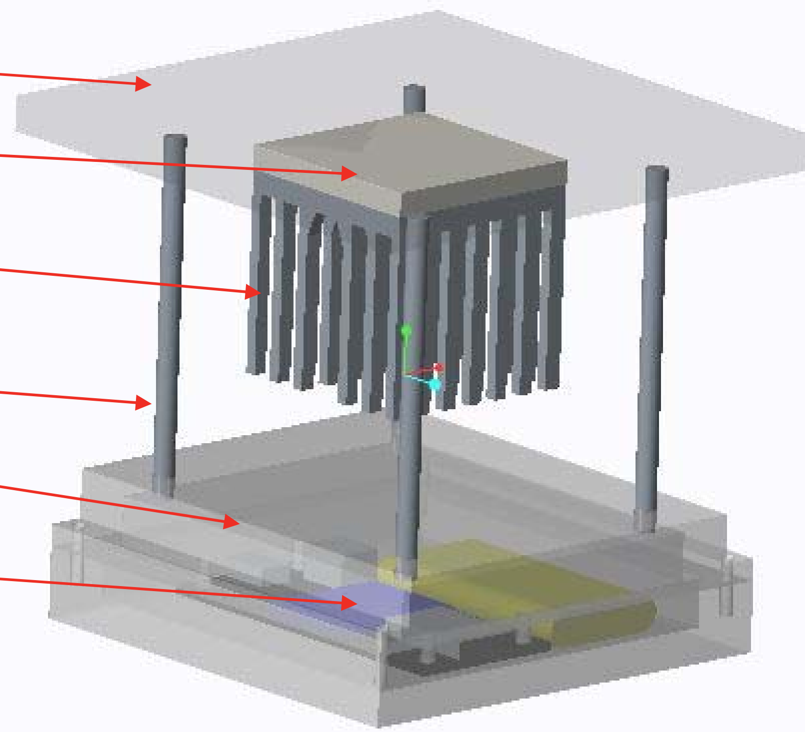
TEG

Fins

Standoffs

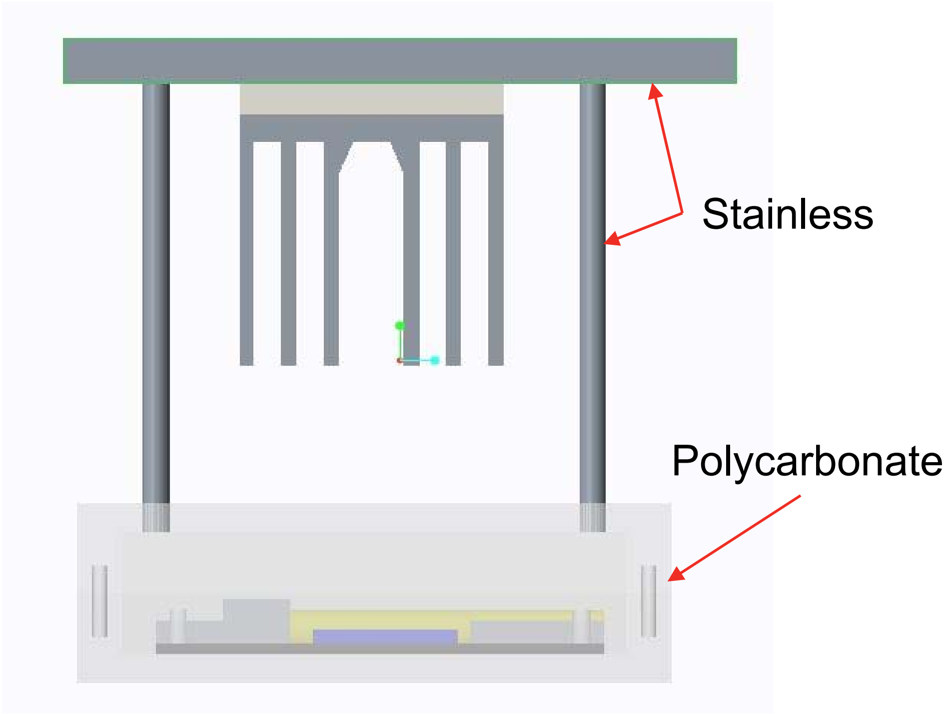
Protective Housing

Electrical Components
(Feather board, Battery,
Amplifier)



Housing

- Compact, integrated design for ease of assembly
- Thermally and electrically protected, waterproof, robust design for harsh environments
- Manufacturing and materials
  - Prototype is 3D printed
  - Final design uses stainless steel hardware and a polycarbonate housing
- Wires run through hollow standoffs for protection



Energy Harvesting Design

- Self-powered implies must produce at least as much electrical power as it consumes
  - Preliminary analysis using worst-case manufacturer specifications:
    - Maximum consumption is 0.026W
    - Minimum produced is 0.61W
      - Given a 60˚C temperature difference across TEG
- Need to verify power output of TEG
  - To produce 0.03W requires ~10˚C temperature difference across TEG
  - Need to design suitable heatsink to maintain at least a 10˚C temperature difference from TEG hot side (~140˚C) to cold side

Thermal Analysis

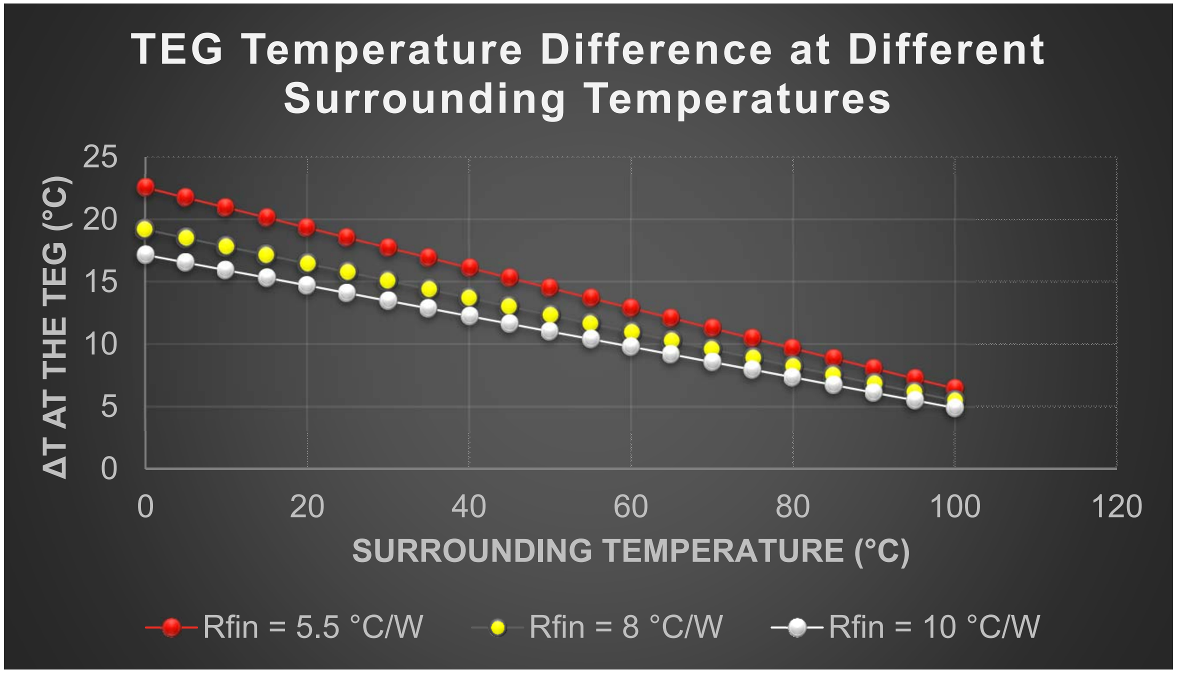


Figure 1.
The calculated temperature difference across the TEG at different surrounding temperatures.

- $T_{oil} = 140°C$
- Purchased Heat Sink Resistance at 1 m/s air flow:
  - $R_{fin} = 5.5°C/W$

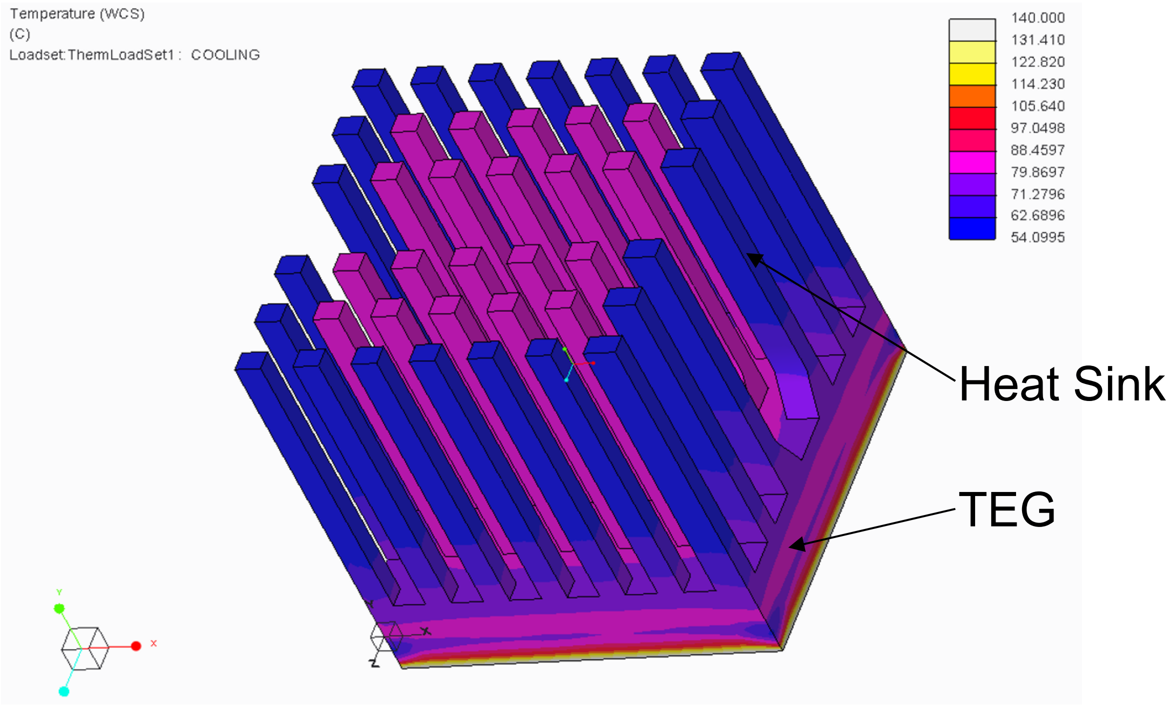
Energy Harvesting Analysis (FEA)

Initial Conditions

- Hot temperature 140 ˚C
- Ambient temperature 50 ˚C
- Natural convection

Results

- Fins maintain a $\Delta T \approx 45$ ˚C
- Allows TEG to sustain power output of ~0.3W



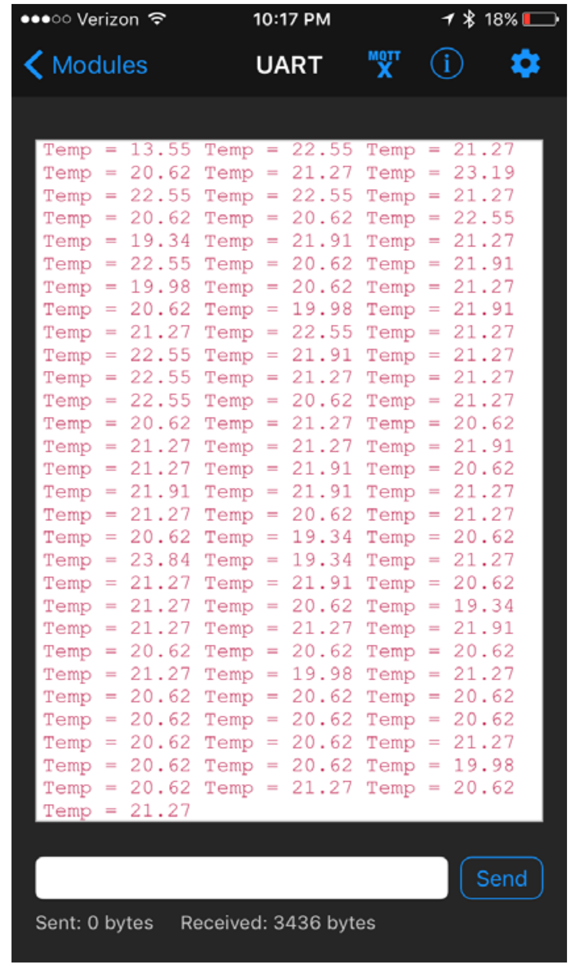
Testing & Validation

Current Design Performance

- Transmits engine oil temperature in ˚C up to 12m at a frequency of 1Hz using Bluetooth5 wireless protocol
- Ultra-low power consumption
  - 0.026W max, 20 year standby time
- Thermoelectric energy harvesting
  - Uses waste engine heat as power source
  - Worst-case power output of 0.047W

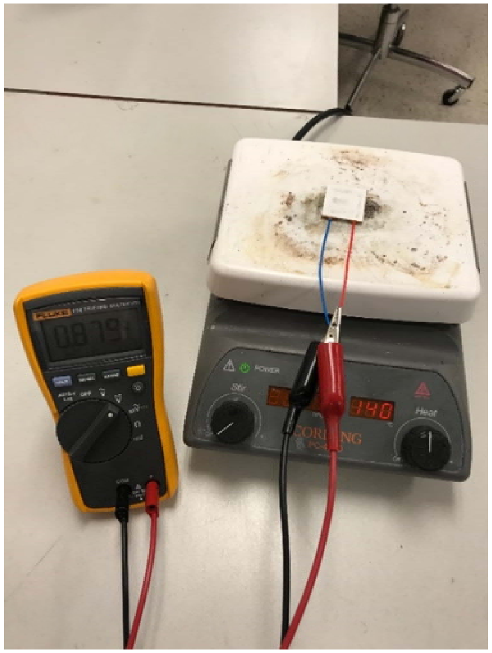
Wireless Sensor Testing

- Outputs temperature in ˚C at 1Hz
  - Tested at room temp of 70 ˚F (21 ˚C)
  - Normal thermocouple error is ∓ 2 ˚C
  - Discrepancies thought to be due to loose connections in circuit (unsoldered)
- Wireless communication via the Bluefruit mobile app (right) and Bluetooth5
- Arduino platform offered ease of software testing and debugging

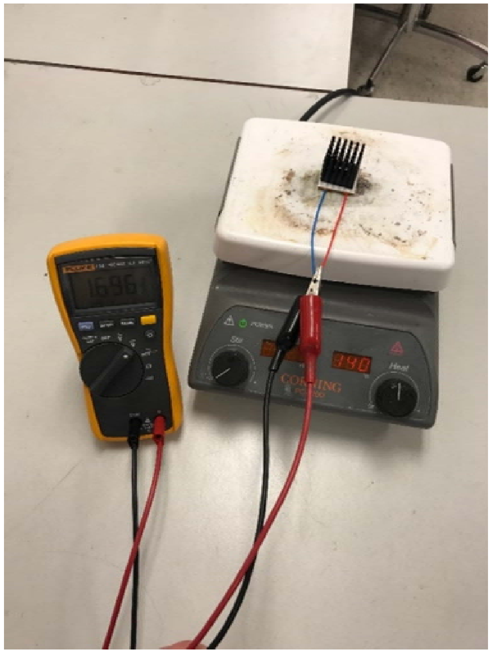


TEG Testing Set-up

- Test voltage and amperage (power) with and without heat sink on hot plate at 140°C in natural convection with surrounding temperature at 21°C



Without Heat Sink



With Heat Sink

TEG Testing Results

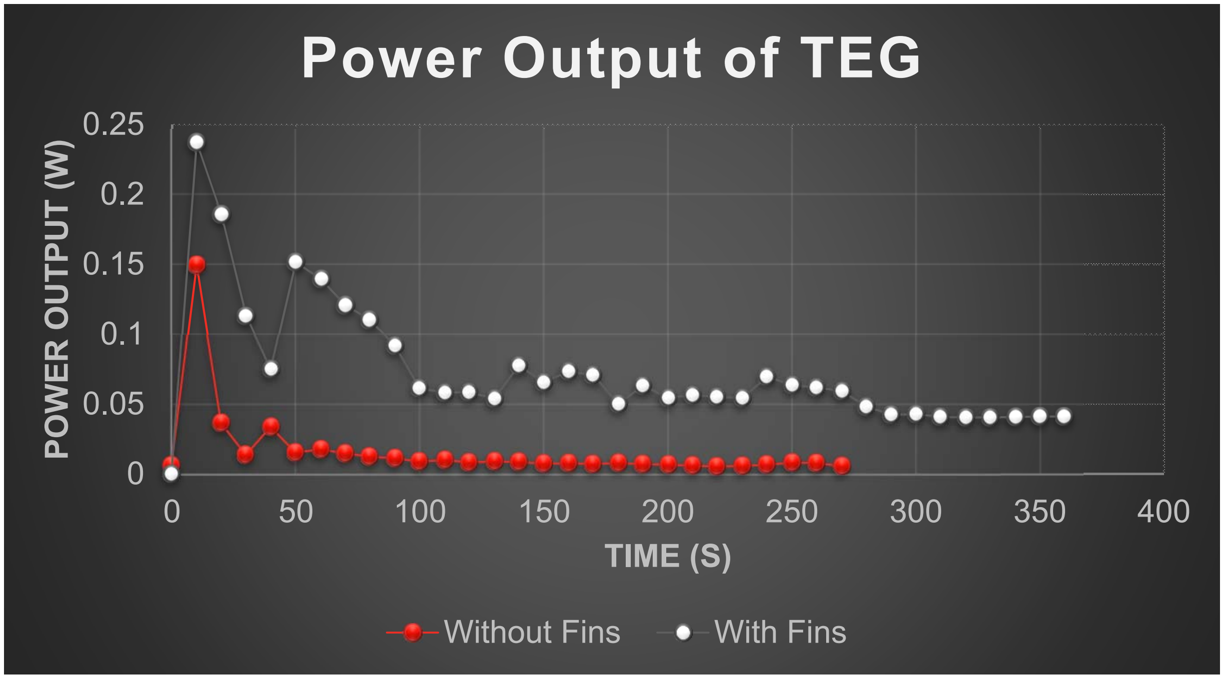


Figure 2.
Comparison of output power generated by the TEG versus time with and without the heat sink.

- Goal : **0.026 W**
- Steady State Power Output <u>without</u> Heat Sink: **0.0073 W**
- Steady State Power Output <u>with</u> Heat Sink: **0.0466 W**

Conclusion

Budget

Table 1.
Items Purchased Against Allotted Budget

Budget Remaining:
$1,535.13

Item	Cost
Adafruit Board and Sensor Modules	$ 65.40
Thermal Electric Generator (2)	$ 46.72
Heat Sink (2)	$ 19.50
Thermal Paste	$ 6.24
Soldering Station	$327.01
Total:	$464.87

Concluding Remarks

- Testing showed:
  - The electronics used very little power
  - Fins as heatsink provided small but sufficient temperature difference for TEG to power a wireless temperature sensor
- Attempted to optimize design by:
  - Integrating components for maximum robustness/reliability with minimal overall size
  - Choosing heatsink that produced optimal power output
- Future project might look at:
  - Integrating different energy harvesting methods

Thank You!

Questions?