UCI Thermoelectric

2020 Winter Design Review

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UCI W.A.T.C.H. Team

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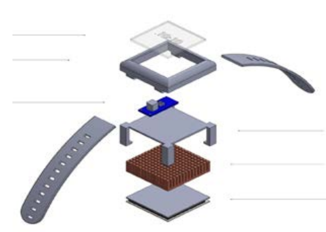
Background

- An average human body at rest emits about **350,000 J/hr**.
- The average surface area of the human skins is 1.7 m^2 (17,000 cm^2)
- Heat Flux of **5700 $\mu W/cm^2$**.

- Bismuth Telluride (Bi2Te3) at room temperature ~ 4% Efficiency
- Power Density of **228 $\mu W/cm^2$**.
- Enough to power health monitoring devices
  - Accelerometer (10 μW with 0.044 cm^2)
  - Ozone sensor (150 μW with 0.66 cm^2).

- Sparks interest in creating wearable body-heat -powered mobile electronics and sensors using TEGs.

- Past research for this project involved creating a prototype for a digital watch.
- Currently research seeks to design a "UCI"- LED patterned wearable sleeve.



Goal

Determine the feasibility of using body heat as a form of energy

Objectives

Design a LED-Badge that is powered by thermoelectric generators

- Investigate TEG performance through analytical modeling, numerical simulation, and experimental testing
- Apply engineering concepts to optimize systematic designs (Heat Transfer; Thermoelectric)

Specifications

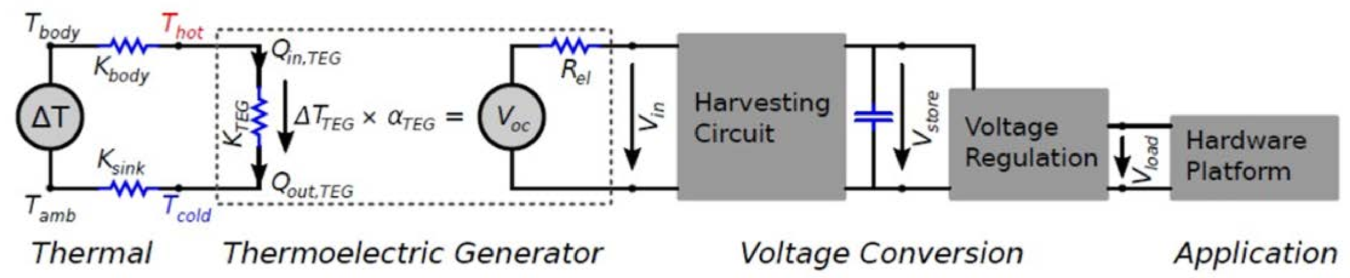
- The LED-badge consists of 13 LED's featuring the patterning of the letter "UCI ".
- Each LED consumes .048W at an operating voltage of 1.6V.

$$Power_{req}\,[W] = 13 \times 0.048 = 0.624]$$
$$= I \times K \times \{(n_r * s_r) + (n_f * s_f)\} \times \Delta T - I^2 \times R_{int}$$

- n_r – *the number of rigid TEG's*
- n_f – *the number of flexible TEG's*
- s_r – *the Seebeck coefficient of the rigid TEG in* [V/K]
- s_f – *the Seebeck coefficient of the flexible TEG.*
- K – *the Voltage boosting factor*
- R_{int} – *Internal resistance of the system*

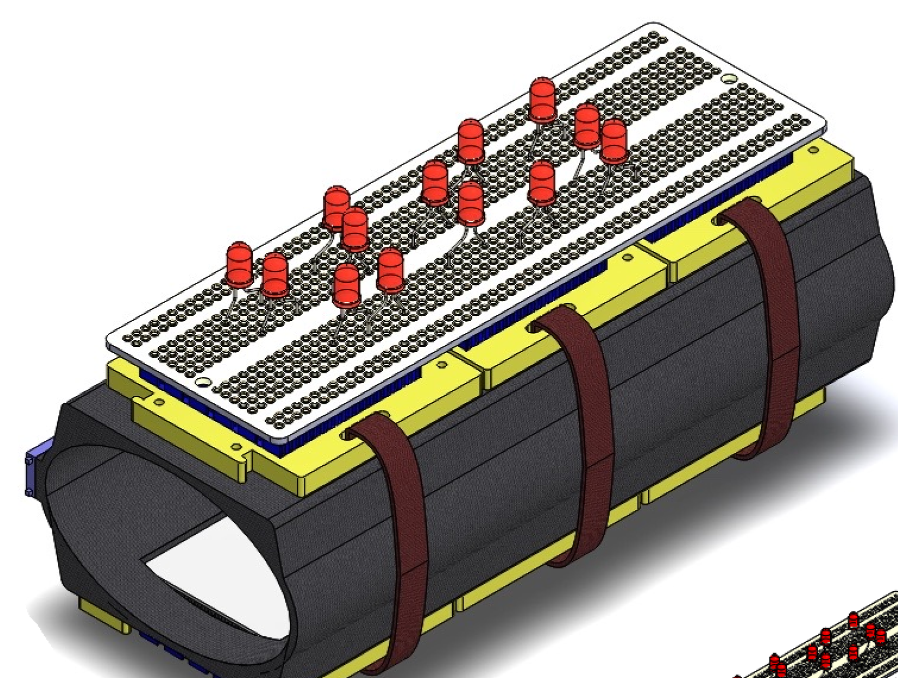
The system requires .624W to power 13 LED's. The power balance equation determine that **6 rigid TEG's and 1 flexible TEG** are required to power the entire system operating at a **temperature range of 8~10°C**.

Design & Concepts



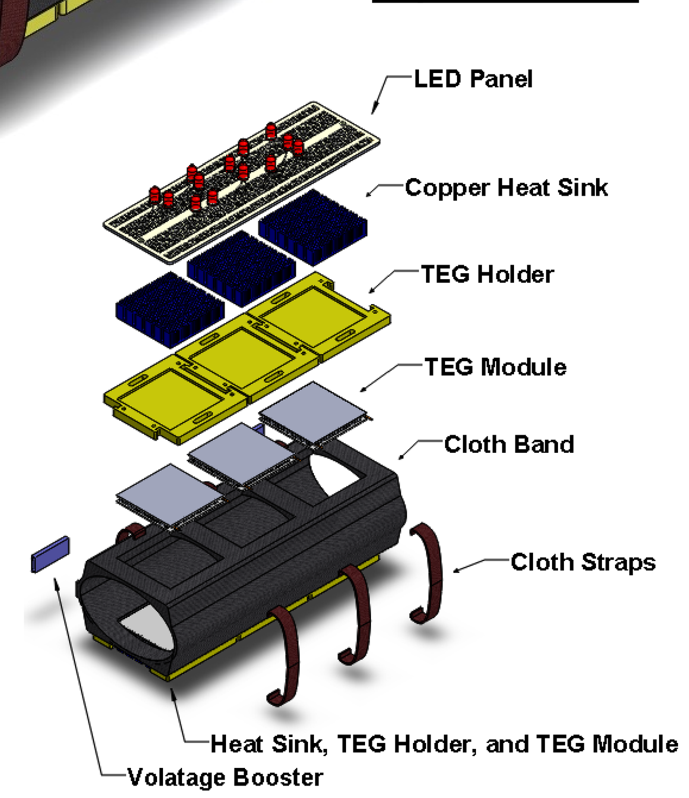
Equivalent circuit of the pathway from human body heat to a wearable hardware platform.

David, Sam. Body Heat Can Be the Source of Power for Wearable Devices, Informa, 2017.



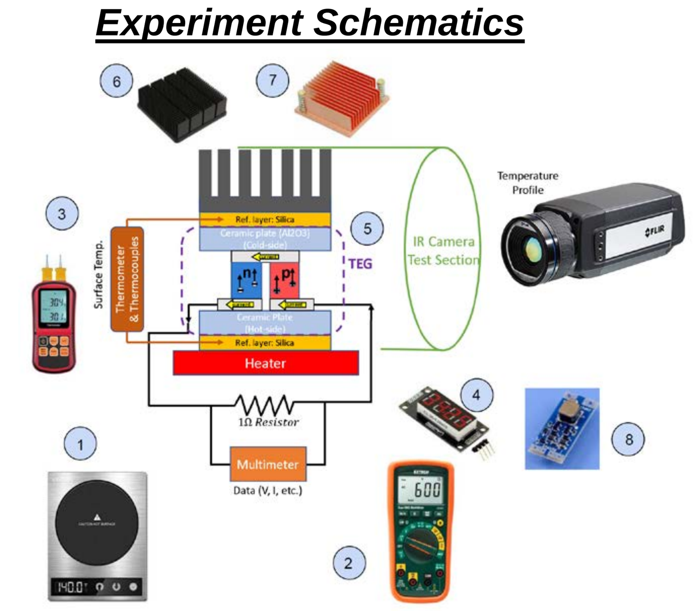
Thermoelectric LED-Sleeve Concept

Exploded View

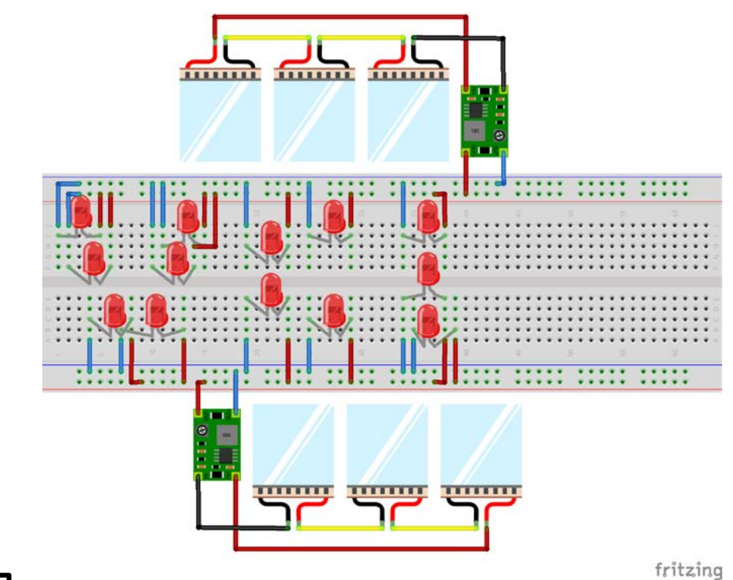


Current Status

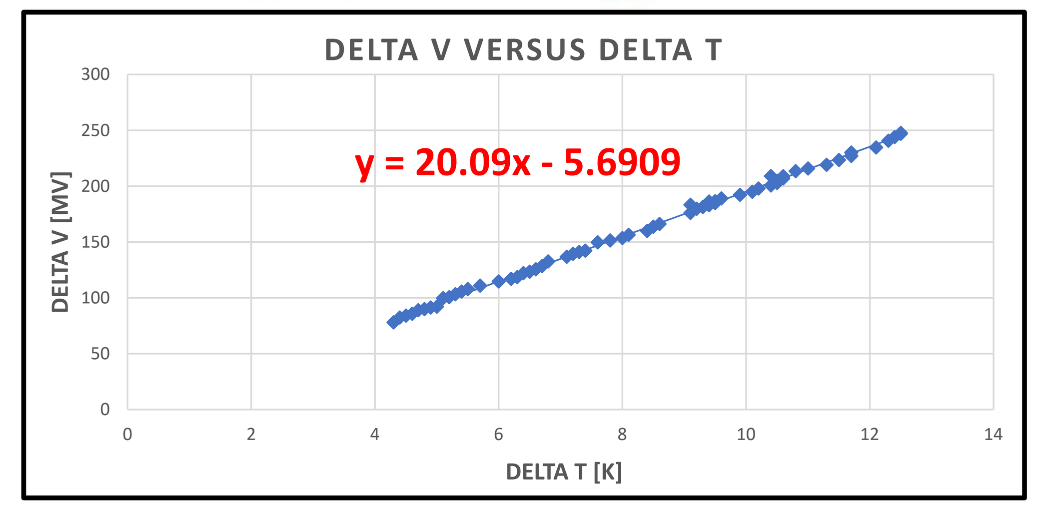
Experiment Schematics

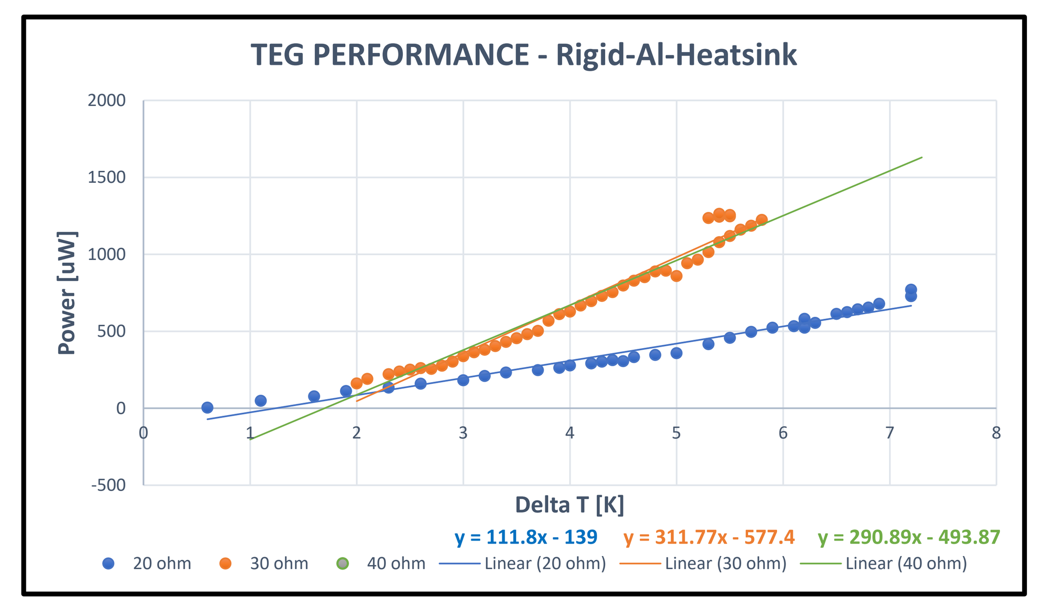


Circuit Schematics



Prototype Testing





- Characterize the **thermal and electrical properties** of the rigid and customized flexible TEG modules.
- Determine the **Seebeck Coefficient** of the modules from the slope of the Voltage versus temperature difference plot.
- Measure the **power generation** of flexible TEG in a closed loop circuit under various electrical load (10Ω - 40Ω).
- Design the **circuit schematics** using analytical calculations and experimental results.
- Run **thermoelectric simulation** to optimize heat transfer within the system and use this to modify the **CAD design** iteratively.
- Test the prototype under **various operating conditions** on the cold-side of the TEGs. (e.g. Conduction with and without heatsink, thermal convection induced by human motions, radiative cooling substrate)

Timeline

Fall 2019 — **Winter 2020** — **Spring 2020**

Nov. 2019
- Team Formation & Contract
- Gantt Chart & Timeline Created
- MS1: Analytical Model is established for a Wearable thermoelectric LED-Sleeve

Dec. 2019
- MS2: Finished Preliminary CAD Design
- Characterization of Flexible TEG modules & Analyze Experimental data
- MS3: First Poster Presentation of the year

January 2020
- Trade Studies
- MS4:Finalized Purchase order
- 1st Purchases Order Sent out; Update Budget Tracking
- Preliminary Safety Report Document

Feb. 2020
- MS5: Prototype Successfully tested and the scope of improvements is identified.
- Task: Modified CAD & Re-design if necessary.

March 2020
- Project Specification Document Due
- MS6: Finalized CAD Design & Assembles
- 2nd Purchases Order Sent out; Update Budget Tracking

May 2020
- Project Realization: Safety Document
- MS7: Product Manufacturing & Integration
- MS8: Product Successful Test Using Body Heat

June 2020
- Testing and Validation Document
- MS9: Project Closure & Celebration

Budget and Cost