Embedded Systems Project Presentation: TEG Characterization

Giacomo Mazzucchi and Filippo Faccini

Dept. of Industrial Engineering
University of Trento

February 23, 2025

Overview

TEG Characterization

- Thermoelectric generators are devices that convert heat into electrical energy
- Their behaviour is regulated by a model based on three key parameters: **Seebeck coefficient**, **electrical resistance** and **thermal conductivity**

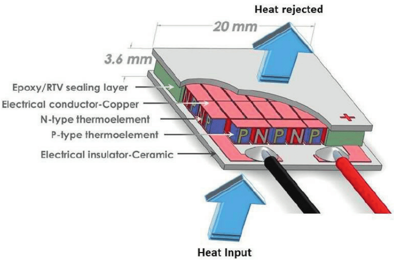


Figure: Thermoelectric Generator

Steps to find the model of a specific TEG device

1. Generate a known delta temperature between two sides of TEG
2. Measure Open Circuit voltage
3. Estimate Seebeck coefficient
4. Measure current on a known load resistor
5. Estimate internal resistance
6. Calculate efficiency of the TEG

HW Setup

Components

- A **wire wound resistor**, used as hot side heating element
- Hot side control circuit, composed of a transistor and a **power MOSFET**
- Temperature acquisition, with the **MAX6675 module**
- Open circuit voltage measurement with the ADC of the MCU
- Current measurements using the MicroCurrent module

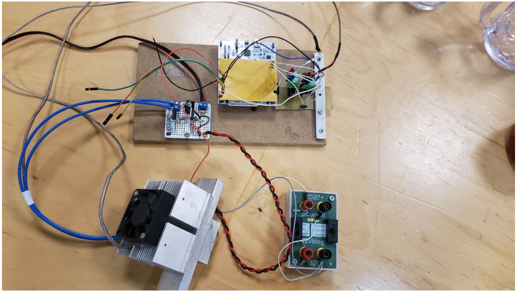


Figure: Data acquisition setup

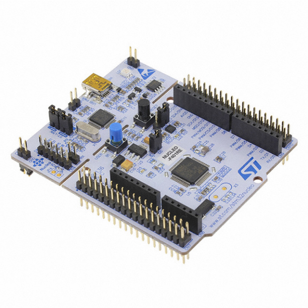
SW Setup

Peripherals used

- Timers
- ADC
- UART
- DMA
- SPI
- PWM

Tasks

- Read temperatures on TEG surfaces
- PID to control temperatures and PWM to activate heating element
- Read ADC for voltage and current
- Send sensor and status data to application with UART
- Schedule ADC readings using timers



Application

Features

- Set temperatures over the two TEG surfaces
- Tune PID coefficients
- Visualize sensors readings and status of the micro
- Save all data in to log file in CSV format

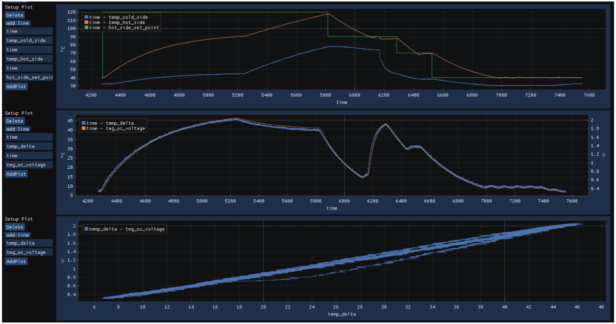


Figure: Plots from the GUI application

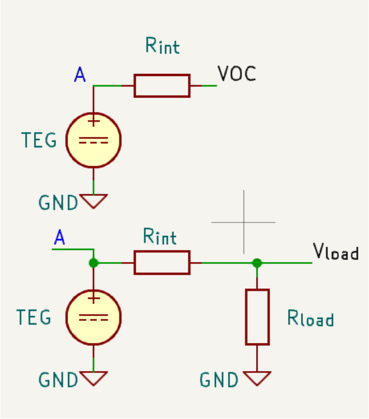
Data fitting

Fit internal resistance

$$S = \frac{V_{oc}}{\Delta T} \tag{1}$$

Fit internal resistance

$$\begin{aligned} R_{int} &= R_{int_0} + R_{int_1} \cdot \overline{T} \\ V_{OC} &= S \cdot \Delta T \\ I &= \frac{V_{OC}}{R_{int} + R_{load}} \end{aligned} \tag{2}$$



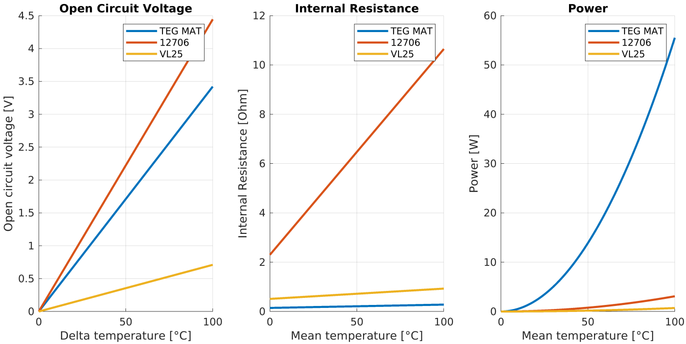
Matlab function

In Matlab the function fmincon allows one to fit a non-linear model with constraints on the parameters. This was used to constrain internal resistance parameters.

Experimental results

Fitted data

TEG model	Seebeck	Internal resistance
TEG MAT	0.034209	0.145028, 0.001342
TEG 12706	0.044441	2.299155, 0.083479
TEG VL25	0.007100	0.511499, 0.004171



Conclusion and future work

- **Fully automated system**: the MCU must be able to automatically follow a cycle of temperatures.
- **Higher delta temperatures**: physical limitations prevented us from reaching high temperature deltas, either because the resistor value was too high or because the cooling system was unable to keep the cold side temperature down.
- **Active cooling**: more powerful cooling system and therefore with possibility of control.