School of Electrical and Computer Engineering
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Lab 2b

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Deliverable 4: Model of Thermistor and Linearization

Objective

The objective of this deliverable is to model the thermistor’s behavior using three different methods: least-squares fitting, the Beta model, and the Steinhart-Hart model. Additionally, we linearize the thermistor’s response using the 3-point method and the “forced inflection point” method. Finally we analyze the results and discuss the implications of linearization on the sensor’s dynamic range and sensitivity.

Thermistor Modeling

The thermistor datasheet provides a table of resistance values at various temperatures ranging from -50℃ to 150℃. Using this data in table 1 , we can plot the resistance versus temperature and fit a least-squares model to the data.

Ohm / Temperature figure

TMP	-50℃	-40℃	-30℃	-20℃	-10℃	0℃	10℃	20℃	25℃	30℃
Ω	44130	23980	13520	7891	4754	2949	1879	1226	1000	819.4

TMP	40℃	50℃	60℃	70℃	80℃	90℃	100℃	110℃	120℃	130℃
Ω	559.2	389.3	276	199	145.8	108.4	81.68	62.35	48.18	37.64

TMP	140℃	150℃
Ω	29.72	23.7

Table 1: Thermistor Ohm / Temperature Figure

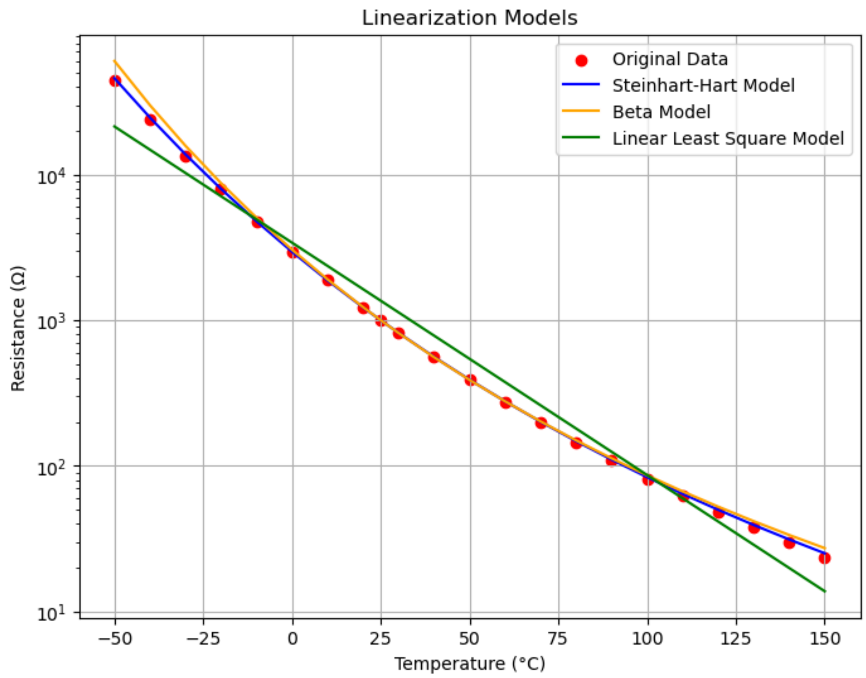

Figure 1: Thermistor Models

Figure 1 shows the three models (least-squares, Beta, and Steinhard-Hart) plotted over the entire range of the thermistor's operating temperature. The Steinhart-Hart model provides the most accurate fit while the Beta model is a good approximation for most temperature ranges. The least-squares model is also a reasonable fit, but does not capture nonlinearity as well as the Steinhart-Hart model.

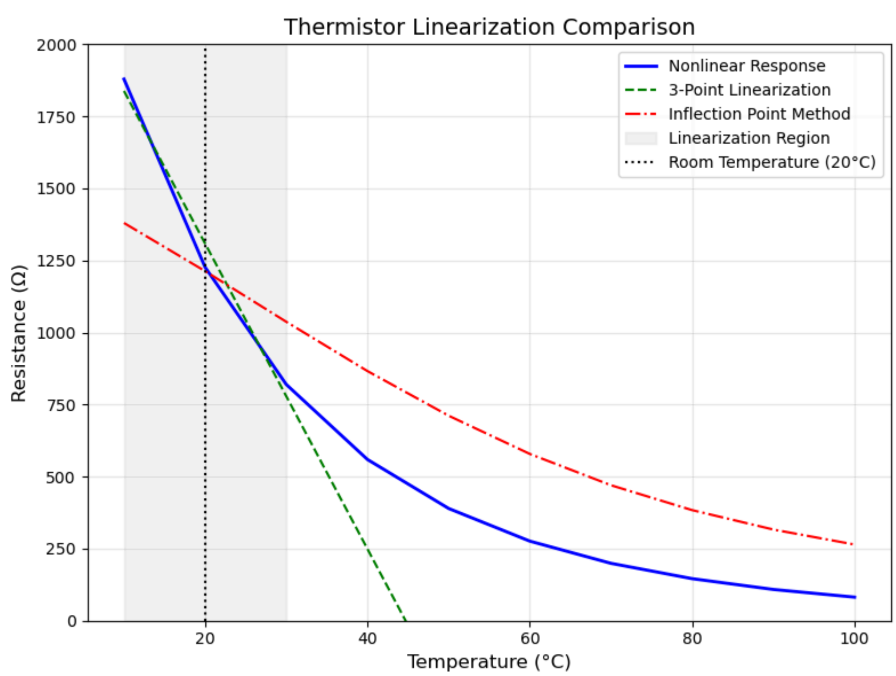

Figure 2: Thermistor Linearization Comparison

Figure 2 shows the nonlinear model of the thermistor over the small region from 10℃ to 30℃, along with the linearized responses using the 3-point method and the "forced inflection point" method. Both methods provide good linearization within the small region, but the "forced inflection point" method is slightly more accurate around the chosen temperature of 20℃. It is also worth noting that the 3-point method is more accurate at 10℃ and 30℃ rather than 20℃. This is due to the nature of this method.

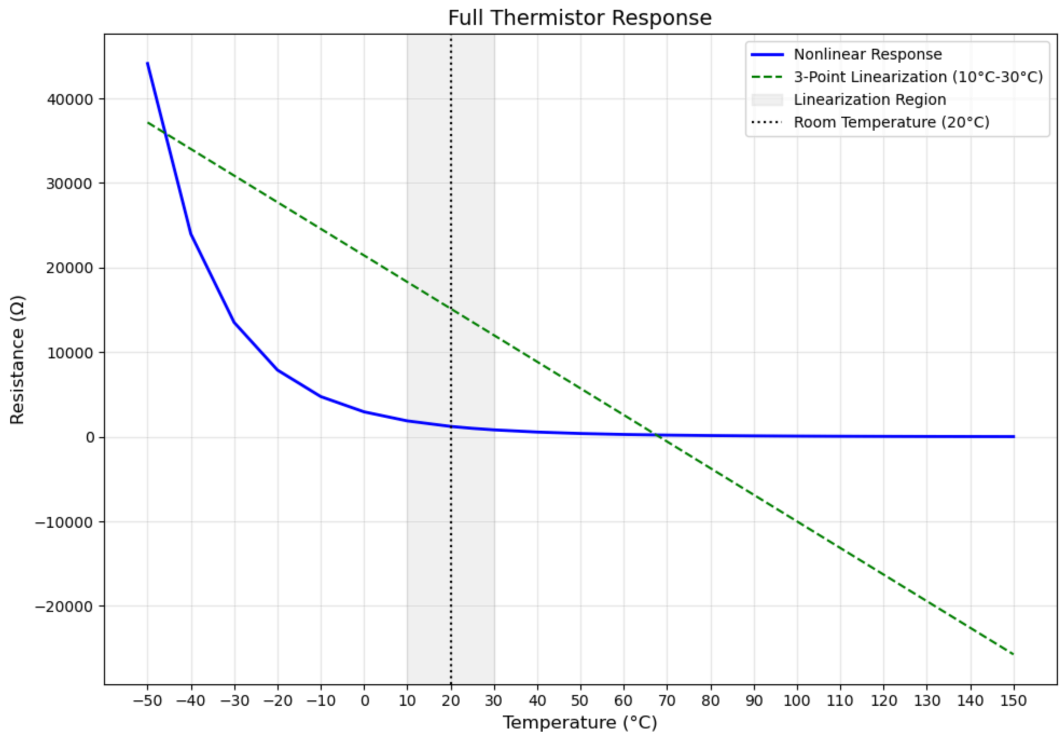

Figure 3: Thermistor Linearized Response Using 3-point Method over Maximum Range

Figure 3 shows the nonlinear model of the thermistor over its entire operating range, along with the linearized response using the 3-point method. The linear response deviates significantly from the nonlinear model at the extremes of the range, but it provides a good approximation for the endpoints of the range (-50℃ and 90℃).

Deliverable 5: Resolution Simulation

Deliverable 6: Instrumentation Op-Amp from In-Amps

Objective

The objective for this part of the lab is to create an instrumentation amplifier using our designated TL084 Op-amps to create a form of amplifying a sensor's output voltage to be read over the entire range of the built in ADC for our ESP32. Using Multisim, and the documentation for the INA126, a instrumentation amplifier was created with two TL084 Op-amps that would boost our given voltage from 0.1V - 0.55V to 0.6V - 3.3V as desired to expand the ADC range based on our given inputs for greater resolution and accuracy when there is a non-linear response.

Instrumentation Op-Amp

This image below is a simulation of the INA126 instrumentation amplifier at which its datasheet for its schematic could be found in this document (https://www.ti.com/lit/ds/symlink/ina126.pdf?ts=1739461052605&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FINA126).

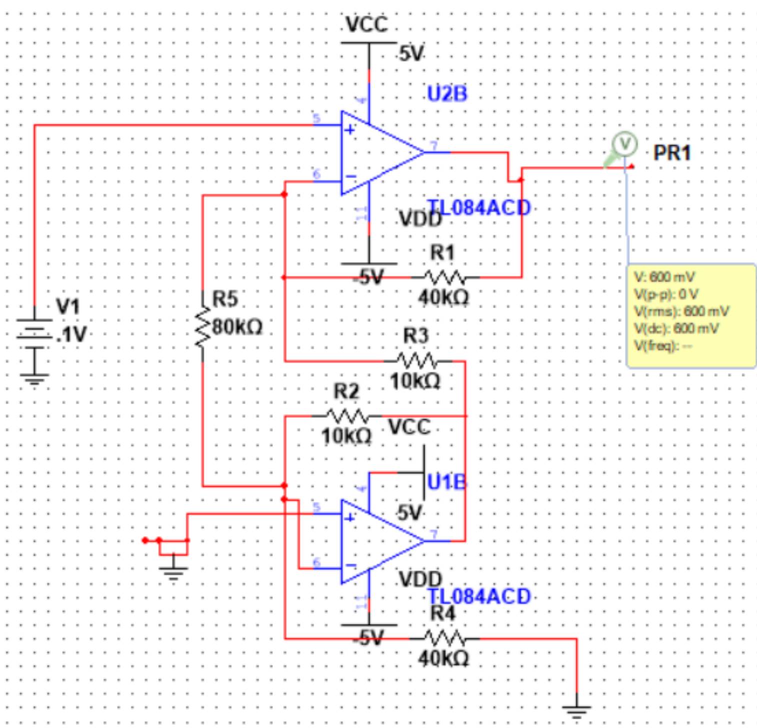

Figure X: Multisim Simulation of INA126

This specific layout of the INA126 results in a gain of 6 times the V1 value as can be seen in the image. For the sake of this lab, a +-5 rail was used to power both Op-amps which allowed for the amplification to the desired 3.3 volts. Resistor 5 is the value that controls the Gain of the INA126 based on the formula listed below.

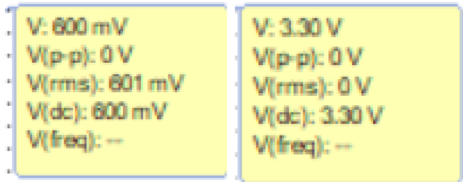

Figure X: 0.1V and 0.55V as inputs and resulting outputs

The specific voltages were applied to the instrumentation amplifier, there was no need for bias voltage as the Op-Amps work in the desired range as needed for the future experimentation with the thermistor.