Instituto Politécnico Nacional

Ingeniería en Sistemas Computacionales

Laboratorio de Instrumentación

Practica N° 2 “Linealización de Sensores Resistivos”

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Fecha de elaboración: 17/09/21.

Index

Objective

The student will implement in a practical way two linearization methods for resistive sensors, as well as their signal conditioning necessary in the design of a linear measurement system.

Equipment employed

- Computer
- Software tool for electronic circuit simulation (Multisim or PROTEUS).
- Internet connection.

Introduction

Resistive sensor linearization

The sensor is an important device in instrumentation, measurement, and control application, but several of them show a non-linear response with the variation of the measurement parameters, also, in many cases, the environmental factors such as temperature, humidity, or pressure affect the sensor characteristics nonlinearly.

An ideal linear sensor is one for which cause and effect are proportional for all values of input and output. There are many well-defined relationships useful in the implementation of sensor linearization.

Continuous function fitting permits the translation of an relationship between an independent input variable and dependent output variable, for example the formulation of a linearized output function employing a nonlinear relationship appropriate for the sensor characteristic of interest. Useful relationships include 1/X, log X, and polynomial expressions such as the cubic equation, whose solution of values for the coefficients permits the definition of a sensor-signal linearizing equation suitable for implementation in software or using analog circuits.

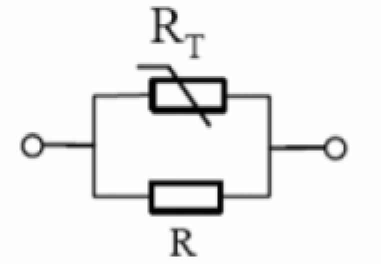
Thermistors are suited for various applications because of small size, rugged construction, less sensitivity to mechanical shock or vibrations, low cost, low-thermass, and high sensitivity. Since temperature measurement is defined in terms of the thermal expansion of materials, expect their temperature readouts to be linear with respect to the same, but the main limitation of the thermistor is the reduced temperature range and high nonlinearity of the response curve. However the nonlinearity of the response is compensated by the series-parallel resistance circuit or Wheatstone bridge circuit by optimizing their components values, other methods utilize Op-amp based inverting amplifier circuits, involving the linear conversion of temperature into frequency or time period of the output signal.

To linearize a sensor using a resistor, we search for a fixed resistance that we call Rlin, in order to calculate this resistance, we use the following model:

$$R_{LIN} = \frac{R_a(R_b - R_j) - pR_j(R_b - R_a)}{p(R_b - R_a) - R_b + R_j} \qquad p = \frac{T_b - T_j}{T_b - T_a}$$

Linearization by parallel resistor

The method consists of finding a fixed value for a resistor that will be placed in parallel with the variable resistance of a resistive sensor as shown in the next figure



$$R_p(T) = \frac{RR_T}{R + R_T}$$

The variable resistance R (T) developed by the 10KΩ thermistor as a function of temperature should be considered in a range that goes from 30 ° C to 100 ° C. Use this range to calculate RLIN, which you should make the sensor linear, using the following equation.

$$R_{LIN} = \frac{R_a(R_b - R_j) - pR_j(R_b - R_a)}{p(R_b - R_a) - R_b + R_j} \qquad p = \frac{T_b - T_j}{T_b - T_a}$$

The subscripts "a" and "b" used in said equation are the lower and upper limits of the measurement range, respectively. And the subscript “j” is the center point of the measurement range.

Development

1. Linearization through parallel resistor

In the PROTEUS simulator, obtain the measurements of Ra, R and Rj using an ohmmeter connected to a 10KΩ thermistor at the temperatures indicated in Table 1 and record your results. These measurements will be used to calculate RLIN. The calculated value will be obtained using the following equation, seen in class, for a 10KΩ thermistor

Thermistor resistance	**Measured value (KΩ)**	**Calculated value (KΩ)**
Ra=R(30°C)	6.9065	8.0149
Rj=R(65°C)	1.9392	2.0454
Rb=R(100°C)	0.6461	0.6744

Tabla 1

$$R_T = R_0 e^{\beta \frac{T_0 - T}{T_0 T}}$$

$$R_a = 10k\Omega e^{4000\frac{298.15-303.15}{298.15*303.15}} = 8014.94\Omega$$

$$R_j = 10k\Omega e^{4000\frac{298.15-338.15}{298.15*338.15}} = 2045.39\Omega$$

$$R_b = 10k\Omega e^{4000\frac{298.15-373.15}{298.15*373.15}} = 674.4\Omega$$

Indicate the practical (using measured values) and theoretical (using calculated values) result for RLIN:

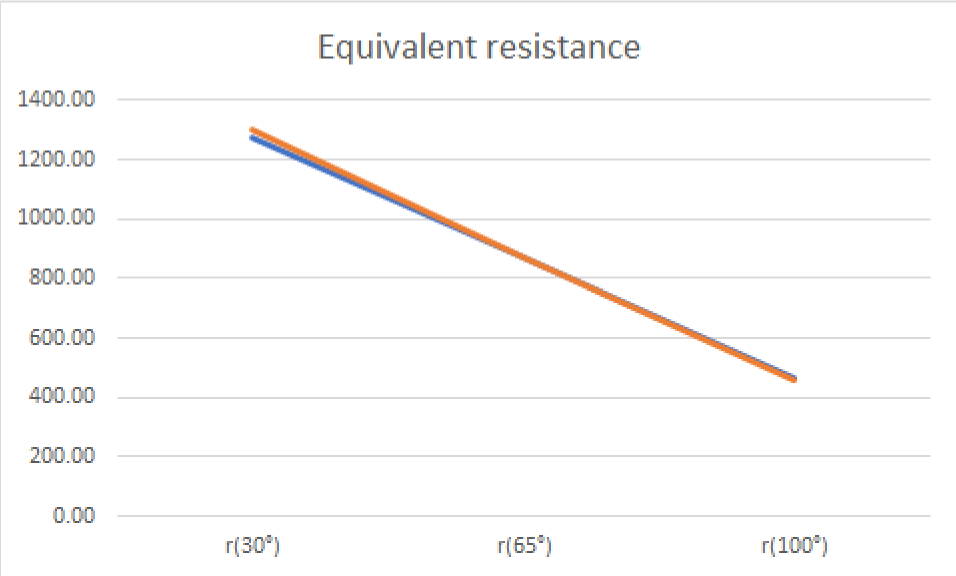
Rlin= 1514.071

Then, in PROTEUS, place the thermistor in parallel with RLIN and measure the equivalent resistance with the ohmmeter. Record the values of the equivalent resistance "r(T)" in table 2 and make the theoretical and practical graphs r(T) vs T, to verify the result of the linearization.

Equivalent resistance	**Measured value (KΩ)**	**Calculated value (KΩ)**

r(30°C)	1.3014	1.2735
r(65°C)	0.8736	0.870
r(100°C)	0.4580	0.4666

Tabla 2



2. **Resistor bridge**

Carry out the equilibrium point calibration, on the resistive bridge, according to the equivalent resistance value resulting from the parallel arrangement between the thermistor and the linearization resistor.

Once the resistor bridge has been calibrated, proceed to measure the potential difference between nodes 'A' and 'B' in the established measurement range, recording the results in Table 3. The calculated thermistor resistance will be obtained by means of the measured VB

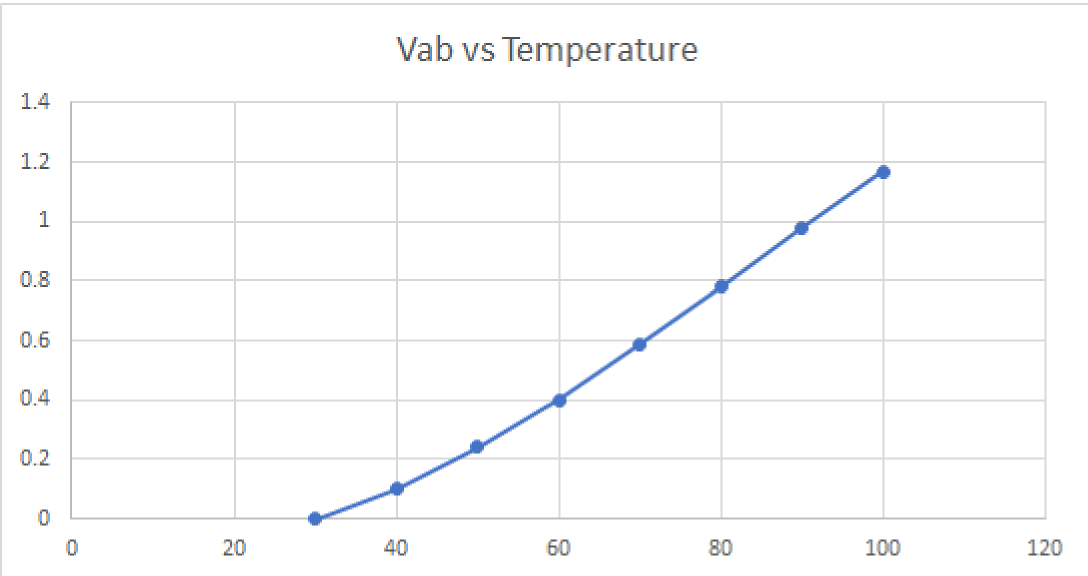
Thermistor temperature (°C)	**Va (Volts) measured**	**Vb (Volts) measured**	**Va - Vb (Volts) measured**	**Thermistor resistance calculated**

				(KΩ)
30	2.32	2.32	0	1298.5
40		2.22	0.11	1188.17
50		2.08	0.24	1068.49
60		1.92	0.40	935.06
70		1.73	0.59	793.57
80		1.54	0.78	667.63
90		1.34	0.98	549.12
100		1.15	1.17	448.05

Tabla 3

mT=7.83k

Then plot the VAB versus temperature graph and, according to it, determine the equation that defines the behavior of the system.



Using the excel line approximation tool, we get the following result:

$$Vab \approx -e^{-6}T^{3} + 0.0004T^{2} - 0.0092T - 0.001$$

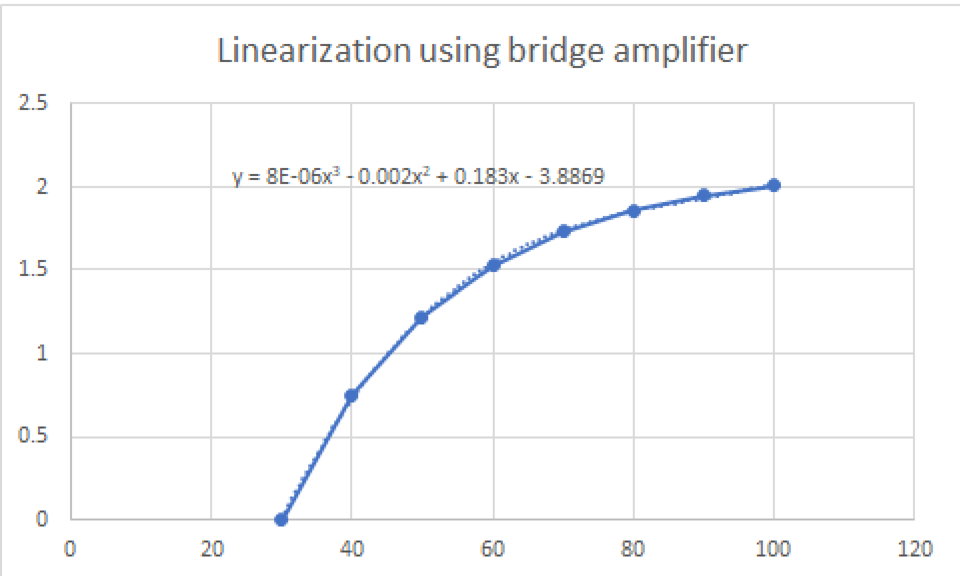
3. **Linearization by basic bridge amplifier.**

Calibrate the value of the potentiometer in such a way that at a temperature of 30°C you have a voltage measurement VSAL equal to 0 Volts.

Once the circuit is calibrated, proceed to fill in the values that are requested in Table 4 for the temperature values requested in the thermistor. Then plot VSAL vs T and determine the type of response as a function of the resulting curve. Find the equation that most closely matches the curve obtained. The calculated thermistor resistance will be obtained by means of the measured Vs.

Thermistor temperature (°C)	**Vsal (Volts)**	**Thermistor resistance calculated (KΩ)**
30	0	3.03
40	0.75	1.995
50	1.22	1.346
60	1.53	0.919
70	1.73	0.643
80	1.86	0.463
90	1.95	0.339
100	2.01	0.256

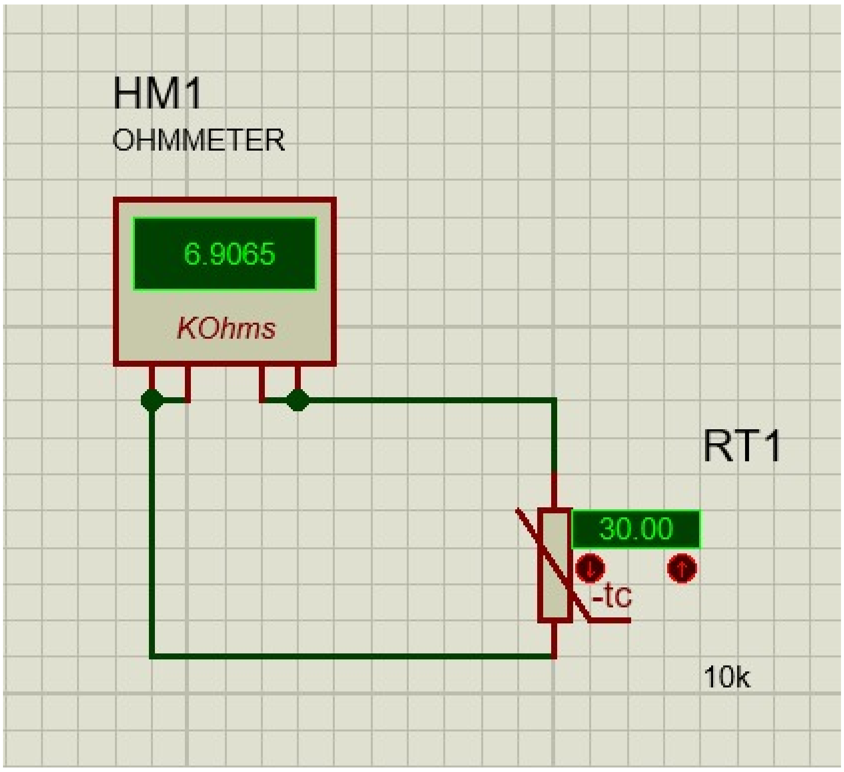
Tabla 4



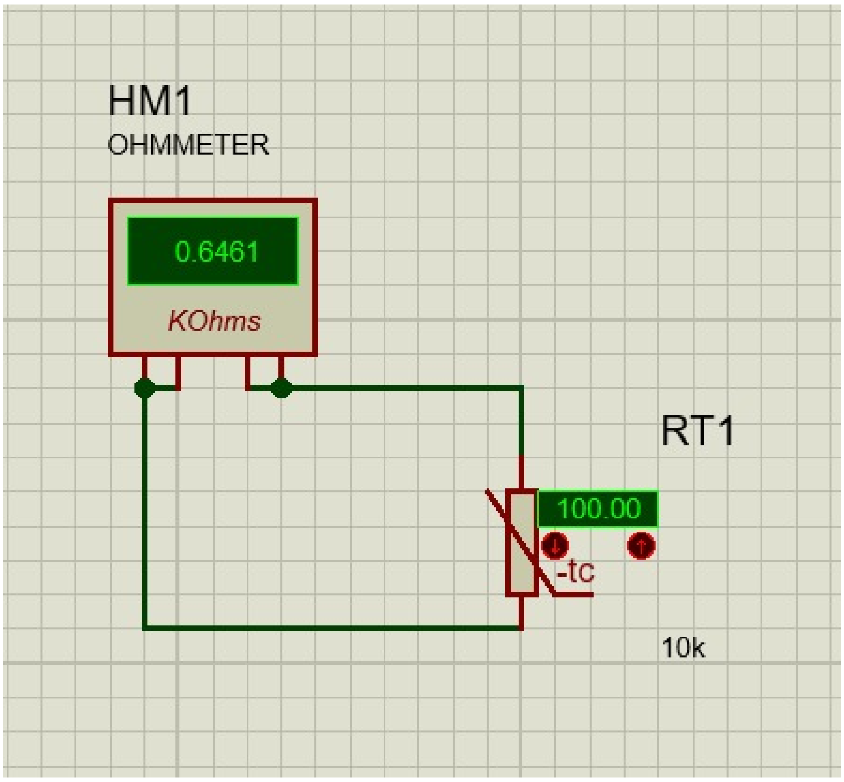
And, as we can see, the approximation to this functions is

$$Vout \approx 8e^{-06}T^{3} - 0.002T^{2} + 0.183T - 3.8869$$

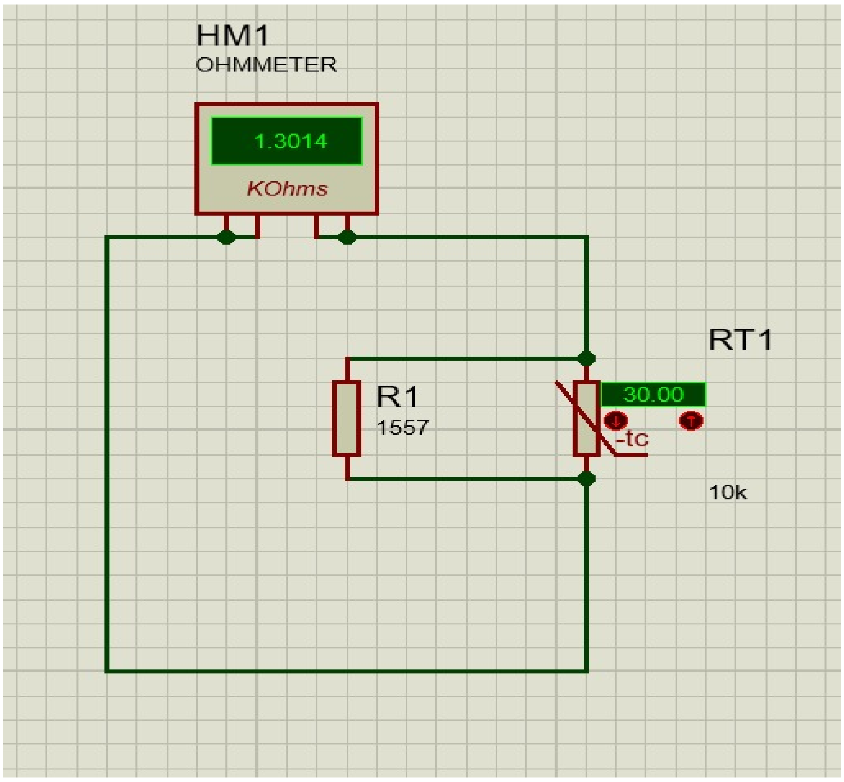
Evidence



HM1
OHMMETER
6.9065
KOhms
RT1
30.00
-tc
10k



HM1
OHMMETER
0.6461
KOhms
RT1
100.00
-tc
10k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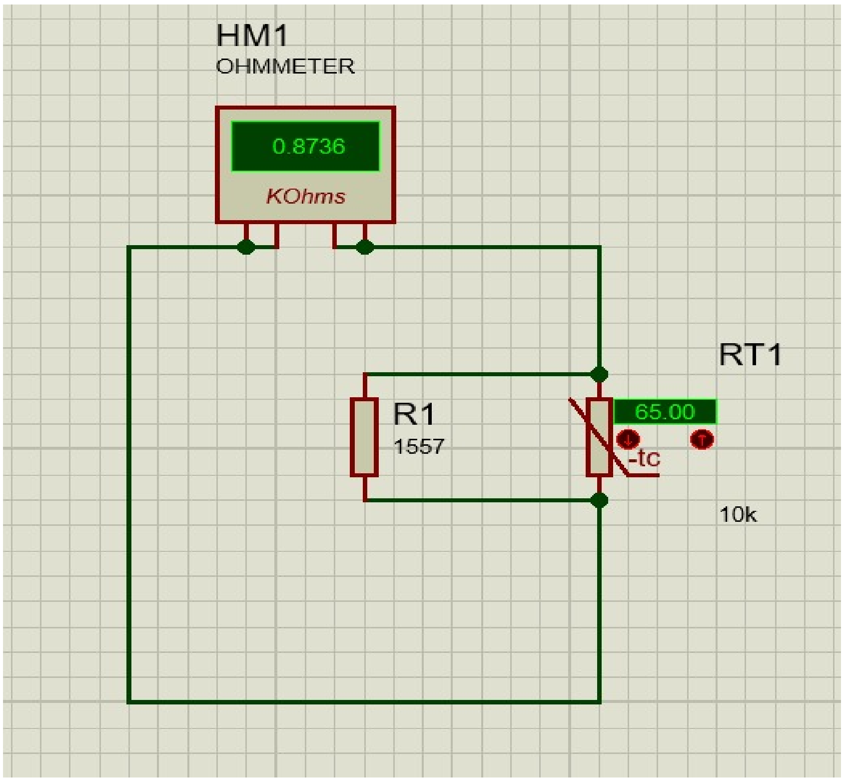
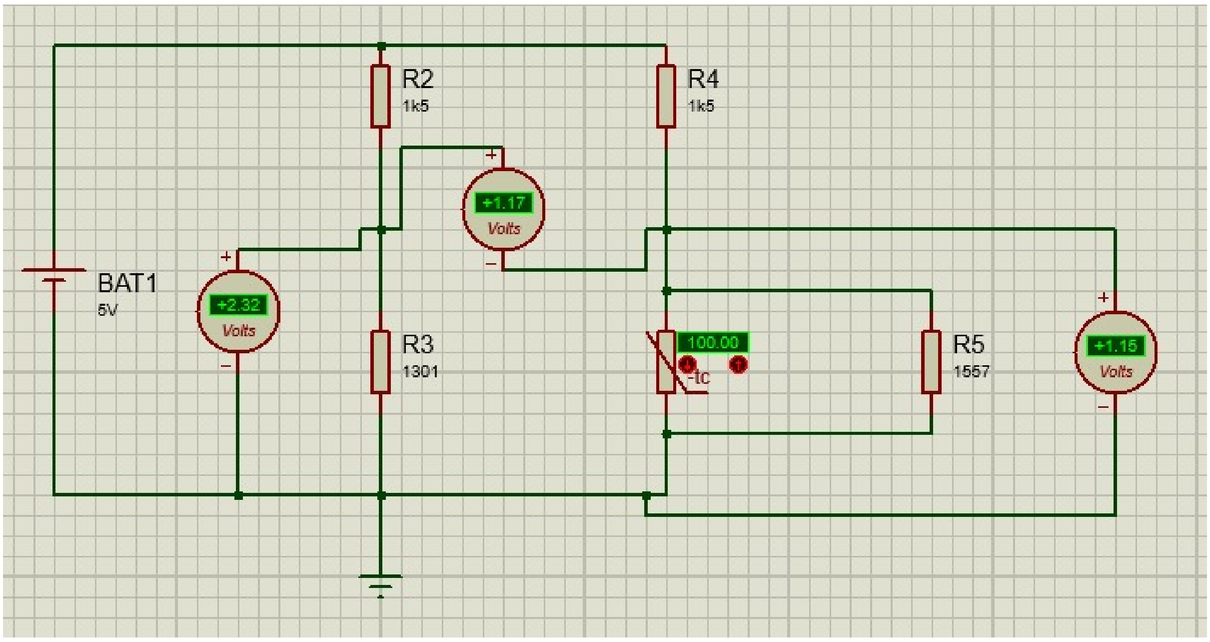
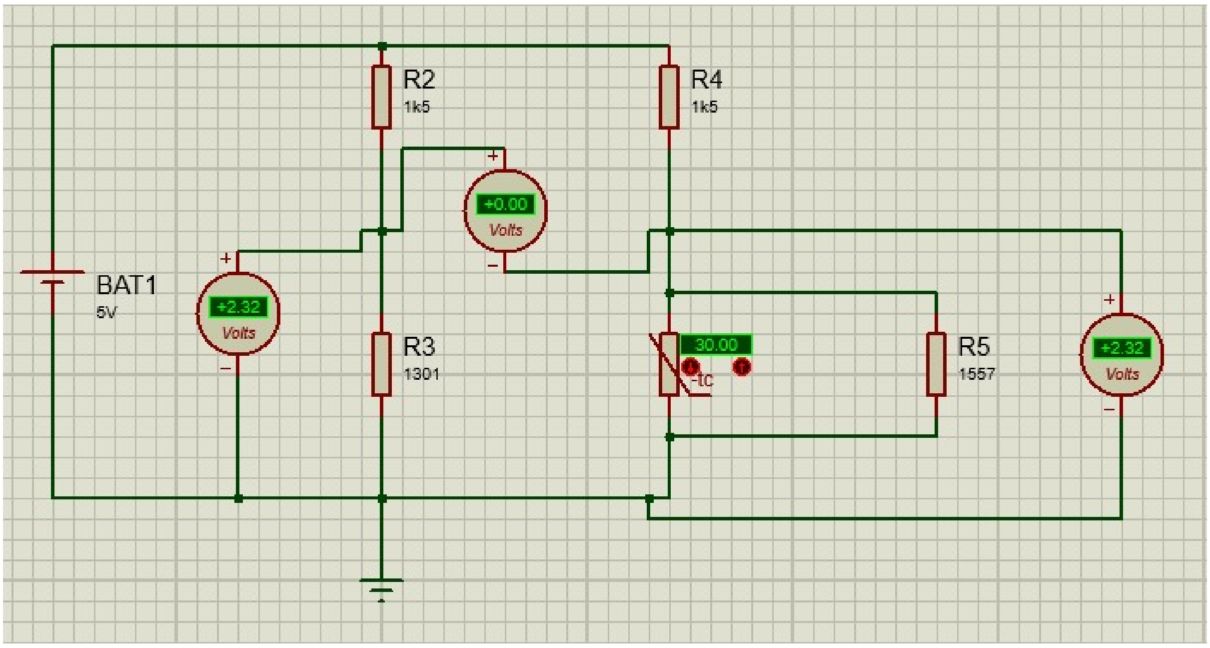
KOhms
RT1
R1
1557
30.00
-tc
10k

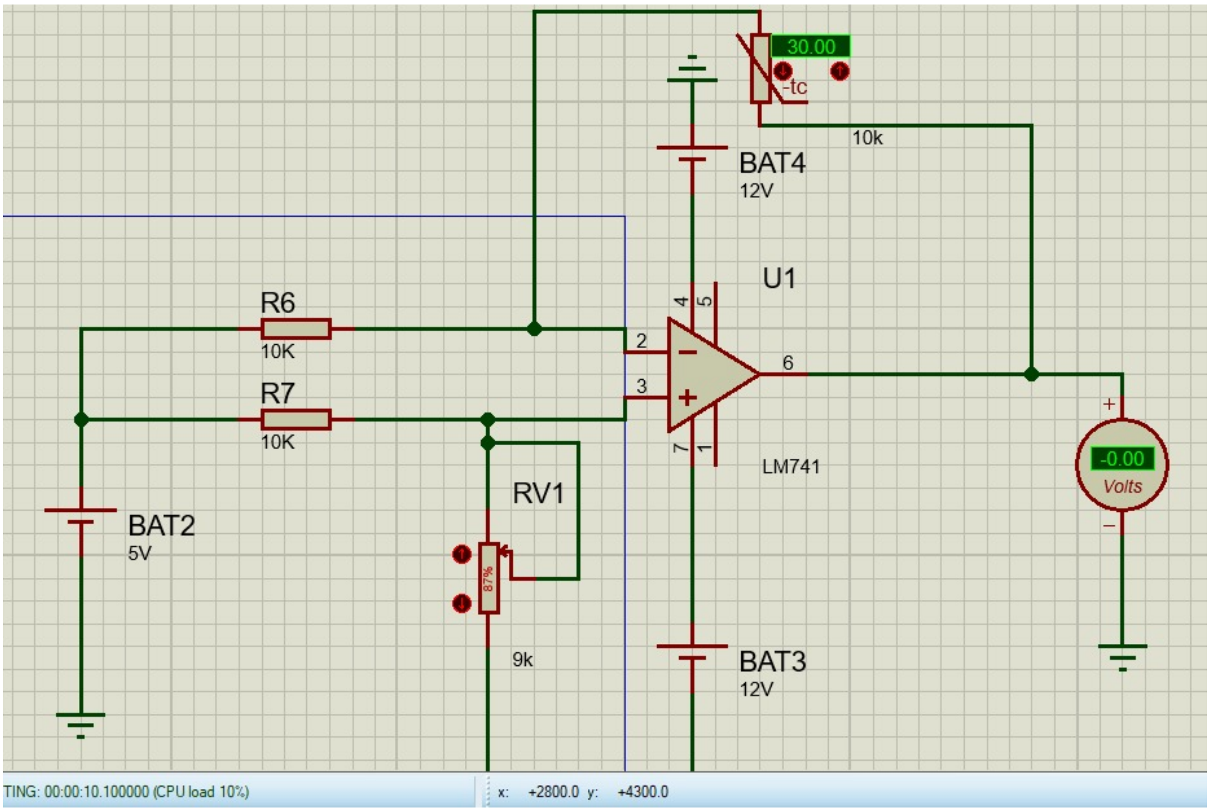

HM1
OHMMETER
0.8736
KOhms
RT1
R1
1557
65.00
-tc
10k



Thermistor at 100°



Thermistor at 30°



Pot 9k at 87%= 7.830 K

Calculations

TABLE 3

$$V_{out} = V_2\left(\frac{R1-R_2}{R1}\right)\left(\frac{R4}{R_3+R_4}\right) - V_1\frac{R_2}{R_1}$$

$$V_o = 5\left(\frac{10K - R_2}{10K}\right)\left(\frac{7.83K}{10K+7.83}\right) - 5\frac{R_2}{10K}$$

$$V_o = \left(\frac{50K-5R_2}{10K}\right)\left(\frac{7.83K}{10K+7.83K}\right) - 5\frac{R2}{10K}$$

$$V_o = \frac{391.5K - 39.15R_2}{100K + 78.3K} - \frac{5R_2}{10K}$$

$$V_o = \frac{391.5K - 39.15KR_2}{178.3K} - \frac{5R_2}{10K}$$

$$V_o = \frac{3915K - 391.5KR_2 - 891.5KR_2}{1783K}$$

$$V_O = \frac{3915K - 1283\,kR_2}{1783K}$$

$$V_O(1783k) = 3915k - 1283\,kR_2$$

$$\frac{V_O(1783k) - 3915K}{-1283\,k} = R_2$$

$$V_O(-1.38k) + 3.05k = R_2$$

TABLE3

Equation To calculate R_T

$$5R_T = (V_A - V_{AB})(R_T + 1500)$$

Questionnaire

1. **Are the graphs obtained for points 2 and 3 in this practice linearized? Why?**

   No, because as we can see, the resulting graphs and the functions that represent them are exponential.

2. **Which of the linearization methods is more advantageous to use? Why?**
   According to the results we obtained, the linearization using the Wheatstone bridge was more precise, throwing a linear function.

3. **Indicate another way in which the linearization of a sensor can be performed, if it is not done in the signal conditioning stage.**

   R=**with a wheatstone bridge and an RTD sensor**

4. **What does the sensor linearization technique consist of?**

   It consists of the implementation of mathematical methods to approximate a nonlinear system to a linear one, without significantly reducing its efficiency.

Conclusions

In this practice we learned different ways to linearize a resistive sensor, observing the outputs they throw and the difference they show with the previous practice and the first result, that is not linearized. In some cases we didn't reach a perfectly linear output, but it is a good improvement compared with the raw output.

References

Mandado Pérez, E., & Murillo Roldan, A. (August 31, 2021). alfaomega. Obtained from https://libroweb.alfaomega.com.mx/book/487/free/ovas_statics/sensores/temas/SA_TEMA_04-RESISTIVOS_1_.pdf

Rodríguez Pozueta, M. Á. (August 31, 2021). unican. Obtained from https://personales.unican.es/rodrigma/PDFs/Puente%20de%20Wheatstone.pdf

García Ares, E. (n.d.). AMPLIFICACIÓN DE SEÑALES (I) INTRODUCCIÓN . http://ocw.uc3m.es/tecnologia-electronica/instrumentacion-electronica-i/material-de-clase-1/Tema4_A1.pdf.

Acondicionamiento de señal. (n.d.). http://www.eudim.uta.cl/files/8313/2215/7786/fm_Ch04_mfuentesm.pdf.

Yallico Tapia, Á. P. (2015, July). Acondicionamiento de Señales Digitales. https://repositorio.uta.edu.ec/bitstream/123456789/13073/1/Tesis_t1051ec.pdf.

Germán Corona Ramírez Leonel, Stephany Abarca Jiménez Griselda, & Carreño Mares Jesús. (2015). Sensores y actuadores: Aplicaciones con arduino. Grupo Editorial Patria.

International Journal on Smart Sensing and Intelligent Systems. (2019, April) Linearization of the sensor's characteristics: a review. Obtained from : https://core.ac.uk/download/pdf/227572562.pdf

Steinmeyer. (n.d.). Linearizing Thermistors for Use as Temperature Sensors. Obtained from: https://www.lpi.usra.edu/lunar/ALSEP/pdf/LinearThermistorsUseAsTempSensors%20-%20ATM-1108.pdf