Instituto Politécnico Nacional

Ingeniería en Sistemas Computacionales

Laboratorio de Instrumentación

Practica N° 1 “Empleo de Sensores Resistivos”

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Index

Objective

The student will learn how to use resistive sensors, as well as how to calibrate the different components of a linear measurement system, in order to obtain the electrical signal corresponding to the variable under measurement.

Equipment employed

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

Introduction

Resistive sensors

Sensors whose physical principle is the electrical resistance variation, either from an electrical component or an electronic one. These sensors can be classified by the variable they measure, example:

- Potentiometers
- Thermistors
- Magnetoresistors
- Photoresistors
- Gas detectors and sensors

Types of sensors

Potentiometer: is an electric resistor with variable resistance value, usually adjusted manually

Strain gauges: sensor whose resistance varies with the force applied.

Photoresistances: electronic component where its resistance varies depending on the light it receives

Thermistors: semiconductor whose resistance varies non-linearly by temperature

Hygrometers: its function is to present a decrease in resistivity and an increase in the dielectric constant, by increasing its humidity

Wheatstone Bridge

It can be used in many ways to measure the resistance, these are some of them:

- Determinate the resistance absolute value, comparing with another known resistance.
- Precisely determinates the relative changes in the resistance value.

Conditioning

The output of a sensor is a fundamental data for a measurement system, but in order to process this signal it is necessary to adapt it to allow the next operation to interpret it according to its needs through an information processing system. The circuits implemented for the adaptation are called signal conditioners and their main objective is to make a conversion to leave the signal in formats easier to process.

The procedures that can be included in the conversion are:

- Amplification, which is responsible for increasing the magnitude of a signal.
- Linearization, involves the conversion of a non-linear signal into one with linear behavior.
- Filtering, a procedure that discards unwanted components of a signal. Filters are classified according to their configuration and therefore based on the components they wish to retain or eliminate.
- Conversion, is generally performed when a contiguous or analog signal is required in its discrete or digital form, to be further processed by a microcontroller. The circuits used in this process are known as converters and can perform analog-to-digital, analog-to-digital, analog-to-digital, frequency-to-voltage, voltage-to-frequency, current-to-voltage, voltage-to-current, direct-to-alternate and alternating-to-direct conversions.
- Electrical isolation, interrupts the signal between the input and output, transmitting it to the output by means of an optical or magnetic signal. This method is used when a measurement is required on a surface above ground.
- Excitation, some sensors require stimulation to function.

Proper output signal conditioning provides a system that is not sensitive to variations such as noise or inability to filter the input data.

Development

1. Resistor bridge

To calculate R_3 y R_4 we have

$V_{AB} = 0V,\ lower\ limit$
$V_{AB} = 2.5V,\ upper\ limit$
$V_s = 5V$
$R_1 = (1K\Omega - 10K\Omega)$
$R_2 = 1K\Omega$, given that it takes the resistivity value of R_1 at its lower limit.

We now that $V_B - V_A = 0V...(1)$, we rewrite the equation in terms of the voltage divider

$$V_s\left(\frac{R_4}{R_2+R_4}\right) - V_s\left(\frac{R_3}{R_1+R_3}\right) = 0V...(1)$$

Substituting V_s, R_1 y R_2 en... (1)

$$5\left(\frac{R_4}{1K\Omega+R_4}\right) - 5\left(\frac{R_3}{1K\Omega+R_3}\right) = 0V...(1)$$

$$5\left(\frac{R_4}{1K\Omega+R_4}\right) = 5\left(\frac{R_3}{1K\Omega+R_3}\right)...(1)$$

Therefore we note that $R_3 = R_4$ and we rename them as

$$R_3 = R_4 = R$$

On the other hand we now that $V_B - V_A = 2.5V...(2)$ and likewise we rewrite the equation in terms of the voltage divider

$$V_s\left(\frac{R_4}{R_2+R_4}\right) - V_s\left(\frac{R_3}{R_1+R_3}\right) = 0V...(2)$$

Replacing V_s, R,R_1 y R_2 en... (2)

$5\left(\frac{R}{1K\Omega+R}\right)-5\left(\frac{R}{10K\Omega+R}\right)=2.5V\ldots(2)$

Solving ... (2)

$\frac{5R(10+R)-5R(1+R)}{(1+R)(10+R)}=2.5\ldots(2)$

$5R(10+R)-5R(1+R)=2.5(1+R)(10+R)\ldots(2)$

$50R+5R^2-5R-5R^2=2.5\left(10+11R+R^2\right)\ldots(2)$

$45R=25+27.5R+2.5R^2\ldots(2)$

$0=25-17.5R+2.5R^2\ldots(2)$

$R=2K\Omega$ y $R=5K\Omega$

2. Signal amplification

Resistor R1 (KΩ)	Vb (Volts)	Va (Volts)	Va - Vb (Volts)	Vsal (volts)	Resistencia R1 (KΩ)
1	3.33	3.33	0	0	1.00
2		2.5	0.83	1.66	2.00
3		2	1.33	2.66	3.00
4		1.67	1.66	3.33	3.99
5		1.43	1.9	3.81	4.99
6		1.25	2.08	4.16	6.00
7		1.11	2.22	4.44	7.01
8		1	2.33	4.66	8.00
9		0.91	2.42	4.85	8.99
10		0.83	2.5	5	10.05

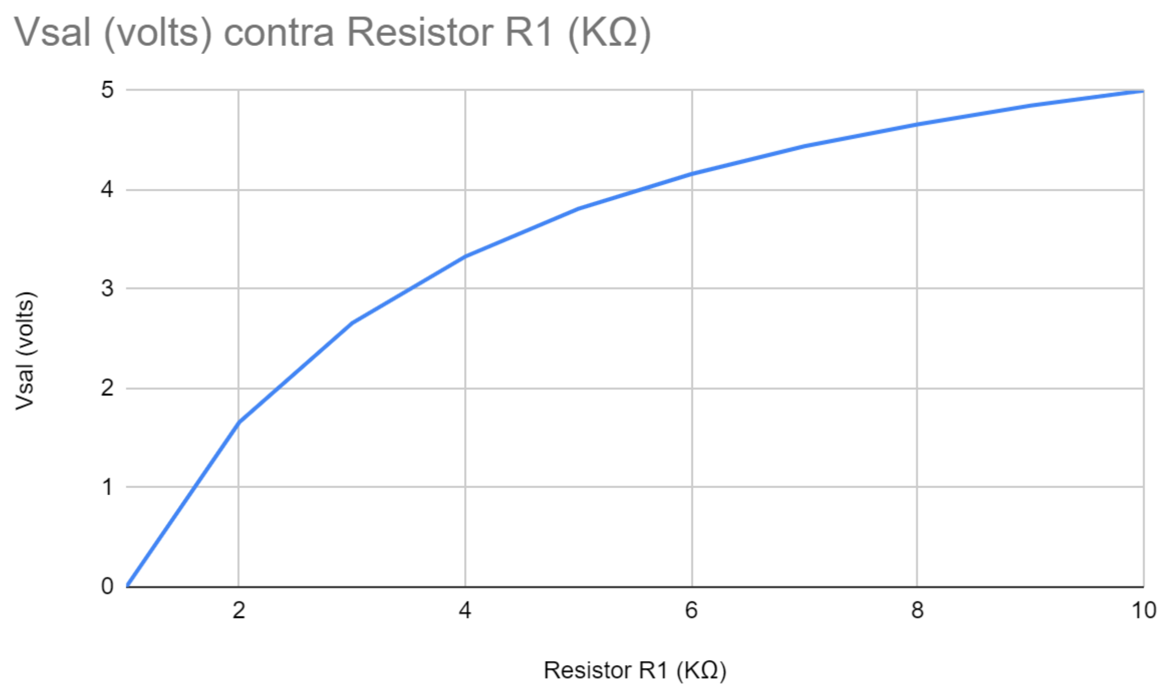
To calculate R1 in the previous table we have

$$V_a=\frac{R3}{R3+R1}V_s$$

$$\frac{V_a}{V_s}=\frac{R3}{R3+R1}$$

$$\frac{R3+R1}{R3}=\frac{V_s}{V_a}$$

$$1+\frac{R1}{R3}=\frac{V_s}{V_a}$$



This graphic shows logarithmic behaviour. In order to obtain the function f(R1) we followed these steps.

$$\log_x 10 = 5$$

$$\frac{1}{\log_{10} x} = 5$$

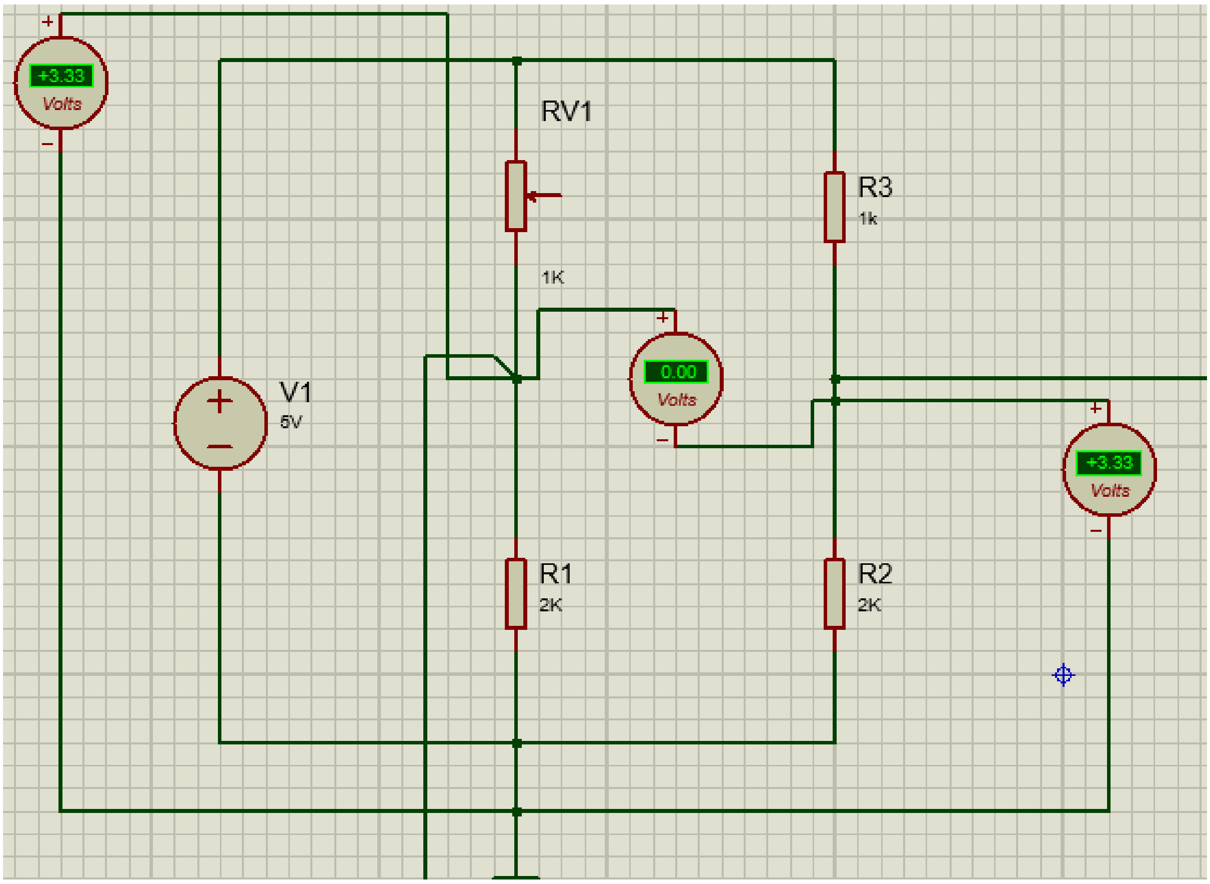
$$\frac{1}{5} = \log_{10} x$$

$$x = \sqrt[5]{10}$$

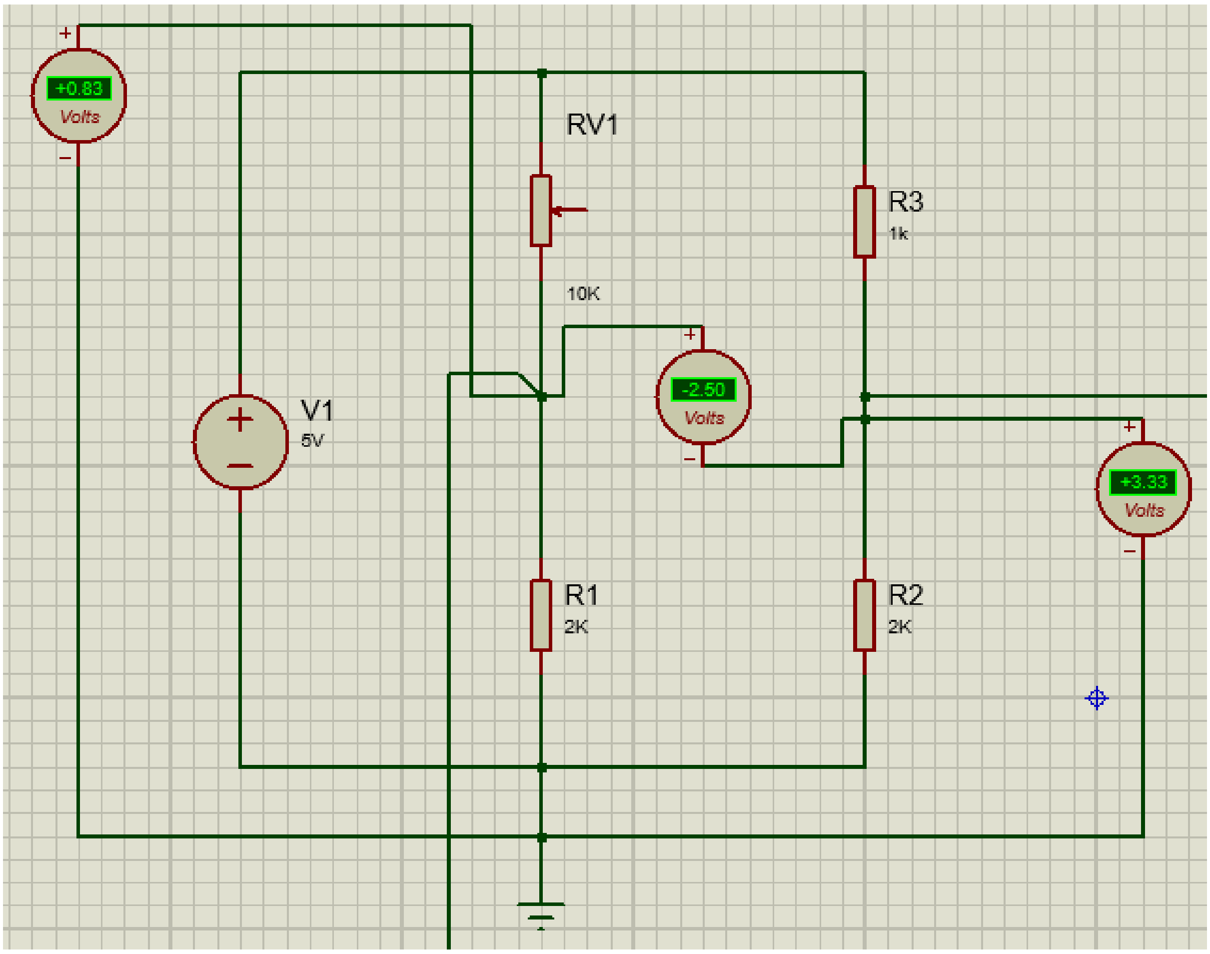
$$V_{sal} = \log_{\sqrt[5]{10}} R1$$

Evidence

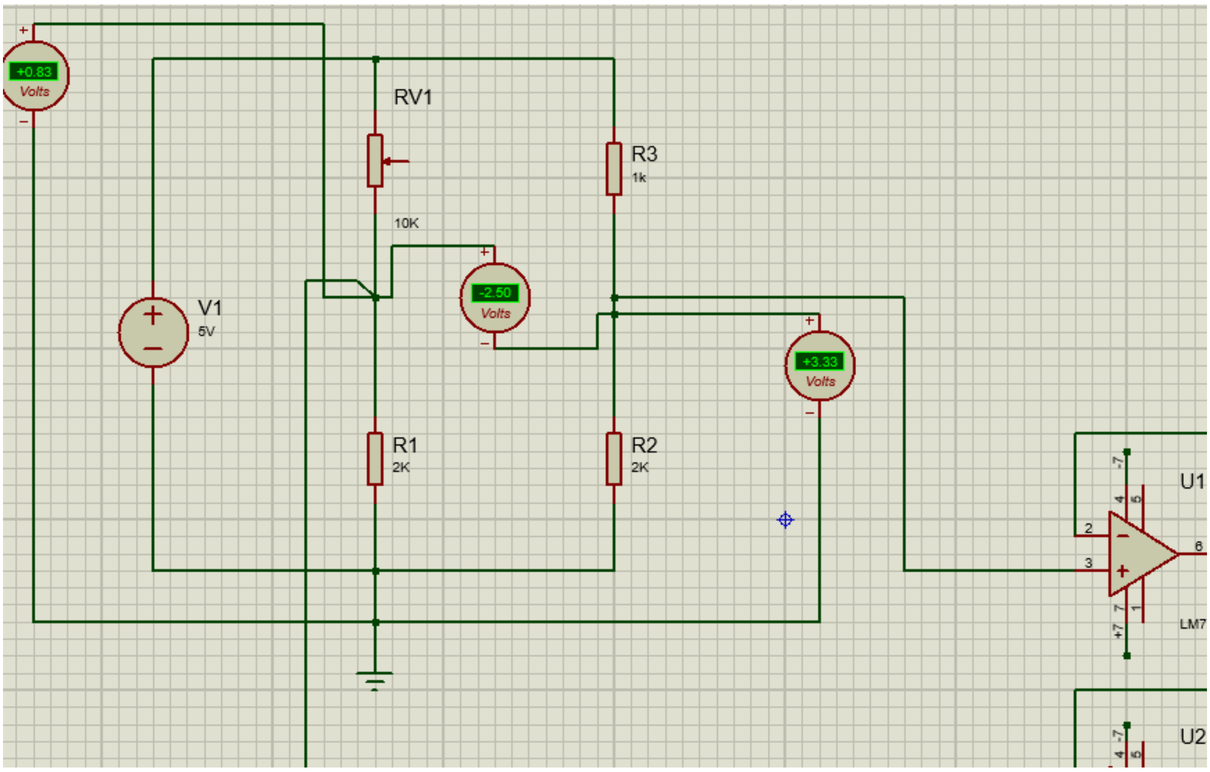
1. Wheatstone bridge in equilibrium

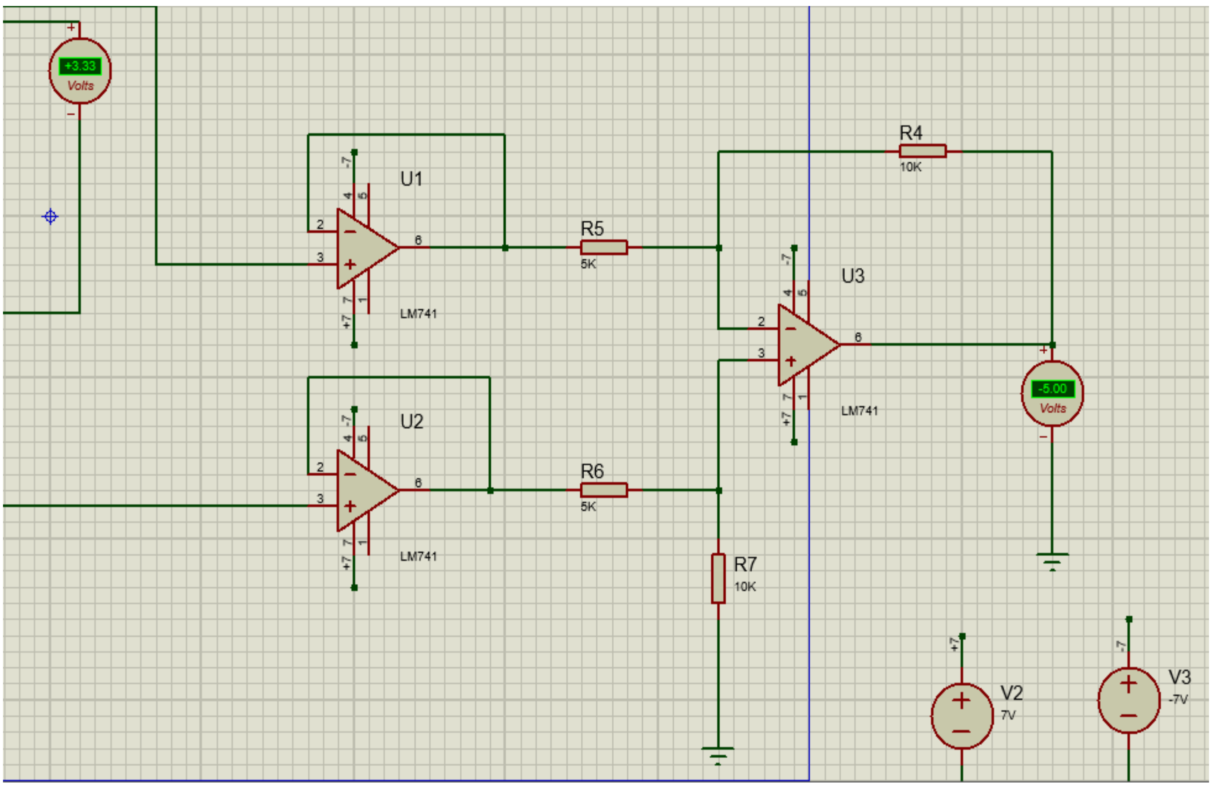


2. VAB(max) = 2.5v



3. VAB(max)=2.5v with the operational amplifier





Questionnaire

1. Which variable are we measuring with the implemented circuit?

   In this case, we are using a potentiometer in the Wheatstone bridge, so we just measure the resistance on it. We can change the potentiometer with another sensor and it will measure changes on his measured variable.

2. With the sensitivity set in mV / Ω, after signal conditioning and if the VREF = 5V, how many bits should the ADC be required for this measurement?

   R= 8 bit

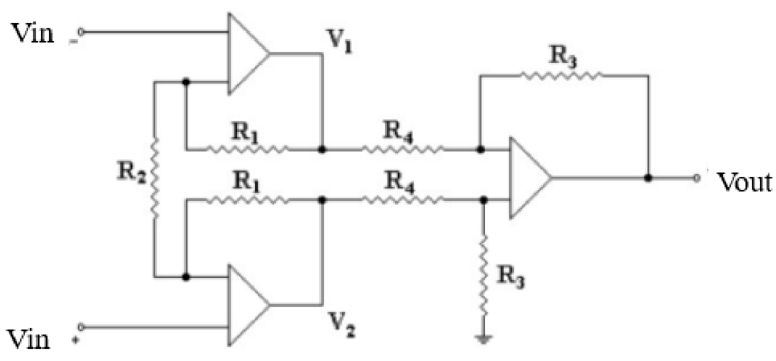
3. Is the final output behaviour lineal?

   No, it is not, because the Wheatstone bridge is not linearized.

4. Investigate and indicate another way to realize the signal amplification performed by the circuit in figure 2.

   It is possible to implement an instrumentation amplifier to amplify the signal.

   These are precision devices designed for the amplification of weak voltage signals, so they are ideal when preamplifying the output of Wheatstone bridge assemblies, in addition they are characterized by providing finite gain and high impedance differential input. The amplifier design is shown below.



If R2=R3 , we have $V_{O2} - V_{O1} = \left(1 + \frac{2R_2}{R_1}\right)(V_{i1} - V_{i2})$

5. Investigate which resistive transducer is recommended? to measure distance.

   A distance sensor

Conclusions

This practice at first cost us work when calculating the resistances, but we could observe and understand in a better way how the wheatstone bridge works and we could graphically observe how it acts in connection with the operational amplifier

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