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Basic operation of rotary potentiometer A, B, C and W

Funcionamiento básico de potenciómetro rotativo A, B, C y W

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Abstract

Presents study of analytical, experimental, and numerical method corresponding a A50K logarithmic, B10K linear, C10K antilogarithm and W20K logarithmic-antilogarithm rotative variable resistances. The basic operation of each potentiometer according to the variation on the input voltage and the spin on degrees of 30° between each measurement is studied using Arduino, MATLAB and Proteus. The functioning of each potentiometer model is complemented with the adjustment of the experimental curve and its characteristic equation. Signal conditioning in a variable resistance is of very important to control and stabilize a basic application, for example the variation of input voltage, or a specific variable such as movement, speed, lighting, etc.

Resistances, Measurement, Stabilize

Resumen

Se presenta el estudio del método analítico, experimental y numérico en resistencias variables modelos A50K logarítmico, B10K lineal, C10K antilogarítmico y W20K logarítmico-antilogarítmico. Se estudia el funcionamiento básico de cada potenciómetro, dependiendo de la variación de voltaje de entrada a 5V y el giro en grados cada 30º entre medición empleando Arduino, MATLAB y Proteus. El correcto funcionamiento en cada modelo de potenciómetro se complementa con el ajuste de la curva experimental, así como su respectiva ecuación característica. El acondicionamiento de señal en una resistencia variable es de suma importancia para controlar y estabilizar una aplicacion básica, por ejemplo la variación de entrada de voltaje, o una variable específica como movimiento, velocidad, iluminación, etc.

Resistencias, Medición, Estabilizar

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Introduction

In basic electronics it is common to use both fixed and variable resistors. As they are simple transducers, they allow the implementation of low-cost electronic arrays avoiding the use of sophisticated modules. In this context, a potentiometer allows to vary its resistance to the passage of electric current, depending on the degree with which its knob is rotated, or how much the lever is slid [1]. For a potentiometer-type electronic component, there are four important elements: connector A and B, a fixed resistor linking these two, and a connector C called a cursor representing the knob that adjusts the resistance between the terminals as shown in Fig. 1a and 1b. The rotary potentiometer contains a resistive strip that is connected to terminals A and B, and a sliding contact that is connected to terminal C thus obtaining the total resistance [2]. Fig. 1c shows the European and American symbols for a variable resistance.

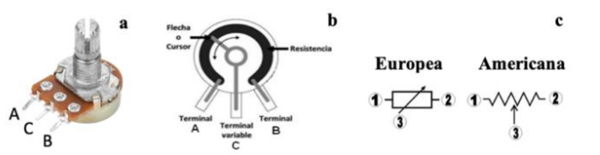

Figure 1 Rotary potentiometer a). Real device, b). Electronic design and c). Symbol.

To understand the main operation of a potentiometer, Ohm's law V=IR is used, which establishes the current intensity through the resistive element directly proportional to the potential difference applied and inversely proportional to the resistance it represents [3]. This law is useful to determine the behavior of the resistance generated by a rotating potentiometer in the arrangement of its degrees of rotation, approximately up to 300º. These degrees can be replaced by the use of percentage with which the potentiometer knob is turned, being a viable and correct alternative. Turning the potentiometer allows varying the amount of output voltage and likewise the resistance in Ohms of the model used [4]. Depending on the type of potentiometer will be the acquired behavior in the degrees of rotation and the % of voltage output. The sequence of Fig. 2 represents the behavior generated by a potentiometer type 2a. A-logarithmic, 2b. B-linear, 2c. C-antilogarithmic and 2d. W logarithmic-antilogarithmic.

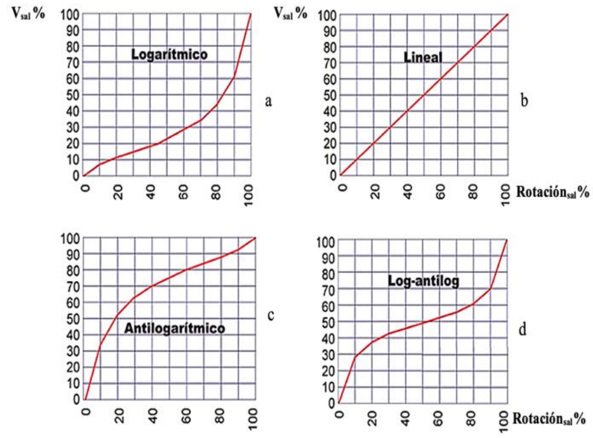

Figure 2 Response of rotary potentiometers: a). A logarithmic, b). B linear, c). C antilogarithmic and d). W logarithmic-antilogarithmic

Now, a potentiometer can be used in two different ways, being the first one as a voltage divider, where the input voltage is divided between each terminal according to the position of C, for example, when handling a 5V source and placing C just at its midpoint, we would have 2.5V between the terminal A and C and another 2.5V between the terminal C and B. And the second way, as a variable resistor, this can be measured by connecting terminal C with any other; C and A, for example, then, by moving the knob to the left end the resistance will be 0 and if it is moved to the opposite end its resistance will be the maximum allowed (without considering tolerances), in this way it is possible to say that, by moving the contact at C along the resistor, the level of the output electrical voltage will be adjusted [5]. The characterization of these devices for basic or complex applications requires the understanding of their response type and curve behavior.

Electronic systems that require variation of input resistance or voltage justify the use of this type of potentiometers, such as motion control, audio, speed, lighting, etc. However, each potentiometer is usually employed in more specific situations: the A-logarithmic is used as volume control in audio equipment since it easily simulates the auditory scale of the human ear [6]; the B-linear represents a practical option to automate processes where distance or position measurement is required [7]; the C-antilogarithmic is used as an operational amplifier in order to make precise adjustments in the signal adaptation of some sensors [8]; and finally the W-logarithmic-antilogarithmic is used in instrument pedals such as guitars to generate certain musical effects [9].

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In this work the experimental and numerical performance of the 4 types of potentiometers is presented. Obtaining the experimental values generates the characteristic equation and the graphical behavior in each potentiometer, which will be correctly adjusted using computational techniques.

Material and methodology

The material consists of four potentiometers: type A of 50KΩ, type B of 10KΩ, type C of 10KΩ and type W of 20KΩ, Arduino Uno board, Proteus and MATLAB. For the experimental case in Fig. 3, each potentiometer is shown with connector A at 5V from the Arduino board (red connection), connector C is sent to ground (black connection) and the output voltage variable is acquired at connector B (yellow connection). This last signal, being analog, is received by ports A1-A4 of the Arduino, monitored in real time and controlled by the angle of rotation of each potentiometer.

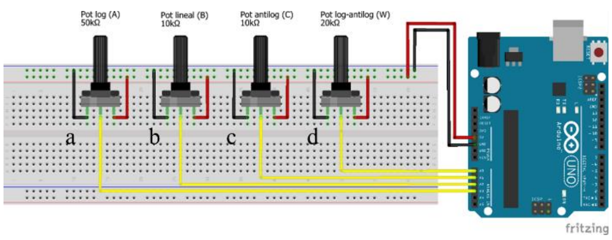

Figure 3 Connections of potentiometers A, B, C and W with the Arduino board

Fig. 4 shows the experimental arrangement for the resistive modules A, B, C and W with their respective degree indicator circle which is mounted on the threaded shaft. For the C-antilogarithmic potentiometer, a potentiometer B is used, which is modified in the Arduino code to acquire the desired behavior [10].

Fig. 5 shows the arrangement of the potentiometers in Proteus, where the Arduino Uno board, a virtual terminal, an oscilloscope, ohmmeter, voltage source and ground are used. For the logarithmic-antilogarithmic W potentiometer, the logarithmic and antilogarithmic potentiometer is used in parallel [11]. In each experimental and numerical case the total measurement swing is 300°.

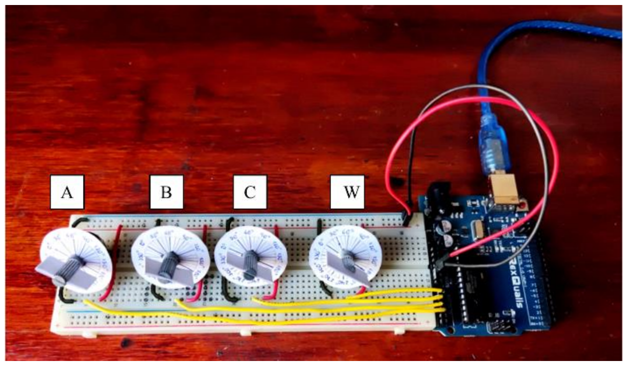

Figure 4 Experimental arrangement of potentiometers A, B, C and W with circle marked in degrees and Arduino board

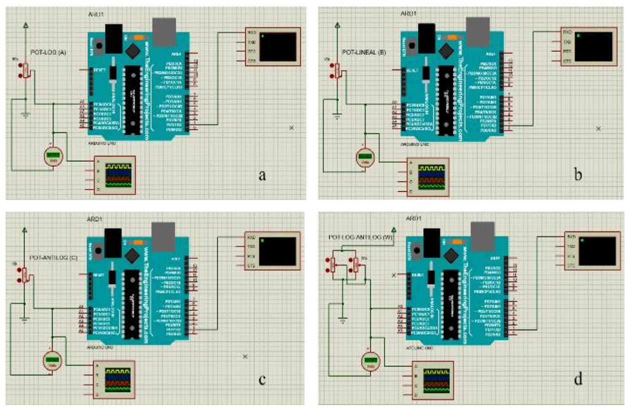

Figure 5 Proteus simulation of the potentiometers: a) Type A, b) Type B, c) Type C and d) Type W

Results

For each potentiometer Table 1 shows the experimental and numerical values of the voltage acquired with the rotation on each potentiometer in a range from 0 to 5V and 0° to 300° directly without signal adjustment. The analog signal acquired so far still represents an unstable signal, which can be adjusted in Matlab.

In particular, a B-linear potentiometer was experimentally used for the C-Anthyrhythmic potentiometer and programmatically adjusted with Eq. (1) and (2). The function map changes the range of values in the reading from 0 to 1023, finally obtaining a range from 1 to 10 with ten levels of 30°. The variable y1 is the reading in levels (1 to 10), y2 is the desired function for the path of those levels. The code in Arduino is adjusted with Eq. 2, likewise values are generated in the Proteus simulation.

$$y_1 = 10 * \frac{lectura - 10}{10} + 10 \qquad (1)$$

$$y_2 = \log(y_1) * 42.997 + 1 \qquad (2)$$

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Angle [°]	Experimental Voltaje [V]				Simulation			
	Pot. A	Pot. B	Pot. C	Pot. W	Pot. A	Pot. B	Pot. C	Pot. W
0	0	0	0	0	0	0	0	0
30	0.2	0.46	1.54	0.05	0.11	0.5	2.50	0.73
60	0.24	0.95	2.41	0.23	0.24	1	3.26	1.30
90	0.44	1.42	3.03	0.34	0.39	1.5	3.70	1.77
120	0.61	1.96	3.51	0.6	0.56	2	4.01	2.17
150	0.77	2.48	3.90	2.07	0.75	2.5	4.25	2.50
180	1.32	3.03	4.23	3.52	1	3	4.45	2.80
210	2.90	3.53	4.52	4.71	1.31	3.5	4.62	3.08
240	4.37	4.03	4.77	4.85	1.75	4	4.76	3.35
270	4.95	4.63	5	4.96	2.5	4.51	4.89	3.66
300	5	5	5	5	5	5	5	5

Table 1 Values without curve fitting acquired in each potentiometer by the experimental and numerical method

The values acquired in Table 1 are processed with the respective Polyfit function in Matlab. Table 2 shows the type of polynomial fit used in each potentiometer and its characteristic equation for the experimental and numerical case.

Potentiometer	Polynomial fit function	Equation
A	Logarithmic	3 and 4
B	Linear	5 and 6
C	Antilogarithmic	7 and 8
W	3rd degree and exponential	9 and 10

Table 2 Potentiometer type, polynomial function and its respective experimental and numerical equation

Potentiometer type A

$$y_{A.Exp} = 31(0.018447 + 2.8508 * \log x + 4.3) \quad (3)$$

$$y_{A.Sim} = 41(0.012173 + 2.2188 * \log x + 4.3) \quad (4)$$

Potentiometer type B

$$y_{B.Exp} = 0.01918x - 0.395 \quad (5)$$

$$y_{B.Sim} = 0.01601x - 0.0009091 \quad (6)$$

Potentiometer type C

$$y_{C.Exp} = (0.7328652 * \log x * 2.3) - 3.5 \quad (7)$$

$$y_{C.Sim} = (0.0020914 + 1.0495 * \log x) - 1 \quad (8)$$

Potentiometer type W

$$y_{W.Exp} = -1.158e^{-6}x^3 + 0.0005615x^2 - 0.05241x + 1.283 \quad (9)$$

$$y_{W.Sim} = 1.227e^{0.004429x} - 2.051e^{-0.03649x} \quad (10)$$

Table 3 presents the experimental and numerical values for each potentiometer with their respective polynomial fit. Fig. 6 shows the representative plots for the experimental case (a) A50K logarithmic, (b) B10K linear, (c) C10K antilogarithmic and (d) W20K logarithmic-antilogarithmic. The blue dots represent the experimental measurements and the red line represents the fit obtained in Matlab.

Angle [°]	EXPERIMENTAL Voltage [V]				SIMULATION			
	Pot. A	Pot. B	Pot. C	Pot. W	Pot. A	Pot. B	Pot. C	Pot. W
0	0	0	0	0	0	0	0	0
30	0.06	0.17	1.59	0.18	0.11	0.48	2.54	0.71
60	0.24	0.75	2.62	0.09	0.25	0.96	3.26	1.37
90	0.43	1.38	3.23	0.27	0.39	1.44	3.68	1.75
120	0.61	2.02	3.66	1.07	0.56	1.92	3.98	2.06
150	0.80	2.55	4	2.14	0.75	2.4	4.21	2.37
180	1.47	3.15	4.26	3.28	0.97	2.88	4.40	2.72
210	2.76	3.73	4.49	4.31	1.31	3.36	4.56	3.10
240	4.56	4.27	4.69	5.03	1.75	3.84	4.69	3.55
270	4.94	4.85	4.87	5.27	2.5	4.33	4.82	4.05
300	5	5.04	4.87	4.82	4.98	4.8	4.92	4.63

Table 3 Values acquired in potentiometers after curve fitting, experimental and numerical case

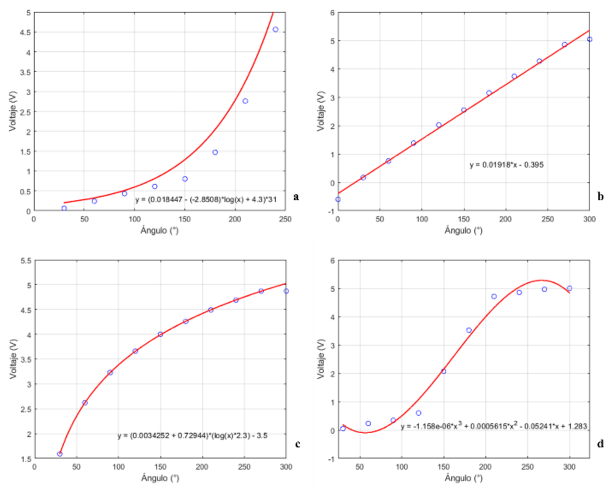

Figure 6 Curve fitting of experimental potentiometer behavior (a) A-logarithmic, (b) B-linear, (c) C-antilogarithmic and (d) W-logarithmic-antilogarithmic

For the numerical case Fig. 7 shows the response curves for (a) A50K logarithmic, (b) B10K linear, (c) C10K antilogarithmic and (d) W20K logarithmic-antilogarithmic.

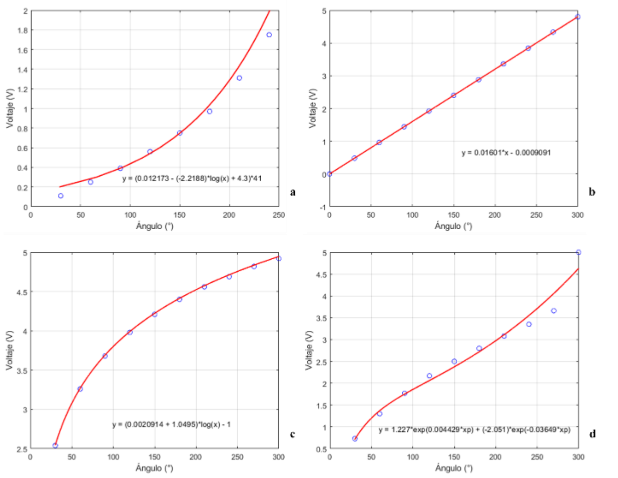

Figure 7 Curve fitting of potentiometer behavior in Proteus simulation: a) A-logarithmic, b) B-linear, c) C-antylogarithmic and d) W-logarithmic-antylogarithmic

The experimental and simulated values, as well as their respective curve fitting show the behavior generated by a basic rotary type potentiometer. It is observed that the polynomial adjustment is optimal to use it in the programming of the resistor, in this way a better control and quality in the signal will be achieved.

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Conclusions

It is relevant to identify the behavior of a variable resistor, using theoretical, experimental and numerical techniques. In practice, if the variable resistor requires a linear, logarithmic, antilogarithmic or logarithmic-antilogarithmic response, it is monitored in a multimeter or electronic software to control its rotation, voltage variation and resistance. Finally, it is recommended to make an adjustment to the potentiometer curve in use to improve the control signal of the electronic system.

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