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Prototype simulation for the measurement of energy consumption in watts for alternating current systems

Simulación de prototipo para la medición del consumo de energía en watts para sistemas de corriente alterna

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Abstract

This research deals with the simulation of a prototype for the measurement of energy consumption in watts for alternating current systems, the purpose is to validate the proposed circuit for its implementation and in turn it provides a low-cost and easy-to-use measurement option for the public generally in their homes. The development of the prototype simulation will be carried out using the Arduino development environment with the components, Simulino Uno and the current sensor ACS712ELCTR-05B-T, from the Proteus Software. The current signal will be taken by the sensor to later pass it through a conditioning stage so that it is received by the microcontroller, where the programming will be carried out so that with the value obtained and the configuration of the voltage value, the power calculation in watts can be made, which will be displayed on a virtual monitor for viewing. This proposal seeks a device that performs the calculation of energy consumption in Watts that can lead the user to quantify and take better advantage of the use of electrical appliances or devices, and thus reduce the cost of their bill.

Simulation, Arduino, Energy consumption

Resumen

La presente investigación aborda la simulación de un prototipo para la medición del consumo de energía en Watts para sistemas de corriente alterna, la finalidad es validar el circuito propuesto para su implementación y a su vez este brinde una opción de medición de bajo costo y fácil uso para público en general en sus hogares. El desarrollo de la simulación del prototipo se realizará empleando el entorno de desarrollo Arduino con los componentes, Simulino Uno y el sensor de corriente ACS712ELCTR-05B-T, del Software Proteus. La señal de corriente la tomará el sensor para posteriormente pasarla por una etapa de acondicionamiento para que la reciba el microcontrolador, donde se realizará la programación para que con el valor obtenido y la configuración del valor de voltaje se pueda hacer el cálculo de potencia en Watts, el cual se desplegará en un monitor virtual para su visualización. La presente propuesta busca un dispositivo que realice el cálculo del consumo energético en Watts pueda llevar al usuario a cuantificar y aprovechar de una mejor manera el uso de aparatos o dispositivos eléctricos, y así disminuir el costo de su factura.

Simulación, Arduino, Consumo de energía

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Introduction

The awareness of electricity consumption within homes is still a culture with which many are not familiar since they do not have easy-to-interpret devices, it should be noted that currently the municipality of Huauchinango Puebla, where the research is developed, there is no regulation in the payment of electricity rates due to the extinction of the Luz y Fuerza del Centro company, which has generated an abandonment of the electrical infrastructure that in the medium term would cause it to collapse. This will lead to the regularization of electricity service payments and users will have to moderate and monitor their electricity consumption as well as visualize in real time how much they are spending per day, based on this data they will be able to manage and organize the use of electrical devices in order to have a benefit reflected in the billing of said service.

Due to the aforementioned, this research seeks to propose a feasible, low-cost and easy-to-use option for the measurement of energy consumption, which is why a simulation of the proposal is proposed at the beginning in order to later develop its implementation.

For the development of this work, a methodology consisting of 4 stages is used, which are listed below: 1) analysis of the components that will be used in the simulation, 2) design of the connection of the components that will form the electronic circuit, 3) programming the microcontroller in the arduino IDE indicating the tasks we want to do taking the reading of the sensors and the conditions of the environment to be programmed, 4) simulation of the proposed circuit using the Proteus software to analyze and validate its behavior.

Analysis

To carry out the simulation of energy consumption in Watts, it was essential to carry out the analysis and proposed the components that make up the circuit.

The design and simulation of the circuit are carried out in Proteus software, an application in which it is possible to design diagrams and simulate the code programmed in the microcontroller in real time. An alternating current source is used within the simulation and an alternating current lamp as load.

The central element for the control of the prototype is the Arduino Uno Module based on the ATmega328 microcontroller. For simulation purposes, the components of the Simulino Uno library are used and the Arduino IDE, the development environment of this microcontroller, to create the programming code.

Finally, the ACS712ELCTR-05B-T current sensor, this allows to measure the electrical intensity in both direct current and alternating current that makes it functional both in industrial applications, communication systems and commercial. It is based on the Hall effect, as the input current flows through the copper conductor and is detected by the sensor, it is converted into an output voltage that is proportional to the input current. Other advantages for which this sensor was used are: the different models for ranges 5, 20 and 30 A; the interconnection with Arduino and its affordable cost.

Design

To calculate the Watts consumed, it is first necessary to quantify the electric current that passes through the alternating current device of which we want to know the consumption in Watts for which a connection is established between it and the sensor, as shown in the figure 1.

Figure 1 Census of the current of the device to be measured
Source: Own elaboration

Once the current is obtained, it is received by the Arduino microcontroller where a programming code is used to calculate the power of the Watts consumed, the communication sequence is shown in figure 2.

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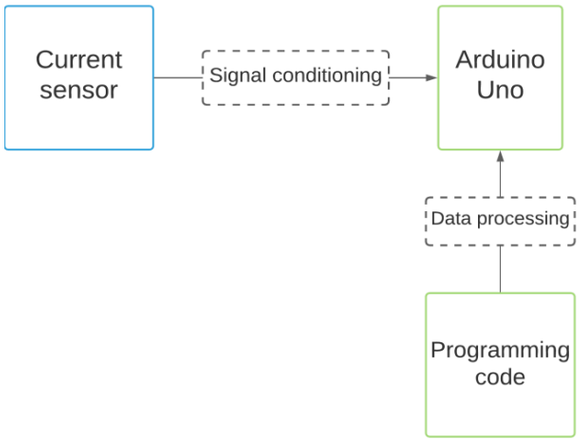

Figure 2 Data processing
Source; Own elaboration

Later this quantification of Watts will be shown by means of a virtual monitor. Prior to the physical assembly and simulation of said census, it is necessary to design the interconnection between the different devices that make up this measurement circuit, Figure 3 shows the general sequence of each element integrated into the circuit.

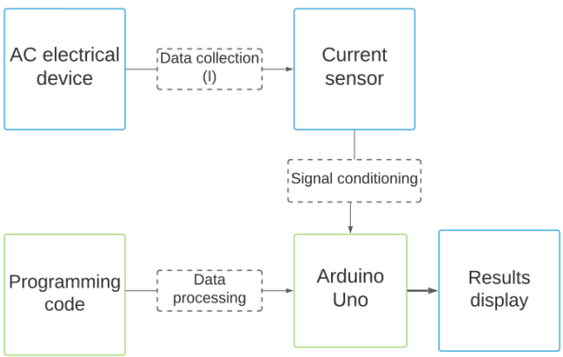

Figure 3 General sequence of the prototype to simulate
Source: Own elaboration

Programming

In the ARDUINO IDE program, the calculations for reading the analog input to the Arduino module were established, taking into consideration the specifications provided in the manufacturer's data sheet where it establishes that the current sensor under input intensity conditions equal to 0A delivers a voltage of 2.5 V and that from this increases proportionally according to the sensitivity (said sensitivity is established by the manufacturer for the case of the ACS712ELECTR-05B-T sensor is 185mV / A) we have that the relationship between the voltage and the current is a straight line where the slope is the sensitivity and the Y-intercept is 2.5 V, represented by the following equation:

$$V = mI + 2.5 \quad (1)$$

Where the slope *m* equals the sensitivity

To find the current from the sensor reading, it is done by means of the equations:

$$I = \frac{V - 2.5}{sensibilidad} \quad (2)$$

$$I = \left(5 * \frac{V_{\text{Censado}} - V_{entrada}}{1023}\right)\left(\frac{1000}{185}\right) \quad (3)$$

Where:

$$\left(5 * \frac{V_{\text{Censado}} - V_{entrada}}{1023}\right) \quad (4)$$

is the calculation to obtain the sensor voltage as a function of the input current, an average measurement of 1000 analog readings was made that subtracted from the input signal (analogRead A0) gives us a more precise value of the voltage tested as a function of the Input current. Incorporated into equation (3) we obtain the current reading.

Figure 4 shows the procedure to obtain the power in Watts, where the calculation for the peak values of the current wave was added in the programming since the current that we have previously found is oscillating at a frequency of 60 Hz.

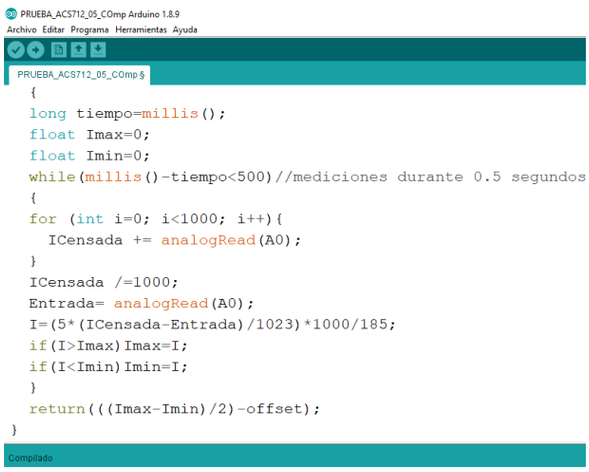

Figure 4 Programming code to obtain the effective current
Source: IDE ARDUINO

Once the peak current was obtained, the calculation of the effective current (RMS) and the code of the equation were added in the programming to calculate the power consumed in Watts. Likewise, as shown in figure 5, the serial.Print () commands are used to display on the virtual monitor the text indicating the parameters obtained as well as the total Watts consumed and serial.Println () to indicate the values to read and display.

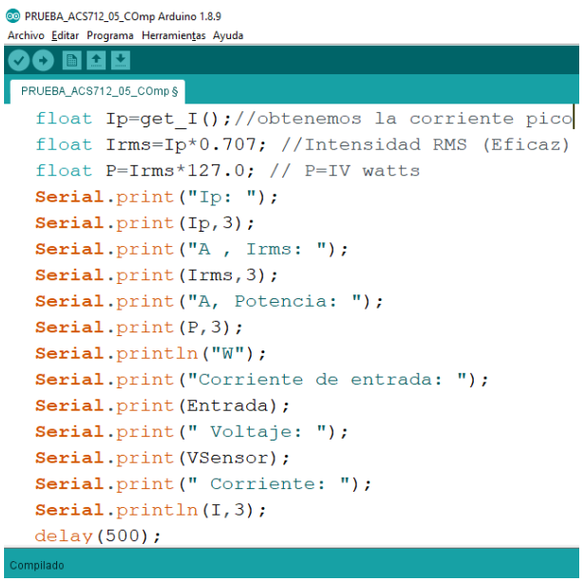

Figure 5 Code to obtain the power consumed in Watts
Source: IDE ARDUINO

Simulation

Based on the general sequence of the prototype to be simulated, the electronic diagram and the electrical connections between each component of the prototype are designed. As previously mentioned, the software used for the simulation was Proteus, in which before starting to add any component it was necessary to make some adjustments such as downloading and adding the SIMULINO libraries corresponding to the Arduino module. Once added in the Proteus software, the electrical components that are part of the circuit were selected and configured as shown in figures 6 and 7, these elements are:

- Sensor ACS712ELCTR-05B-T.
- 0.1µF and 1nF capacitors.
- + 5V power supply for the sensor.
- Arduino module.
- AC source set to 127 V, 60 Hz.
- To represent the load, a lamp with the following characteristics was selected; 127 V, 200 Ω.
- Virtual terminal for visualization of results.

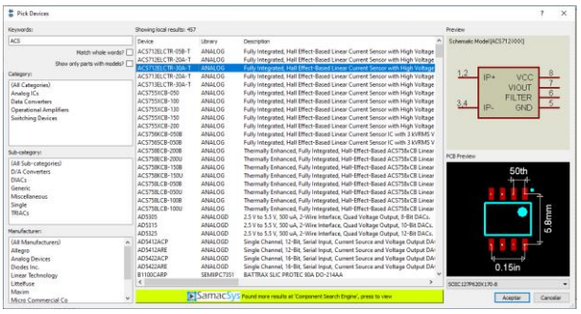

Figure 6 Search and selection of components
Source: Proteus software

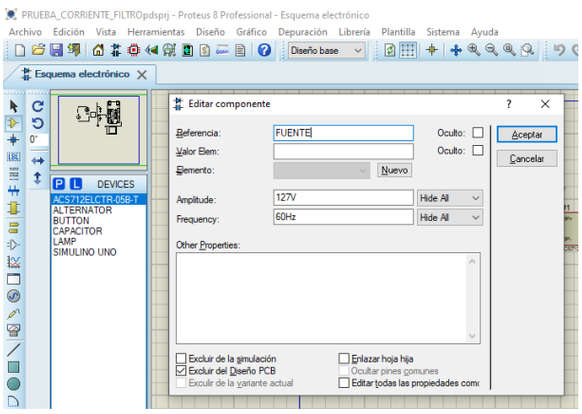

Figure 7 Element configuration
Source: Proteus software

For the configuration of the sensor connection, figure 8, two filters are added in order to attenuate the noise since this sensor generates an analog output signal (Vout) that varies linearly with the sampled AC. Two capacitors are added to the filter, with values (0.1µF and 1nF) for a typical application recommended by the manufacturer's data sheet.

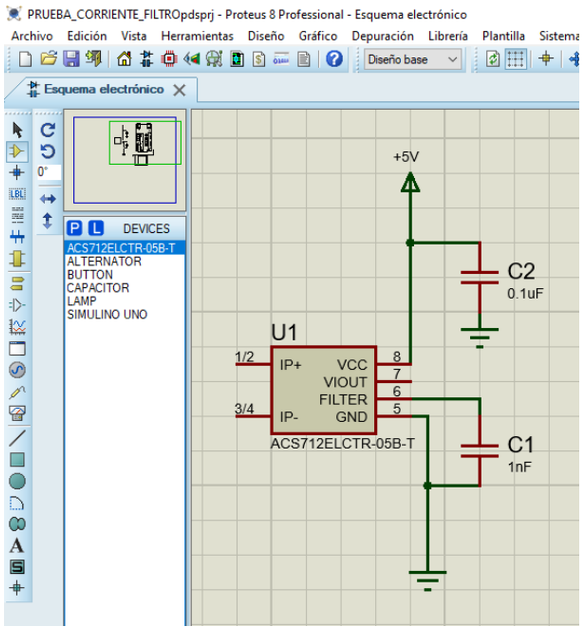

Figure 8 Sensor configuration
Source: Proteus software

Finally, figure 9 shows how all the elements are integrated after each one of them has been configured. In this last figure, the virtual terminal for displaying results can also be seen already integrated.

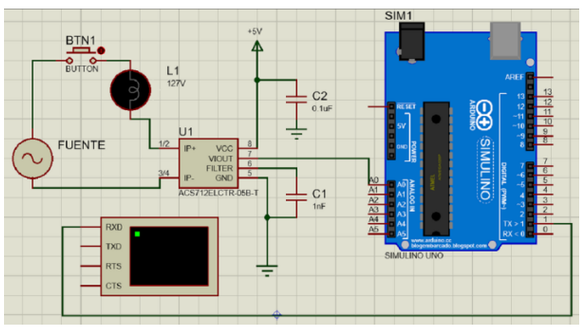

Figure 9 General circuit
Source: Proteus software

When performing the current monitoring simulation to calculate the power consumed by the circuit, the .HEX file generated in the Arduino IDE was loaded to the Arduino module (Simulino) where the program was made and compiled with the code designed to perform the Necessary calculations and obtain the peak current (Ip), effective current (IRMS) and finally the calculation of the power consumed in Watts.

In the simulation stage, the structure and connection between each of the modules used in the system is defined. With this stage it is possible to verify that the designed circuit works correctly as expected and can be implemented.

Results

The design of the final circuit to carry out the simulation in the Proteus Software is as shown in figure 10, in the virtual monitor of the simulation the peak and effective values (RMS) of the current are obtained as well as the value corresponding to the power. In addition to displaying the current and voltage values sent from the sensor to the arduino microcontroller.

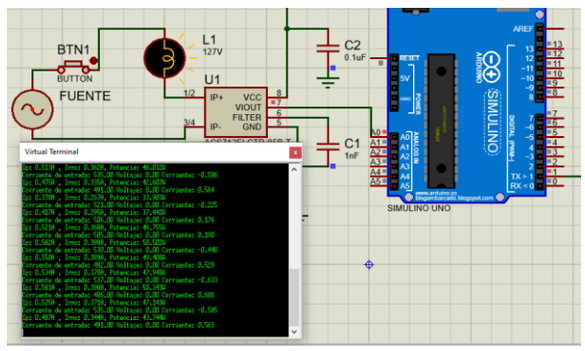

Figure 10 Circuit simulation
Source: Proteus software

Table 1 shows different values of effective current measured in amperes (Irms), the power measured in Watts (Pmed) and the calculated power data (Pcal) are added. The Pmed represents the measurement of the Watts consumed that are displayed in the virtual terminal of the simulator, on the other hand, the Pcal is determined by multiplying the effective current measured Irms by the fixed voltage of 127 V, this to delimit the error between these and validate the values measured power. The% error is determined with the difference of the Pmed and Pcal.

I_{rms} (A)	P_{med} (W)	P_{cal} (W)	%error
0.604	76.710	76.708	0.0026
0.609	77.381	77.343	0.0491
0.610	77.407	77.470	0.0813
0.613	77.888	77.851	0.0475
0.614	77.916	77.978	0.0795
0.617	78.374	78.359	0.0191
0.618	78.427	78.486	0.0752
0.622	78.987	78.994	0.0089
0.623	79.162	79.121	0.0518
0.626	79.492	79.502	0.0126
0.627	79.586	79.629	0.0540
0.628	79.721	79.756	0.0439
0.632	80.290	80.264	0.0324
0.633	80.452	80.391	0.0759
0.634	80.577	80.518	0.0733
0.635	80.685	80.645	0.0496
0.636	80.784	80.772	0.0149
0.642	81.560	81.534	0.0319
0.643	81.654	81.661	0.0086
0.644	81.771	81.788	0.0208
0.652	82.827	82.804	0.0278
0.653	82.939	82.931	0.0096

Table 1 Values to delimit the% error between measured and calculated power
Source: Own elaboration

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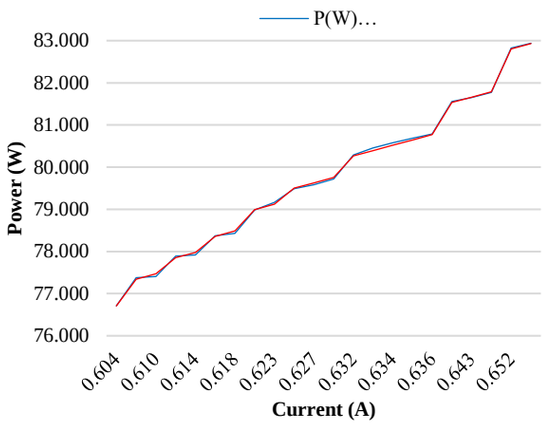
The low percentage of error and the minimum difference between the measured and calculated power can be seen in Graphic 1. This difference is due to the analog signal that the current sensor is detecting and that reflects at the output a measurement proportional to the degree of sensitivity of it.



Graphic 1 Comparison between measured and calculated power
Source: Own elaboration

Gratitude

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Conclusions

This article presents the simulation of a prototype for measuring energy consumption in Watts for alternating current systems. The simulation allows us to validate the electronic circuit proposal for its implementation, and thus generate an attractive device for the general public since it would be accessible in cost and easy to use.

The proposal handles a current sensor, the voltage is specified from the programming this in order to find a functional circuit and with a simple structure in addition to complying with the voltage tolerance of ± 10% established by the Federal Electricity Commission, current and sole electricity marketer in Mexico. With both parameters delimited, the microcontroller calculates the power in Watts, to later print it on the virtual monitor.

It should be noted that to carry out the implementation of a system it is always necessary to carry out a simulation that can guarantee its proper functioning.

References

Guerrero Quichiz, G. M. (2007). Diseño e implementación de un sistema de control digital con conexión a redes de datos para medición de parámetros eléctricos (Tesis para optar el título de ingeniero electrónico). Pontificia Universidad Católica del Perú Facultad de Ciencias e Ingeniería.

Mora-Martínez, A. S., Villalvazo-Laureano, E., & Jiménez-Betancourt, R. O. (2020, 1 enero). Medidor de parámetros eléctricos con visualización remota. Revista de Aplicaciones de la Ingeniería, 7(22), 23-28. https://doi.org/10.35429/JEA.2020.22.7.23.28]

Vázquez Palma, M. G., Flores Figueroa, J., Soto Rodríguez, M., & Romero Ochoa, M. A. (2018, junio). Diseño de un medidor de energía eléctrica bidireccional y monitoreado mediante aplicación móvil. Revista Iberoamericana de las Ciencias Computacionales e informática, 7(13), 5-30. https://doi.org/1 Arduino (2020).

Arduino Products. Retrieved from: https://www.arduino.cc/en/Main/Products

Rosales, M. (2020). Concepto de Programación. Retrieved from: https://www.zonaeconomica.com/conceptoprogramacion. 0.23913/reci.v7i14.84

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