Intelligent Electric Energy Counter

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Abstract This paper lies in this context, particularly in the development of a low voltage and low cost measuring system which measures electric power. The need for such systems has been increasing over the years. The existence of a measuring device capable of informing real-time consumption could result in a more proactive approach to the consumer, (giving him the opportunity to better manage electricity consumption). This work consists on an electric circuit capable of measuring and recording power, via power consumption software. Furthermore, this meter will have the option to graphically display voltage and current signal through a serial port.

Keywords: Electric Energy, Intelligent Electric Energy Counter, LabVIEW.

1. INTRODUCTION:

Nowadays, it is almost impossible to imagine life without electricity. The electricity consumption represents about one-third of the world energy consumption. The production, transmission and distribution of Electric Energy involve high economic costs which are ultimately charged to consumers. As a result, there is a need to create a measurement system capable of accurately indicate the consumption, or an electric energy meter that indicates real-time actual consumption. With this equipment the consumer has a greater possibility of control the consumption [1].

A Electricity counter is an electrical device capable of measuring electrical energy consumption. The unit is kWh. The meter can be connected directly from the power supply and load, or by coupling voltage transformers and current. The supply may be high, medium and low voltage. As in this work, the network chosen to measure the electrical load was the single phase.

The electric digital counter measures the electricity consumed. However, a calibrated meter does not make absolutely precise measurements, and allowed tolerances. As the given error class (usually grade 1 or 2) can introduce a measurement error up to ± 2% (class 2). In the home network is usually the class assigned to Class 2 because the devices of Class 1 devices are targeted for very sensitive to disturbances from the mains and Class 3 for high power motors or loads supllied through converters [2]

This work aims to build an electrical circuit capable of measuring the power consumed by a microcontroller. The counter is able to indicate the consumption in kWh, the corresponding cost in euros, the RMS voltage and current of electricity. This information is displayed in real time in an alphanumeric LCD. This device, compared to electromechanical

meters is much more efficient due to its ability of miniaturization of electronic systems (this system is compact in terms of volume and weight). This device has the major advantage accounted for the value to be submitted digitally by allowing the consumer to take a greater control of the consumption to be charged.

In Figure 1 a diagram of the electric power receiver and the consume value is presented.

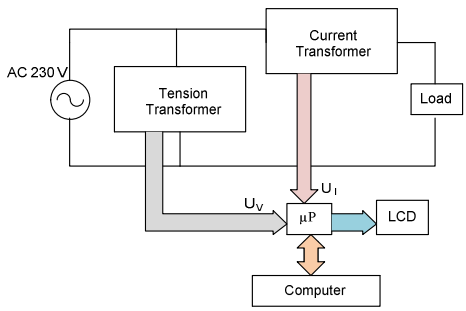

Figure 1- Wiring diagram developed Dissertation

After processing and transmission, the electricity is distributed in this case to the home network. The value of domestic supply voltage is 230 V AC with a frequency of 50 Hz. A current transformer measures the current through the load, while a voltage transformer measures network voltage. The values of voltage and current are sent to a microcontroller (µP) through a circuit with operational amplifiers, in order to limit the voltage of the same. The microcontroller converts the analog voltages into digital through an A/D converter. Is with these digital voltage that the power consumed is calculated by the load digitally. This calculation (active power) is done by programming the microcontroller and by processing the values that are sent to an alphanumeric LCD.

2. ELECTRIC ENERGY MEASUREMENT

For the calculation of the digital power consumption, it is necessary to discretize the information on the current and voltage present at the load impedance Zc. These signals are sampled at a frequency Fs with a sampling period: Ts = 1/Fs. Initially the sample values of voltage and current are scanned over time: v (kts) and (KTS), where k is a positive integer constant. As the sampled voltage and current do not correspond to the supplied by the mains (due to the use of transformers in the network) the result must also be multiplied by a voltage and current constant of proportionality, Kv and Ki respectively. This proportionality constant, when multiplied by the sample, results in the RMS voltage or current supllied by the mains.

$$E \cong A\sum_{k=0}^{n} v(kTs)\times i(kTs) \text{ for } T_S > 0 \quad (1)$$

Electrical power is calculated by summing the product of the voltage and current samples for each time instant kts and turn to the product of the constants of proportionality of the voltage and current. The proportionality constant Kv and Ki are proportional to the voltage and current.

The constant stream of Ki was calculated through the relation of the RMS voltage measured at the terminals of the current transformer and the voltage measured directly between the terminals of a load The calculated value was 0.205788 [3]

The calculation of the proportionality constant of the voltage transformer was made experimentally. As the voltage supplied by power supply is 230 V RMS and the measured voltage at the transformer terminals is 2.14 V RMS, it results in a constant value of 107,477 [4].

3. ANALOG TO DIGITAL CONVERTER

The A / D converter of 10-bit PIC24 has the following characteristics: converter with successive approximation (SAR) conversion speed up to 500 ksps, 16 terminals with analog inputs, reference voltage input terminals and a 16 words buffer that contains the conversion result.

The A/D converter has a maximum time for the sample to be converted. The T_{AD} controls the conversion time of the sample. The A/D requires a minimum of 12 clock periods to convert a sample. In the following equation the calculation of the T_{AD} is represented as a function of ADCS and TCY. The ADCS is a constant, in order to regulate the frequency conversion of the sample.

$$T_{AD} = T_{CY}(ADCS + 1) \qquad (2)$$

For the above equation it is known that the sampling frequency depends on T_{AD}, which in turn is dependent on the ADCS and TCY. For such a variation was made in order to acquire ADCS at least two periods. As a better perception of the signal being sampled [5].

$$T_{AD} = \frac{1}{8\times10^{6}/2}(39+1) = 10\mu s \qquad (3)$$

Thus, calculating the frequency of sampling is done as follows:

$$F_{amostragem} = \frac{1}{12\times TAD} = 8{,}33\,kHz \qquad (4)$$

4. ELECTRIC DIGITAL COUNTER

The work for the electric meter was divided into the following phases:

1 Familiarization of the RS232 communication between the PIC24 and a computer with LabVIEW;

2. Completion of an electrical circuit for measuring voltage and current from the power supply with a current transformer and voltage;

3. Carry out a program for sampling the voltage and current in the PIC24 and sending this information to LabVIEW through the electrical circuit described in phase 2;

4. Completion of the new circuit by replacing the voltage transformer with a resistive divider;

5. Realization of the power supply meter reading;

6. Implementation of a circuit with the PIC24 and circuit realization isolation GND.

5. MEASURING CIRCUIT

In this section, the sizing of the resistive divider which is replaced by a voltage transformer is explained.

Figure 2 represents the resistive divider used for this job.

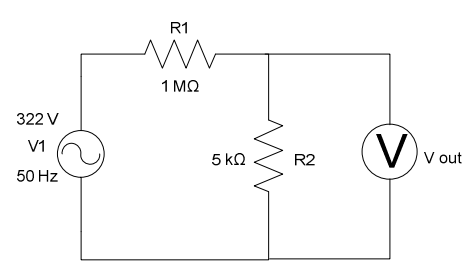

Figure 2 – Resistive divider of the counter energy.

This circuit generates an output voltage, V_{OUT}, proportional to the input voltage, V_{IN}. The output voltage is proportional to the input voltage multiplied by a gain.

$$V_{OUT} = \frac{R_2}{R_2 + R_1} \times V_{IN} \qquad (5)$$

Being intended to be an output voltage range with a limit of 3.3 VPP, a sizing is done based on the output voltage closer to the desired. Figure 3 presents the design chosen for the resistive divider.

The voltage Vin corresponds to the input voltage from the mains voltage and the output voltage Vout. The resistors R1 and R2 were designed with the aim to get a gain closer to the desired. With the resistances chosen and using the previous equation, we can calculate the maximum voltage at the output.

$$V_{OUT} = \frac{5\times10^3}{5\times10^3 + 1\times10^6} \times 230\sqrt{2} = 1{,}6115 \text{ V} \qquad (6)$$

For the above equation it is apparent that the value of the output voltage varies in the range of 1.6115 PPV. It was given a margin of 0.035 V in case of loss or gain in the circuit. Thus, it was implemented the resistive divider scales in Figure 2 including a printed circuit. This new PCB comprises a current transformer, a resistive divider and an operational amplifier with two inputs (one input voltage and one for current). The operational amplifier used was LM6132BIN which has the rail-to-rail feature. In Figure 3 a photo of the PCB is shown.

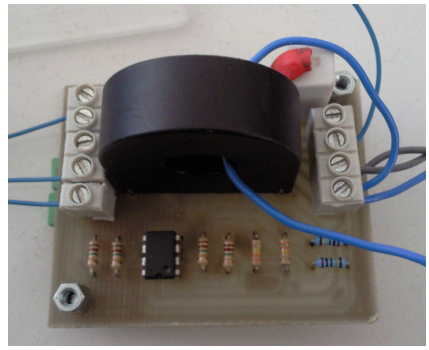

Figure 3 – PCB to measure the voltage and electric current.

The results measured from the current and voltage of the electricity grid with the PCBs did not correspond to the reality, due to the fact that the theoretically calculated values were not equal to the theoretical calculations. This is because the standard output transformer was saturated and when the PCB was connected to another circuit, there was a large current consumption. To do so, the values of the resistive divider have been changed, this is R1 (Figure 2) was changed to 1.6 MΩ. Therefore, the new value of the output voltage becomes:

$$V_{OUT} = \frac{5\times10^3}{5\times10^3 + 1{,}6\times10^6} \times 230\sqrt{2} = 1{,}01 \text{ V} \qquad (7)$$

The following figure is an example of measuring the network voltage through the PCB shown in Figure 4.

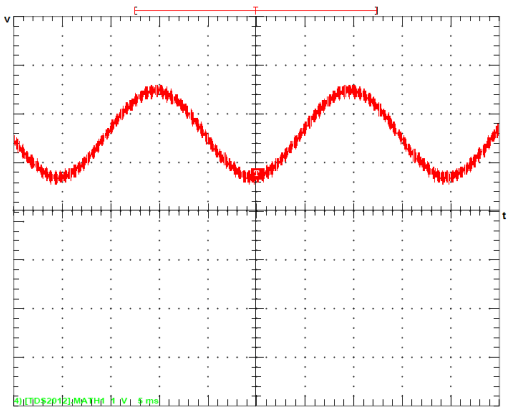

Figure 4 – Mains voltage with 1 V and 5 ms per division.

In Figure 4 we can see that the voltage varies in the range of 2 VPP and that it is not centered at the origin. This is due to the DC 1.65 V generated by inverting operational amplifier assembly. The time scale is 5 ms / div, ie, it is confirmed that the resulting signal has a frequency of 50 Hz.

On the other hand, for measuring the current, many results were acquired. We measured the current in a lamp of 75 W, represented in Figure 5.

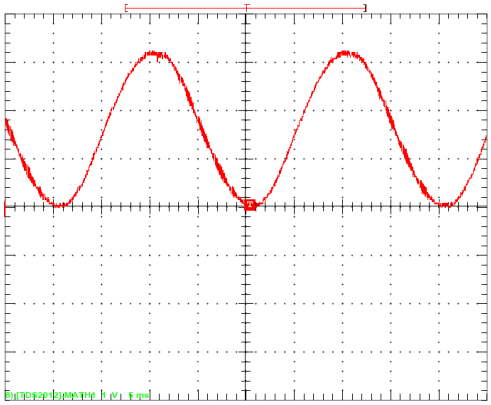

Figure 5– Measurement of current in a lamp of 75 W with 1 V and 5 ms per division by division.

6. POWER SUPPLY

In the power supplies, for the majority of the applications it is required that a supply voltage is decreased in order to obtain a value closer to power circuits. This is usually done through a transformer, which is an expensive component. However, as this thesis aims to create a low-cost equipment a power supply was completed without transformers. In the circuit of Figure 6 is depicted the circuit of power supply without voltage regulators. This circuit consists of passive and capacitive components. Dimmers are to convert the AC voltage of 3.3 V and 5 V voltages.

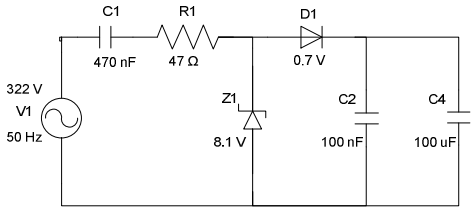

Figure 6 – Electrical circuit of the power supply meter.

On the positive half cycle the energy is stored in the capacitor C1, while, in the negative half cycle it begins to be unloaded. The capacitor C2 is used here to decrease the load ripple of C1, ie, do not let the capacitor C1 to discharge completely, and the higher the value of C2, the lower the load ripple will be. In the positive cycle current flows through C2 and, in the negative half cycle, through the diode zenner. The resistance R1 is here intended to limit the current flowing in the diode zenner imposing an alternating voltage of 8.1 V to the terminals of the voltage regulators. We also used, in this source, two coupling

capacitors C4 and C5 of 10 mF which aim is to stabilize the load ripple output. When the circuit consumes more power, these capacitors tend to stabilize the output voltage of the source.
The sizing of the electrical circuit was based on a circuit from Microchip that aims to create a DC power via the mains voltage. The components used were chosen with the aim to achieve a value close to the desired output voltage. Figure 7 is an image of power supply in this counter [6].

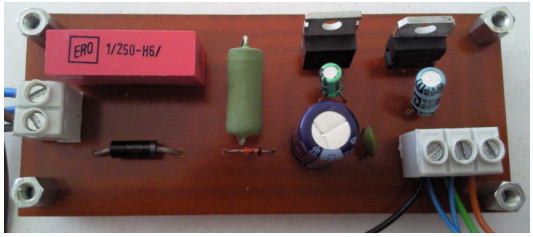

Figure 7 – PCB power supply of electric energy meter.

With this power supply, it becomes possible to feed the energy meter.

7. PIC24 BOARD

The circuit consists of the PIC24 microprocessor PIC24FJ128GA010 (for metering), an LCD (to display the count), an RS232 port (for communication with LabVIEW) [7], two switches (only used for testing) and two LEDs (one that illuminates when the PIC24 is powered up, and another to light only when a count is made).

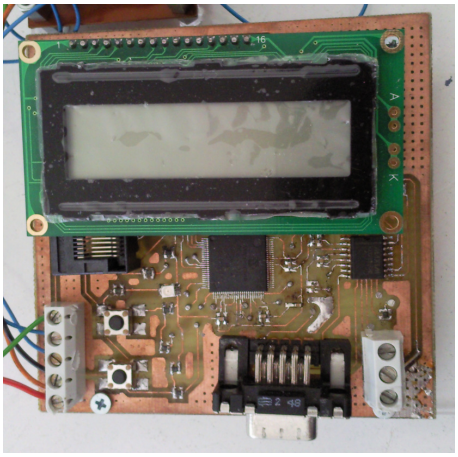

Figure 8 – Microprocessor circuit.

Since the meter connected to a computer with LabVIEW to visualize the signal, and the computer has a different reference voltage circuit of the meter, a circuit isolator is designed to isolate the circuit GND. This circuit is used to isolate the reference voltages. This circuit consists of an optical isolator, 6N133, which makes the isolation of the reference voltage. With the circuit isolation is possible to connect all circuits without the worry about the GND connection.

8. COUNTER CIRCUIT OF ELECTRICITY.

After the implementation of the circuits essential for the electricity measurement, the accounting program is also implemented. This program is implemented on the PIC24, that calculates the real time consumption to be performed. As the accounting for the energy of this counter is reserved only for home network, with equipment and power up to 75 W, only the active power of the network was calculated.
Thus, the work was summarized in the hardware implementation of the following circuits: power supply meter, a circuit for

measuring voltage and current from the mains, a circuit with a microprocessor and a PIC24 board insulation GND. Concerning the software, it was created by a program that calculates the real time active power and introduced the euro value and KWh. The amount recorded in euros was based on the snake in the EDP simple fare (€ 0.1285 per kWh)

[8]. The accountant also has the ability to connect to a computer with LabVIEW through the RS232 serial port, so as to graphically display the voltage and current.

The following general equation is the calculation of the power consumed in real-time kilowatts.

$$P_i(kWs) = \sum_{i=0}^{\infty} \frac{|V_i \times I_i| \times T_s}{1000} \qquad (8)$$

From a general point of view, the calculation of power is made from 0 to infinity, where infinity means that the equipment is disconnected from the supply. This product is multiplied by the sampling frequency because is the time interval between samples, and is divided by the conversion to 1000 kW. To calculate the consumption in euro, it is only multiplied by the instantaneous power P_i in kWh to euros. In figure 8, it is shown the signal voltage and lamp current of 15 W in LabVIEW.

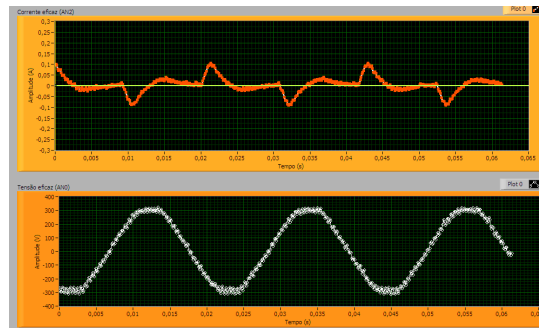

Figure 9 - Signal voltage and current of a lamp of 15 W in LabVIEW.

In Figure 9 is represented the signal voltage and current of a soldering iron in LabVIEW.

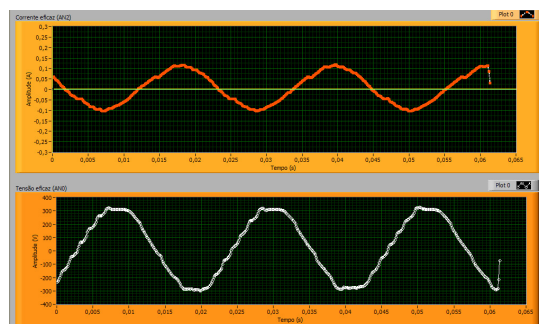

Figure 10 - Signal voltage and current of a soldering iron in LabVIEW

Through the figures above we can conclude that the result of the voltage and current rebuilt are near sinusoidal.

9. Conclusions and Future Work

This article reflects an innovation work in accounting for the electricity under a practical and real point of view. The fact that the accounting is done digitally and accessible to the consumers, offers the possibility of having an evolved measurement system. This system indirectly decreases a small percentage of the consumer's consumption through the possibility of having an easy access to the real-time consumption.

Not all the proposed objectives have been achieved due to the fact that about 60% of the time spent on the thesis has been spent studying the PIC24 microprocessor and built-in functionality and in its association with the LabVIEW. The measurement of consumption was made with the most widely technology used nowadays, a microprocessor. This counter has a practical utility for any consumer because it has low power, it is small and mainly because it is digital. As future work the consumption accounting could be done for different levels of tariffs and the implementation of the meter could have PLC communication. It can also incorporate more features to the counter, such as buttons and menus with various network information.

Furthermore, as an innovation, it could e incorporated into a battery energy meter. With the battery meter, it does not need always to be plugged in to store the information of the consumption measured. In the case of this counter, it is used only for comparison of consumption, and while it is not intended to be used, can be shut down. And then, with the battery, this continued with the stored information. Like other features in the counter, it could be incorporated other types of serial, or USB.

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