

# Lab1: Power in home appliances

Jorge Lambraño<sup>3</sup>, Julian Rojas<sup>2</sup>, Juan Sánchez<sup>3</sup>

<sup>1</sup>jelambrano, <sup>2</sup>drojasj, <sup>3</sup>paradac @uninorte.edu.co

**Abstract**—This report presents the design and implementation of a security box and a dimmer circuit using DIACs and TRIACs. The reader also can find the validation review with the theoretical model seen in class.

**Keywords**—Current, Power, Power Factor, Voltage, Waveform.

## I. INTRODUCTION

The main purpose of this practice is to perform an analysis on the wave form and measurements of three different type of load. Inside the security box there is a fuse to protect the equipment from any shortcut. We used a shunt resistor of  $1\ \Omega$  and  $10\text{ W}$  to measure current dividing the voltage by 1 to obtain the actual current value. All electronics devices are composed of resistances, capacitors and inductances, a soldering iron is a resistive linear load, they require heat to work. The voltage measured would be the same as the source but the current will vary depending on the power consumption of the device. We expect the same waveform for the voltage and current and no phase shift between them.

A drill would be an inductive linear load, based on the fact that motors are made of inductive coils. It should be a phase shift between voltage and current. The laptop is a nonlinear load, the voltage waveform would be the same but we expect a different shape for the current [1].

The second part consists on designing and developing an AC controller made of DIACs and TRIACs. This kind of circuit is able to change the RMS voltage on the terminals of a linear load by manipulating the firing angle of the TRIAC using a potentiometer. The load will not be linear anymore because of the electronic circuit resultant of the resistive load in series with the AC controller.

## II. PROCEDURE AND RESULT ANALYSIS

### A. Power Computations

The purpose of this practice is to measure the power consumption on electrical home devices, such as a laptop, a drill and a soldering iron. Taking into account that they work with high values of voltage and current compared with previous labs, precautions were taken in order to protect the devices and our integrity. The Figure 1 shows the circuit proposed by the teacher to measure voltage and current safely.

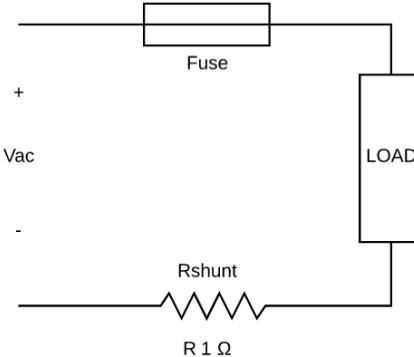


Fig. 1. Circuit Diagram.

$V_{ac}$  represents the  $120\text{ Vrms}$  sine wave obtained from the university phase line, *Fuse* represents a  $3\text{A}$  circuit breaker, *Load* represents the load and *Rshunt* represents the  $1\ \Omega$  and  $10\text{ W}$  power resistor. We chose a small value for the resistor to do not affect the functioning of the circuit.

The gauge of the wire was selected depending on maximum current needed by the higher power load according to electrical parameters of each device. Current values of devices are shown on the Table I. Based on this, AWG 14 wire was selected to build the power meter, because it is able to conduct a maximum of  $15\text{ A}_{rms}$ . In addition to this,

TABLE I  
POWER AND CURRENT VALUES OF EACH DEVICE.

Device	Power (W)	Voltage (V <sub>rms</sub> )	Current (A <sub>rms</sub> )
Soldering Iron	40	120	0.33
Drill	130	120	1.08
Laptop	140	120	1.16
Light Bulb	70	120	0.58

the circuit uses a 3A fuse to protect load and wires of high currents.

The circuit is inside a 4x4 box with a fuse holder to change the breaker, 4 measuring terminals; the white one for neutral, green one for ground and both black one for phase. The box is shown in the Figure 2.



Fig. 2. Circuit box.

For this practice three different loads are chosen to analize their voltage and current waveform: a soldering iron like resistive load, a drill like inductive load and a laptop like non-linear load. These loads are conected to an electrical outlet, using the power meter. Owing to high electrical network inertia, the voltage waveform do not depend on the load. For this reason, the voltage signal is similar in all measurings. However, current waveform depend on impedance load and voltage, and the first parameter is realted to load features. Therefore, the power analysis will be centered on current waveform.

1) *Solderin Iron (resistive load):* The current waveform is a pure sine signal and it does not

present any distortion and between voltage and current there are not phase difference. This can be observed in the Figure 3.

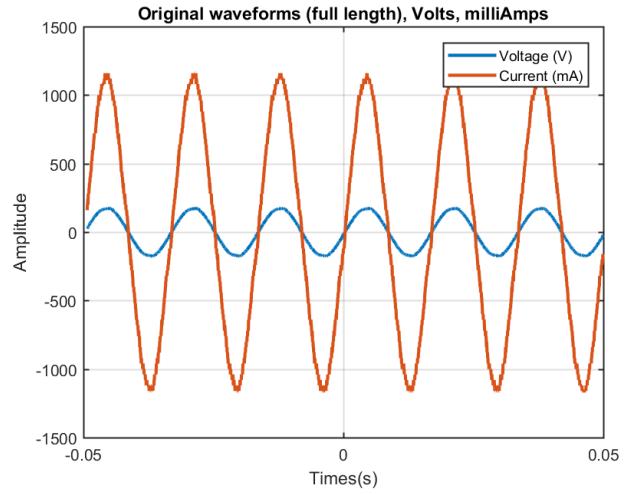


Fig. 3. Voltage and current waveforms of a resistive load.

Additionally, in a resistive load, product between current and voltage always is positive, this means that soldering iron is a power consumer and it is not able to supply energy.

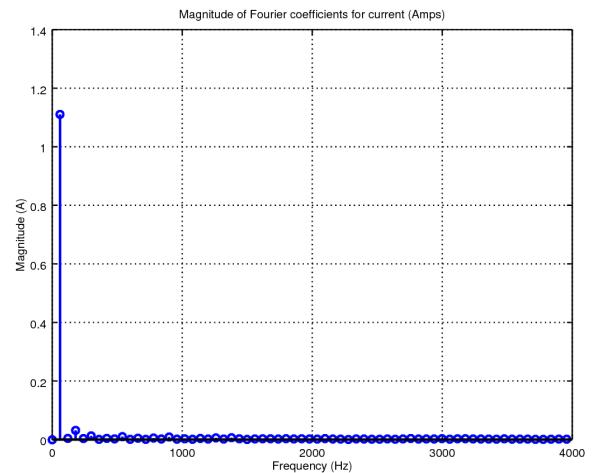


Fig. 4. Fourier current coefficients for resistive load.

Fourier Transform allow to identify harmonic components of current signal. According to Figure 4, current waveform of a resistive load only have a 60 Hz component and it does not have any different harmonic component. So, there are not distortion, the power factor *PF* is high and Total Harmonic Distortion *THD* is very small. This is an important feature from resistive loads.

Listing 1. Output for resistive load.

T	=	0.0167	s
f <sub>0</sub>	=	59.9520	Hz
V <sub>rms</sub>	=	123.3322	V
I <sub>rms</sub>	=	0.7860	A
S	=	96.9336	VA
P <sub>avg</sub>	=	96.8309	W
P	=	96.8309	W
Q	=	-1.8282	VAR
D_fast	=	4.0701	VA
D	=	4.0562	VA
PF	=	0.9989	
THD_V	=	1.8878	%
THD_I	=	4.0154	%

2) *Drill (inductive load)*: The current behaviour for inductive loads is different to resistive loads. Current waveform is not a pure sine signal, because there are harmonic components that change shape current signal. This can be observed in the Figure 5 and 6. The waveform present peaks as a result of current harmonic component:  $3f_0$ ,  $5f_0$ ,  $7f_0$  and  $9f_0$ , where  $f_0$  is fundamental frequency (60 Hz). In addition, there are an phase difference between both signal: current signal is slow respect to voltage signal.

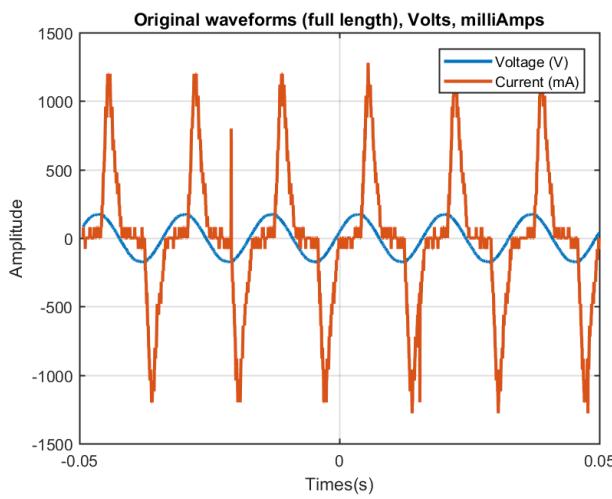


Fig. 5. Voltage and current waveforms of a inductive load.

In contrast to resistive load, the power factor value is very low and reactive power  $Q$  and  $THD_I$  are very high. According to Listing 2, for this device, Reactive Power  $Q$  is higher than Active Power  $P$ . This high  $Q$  value mean that drill is a reactive element.

Listing 2. Output for inductive load.

T	=	0.0167	s
f <sub>0</sub>	=	59.9520	Hz
V <sub>rms</sub>	=	123.8850	V
I <sub>rms</sub>	=	0.4831	A

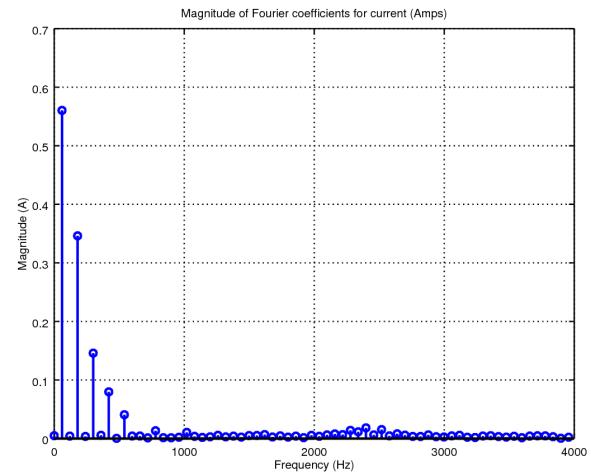


Fig. 6. Fourier current coefficients for inductive load.

S	=	59.8537	VA
P <sub>avg</sub>	=	30.4372	W
P	=	30.4372	W
Q	=	38.7767	VAR
D_fast	=	33.9472	VA
D	=	33.9434	VA
PF	=	0.5085	
THD_V	=	1.8561	%
THD_I	=	69.7550	%

3) *Laptop (non-linear load)*: Finally, according to Figure 7, current signal of non-linear load do not present any sine shape. The current waveform present peaks more narrow than inductive peaks loads. Those peaks presents a high harmonic components which can be observed in the Figure 8. The harmonic components of non-linear load are much higher than harmonic components of inductive load.

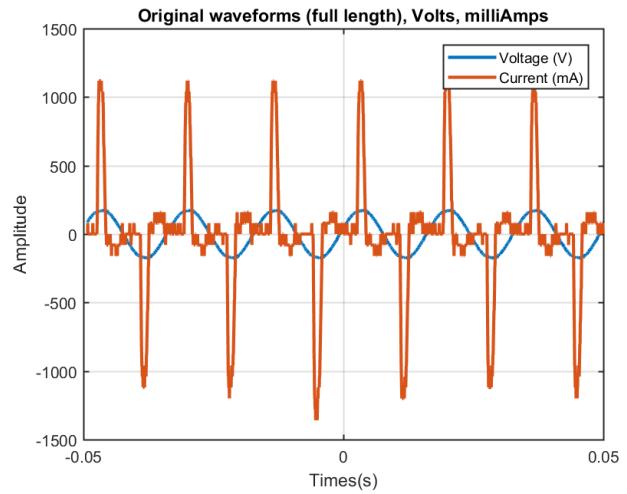


Fig. 7. Voltage and current waveforms of a non-linear load.

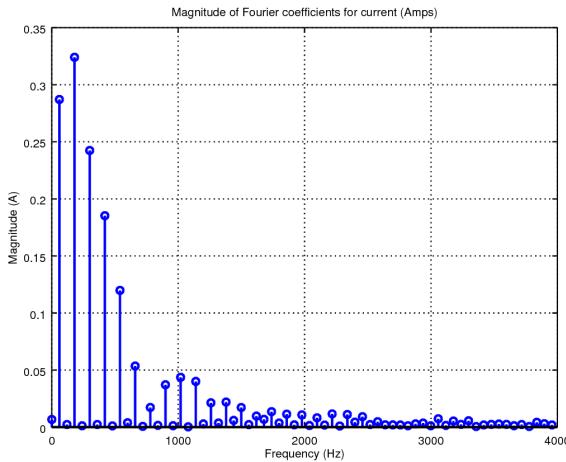


Fig. 8. Fourier current coefficients for non-linear load.

Nevertheless, a laptop does not have reactive elements like electrical coils, the power factor values is very low. The electronics circuits inside a laptop (or other complex electronic device) do not respond linear way. For this reason, current waveform presents a lot of distortion, as a result, Harmonic Power  $D$  and  $THD_I$  value are very high while  $PF$  is small.

Listing 3. Output for non-linear load.

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T      = 0.0167 s
f0     = 59.9520 Hz
Vrms   = 124.3447 V
Irms   = 0.3916 A
S      = 48.6915 VA
Pavg   = 23.9965 W
P      = 23.9965 W
Q      = -5.7979 VAR
D_fast = 41.9692 VA
D      = 41.9644 VA
PF     = 0.4928
THD_V = 2.2668 %
THD_I = 164.9239 %

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### B. AC controller

For the second part of the practice, a circuit using thyristors was designed to control the amount of power delivered to the light bulb. The input is the 120 V AC and the output is an AC waveform where there is a delay angle before triggering the AC voltage. The phase control is done with a potentiometer. The circuit designed is shown in the Figure 9.

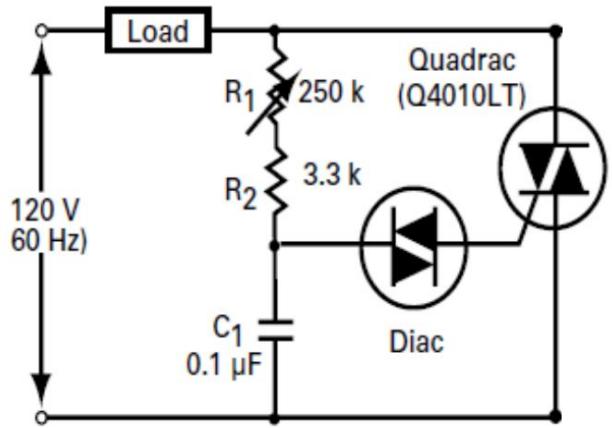


Fig. 9. AC controller circuit.

TABLE II  
POWER MEASURES FROM DIFERENTS CONTROLLER VALUES

	P (W)	Q (VAR)	D (VA)	S (VA)	PF	THDI (%)
NoCtrl	77.24	-3	3	77.36	0.999	4.01
Pos 0	74.2	0.1	5.1	74.37	0.998	6.23
Pos 1	69.8	10.5	17.29	72.68	0.96	23.99
Pos 2	53.64	23.48	31.41	66.45	0.807	53.48
Pos 3	40.19	27.81	35.69	60.51	0.664	73.58
Pos 4	30.47	28.41	37.36	55.96	0.545	89.63

### III. CONCLUSIONS

The resistive load shows a power factor of almost 1. The inductive load has a curly current shape, thanks to the type of motor being used in the drill. The non-linear load shows a kinky wave shape that depends on the circuit inside the electronic device.

Power computations let understand better the circuits, taking into account the meaning behind the power factor and the different kinds of power related to a circuit.

The dimmer allows to regulate the power taken by the light bulb. Taking into account that a light bulb is resistive, the effectiveness depends on the efficiency voltage and effective current.

The circuit is controlling the AC power to the light bulb by switching on and off during the positive and negative regions of the input sinusoidal signal. During the negative part of the input signal,

the same type of response will be obtained since both the DIAC and TRIAC can be triggered in the reverse direction. Varying the resistance R, it is possible to control the driving angle. [3]

About inductive and non-linear loads, you shouldn't use the dimmer circuit, because both rely on the PF and the voltage and current wave shape.

Electronic devices, such as, DIACs and TRIACs let us build circuits to control the power taken by a resistive load.

## REFERENCES

- [1] H. Kopka and P. W. Daly, *A Guide to L<sup>A</sup>T<sub>E</sub>X*, 3rd ed. Harlow, England: Addison-Wesley, 1999.