Electric Circuits Final Project - Alternative Chua's Circuit

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1. Abstract

The Chua's circuit is one of the simplest circuits that presents a chaotic behavior. This behavior is difficult to predict due to the nonlinearity of of the functions that models it. In general, the Chua's circuit has an oscillatory behavior based on a piecewise linear function (Fig 2). This alternative Chua's circuit exhibits a smoother function and even a faster response when compared to the traditional Chua's circuits.
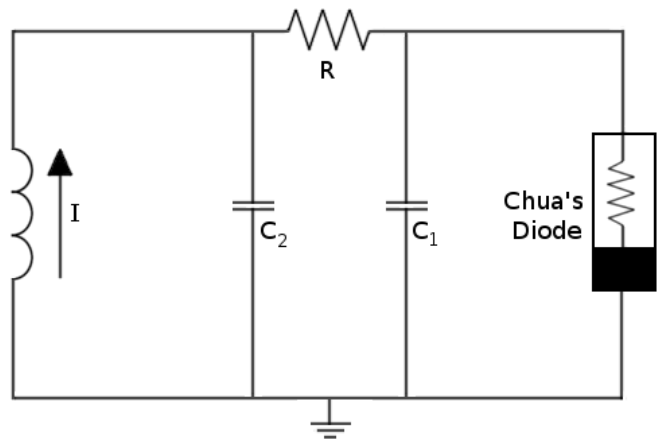
Figure 1. Simple Chua's Diagram

2. Introduction

Chua's Circuit is a simple electronic circuit that implements a chaotic behavior (autonomous circuit). This circuit can show non periodic oscillations . But for one circuit to be an autonomous circuit, they must satisfy three criteria:

1) one or more nonlinear elements;
2) one or more locally active resistor;
3) three or more energy-storage elements;

The Chua's Circuit is simple because use the minimum to be an autonomous circuit. In the Chua's Circuit we have two Capacitor, one Inductor, one simple resistor and on Chua's diode, that can be implemented with several different forms. The example os Chua's Circuit can be seen below. Figure 1.

In the default circuit the nonlinear element has the following curve (Current x Voltage). Figure 2:

Figure 2. Nonlinear Chua's Diode
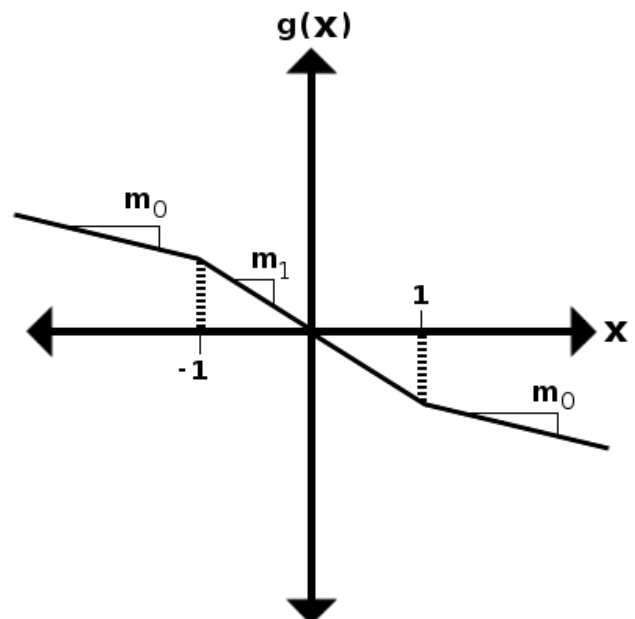
As stated above, the Chua's diode can be implemented with several different forms, but the equations that governing the circuit stay with the same model. In this article the objective is implement non the original circuit, but the alternative circuit, that has a more simple equation to the nonlinear diode, and can be implemented with simple additional circuits.

The alternative circuit of Chua used as base in this project is the implementations proposed for K. Tang and K. Man of Department of Electronic Engineering of City University of Hong Kong, published in the International Symposium IEEE - 1998.

The objective of this project is put into practice the knowledge gained during the course of Electronics Circuits, and see beyond, for the beginning of a large area not contemplated for the course, the non linear circuits.

Some noises is expected in the circuit implemented, due to the sensitivity of the circuit, that was done in a protoboard instead of welding the components. Since the protoboard allows a several contact with external ambient, and the trails has many imperfections. So, to get a better result is recommended that circuit be welded.

3. Theoretical Calculations

The Chua's Circuit is a most basic circuit that can implement a chaotic circuit. To define the equations of the circuit let see the image of the original curve of chua's diode above. As seen in the picture, the nonlinear diode is nonlinear only in three parts, but is linear between them, so we can calculate the equations of the circuit for parts, or we can use a generic non linear function called here as g(x) to define ours Differential equation. g(x) is a functions represented by the Figure 2, where g(x) is the current in function of tension on diode. Using the node and mesh analysis we can get the following equations.

$$\frac{dV_1}{dt} = \frac{1}{C_1}[\frac{1}{R}(v_2 - v_1) - g(v_1)] \tag{1}$$

$$\frac{dV_2}{dt} = \frac{1}{C_2}[\frac{1}{R}(v_1 - v_2) + i_L] \tag{2}$$

$$\frac{di_L}{dt} = \frac{1}{L}[v_2 - R_o i_L] \tag{3}$$

Following the original model of Chua's circuit we can represent g(v1) as a linear function.

$$g(v_1) = \begin{cases} m_0 v_1 + (m_0 - m_1)E1, & if \quad v_1 \leq -E1 \\ m_1 v_1, & if \quad -E1 < v_1 < E1 \\ m_0 v_1 + (m_1 - m_0)E1, & if \quad E1 \leq v_1 \end{cases} \tag{4}$$

Or we can represent the diode function completely.

$$g(v_R) = i_R = G_b v_R + \frac{1}{2}(G_a - G_b)[|v_R + E| - |v_R - E|] \tag{5}$$

Where Gb, Ga and E is constants. The above equations define the original Chua's circuit, but in this document we will implement the alternative Chua's circuit that have a more simple diode equation, the curve of g(x) in original circuit it is similar a cubic equation, however with discontinuities. In the alternative Chua's circuit the proposed model is similar a cubic equation but more smoothed, without discontinuities. For the alternative Chua's circuit the equation proposed is the below:

$$g(v_R) = av_R + bv_R|v_R| \tag{6}$$

where a < 0 and b > 0.

For the proposed diode equation, we have a circuit that consists of two Op-amps (AD711 and LF347), one multiplier (AD633), one comparator (LM319), a analog multiplexer (74HC4052) and six resistors.

Figure 3. Circuit of alternative Chua's Diode
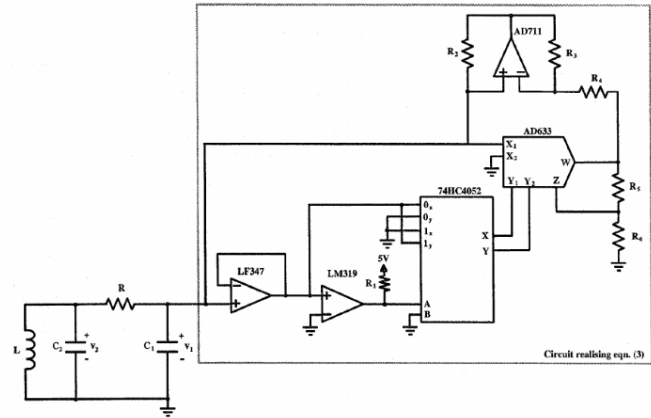
So, the driving-current for g(x) proposed is:

$$i_R = g(v_R) = -\frac{1}{R_4}v_R + \frac{R_5 + R_6}{R_4 R_5}\frac{1}{10V}v_R|v_R| \tag{7}$$

In this equation we can choose the value of R4, R5 and R6 but limited to the limit of logical, analogical and Op-amps of circuit.

4. Computer Simulation

The software used in this simulation was Multisim from National Instruments.

Because of software limitations the components used were not from the same type as the ones of the proposed circuit, therefore, the values of C1, C2 and L needed to be altered and the double scroll result was not achieved. The circuit was simulated as shown below:
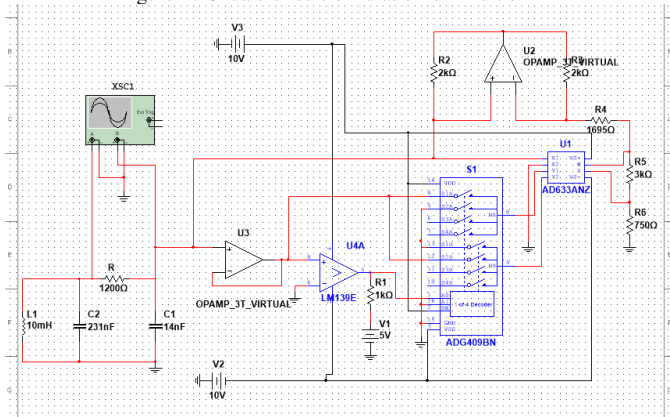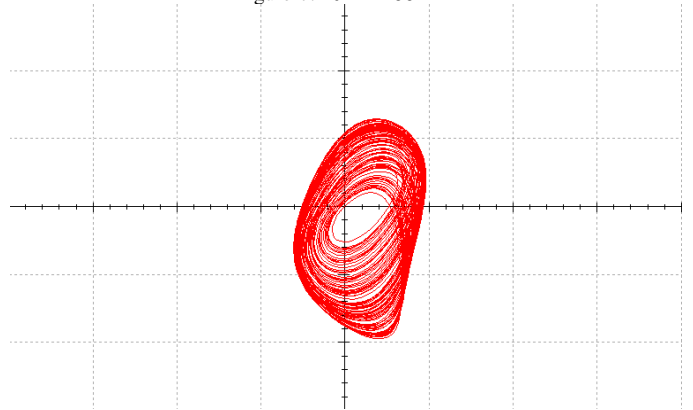
Figure 4. Chua's circuit simulation on Multisim

Figure 7. $R = 1200\Omega$

To observe a chaotic behavior, we varied the resistance R and saved the oscilloscope's results for each different value of R as shown:
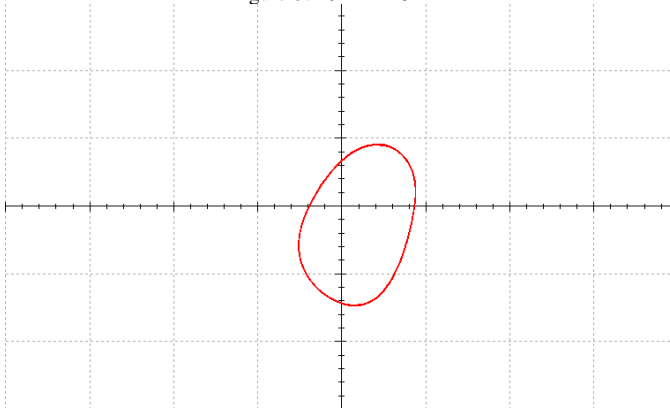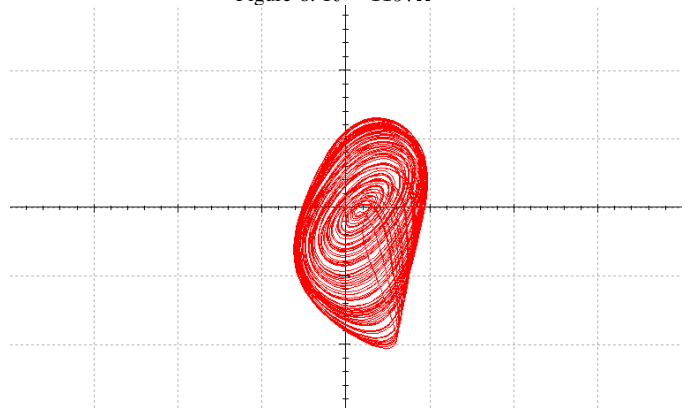
Figure 5. $R = 1220\Omega$
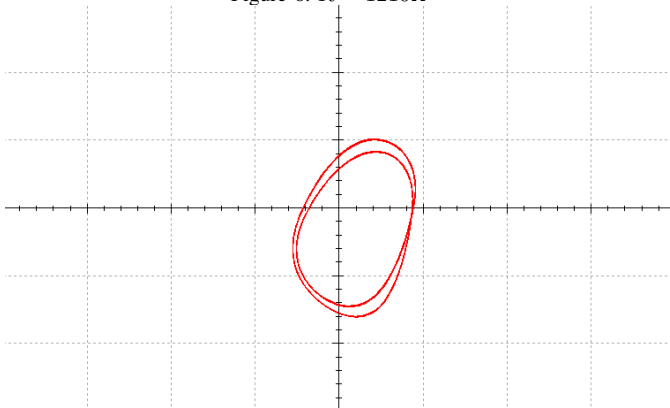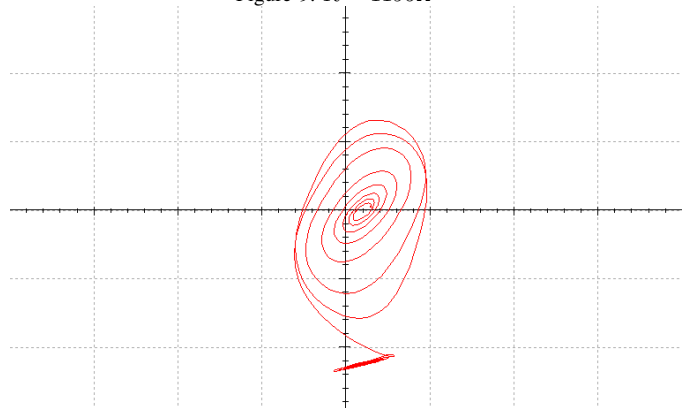
Figure 6. $R = 1210\Omega$

Figure 8. $R = 1197\Omega$

Figure 9. $R = 1196\Omega$

Note that the minimum value for R to stay oscillating is 1197Ω, and when we choose a lower value, it oscillates just for a very short time and them it drastically varies the trajectory of the graph and stops oscillating.

5. Experiment

5.1. Experimental Components

In general Chua's circuits can be composed simply by capacitors, inductors, resistors and a Chua's diode, that can be implemented using Op Amps and diodes, or even Op Amps alone.

But for this circuit implementation the following components are required:

- 1 Inductor.
- 2 Capacitors.
- 2 Op Amps (TL074).
- 1 Comparator (LM393).
- 1 Analogic multiplexer (TLHEF4052).
- 1 Analog Multiplier (AD633).
- Resistors.
- 1 Trimpot.

5.2. Experimental Procedure

The circuit should be implemented in accordance with Fig 3. In the experiment, the value of R is varied while the other components have the constant values:

$R_1 = 1k\Omega$ $R_2 = R_3 = 2k\Omega$
$R_4 = 1695\Omega$ $R_5 = 3k\Omega$ $R_6 = 750\Omega$
$C_1 = 7nF$ $C_2 = 78nF$
$L = 18.84mH$

To obtain the necessary inductance, a inductive decade from the laboratory will be used. It has an internal resistance of 45Ω per Henry, which implies a total resistance of 0.8478Ω for $18.84mH$. It is important that the internal resistance of the equipment is less than 30Ω because the resistance influences in the distribution of chaos when R is adjusted.

After assembling the circuit, the parameters to be analyzed are X, Y and Z, which represent the voltage across the capacitor C1, the voltage across capacitor C2 and the current across the inductor L respectively.

Figure 10. Variables to be analyzed in the Chua Circuit.
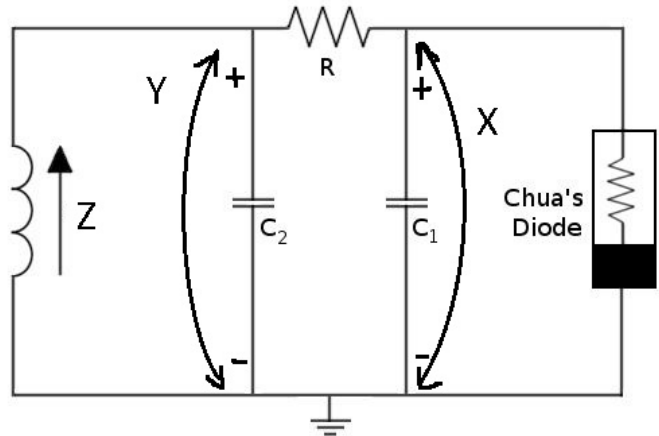
With this parameters in hand and the oscilloscope properly configured in a Voltage x Voltage display, we can obtain curves like these:

Figure 11. Chua attractor with double scrolling seen from an analog oscilloscope. Image taken from: http://www.chuacircuits.com/howtobuild4.php
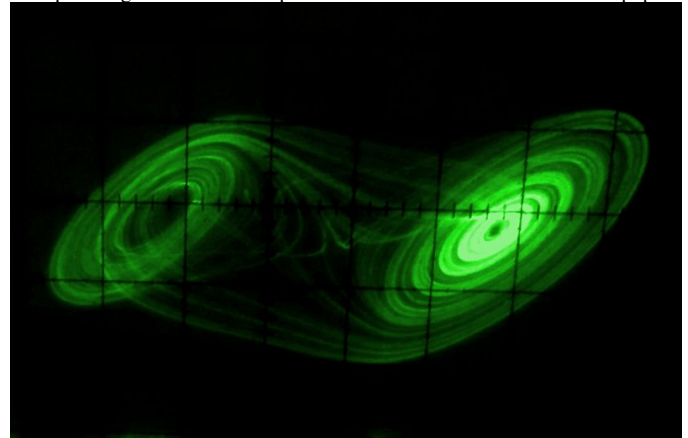
6. Conclusion

The implemented circuit was proposed as an alternative circuit with chaotic behavior and with a smoother nonlinearity than the traditional Chua's circuits nonlinearity. Unfortunaly, in the real circuit implementation, the calibration of the capacitance, inductance and the value of resistor R is very sensitive and it was dificult to obtain a clear chaotic behavior.

References

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