Chua's circuit

Chaos can be found across a wide variety of physical systems. In this lab, we will learn about chaos and simulate chaotic systems, and then we will explore it in a circuit known as a Chua circuit, which demonstrates a Lorenz attractor.

Components of this activity

1. Take notes throughout this activity
   a. Your notes should be a record of the research and activities you did in class, including software used, websites visited, readings that you looked at, and any search terms used when looking for more information. Include screenshots and plots where appropriate. The purpose is to help us follow along with the work that you did in class, and to make it possible for someone to be able to re-create this later.
2. Answering questions
   a. Answer the questions bolded throughout this document
3. Following the activities described below, including
   a. Learn about Chua's circuit and why it exhibits chaos
   b. Build Chua's circuit at multisim.com -> requires making an account!
   c. Probe the simulated circuit and study its behavior
   d. Simulate the circuit behavior using Matlab

These activities should be completed in one lab session. (d) can be skipped if there is insufficient time.

Q1. Circuits 101

   a. Sketch an example plot of voltage (x-axis) vs current (y-axis) for a resistor with a voltage applied to it. What equation does it follow? What kind of behavior does it exhibit?
   b. Read this page to learn about what a diode is and how it behaves:
   https://learn.sparkfun.com/tutorials/diodes/real-diode-characteristics

   Sketch an example of voltage vs current for a **diode**. What is special about its behavior?

   c. Can you sketch a simple voltage vs current plot for a capacitor or an inductor? Why not?

Q2. Read this article on the basics of Chua's circuit and chaos, and give a brief summary of what Chua's circuit is, and why it is special : http://www.scholarpedia.org/article/Chua_circuit

Q3. What is a Chua Diode? Why is it called a diode? Sketch the voltage vs current plot for a Chua Diode.

We will use multisim.com to construct Chua's circuit. There are example circuits that you can copy. You can use these as a reference, but you should build the circuit yourself from scratch. This will help you understand the components, and how to use Multisim (this is very similar to many widely used circuit simulation tools).

You will need to make an account on Multisim. This should be straightforward.

Once you have made an account, let me know so I can add you to our group so I can view your circuit.

First, make a practice circuit to get used to using Multisim. Start a new circuit, making a simple circuit with a resistor and a voltage source. Use probes to measure both the voltage and current. The "grapher" tab is like an oscilloscope, showing the signal vs time.

Note: I couldn't figure out how to plot voltage vs current (instead of vs time), possibly because this is free software. You can try for a few minutes to see if you can get it to plot that, but I think you have to download the data and do it in another program (Python, Matlab, Excel).

Change the voltage to a few different values, to see how the voltage and current change in the grapher view.

At the upper right, there is an arrow icon to export data. Export the grapher data as a .csv file, and use Python, Excel, or similar, to load this data and plot voltage vs current. The voltage was controlled manually, so that should be the x-axis (independent variable). **Be sure to include this plot in your lab notebook along with a description of how you generated it.**

Change the resistor to a diode, and repeat the measurement, downloading the data and plotting voltage vs current, and take screenshots and include plots in your lab notebook.

Share this circuit with the group so that I can see it (ask if you can't find the share feature).

Next, we'll look at Chua's circuit using the op-amp-based "gyrator."

Read the pdf called "BuildingChuasCircuit.pdf" – this describes how to build the circuit.

There is one special component that you will need, the LMC6482.
Go to the group "Physics 307L - Simulating Chaos with Chua's Circuit" and you should see a shared circuit called "Chua's Circuit – Starter."
Copy this to your account so that you can modify it and build the circuit around the LMC6482.
You should be able to build a Multisim circuit that is identical to the diagram in the pdf describing the circuit.

Note: There is also a completed Chua's circuit in the same group folder, which you can compare to the one that you build. If you have less than 1 hour left, you can copy this circuit and use it so you can complete the measurements.

Use the probes to measure the voltages across the two capacitors.
Display the voltage across C_1 on channel 1, and then across C_2 on channel 2.

The behavior we want to see is in plotting these two voltages against each other, like we plotted voltage vs current in the previous example. If we had built this in lab, we would change the oscilloscope display mode to XY. Instead, we can download the time-series data and make plots in another program (like we did for the simple circuit).

Vary the resistance, *R* (the top resistor in the circuit), and make "XY" plots of the two voltages.

Q4. Describe what you are seeing, for several values of *R*. Many behaviors can be observed including dc equilibrium, period doubling, single Rossler-type attractor, strange attractor (double scroll), large limit cycle beyond the double scroll.

Q5. By varying the resistance, determine the minimum (R_{min}) and maximum (R_{max}) values of the variable resistance that give chaotic behavior (*i.e.*, two distinct attractors should be evident).

Bonus – Simulating Chua's Circuit

If you have completed the first section and still have time, download the MATLAB simulation of Chua's circuit from chuacircuits.com (http://www.chuacircuits.com/matlabsim.php)

Edit the code so that it uses the component values that you used in your Multisim circuit.

Run the simulation for each of the R_v values from Question 4 and (qualitatively) compare the simulation to the data that you collected. Also see if you can re-create some of the other observed patterns.