

ELEC 1908 - Deterministic Chaos in Circuitry

Due Midnight April 5, 2018 to David

March 23, 2019

1 Chaos Theory

”Chaos” is one of those words that has one meaning in common usage and another, much more precise meaning in science. When used in the technical way, chaos does not describe random or disjointed madness, but rather a highly complex web of interconnected impulses which lead to a non-predictable but deterministic outcome.

It may be easier to distinguish what makes a system chaotic. In particular, a chaotic dynamical system is generally characterized by:

1. Having a dense collection of points with periodic orbits,
2. Being sensitive to the initial condition of the system (so that initially nearby points can evolve quickly into very different states), a property sometimes known as the butterfly effect, and
3. Being topologically transitive. This basically means that groups of points which are initially contained can expand rapidly to large sets,

which are not necessarily related in the same way. However, it is important to remember that chaos is a deterministic evolution.

Systematic behaviour may change from regular to chaotic when its function begins "period doubling", also known in this context as *bifurcation*.

A simple example of a physical system is a double pendulum (a pendulum with another pendulum attached to its end) Its trajectory depends entirely on the initial conditions of each component of the pendulum.

1.1 Chaos in Electronics

Likewise, in electronics, The behaviour of a system depends on its initial conditions. In a circuit exhibiting chaotic behaviour, the initial conditions, for example the exact value of a resistor, can greatly change its behaviour from one value to the next.

In this lab, you will explore the limits of chaotic behaviour with a defined circuit using LTSpice and then you will build the circuit and analyse its behaviour with an oscilloscope.

2 Chua's Circuit

2.1 Components

- 8.2 mH Inductor
- 47 nF Capacitor
- 4.7 nF Capacitor
- Two Diodes (1N4148)
- Operational Amplifier (TL082CP)
- Resistors:
 - Two 270 Ohm
 - Two 47 kOhm
 - Two 3.3 kOhm
 - 1.2 kOhm
 - 680 Ohm
 - 1.0 kOhm (Potentiometer)

2.2 Building the Circuit

Construct Chua's Circuit as shown in Figure 1, replacing the 1.6kOhm resistor with the 680Ohm resistor and 1kOhm potentiometer in series. Since the circuit is very sensitive to component values, this trick will let you tune this resistance to switch between the oscillatory and chaotic behavior of this circuit.

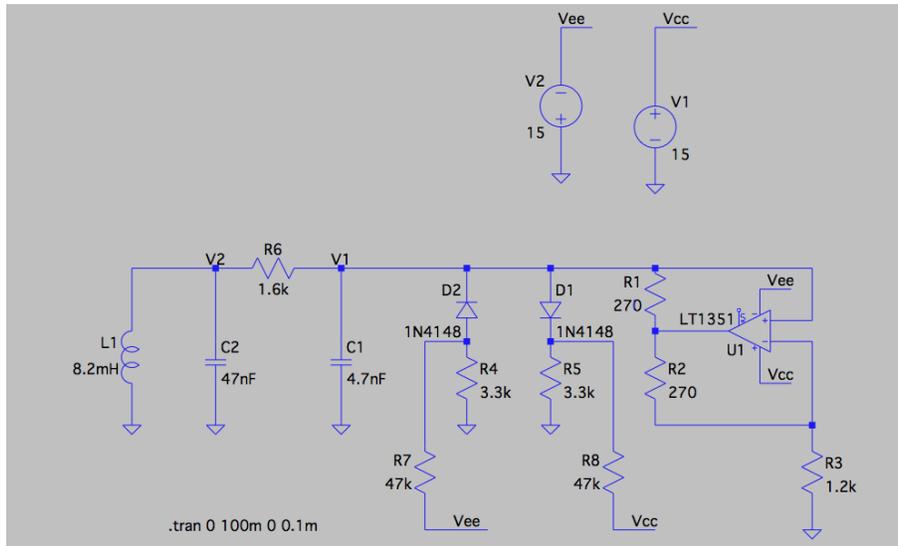


Figure 1: Schematic for Chua's circuit

The expected output of this circuit (simulated in LTSpice) as a function of time is shown in Figure 2. Plotting the voltages across the two capacitors vs one another gives the double scroll attractor, indicative of the chaotic behavior, as shown in Figure 3.

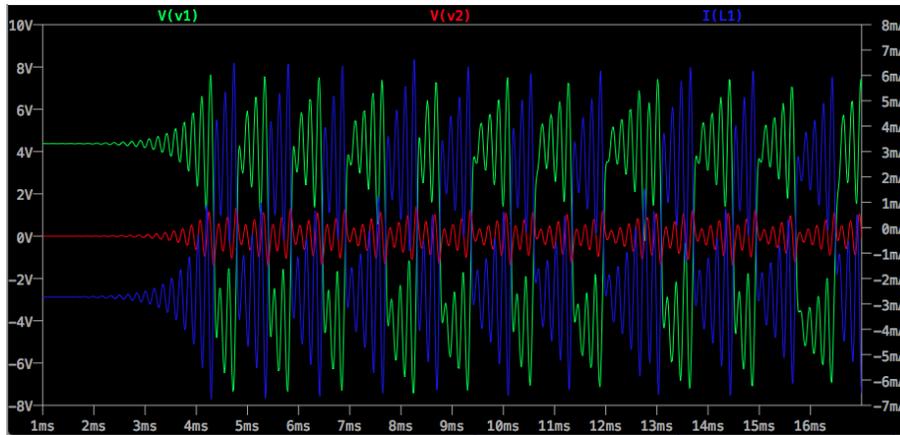


Figure 2: Potential difference over capacitors and current through inductor over time

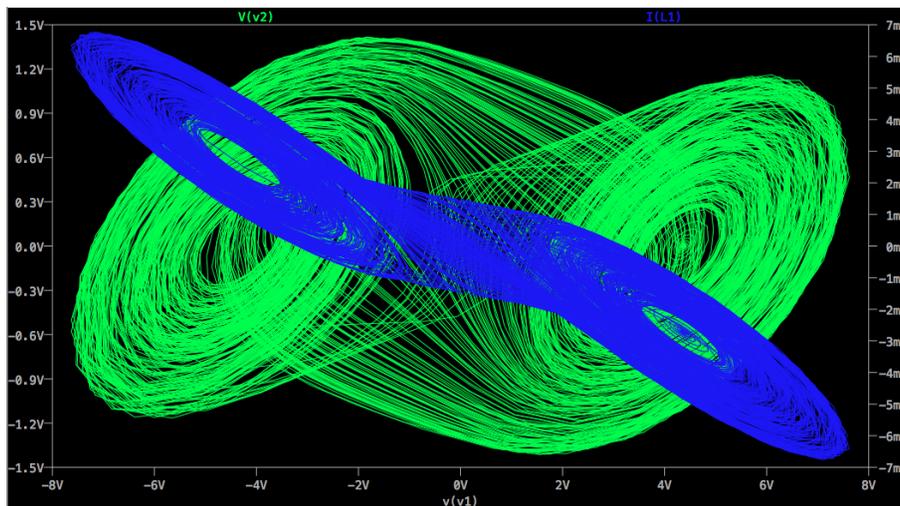


Figure 3: Double scroll attractor

2.3 Using the Oscilloscope

After carefully checking that all connections have been made, connect the circuit to the voltage supply (+V, -V and G). Connect the oscilloscope in two places, at each capacitor, as indicated by V1 and V2 in Figure 1. Af-

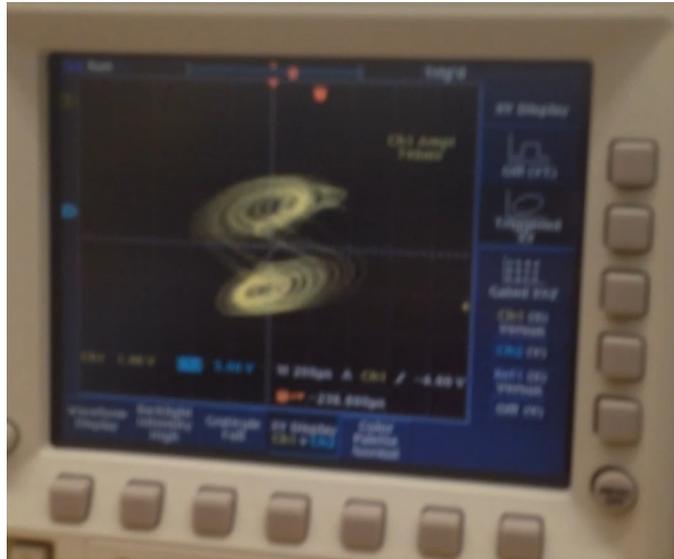


Figure 4: Double Scroll in Oscilloscope

ter adjusting the horizontal and vertical scales for both waveforms vs time, display an XY scatter plot of V1 vs V2 as follows:

1. Press the 'Display' button on the oscilloscope.
2. Using the soft keys set the 'Display Mode' to 'XY'
3. Adjust the 'XYZ - Setup' to display V1 on the X axis and V2 on the Y axis

If you do not see a double scroll attractor as in Figure 4, use the screwdriver to adjust the potentiometer resistance until the double scroll appears. You might have to adjust the vertical and horizontal scales for both V1 and V2 to get a good image.

There are two ways for you to save your data for your report. You can either take screenshots of your waveforms or save the xy-data in a .csv file

for post processing in Excel. To get a screen capture follow these steps:

1. Press the 'Setup' button on the oscilloscope
2. Using the soft keys navigate to 'Device Information' → 'Interface'
3. A window with information will pop up. Under USB LAN there will be an IP address
4. Open an internet browser window on the computer and enter this IP address in the URL field

To save the xy-data do the following:

1. Insert a USB key into the slot on the oscilloscope
2. Navigate to 'File' → 'Waveforms' → 'Save'
3. Choose the channel for which you'd like to save the data. The saved data will be a comma-separated file of time and voltage datapoints for one chosen channel only!
4. Repeat the saving procedure for all channels of interest.

3 Example Circuit

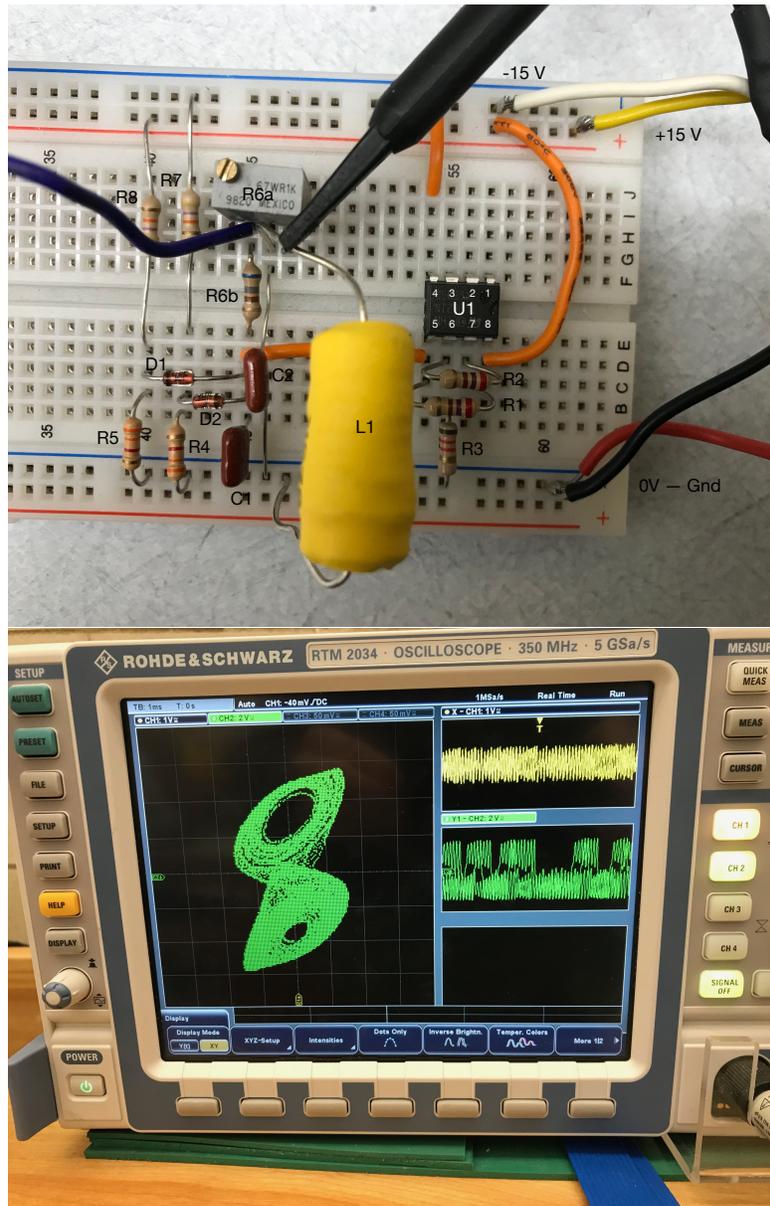


Figure 5: Example Circuit Implementation and Oscilloscope in Action

4 Applications

Choose two of the topics below to develop in detail. Each answer should be at least 100 words and you should reference your sources appropriately.

- What are some real-life applications of chaos?
- When is chaos useful?
- Describe the main properties of a chaotic system.
- How does a diode work?
- What is the role of the Op-Amp in the circuit?
- Describe a system in nature or engineering that exhibits chaotic or non-linear behaviour.
- What is the range of values for each major component in the circuit for which chaos occurs? (use LTspice) What is significant about this?
- Given the equations for the non-linear system, what do each of the variables represent?
- What do Eigenvectors have to do with this circuit?

5 Due Date

Complete the circuit, including diagrams, and hand in your report to David by midnight April 5, 2019.