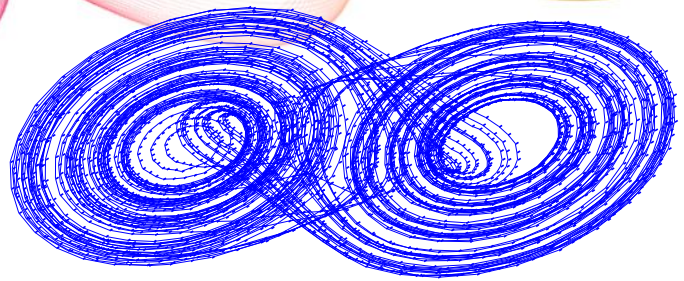
Dany Masante

Chua Circuit Experimental Realization



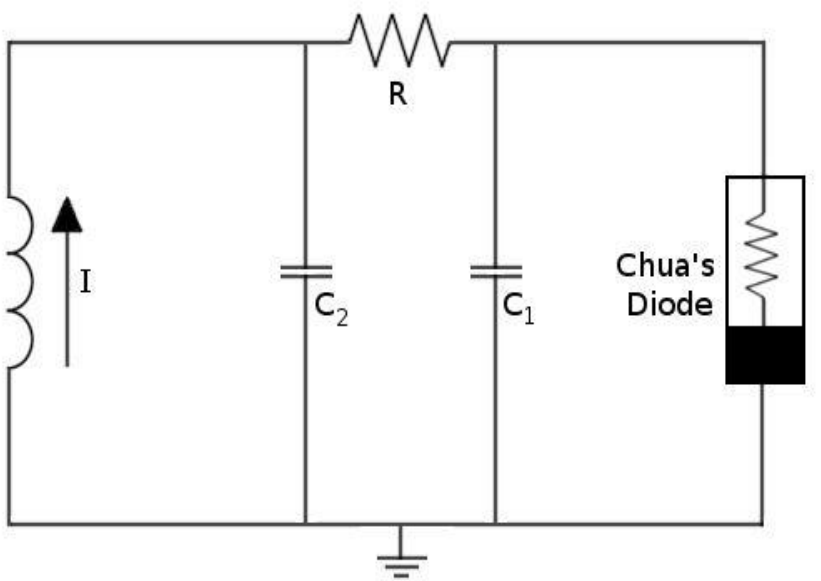
PHY256: NCASO – Final Project

UC Davis Physics

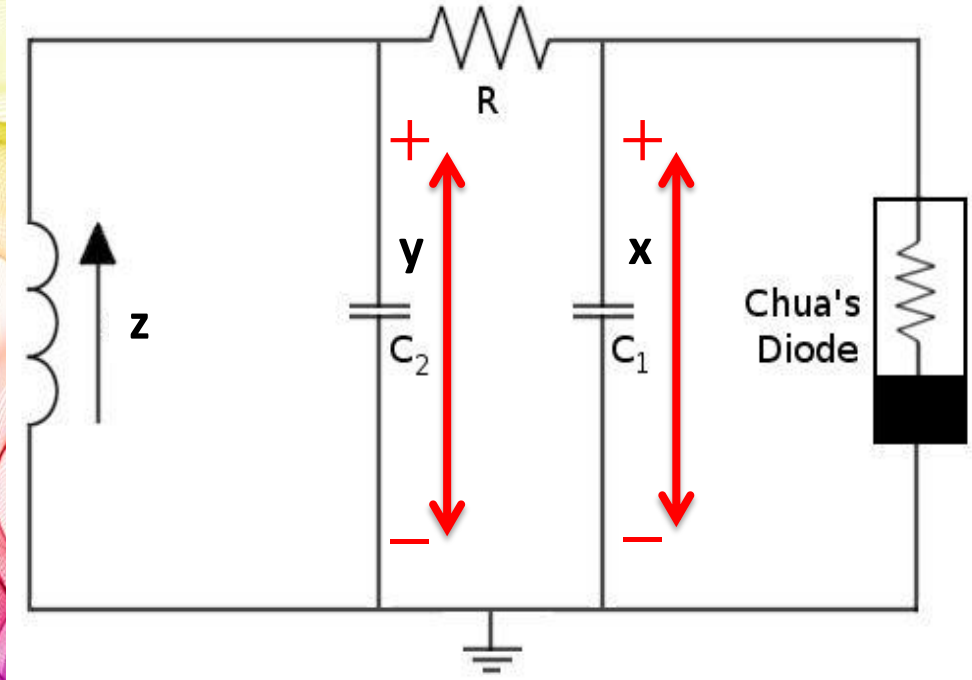
6 June 2017

1

Chua’s Circuit



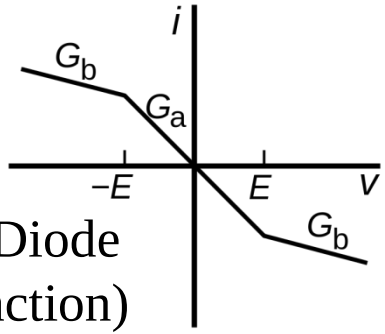
The equations of motion



$$\dot{\boldsymbol{x}}\,'' \rightarrow \frac{dV_1}{dt} = \left[\frac{1}{RC_1}\right]((V_2 - V_1) - R * \boldsymbol{g}(\boldsymbol{v_1})$$

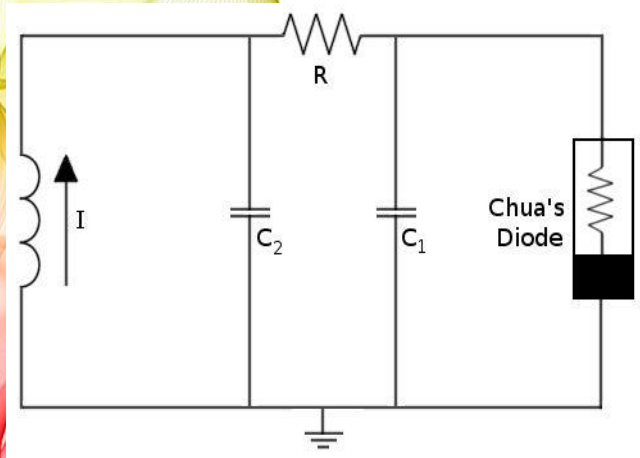
$$\dot{\boldsymbol{y}}\,'' \rightarrow \frac{dV_2}{dt} = \left[\frac{1}{RC_2}\right]((V_1 - V_1) - R * i_L)$$

$$\dot{\boldsymbol{z}}\,'' \rightarrow \frac{di_L}{dt} = \left[\frac{1}{L}\right](-v_2)$$

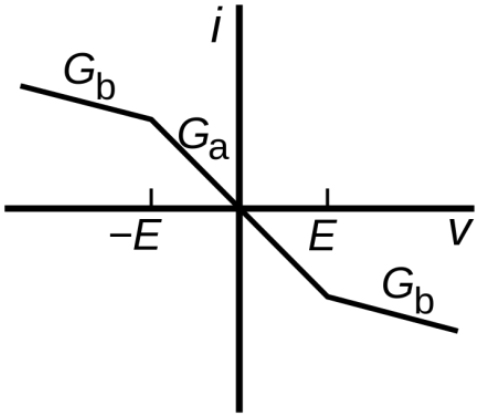


Where $g(x)$ is Chua's Diode (piecewise function)

Three Fixed Points



$$p_0 = [0\,, \quad 0, \quad 0]$$



$$p_{1,2} = \pm\left[\frac{-E(G_b-G_a)(r_L+R)}{1+(R+r_L)G_b} \quad , \quad \frac{-E(G_b-G_a)(r_L)}{1+(R+r_L)G_b} \quad , \quad \frac{+E(G_b-G_a)(r_L)}{1+(R+r_L)G_b}\right]$$

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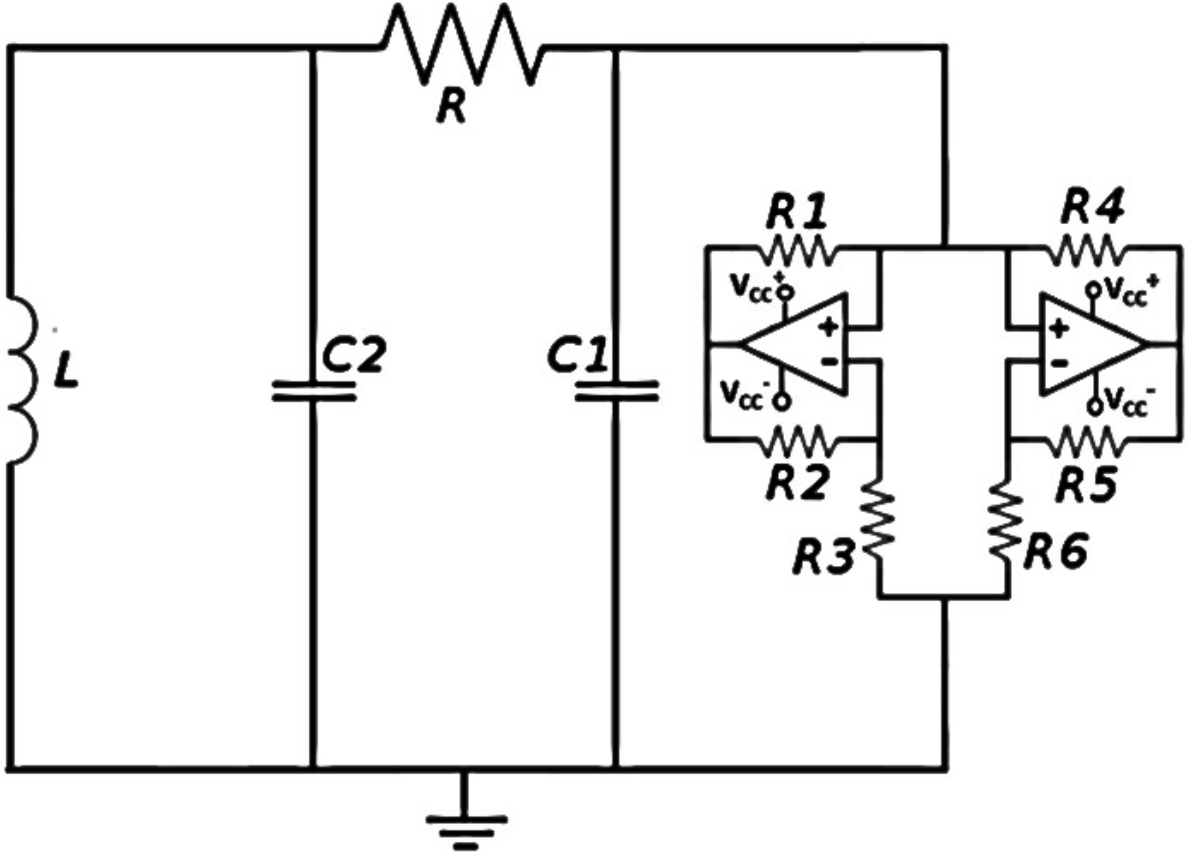
EXPERIMENTAL REALIZATION

Experimental Realization



Where

$R_1 = 220\ [\Omega]$

$R_2 = 220\ [\Omega]$

$R_3 = 2.2\ [k\Omega]$

$R_4 = 22\ [k\Omega]$

$R_5 = 22\ [k\Omega]$

$R_6 = 3.3\ [k\Omega]$

$C_1 = 10\ [nF]$

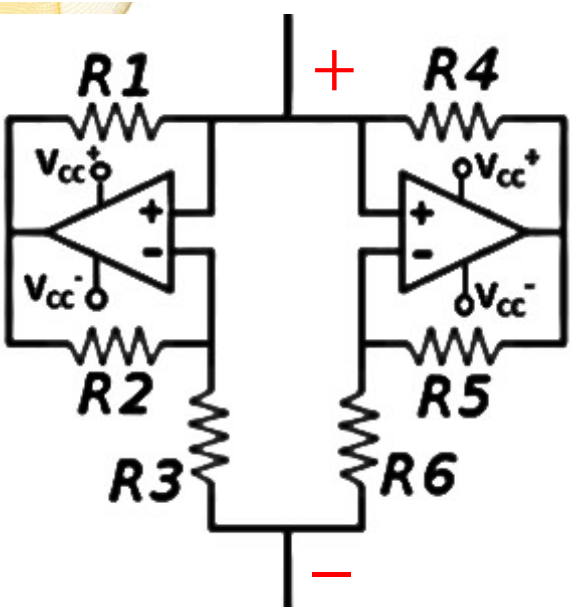
$C_2 = 100\ [nF]$

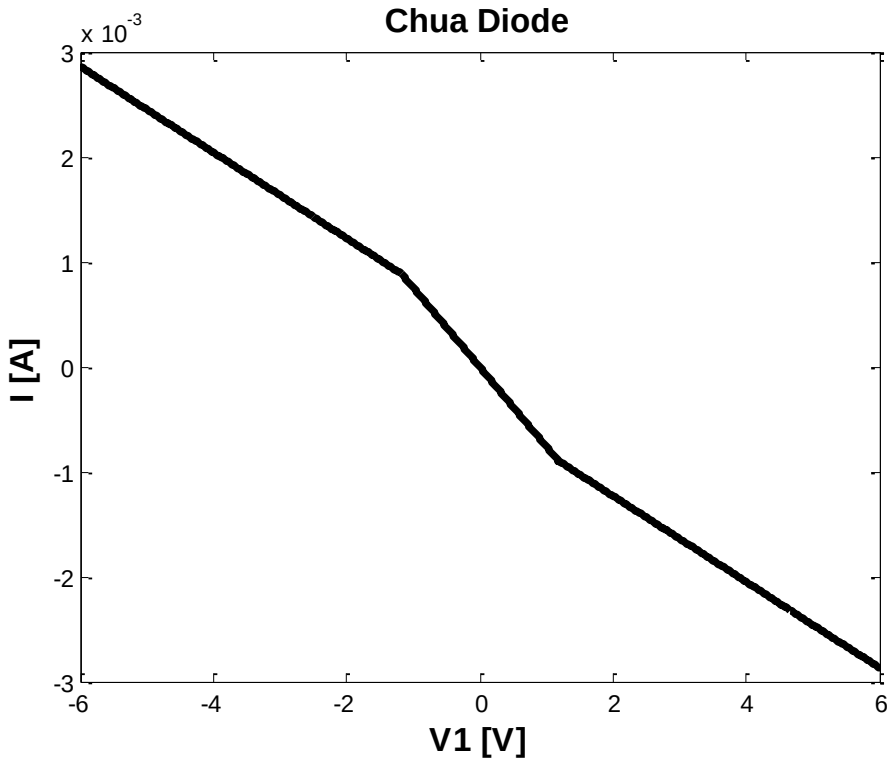
$L = 18\ [mH]$

And R is a potentiometer (variable resistor)

Chua Diode

$$g(v_1) = \begin{cases} m_0 v_1 + (m_0 - m_1)E_1, & v_1 \le E_1 \\ m_1 v_1, & -E_1 \le v_1 \le E_1 \\ m_0 v_1 + (m_1 - m_0)E_1, & v_1 \ge E_1 \end{cases}$$





Where

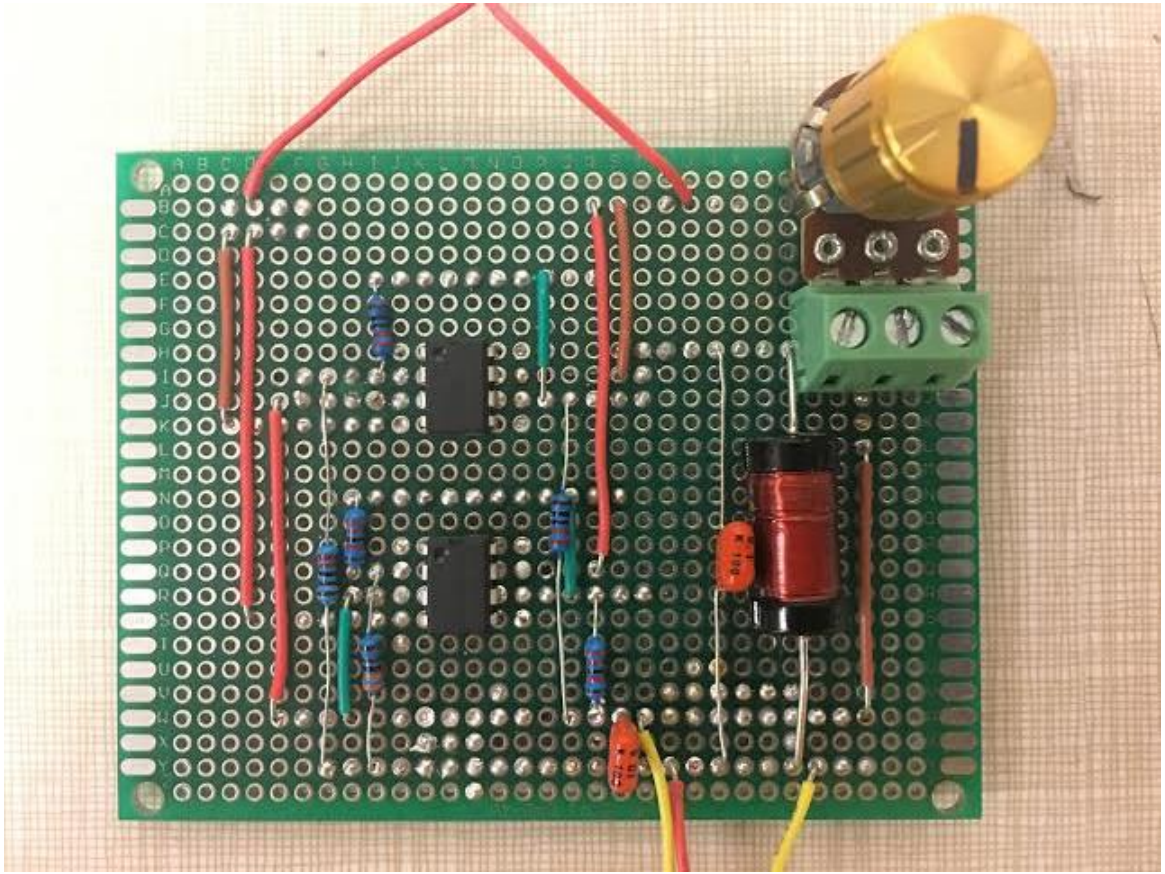
$$m_0 = \frac{1}{R_4} - \frac{1}{R_3} \quad , m_1 = -\frac{1}{R_3} - \frac{1}{R_6} \quad , \quad E_1 = \frac{R_3}{(R_2+R_3)} E_{sat}$$

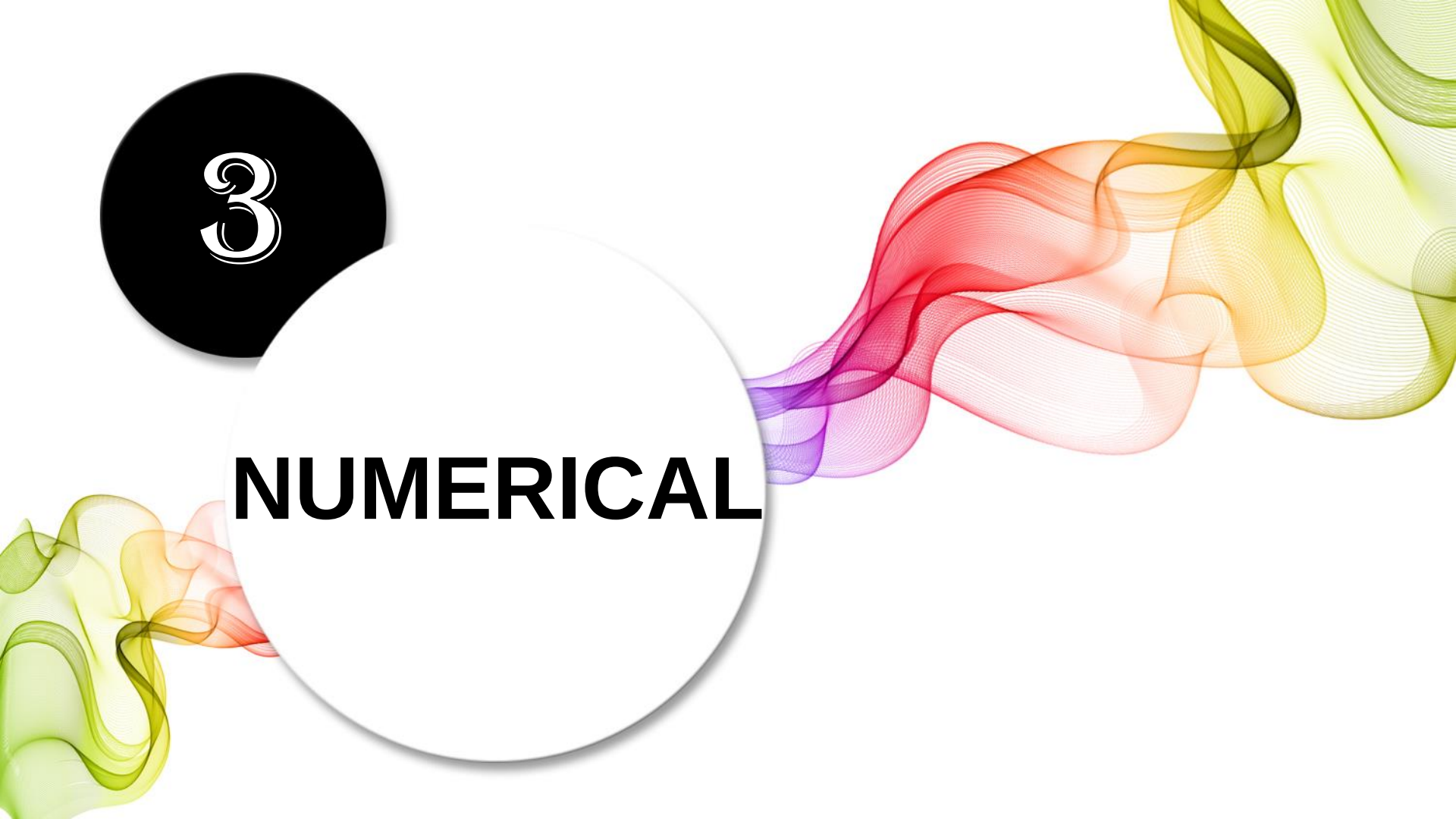
List of Materials

Device	Stock Code	Quantity	Description
Capacitor	Mapln Sc Series	2	Metallized Polyester Film (MKT) Capacitors
Inductor	PCH45X186KLT	1	Axial Lead Power Choke
Resistor	TOPCOFRLD008	6	Metal Film full range resistor
Potentiometer	B01LYHMKNN	1	Logarithmic Dual Rotary Potentiometer
Operational Amplifier	TI6PCSUA741CP	2	General Purpose Operational Amplifier

All elements are Rohs complilant

Experimental Realization




3
NUMERICAL

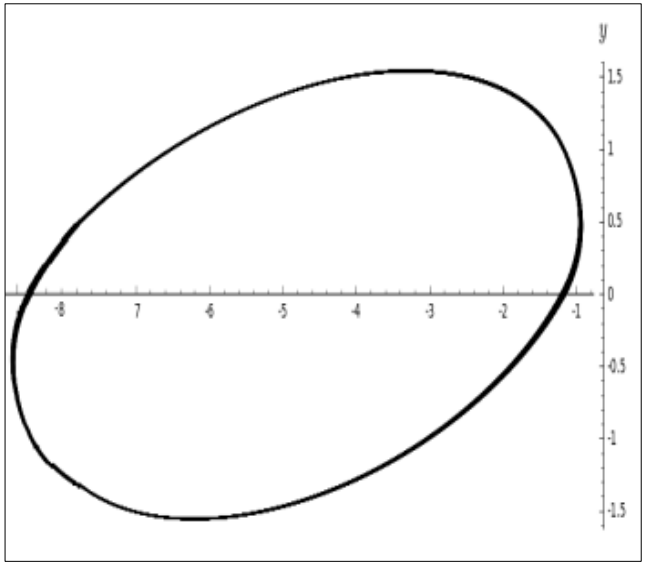
Numerical Realization

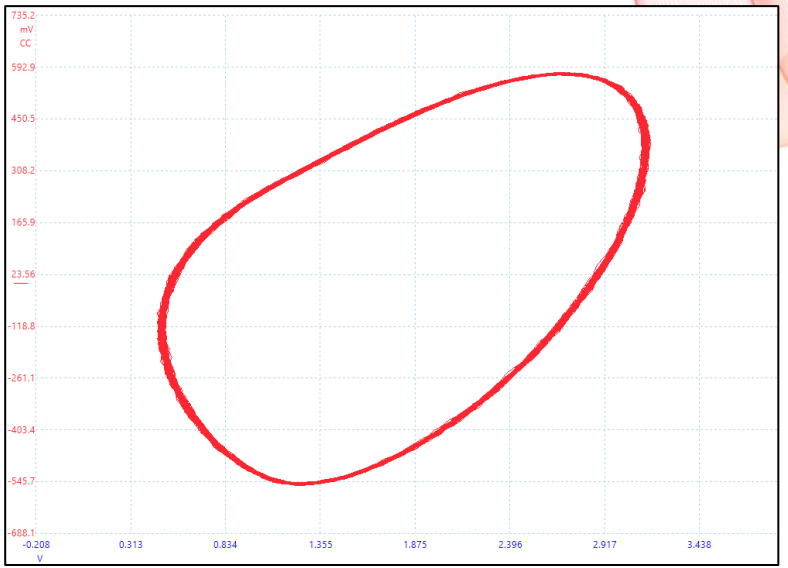
- Sagemath
- Dimensionless Chua Eqs.
- Finite difference method
- Timestep = 0.000001
- Iterations = 100000
- Discarded (transtients)= 10%
- Initial Conditions= Aleatory negative initial conditions (-10 to 0)

4

RESULTS

Numerical VS Experimental



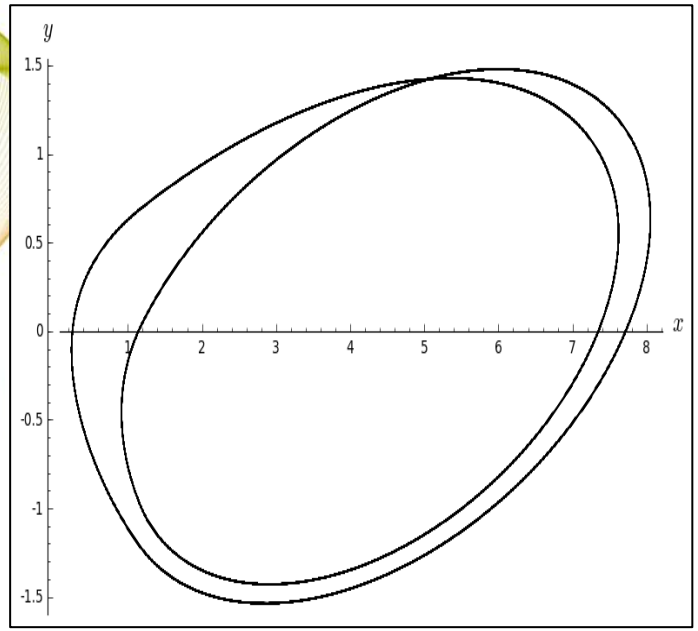


$\mathbf{R = 2015\ [\Omega]}$

$\mathbf{R = 1777\ [\Omega]}$

$\mathbf{\Delta = 11.81\%}$

Numerical VS Experimental

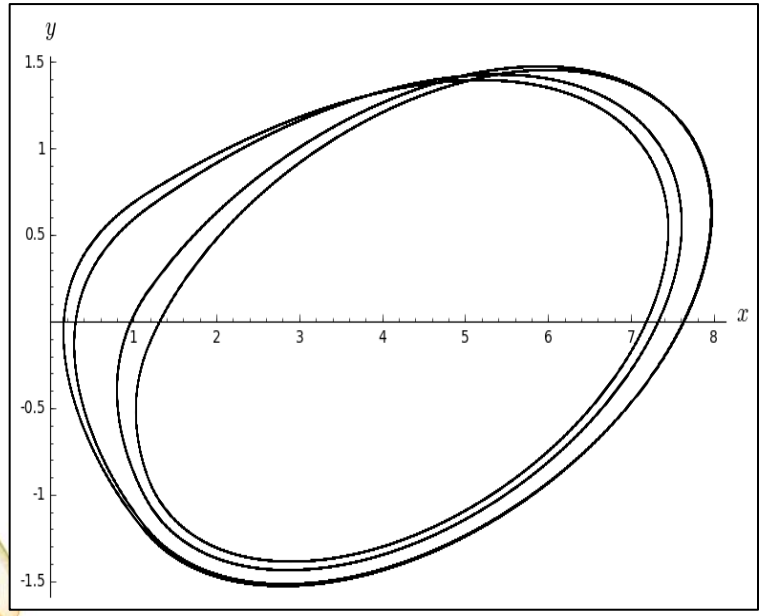


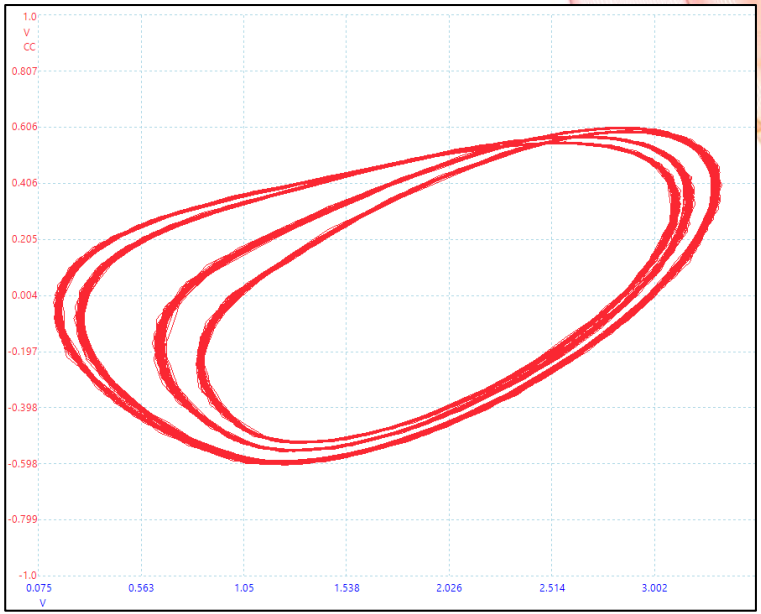
$$\mathbf{R = 2001\ [\Omega]}$$

$$\mathbf{R = 1714\ [\Omega]}$$

$$\Delta = \mathbf{14.34\%}$$

Numerical VS Experimental



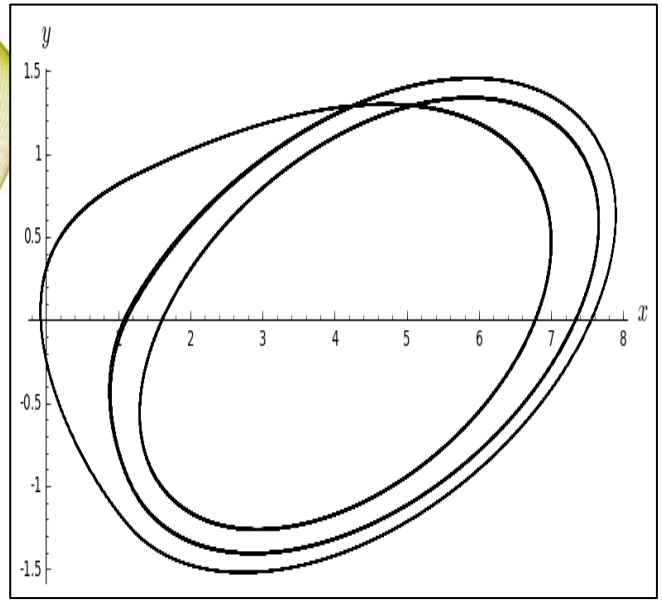


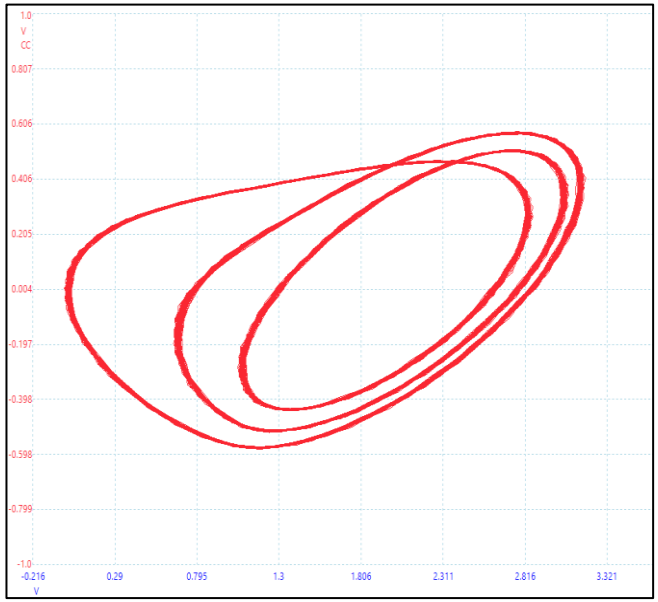
$$\mathbf{R = 1998\ [\Omega]}$$

$$\mathbf{R = 1701\ [\Omega]}$$

$$\mathbf{\Delta = 14.86\%}$$

Numerical VS Experimental



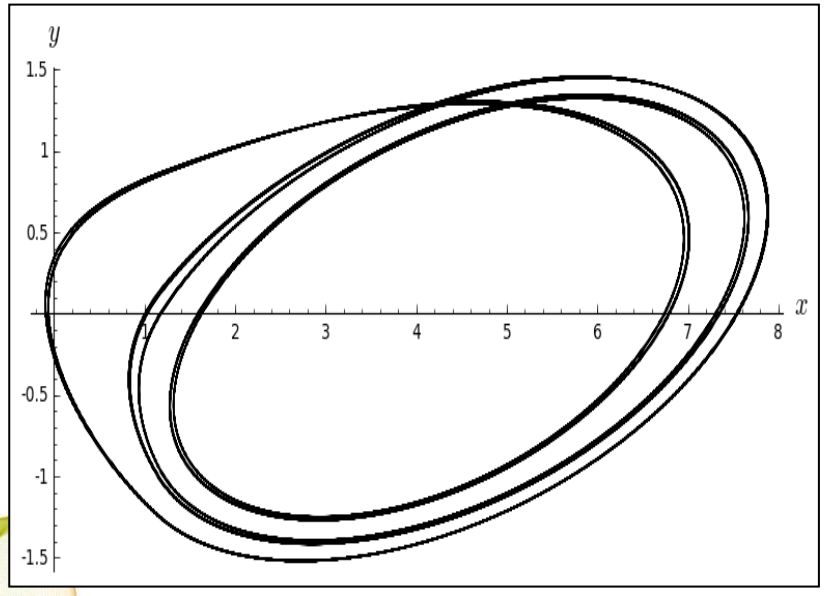


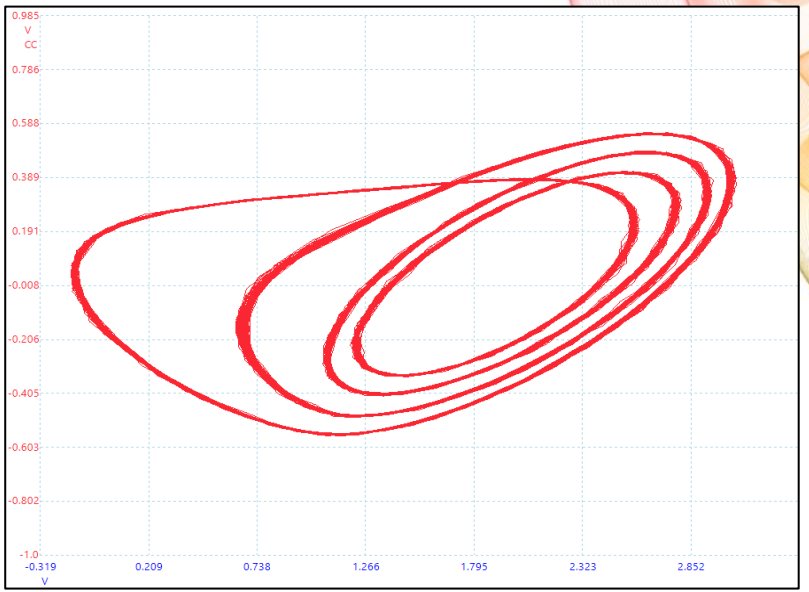
$\mathbf{R = 1993\ [\Omega]}$

$\mathbf{R = 1677\ [\Omega]}$

$\mathbf{\Delta = 15.85\%}$

Numerical VS Experimental



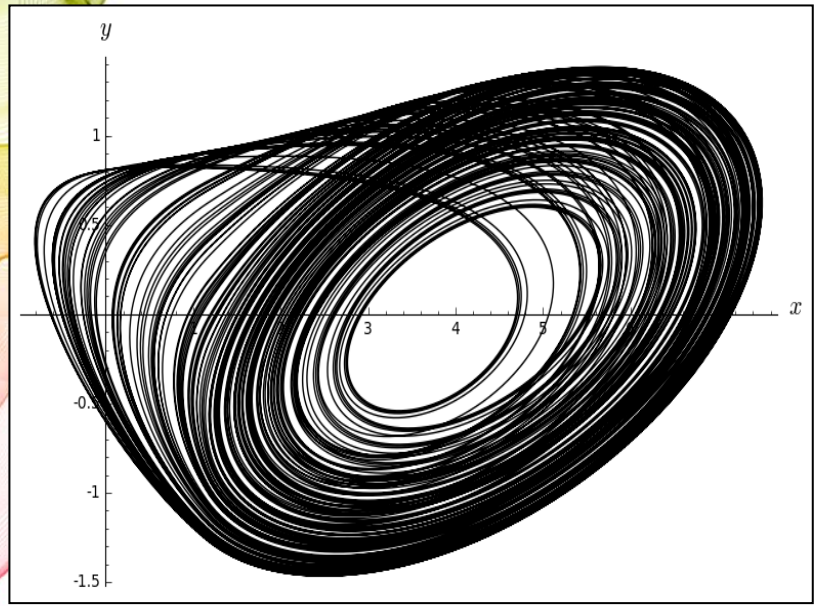


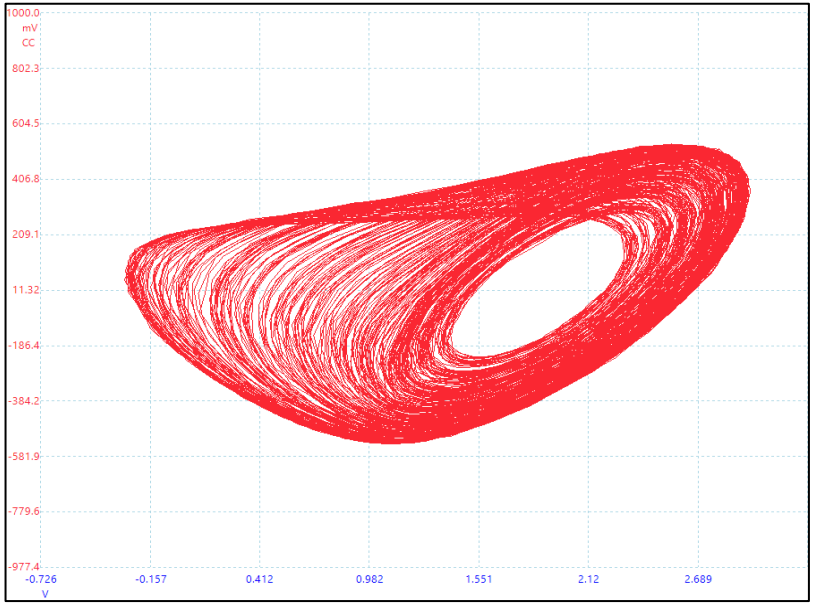
$\mathbf{R = 1992\ [\Omega]}$

$\mathbf{R = 1669\ [\Omega]}$

$\mathbf{\Delta = 16.21\%}$

Numerical VS Experimental



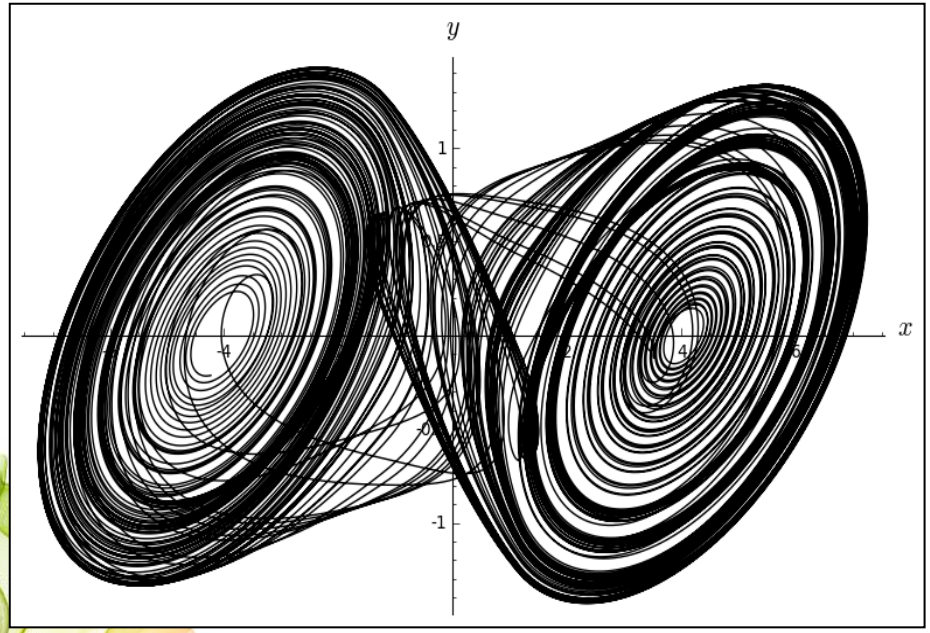


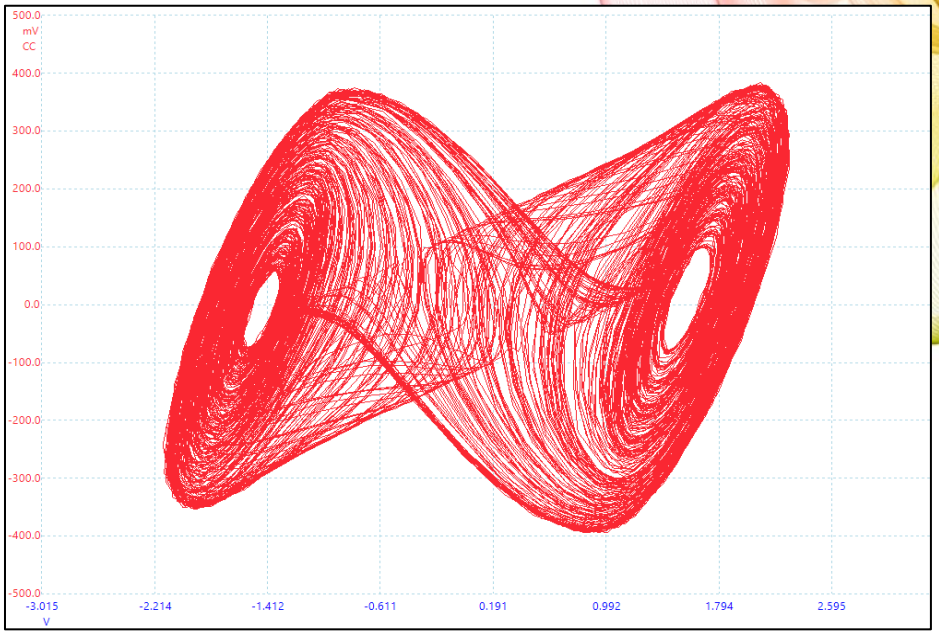
$\mathbf{R = 1974\ [\Omega]}$

$\mathbf{R = 1650\ [\Omega]}$

$\mathbf{\Delta = 16.41\%}$

Numerical VS Experimental



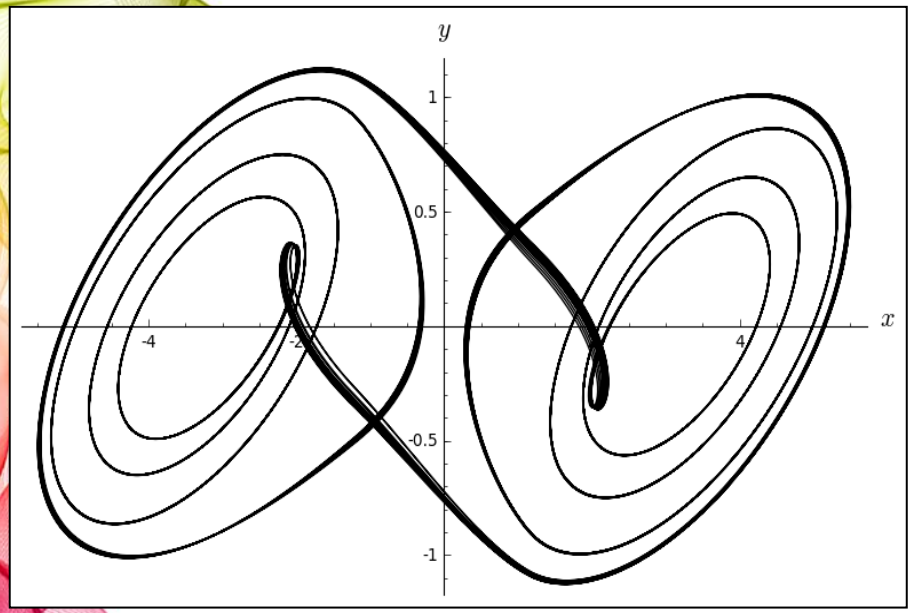


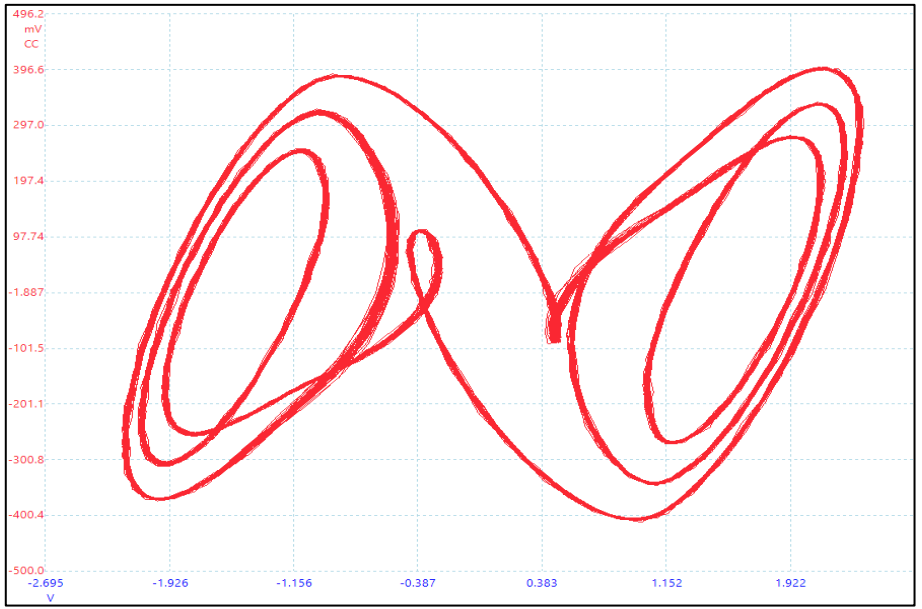
$$\mathbf{R = 1961\ [\Omega]}$$

$$\mathbf{R = 1627\ [\Omega]}$$

$$\mathbf{\Delta = 17.03\%}$$

Numerical VS Experimental





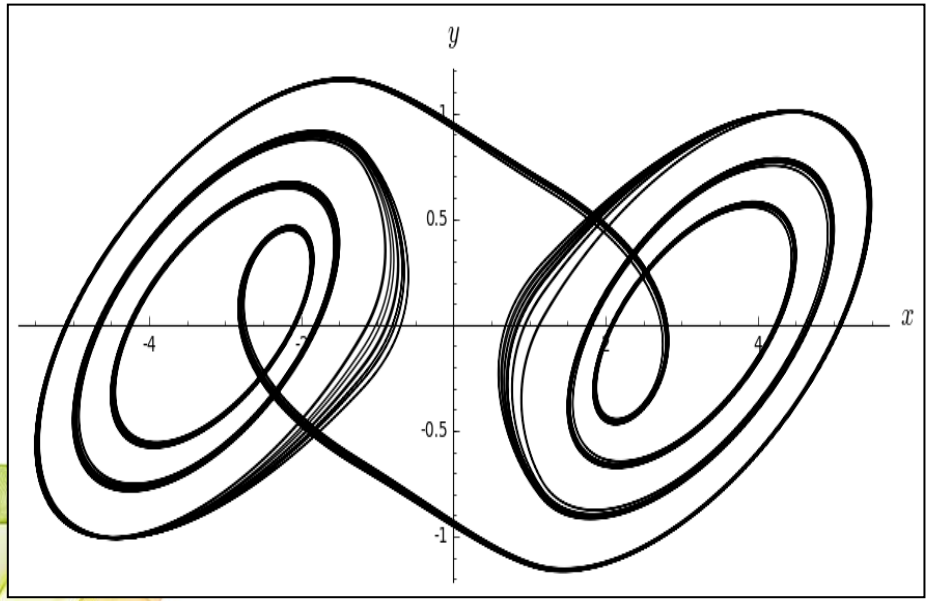
$\mathbf{R = 1955\ [\Omega]}$

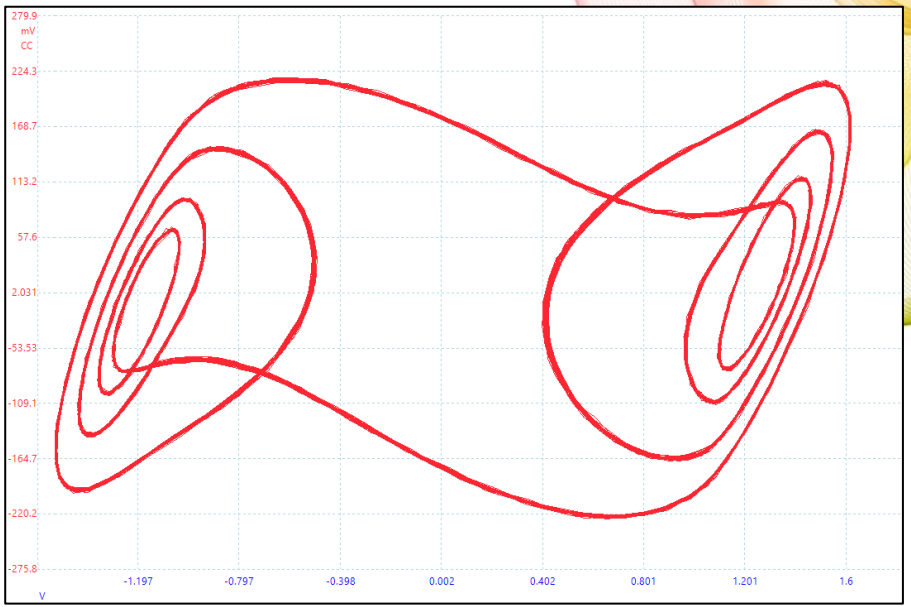
$\mathbf{R = 1614\ [\Omega]}$

(Not the same limit cycle …)

$\mathbf{\Delta = 17.44\%}$

Numerical VS Experimental



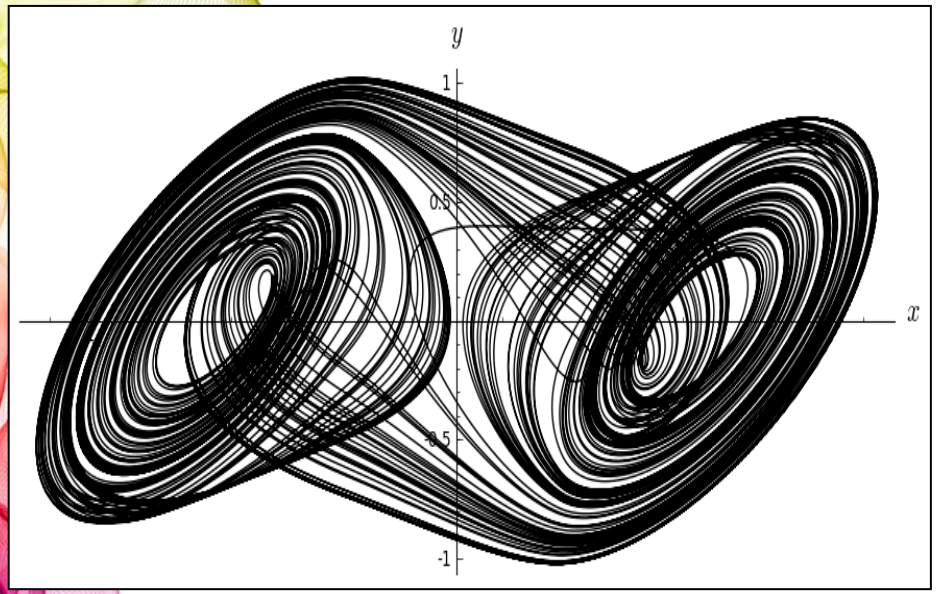


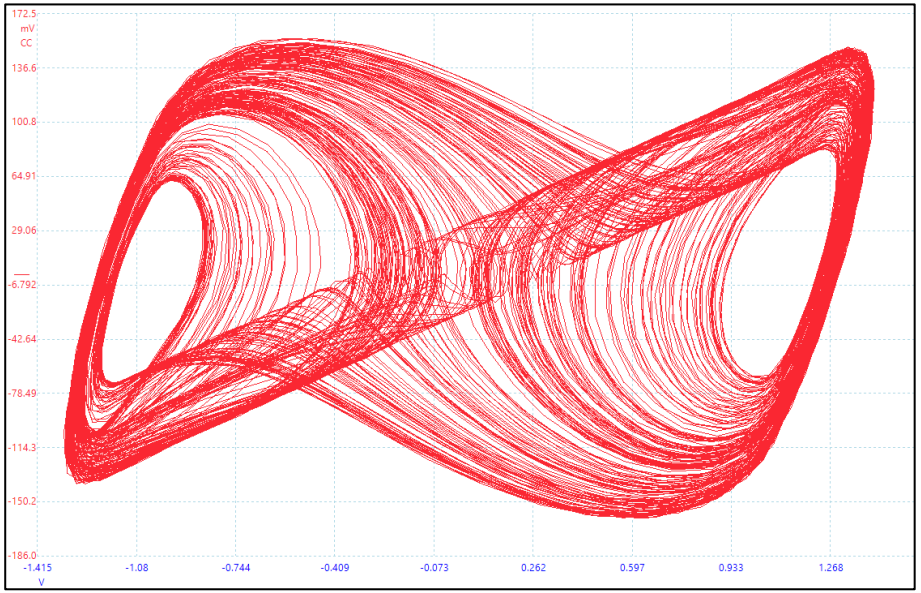
$\mathbf{R = 1851\ [\Omega]}$

$\mathbf{R = 1607\ [\Omega]}$

$\mathbf{\Delta = 13.18\%}$

Numerical VS Experimental



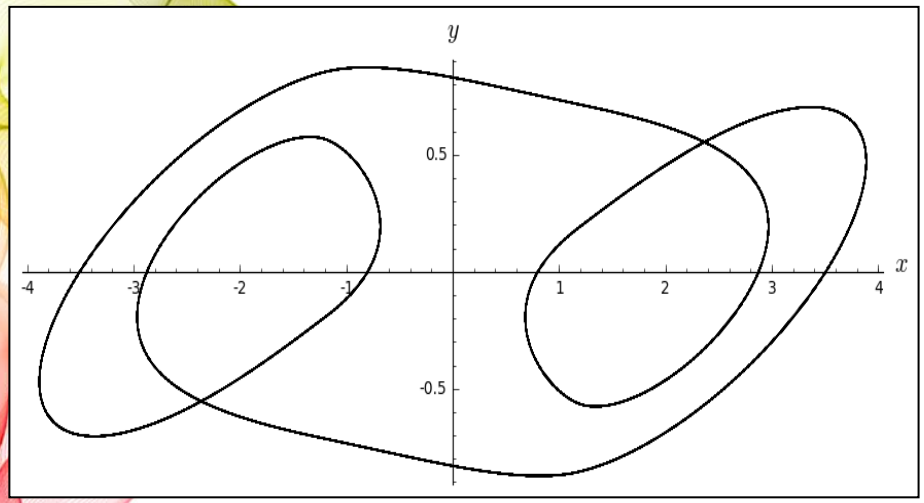


$$\mathbf{R = 1783\ [\Omega]}$$

$$\mathbf{R = 1532\ [\Omega]}$$

$$\mathbf{\Delta = 14.07\%}$$

Numerical VS Experimental

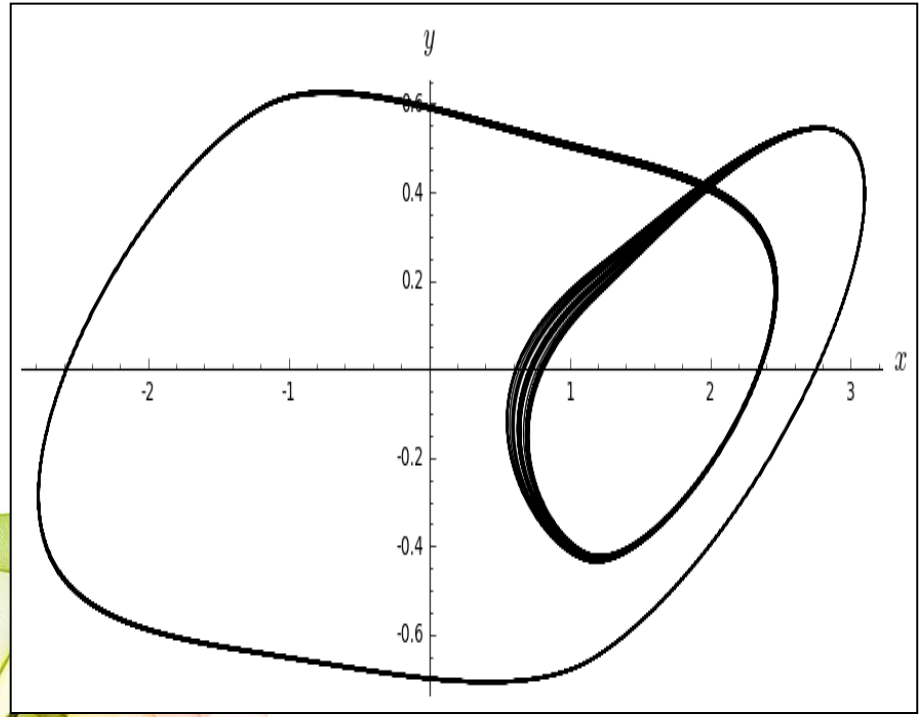


$\mathbf{R = 1706\ [\Omega]}$

$\mathbf{R = 1427\ [\Omega]}$

$\mathbf{\Delta = 16.35\%}$

Numerical VS Experimental

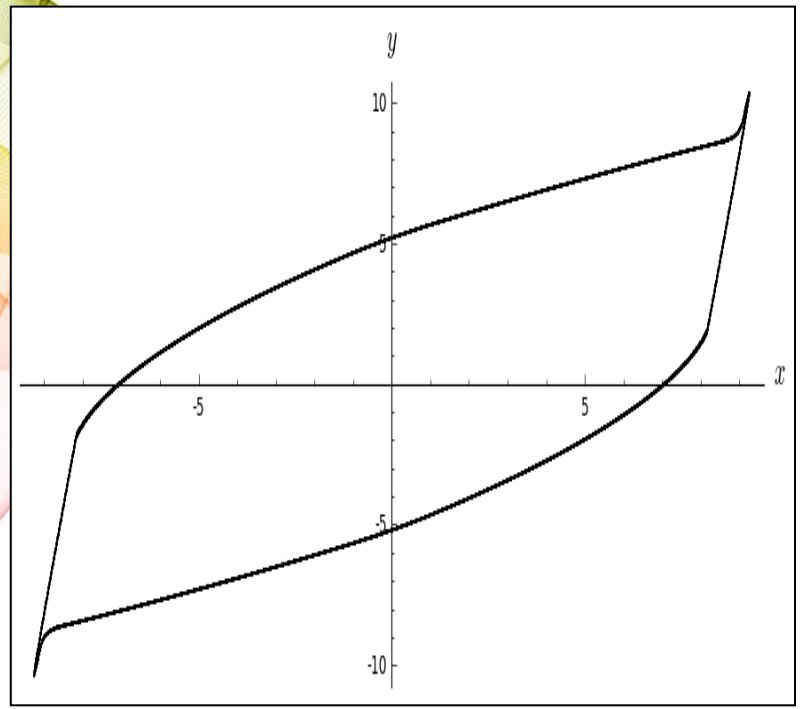


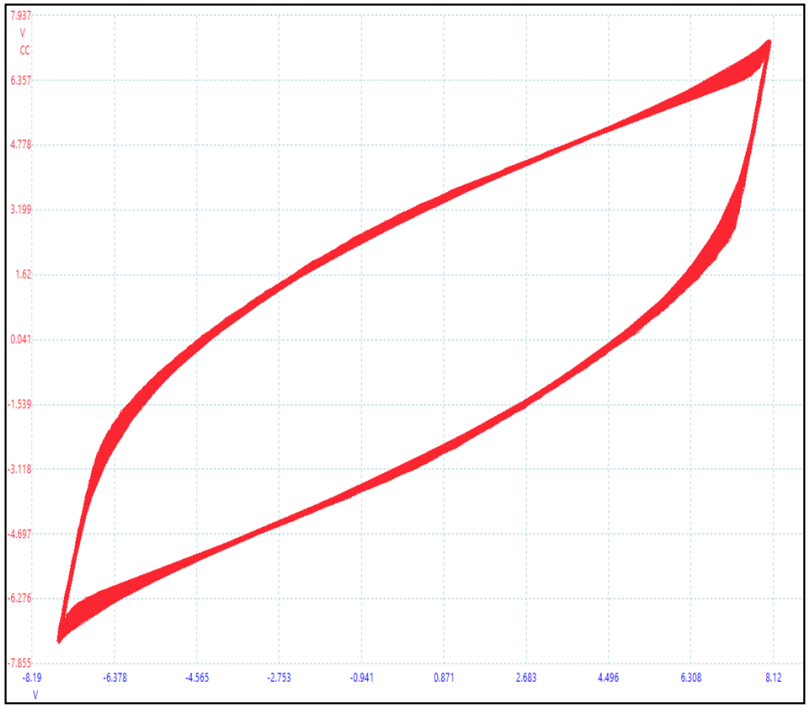
$\mathbf{R = 1610\ [\Omega]}$

$\mathbf{R = 1307\ [\Omega]}$

$\mathbf{\Delta = 18.81\%}$

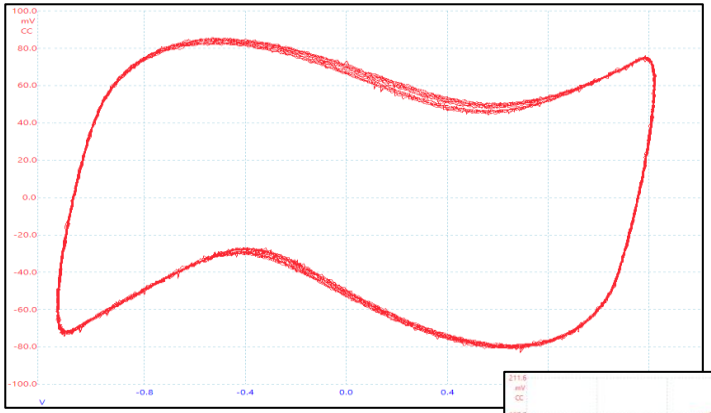
Numerical VS Experimental

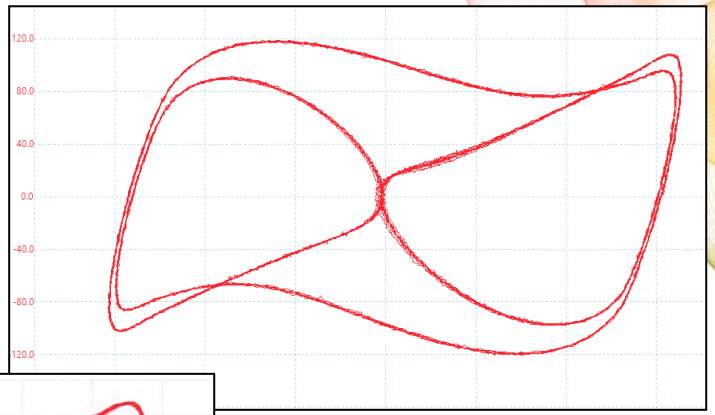


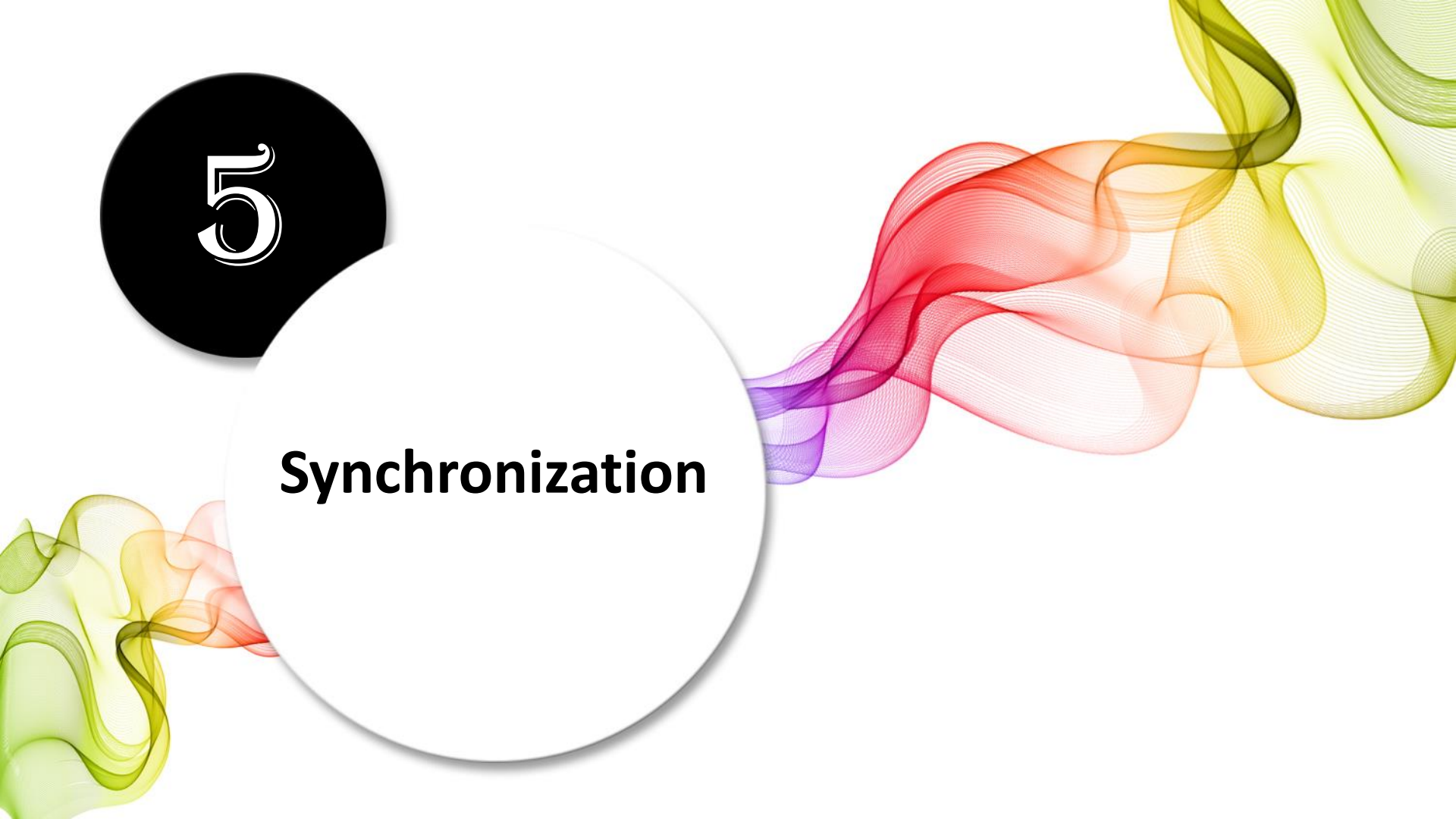


The outmost limit cycle

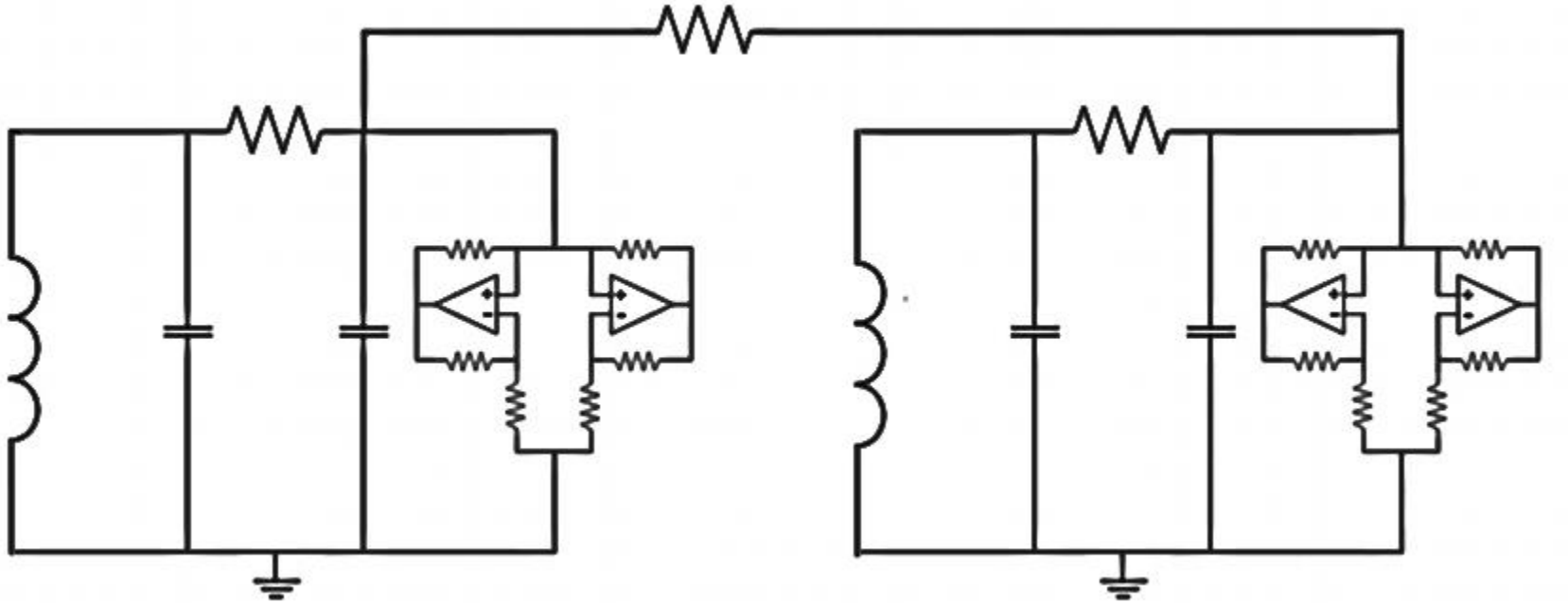
Experimental: Dancing around the outmost limit cycle



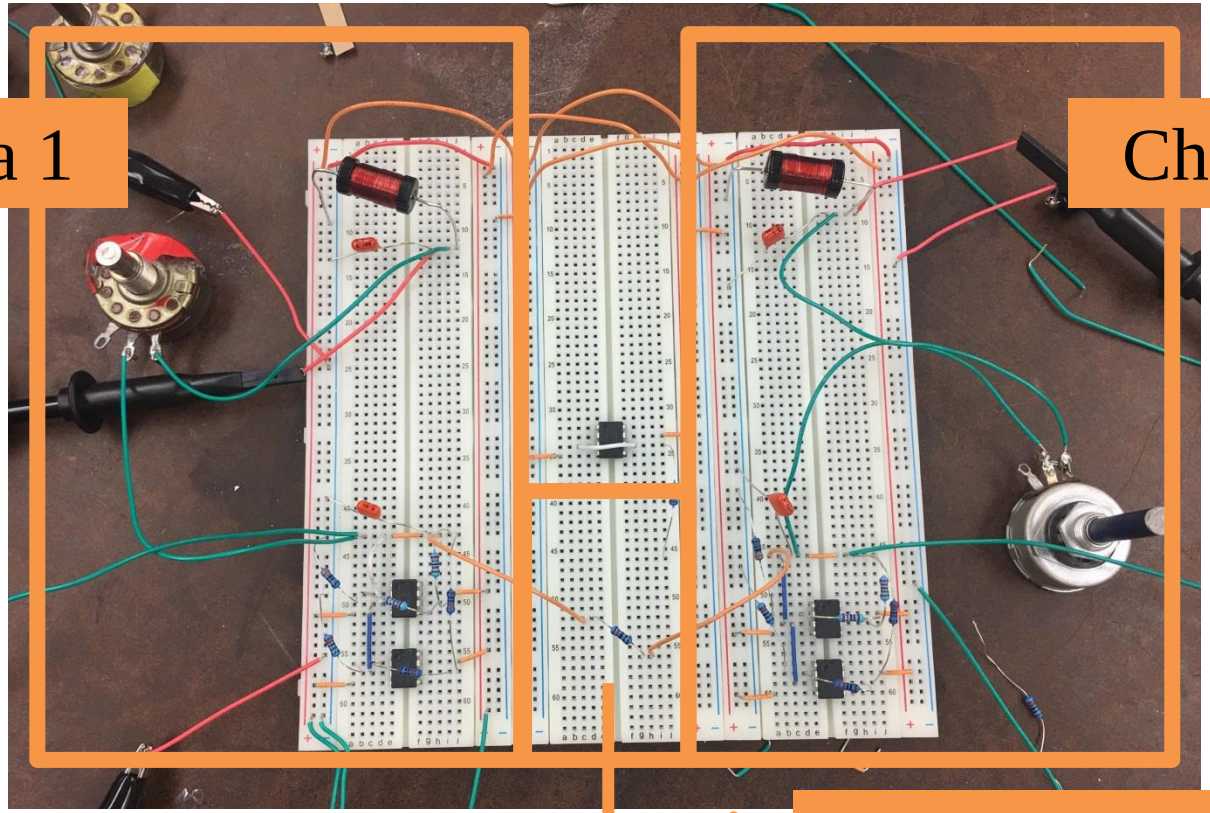



5
Synchronization

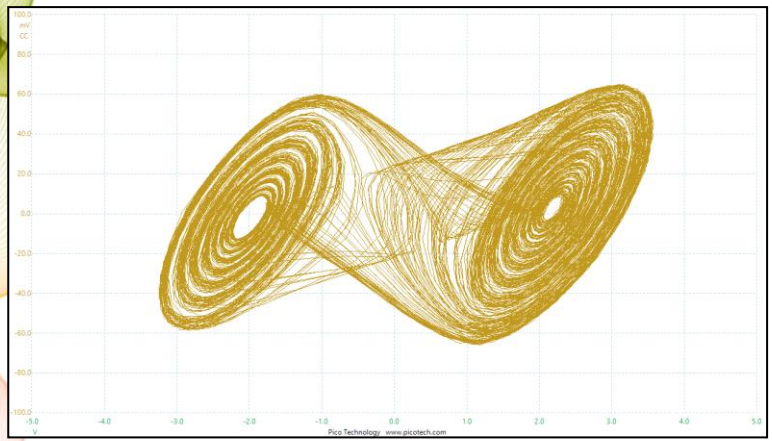
Bidirectional Chua's Circuit

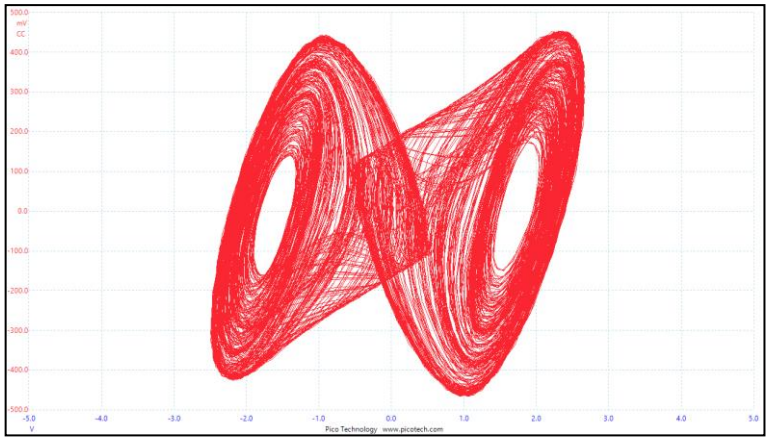


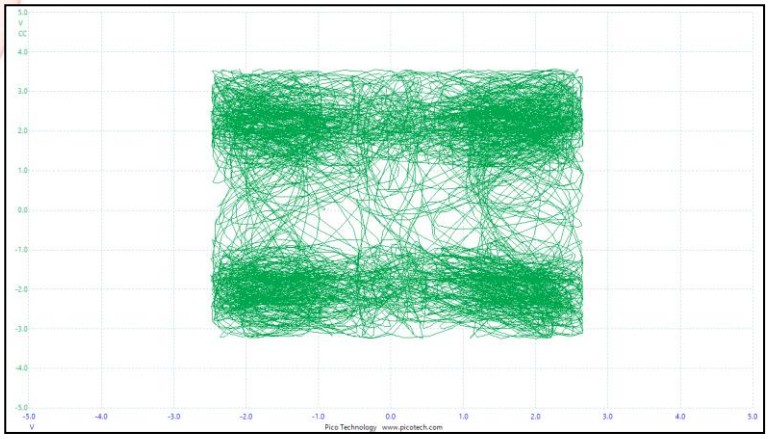
Experimental Realization

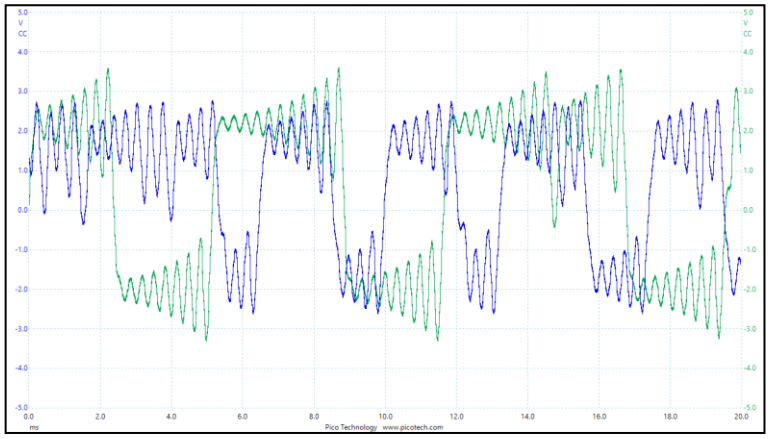


Bidirectional Chua's Circuit

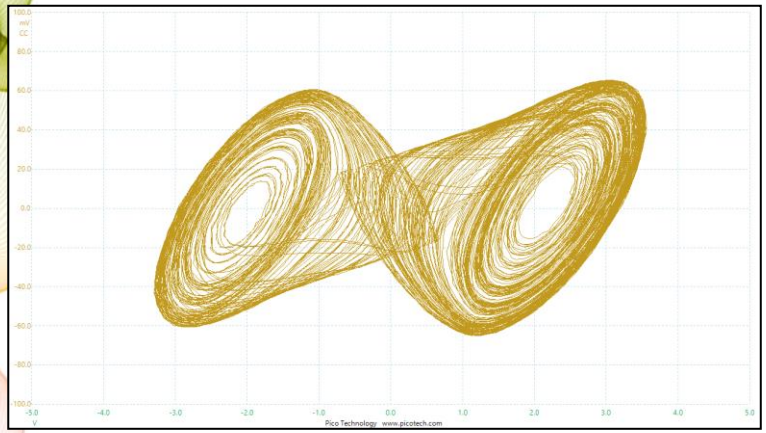


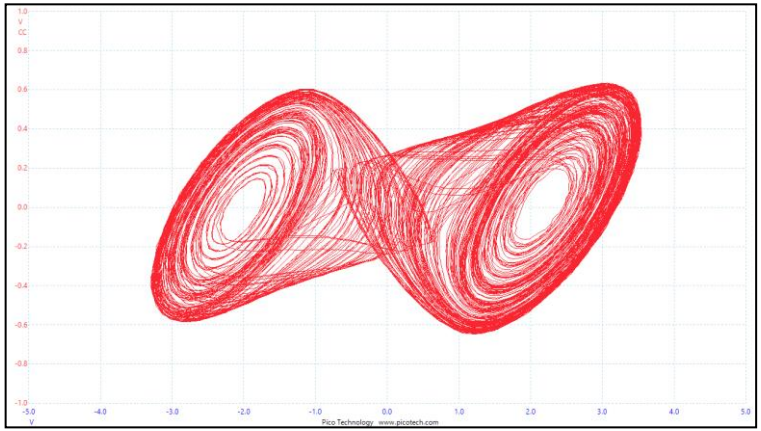


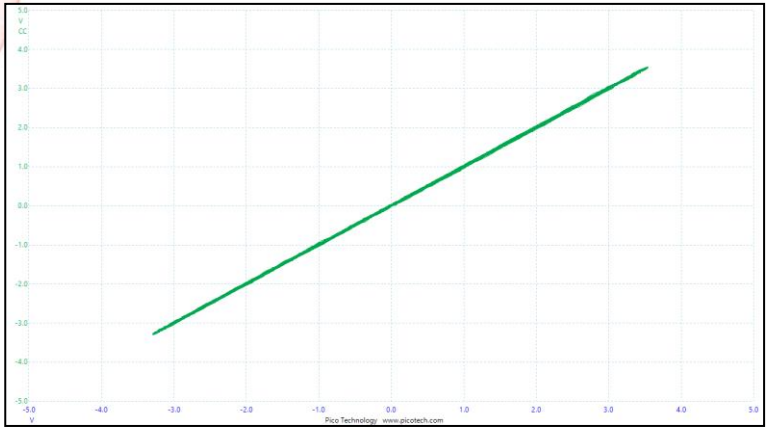


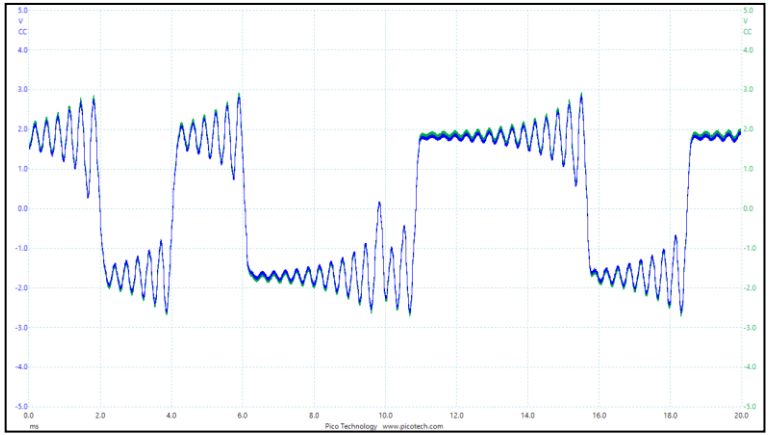


Bidirectional Chua's Circuit









List of Sources

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