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COLPITT AND SPROTT OSCILLATORS CIRCUIT IMPLEMENTATION

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Abstract: **Colpitt oscillator with high frequency dynamics serve as a good form for real systems in nature. In this paper, we presented the numerical and experimental investigation of Colpitt and Sprott chaotic systems. The numerical simulations were carried out using the 4th order Runge-Kutta integration method to solve the systems of nonlinear differential equations on MATLAB while off-the shelf-components on breadboard were used to experimentally implement the systems. We were able show that these systems transit from periodic to chaotic behavior as the value of parameter changes. Also, the experiments results reproduce the exact behavioral structures obtained from numerical simulations.**

Keywords: **Chaos, periodic, dynamics.**

I. INTRODUCTION

This study presents the experimental implementation of nonlinear dynamic oscillators, the studied systems are Sprott I and Colpitt oscillators. Dynamics is when we the effect of force on objects the effective motion can be described by a set of ordinary nonlinear differential equations and parameters. In physics, most of the natural phenomena under study, planetary orbits, motion of fluid or earth's atmosphere, swinging of a pendulum clock, flow of water in a pipe, movement of neurons in the brain etc., may be considered as a dynamical system. While studying dynamics in natural phenomena the nonlinear parts are removed tactically for convenience of analysis. Nonlinearity is a very important aspect of any dynamical system in reality because it usually reveals the rich dynamical behaviors of the system under studying. Dynamical systems form the basis of the nonlinear methods of signal [1]. The study of the electronic implementation of dynamical systems has found applications in a number of fields like Physics [2], Engineering, Biology, Medicine etc. [3]. Chaotic behavior is known to be a common occurrence in nonlinear electronics circuits. Electronic practical's circuits usually contain the basic active electronics components like capacitors, resistors, transistors, operational amplifiers (Op-amps), multiplier and MOSFETs etc. [4]. The dynamics of active elements in a system are reduced and assumed to be linear for understanding the basic operation of the components in linear dynamics system theory, but in reality the components are nonlinear and, therefore, electronic circuits containing these nonlinear components like capacitor, transistor, resistor etc. exhibit nonlinear dynamics [5]. Kennedy in 1994 reported the chaotic behavior of Colpitts oscillator and shows that it was not a parasitic effect but due to presence of a nonlinear element, since then there has been an extensive research numerically and experimentally to provide evidence of the chaotic behavior. Colpitt oscillator is an LC oscillator with high frequency and a lot of applications. The frequency of it oscillations is determined by the value of the capacitors and inductor in the tank circuit. The motivation for this study lay in the fact that a form of Colpitt oscillator with high frequency dynamics serve as a good form for real systems in nature. Such a system may arise in a natural situation such as neuronal hormone in the brain. Application of different coupling scheme on Sprott and Colpitt system will provide additional information on how to secure communication from one end to the other. In this work, the dynamic behavior of chaotic Colpitts and Sprott oscillator circuits were firstly investigated using Multisim circuit simulator. The

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phase portraits and time series were drawn from the simulation results. Then chaotic oscillator circuits were built using off-the-shelve components and tested experimentally in the laboratory to validate the numerical simulations.

II. NUMERICAL SIMULATION

Description of Models

The system of differential equations of Colpitts and Sprott, are given by equations 1 and 2.

Sprott I oscillator:

$\dot{x} = -ay$

$\dot{y} = x + z$ (1) $\dot{z} = x + y^2 - z$

where *a* is the system parameter with the value a is 0.2 for chaotic behaviour.

Colpitts oscillator:

$$\dot{x} = y - aF(z)$$
$$\dot{y} = c - x - by - z \qquad (2)$$
$$\dot{z} = y - dz$$

where a, b, c and d are the system parameters with the value a = 81.41, b = 0.8, c = 7 and d = 0.73. F(z) is the forcing factor that makes the system chaotic.

This section contained the numerical simulations carried out by using the MATLAB simulation software to confirm the systems transitions. The 4th order Runge-Kutta integration method was applied to solve the systems of nonlinear differential equations. The parameters for the systems to exhibits chaotic behavior are has stated above. The initial conditions for the system of equations are: Colpitt (x=0; y=0; z=0) and Sprott (x=0.01; y=0.001; z=0.1) respectively. In addition, a time step of 0.01 is employed. Figures (1 - 8) shows the results obtained for the two oscillators as they transit from periodic to chaotic behaviors. For Colpitt oscillator transition occurred when F(z) is introduced to the systems of differential equations but Sprott oscillator changed behaviors from periodic to chaotic when the parameter *b* changes from 0.15 to 0.20.

When the supply current is turned “OFF” (de-energised) the electromagnetic field generated previously by the coil collapses and the energy stored in the compressed spring forces the plunger back out to its original rest position. This back and forth movement of the plunger is known as the solenoids “Stroke”, in other words the maximum distance the plunger can travel in either an “IN” or an “OUT” direction, for example, 0 to 30 mm

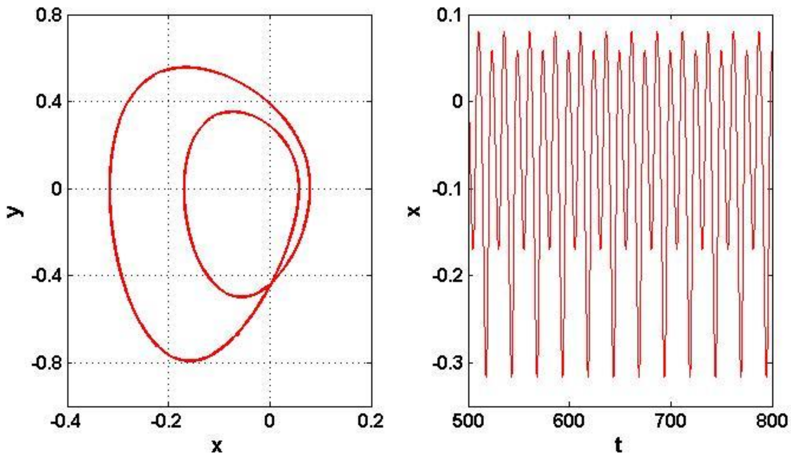

Figure 1: Two dimensional phase portrait (x vs y) and time series of periodic attractor for Sprott I system from numerical simulations with parameter values *a* = *0.15.*

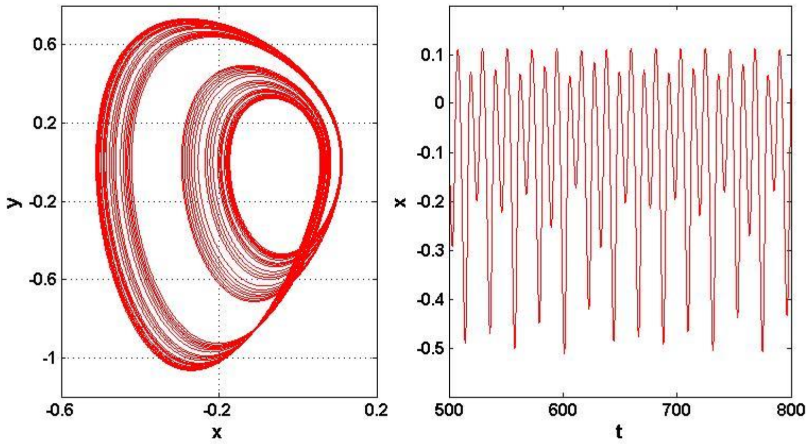

Figure 2: Two dimensional phase portrait (x vs y) and time series of chaotic attractor for Sprott I system from numerical simulations with parameter values *a = 0.2.*

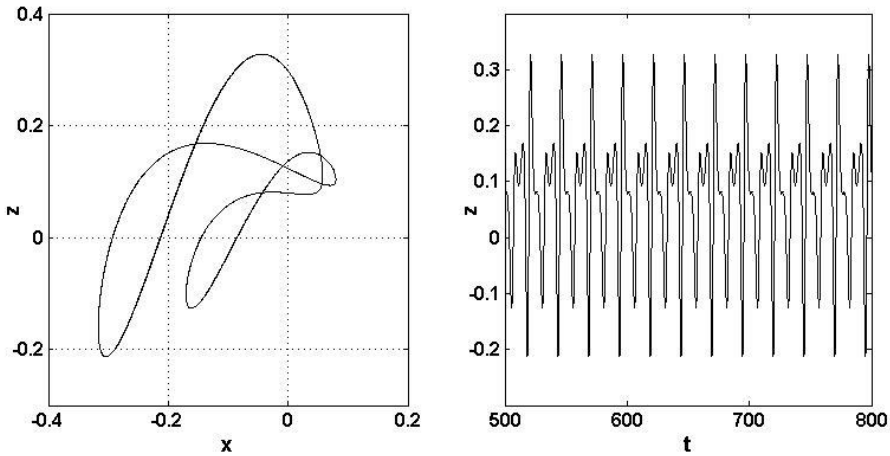

Figure 3: Two dimensional phase portrait (x vs z)and time series of periodic attractor for Sprott I system from numerical simulations with parameter values *a = 0.15.*

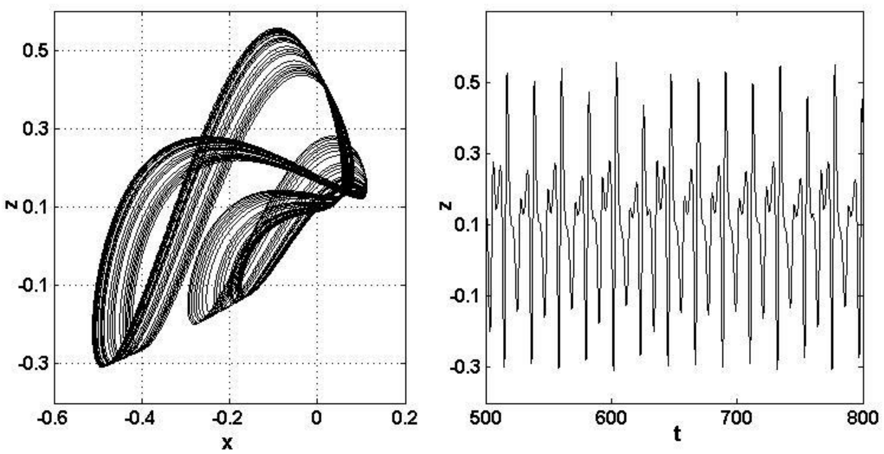

Figure 4: Two dimensional phase portrait (x vs z) and time series of chaotic attractor for Sprott I system from numerical simulations with parameter values *a = 0.2.*

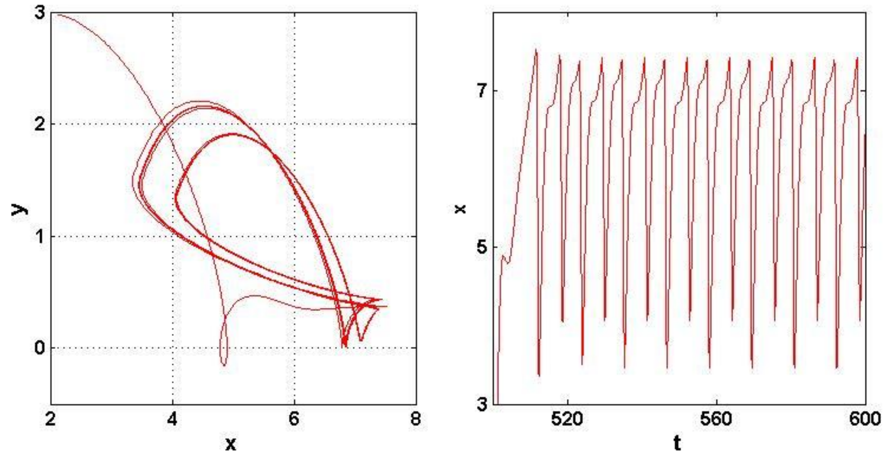

Figure 5: Two dimensional phase portrait (x vs y) and time series of periodic attractor for Colpitt system from numerical simulations with parameter values *b = 1.30*

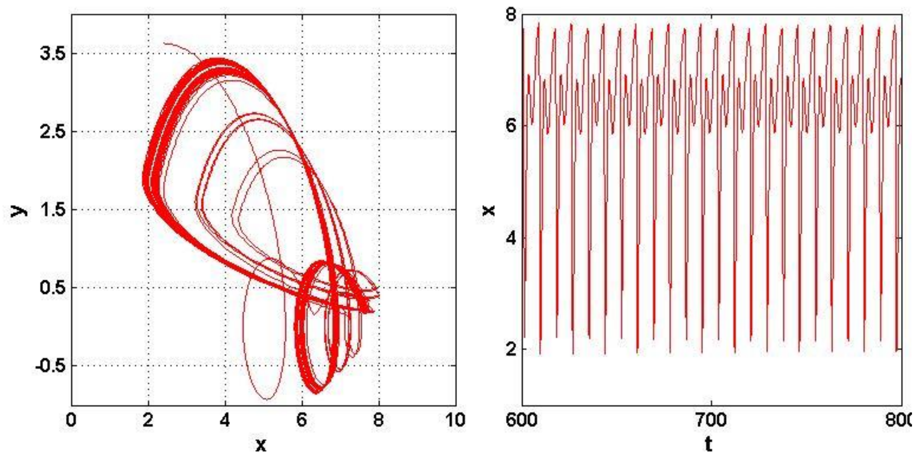

Figure 6: Two dimensional phase portrait (x vs y) and time series of chaotic attractor for Colpitts system from numerical simulations with parameter values *a = 0.2.*

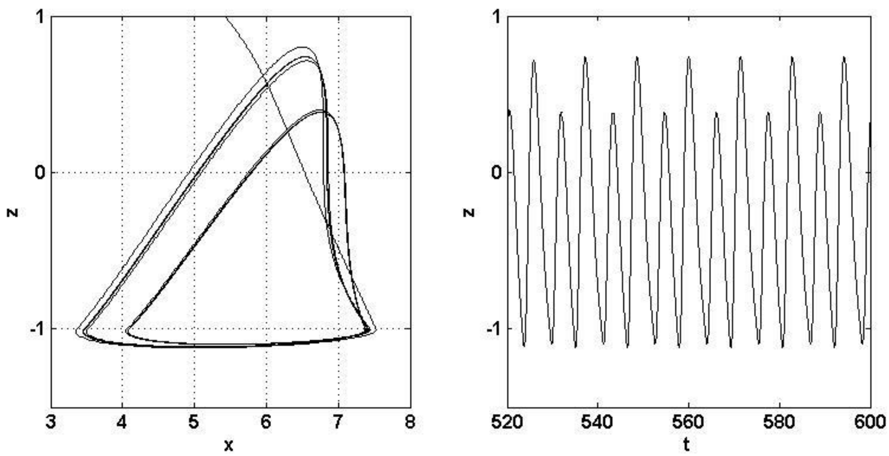

Figure 7: Two dimensional phase portrait (x vs z) and time series of periodic attractor for Colpitt system from numerical simulations with parameter values *b = 1.30*

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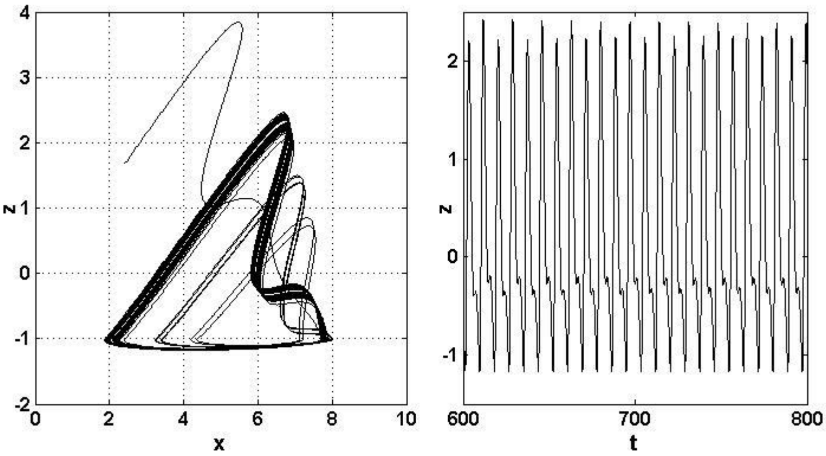

Figure 8: Two dimensional phase portrait (x vs z) and time series of chaotic attractor for Colpitts system from numerical simulations with parameter values *a = 0.2.*

III. EXPERIMENTATION IMPLEMENTATION

We present here the experimental evidence of Colpitts and Sprott systems transition dynamic as they changed behavior from periodic to chaotic. The electronic circuit realization of the systems was done using micro-controller based programming as illustrated in Figure 9 and off-the-shelve components. The hexadecimal form of the system code was saved in the AVR micro-controller (ATMEGA 328P-PU) EPROM memory using micro-controller programmer (Arduino). The generated pulse width modulated (PWM) output is fed into a low pass filter to obtain continuous output waveform observed in a digital oscilloscope (Hantek DSO4254B, 1GS/s, 250MHz). The frequency of the PWM output may be varied to ensure its compatibility with the bandwidth of the oscilloscope. The timer of the micro-controller is used to vary the frequency. In Figures (10-17), we display the oscilloscope traces of the phase portrait and time series showing the periodic and chaotic attractors for Colpitt when R = 32.5Ω and R = 36Ω, and for Sprott when R = 71.5kΩ and R = 61.9kΩ. The system parameter a and resistance value R are related as follows, $a = \frac{10k\Omega}{R}$. To further confirm the experimental results obtained using the micro-controller based programming we implement the system using Multsim electronic simulation software (see figures 18 – 19). The system models differential equations were integrated using Op-amp 741; this op-amp was also used for inverting input signals. It was observed that the results are in conformity with each other. Notice that experiments results reproduces the exact behavioral structures obtained from numerical simulations as shown in Figs. 1 - 8, respectively.

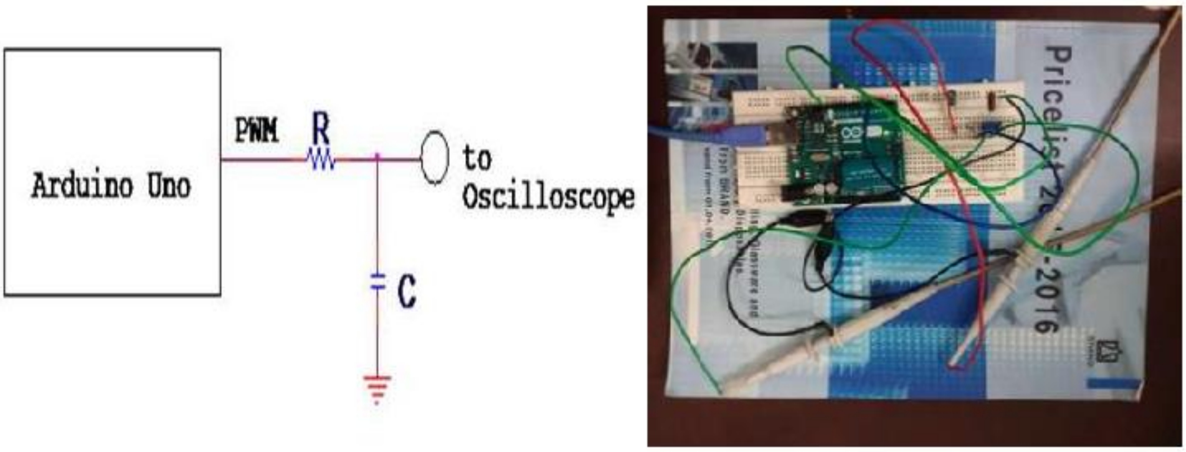

Figure 9: Schematic diagram for experimental implementation using Adruino UNO hardware (microcontroller),

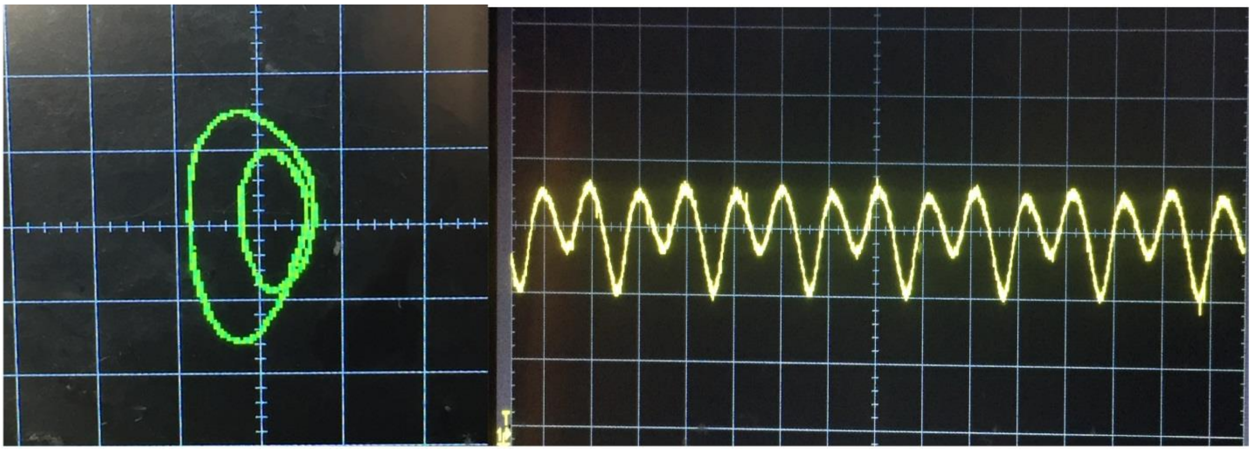

Figure 10: Experimental oscilloscope pictures of Sprott I oscillator: 2D projection of the periodic attractors for (x vs y) on the LHS and time series (RHS) for R2 = 71.5kΩ.

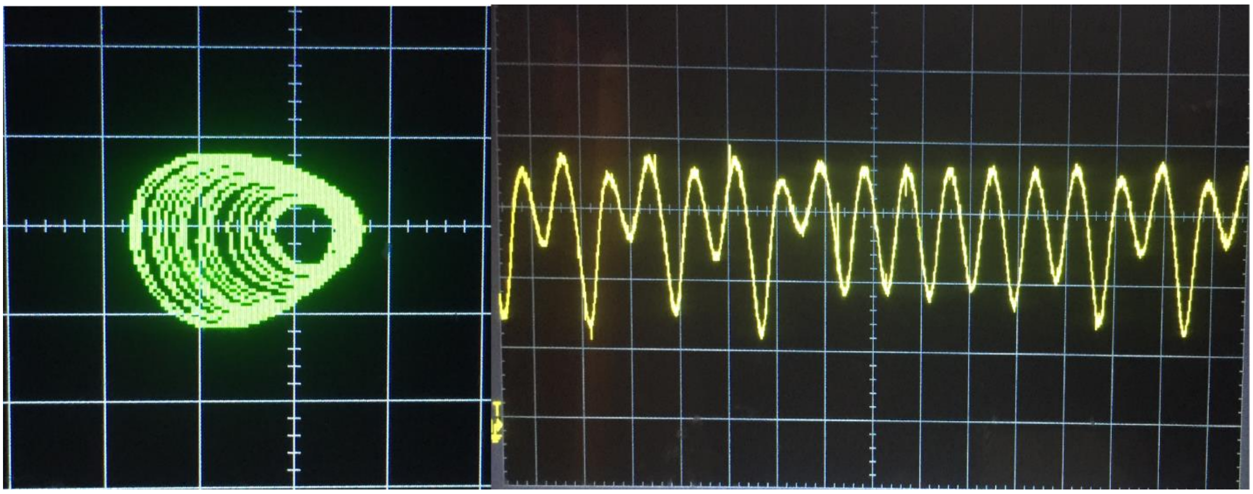

Figure 11: Experimental oscilloscope pictures of Sprott I oscillator: 2D projection of the chaotic attractors for (x vs y) on the LHS and time series (RHS) for R2 = 61.9kΩ.

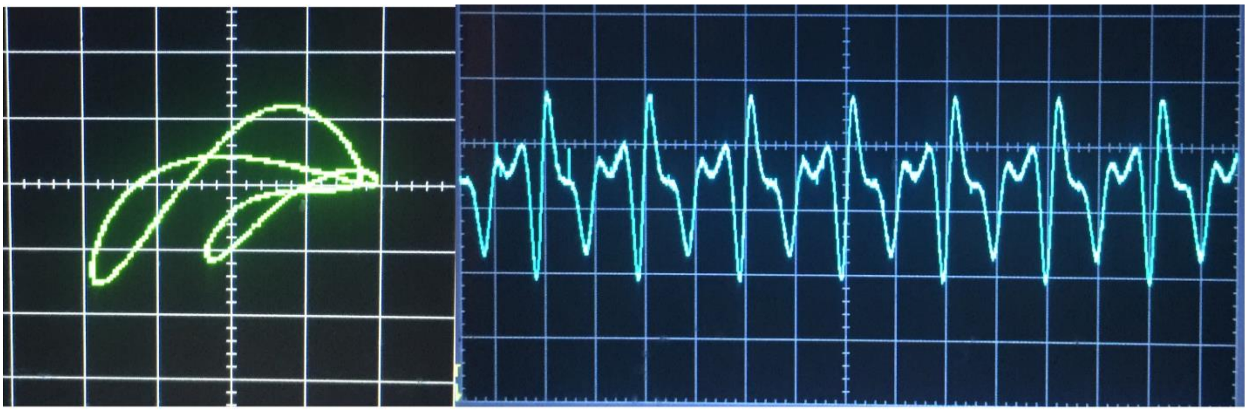

Figure 12: Experimental oscilloscope pictures of Sprott I oscillator: 2D projection of the periodic attractors for (x vs z) on the LHS and time series (RHS) for R2 = 71.5kΩ.

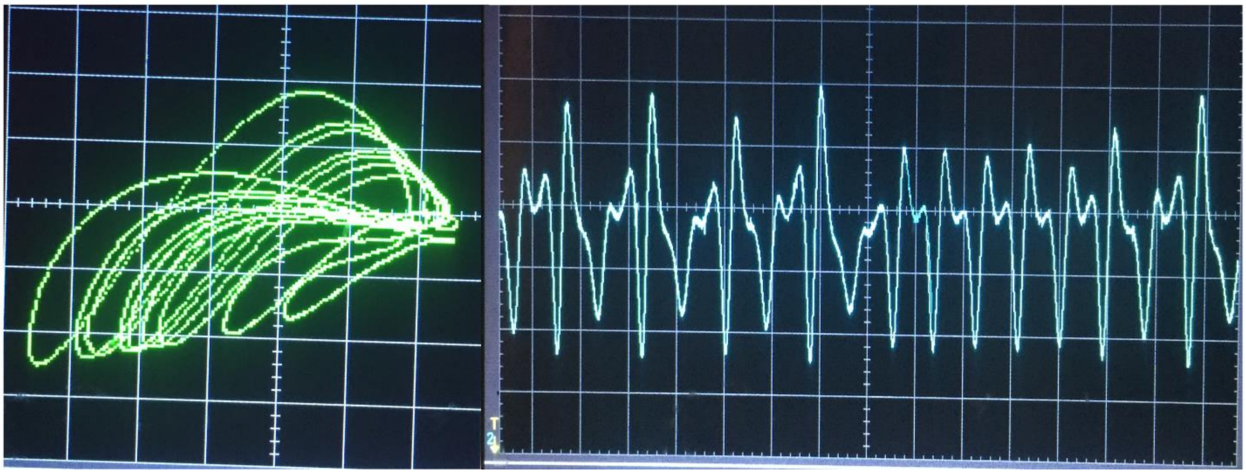

Figure 13: Experimental oscilloscope pictures of Sprott I oscillator: 2D projection of the chaotic attractors for (x vs z) on the LHS and time series (RHS) for R2 = 61.9kΩ.

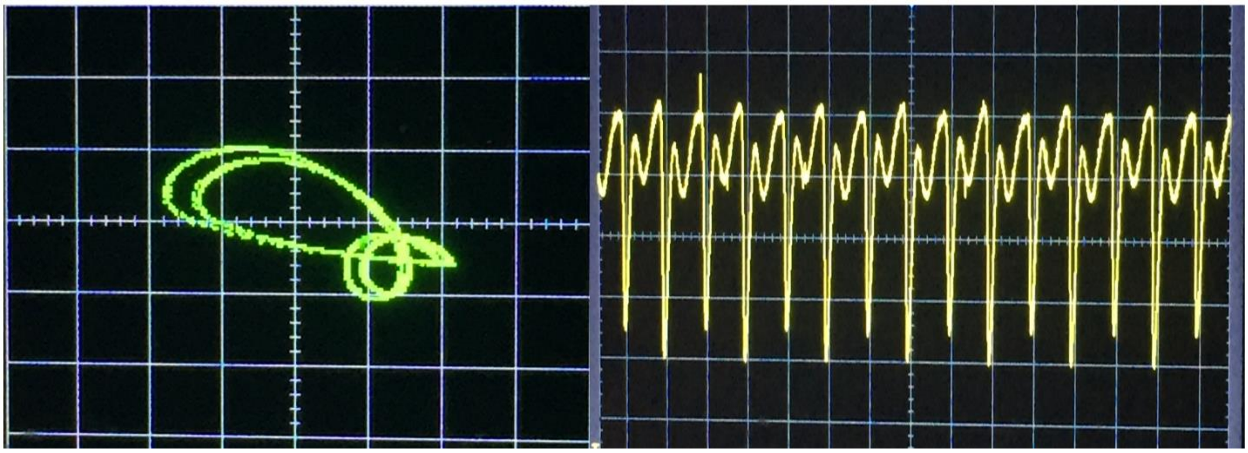

Figure 14: Experimental oscilloscope pictures of Colpitts oscillator: 2D projection of the periodic attractors for (x vs y) on the LHS and time series (RHS) for R = 32.5Ω.

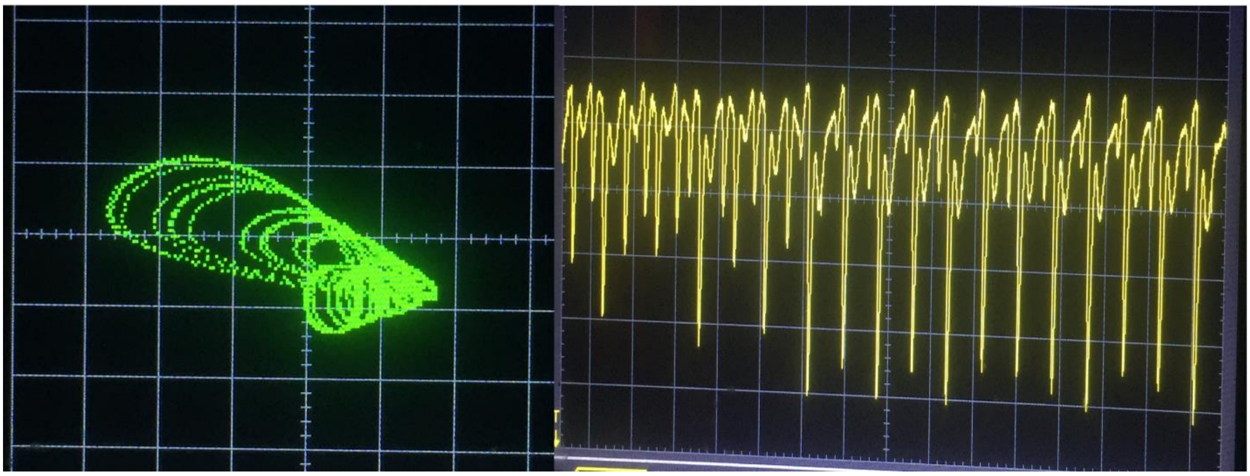

Figure 15: Experimental oscilloscope pictures of Colpitts oscillator: 2D projection of the chaotic attractors for (x vs y) on the LHS and time series (RHS) for R1 = 36Ω.

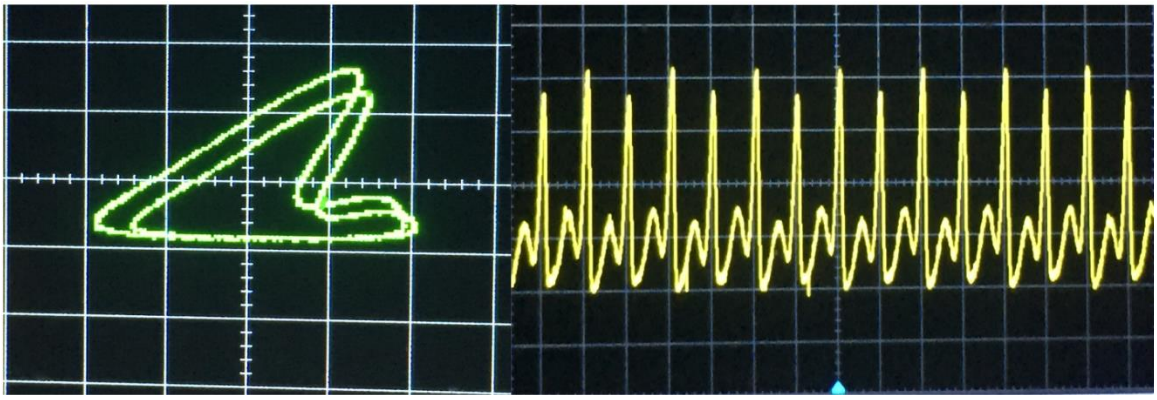

Figure 16: Experimental oscilloscope pictures of Colpitts oscillator: 2D projection of the periodic attractors for (x vs z) on the LHS and time series (RHS) for R = 32.5kΩ

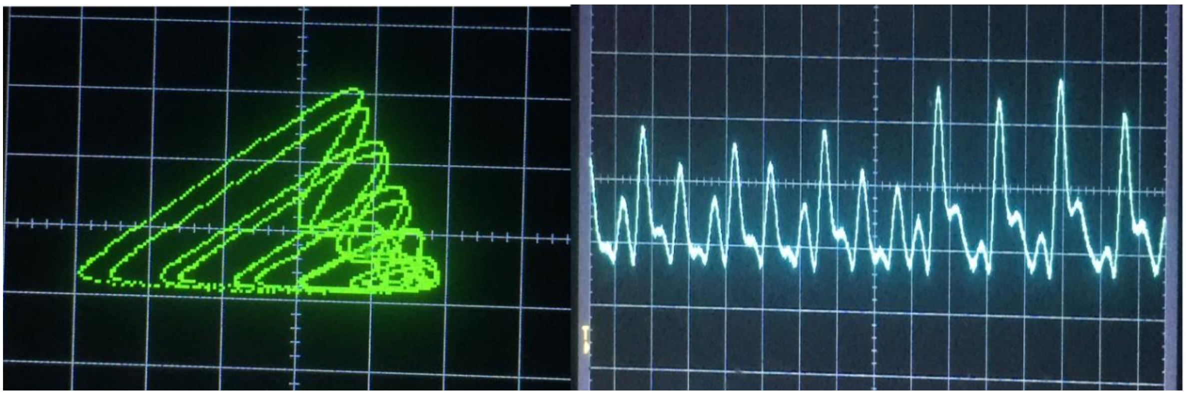

Figure 17: Experimental oscilloscope pictures of Colpitts oscillator: 2D projection of the chaotic attractors for (x vs z) on the LHS and time series (RHS) for R1 = 36Ω.

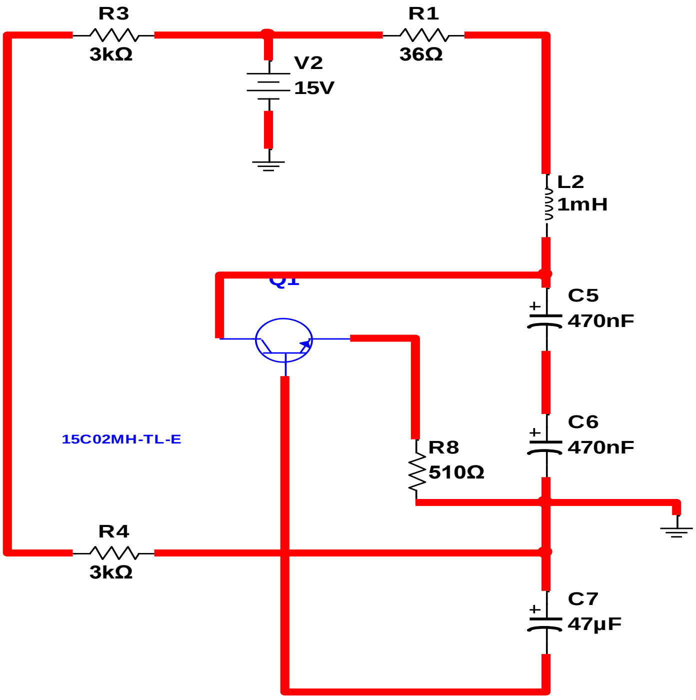

Figure 18: Colpitts system circuit designed with resistors R1, R3, R4 & R8, inductor L2, transistor Q1 and capacitors C5 – C7 were used to design the circuit.

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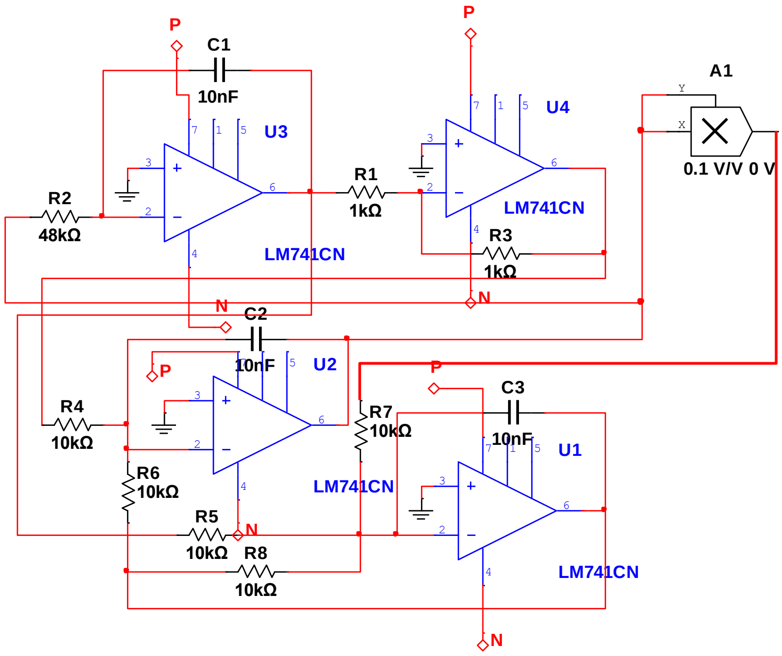

Figure 19: Sprott I system circuit designed with linear integrators U1 – U4, multiplier AD633 – A1, resistors R1-R8, and capacitors C1 – C3 were used to design the circuit.

IV. CONCLUSION

The results of dynamic transition using numerical simulation and practical implementation using off-the-shelve components on breadboard and Arduino are presented. We design the analog simulator of the oscillators using electronic components: resistors, capacitors, operational amplifiers, multiplier, transistor, power supply etc. The control parameters were varied to study the transition dynamics of Sprott and Colpitts systems. First, we employ the MATLAB numerical software simulator followed by the multiSIM 14.0 software to design the systems circuits for experimental implementation and engage the control parameter on different variables and lastly we implemented the systems using off-the-shelve components. The systems show transition phenomenon as the parameters were varied and the experimental results agreed with the results obtained in numerical simulations.

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