CHAOS TEORY AND APPLICATIONS
Volume 01, Number 1, Pages 29–37

A MULTISCROLL CHAOTIC ATTRACTOR AND ITS ELECTRONIC CIRCUIT IMPLEMENTATION

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Abstract. Chaotic systems and signals are used in a variety of technical and technical applications due to their wide range of noise-like performance and random behavior. In this study to diversify potential chaotic signal generator circuits; Lu-Chen 2003 system with multi-scroll attractors was first designed an electronic oscillator circuit in a computer environment and then a real electronic circuit was manufactured. The presented results of the comparison simulation and the oscilloscope show that a successful design has been achieved.

Keywords: Chaos, Multiscroll chaotic systems, Circuit Design

1. Introduction

Chaotic systems are hypersensitive to initial conditions, non-periodic, noise-like broadband systems. Therefore, they help to understand many systems that are considered random. There are many nonlinear structures in the universe. Novadays, the importance of chaotic structures is increasing.

The science of chaos began to develop in 1963 with the leading of Edward Lorenz[1]. Then, a rapid progress is made with researchers such as Rssler and Chua [2, 3]. It continues to develop in a wide range of fields such as physics and mathematics. The science of chaos has been and is used in many researches, from weather forecasting to the spread of cigarette smoke in the air, population science, and the survival of single-celled organisms.

An electronically chaotic system can be obtained via implementing circuits that provide the corresponding dynamic equations. The first simple electronic circuit related to the chaos event was Chua [4]. The developed circuit was later used in many areas as a chaos generator. There are many electronic circuit applications which have been developed that exhibit chaotic behavior, such as simple RLC, RC circuits [5, 6, 7, 8], oscillators [9], power circuits [10, 11], digital filters [12, 13, 14] and capacitor circuits. In recent years, new chaotic systems have been incorporated into the literature, implemented in different fields with different circuits [15, 16].

In this study, next section details the chaotic Lu-Chen system with the implementation of the electronic circuit for the introduced chaotic system and the scale operation. The third chapter discusses the analysis of the modelling of the electronic circuit design of a chaotic system. In the fourth chapter, the OrCAD-PSpice simulation results of the chaotic system with circuit model and oscilloscope outputs of the real-world environment circuit application are presented. The last section provides results and draw futurework.

2. Lu-Chen Chaotic System and Scale Process

The system of nonlinear equations in equation (2.1), introduced by Jinhu Lu and Guanrong Chen in [27], is known as the chaotic Lu-Chen system in 2003.

$$\begin{aligned} \dot{x} &= a.x + d_1.y.z \\ \dot{y} &= b.y + d_2.x.z \\ \dot{z} &= c.z + d_3.x.y \end{aligned} \tag{2.1}$$

Typical parameter and initial condition values of the chaotic system are as follows:

$$d_1 = -1, d_2 = 1, d_3 = 1, a = 5, b = -10, c = -3.4, x_0 = -3, y_0 = 0, z_0 = 3$$

The time series (for x,y and z) of complex multiscroll attractors obtained in the MATLAB using typical parameter and initial conditions are shown in Figure 1. Also, the phase portraits are given in Figure 2 for x-y, x-z, y-z and x-y-z planes.

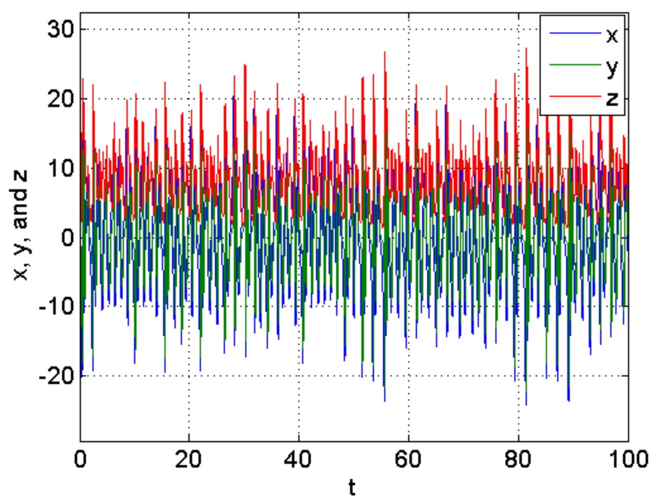
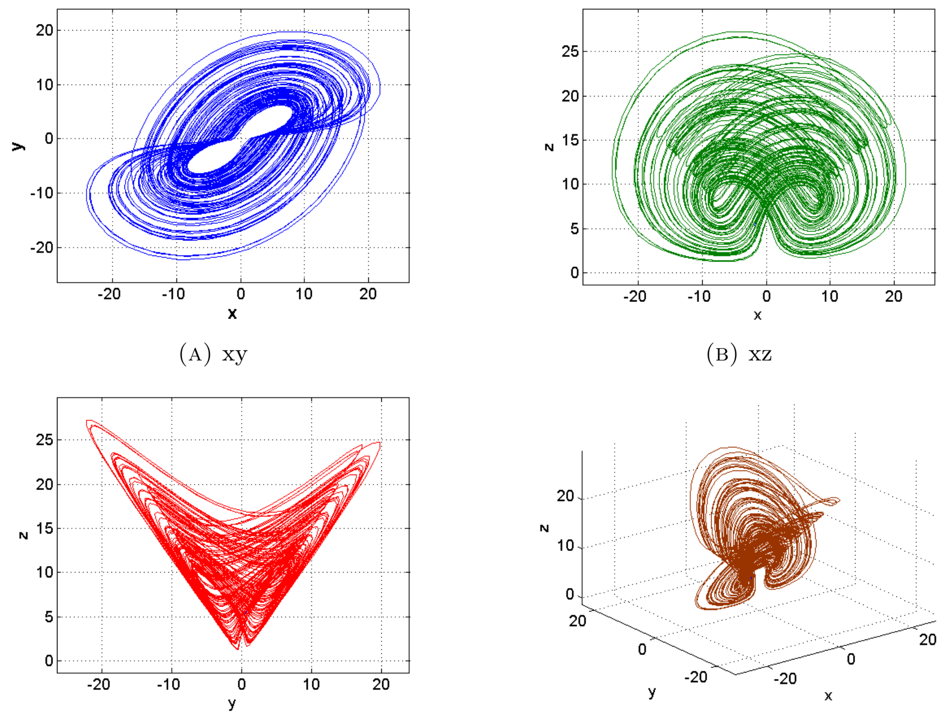


Figure 1. Time series of the Lu-Chen system for x, y and z.



(A) xy (B) xz

(C) yz (D) xyz

Figure 2. (A) x-y, (B) x-z, (C) y-z, (D) x-y-z chaotic attractors of the Lu-Chen system.

Since the dynamic limits of the Lu-Chen system exceed the limits of the power supply, the variables x, y, z should be scaled for electronic circuit implementation and other real time applications. Similar to Pehlivan's scale method [28], it was defined as a new variable of the system. The last scaled equations obtained are shown in equation (2.2).

$$\begin{aligned} \dot{x} &= a.x + 5.d_1.y.z \\ \dot{y} &= b.y + 5.d_2.x.z \\ \dot{z} &= c.z + 5.d_3.x.y \end{aligned} \tag{2.2}$$

The time series (for x,y and z) of scaled multiscroll attractors obtained in the MATLAB using typical parameter and initial conditions are shown in Figure 3. Also, the phase portraits are given in Figure 4 for x-y, x-z, y-z and x-y-z planes.

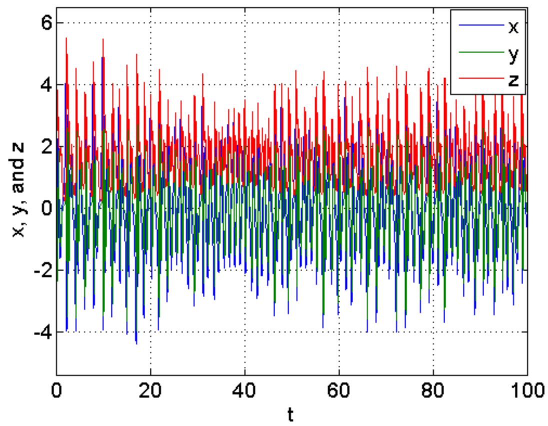
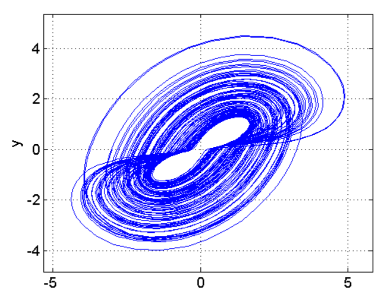
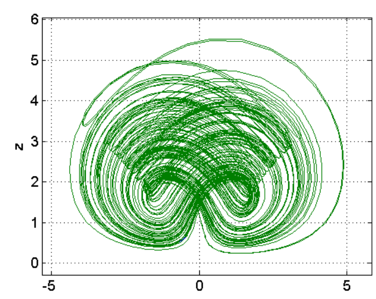


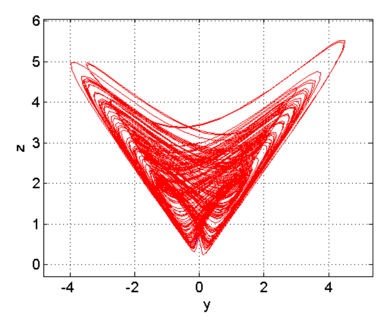
FIGURE 3. Time series of the scaled Lu-Chen system for x, y and z.



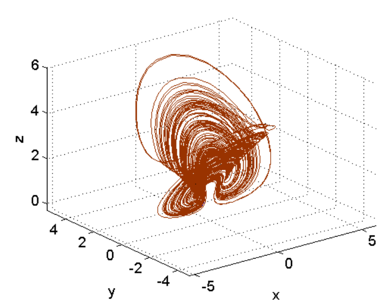
(A) xy



(B) xz



(C) yz



(D) xyz

FIGURE 4. (A) x-y, (B) x-z, (C) y-z, (D) x-y-z chaotic attractors of the scaled Lu-Chen system.

3. Circuit Design

The electronic circuit of the designed chaotic system Lu-Chen is detailed in Figure 5. For example, consider the equation z for calculating the circuit resistors. Taking into account $c = -3,4$ and $C3 = 1nF$ in the circuit, $R7 = 117.64K$. Since d3 is equal to 1 for the resistor R3 and the signals applied to the integrated AD633 multiplier, inputs are multiplied and then the result divided by 10, R8 is calculated as $8K$. If these resistance and capacitor values are calculated like others;

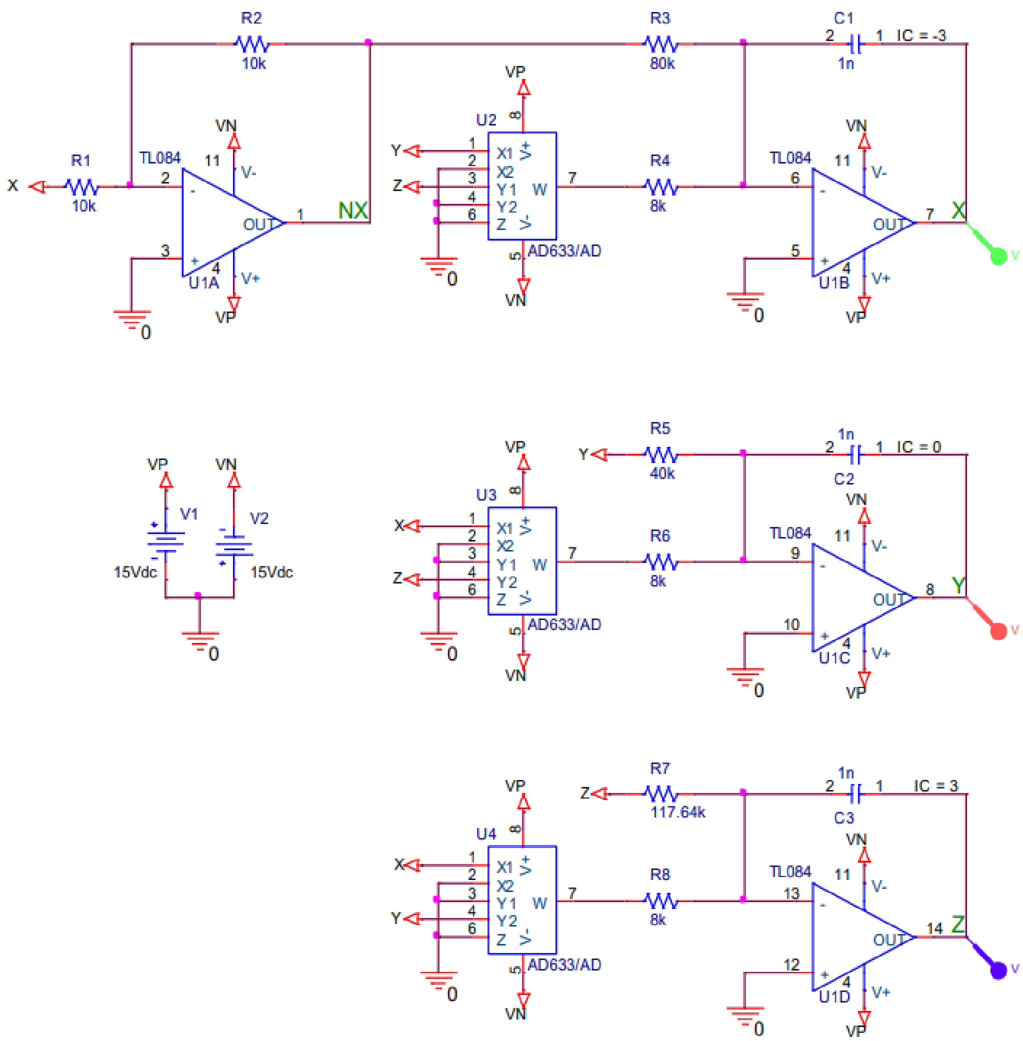


Figure 5. Schematic of the designed electronic oscillator of the Lu - Chen system

4. Lu - Chen Oscillator Pspice Simulation and Real World Application

4.1. **OrCAD-PSpice Simulation.** In this section, the PSpice simulation results of the modeled Lu-Chen chaotic oscillator and oscilloscope outputs of the real-world circuit are given. The electronic circuit of the chaotic Lu-Chen system, shown in Figure 5, was simulated for in the PSpice program. The signals of the x,y and z outputs as a result of the simulation and the phase portraits obtained for x-y, x-z and y-z outputs are shown in Figures 6.

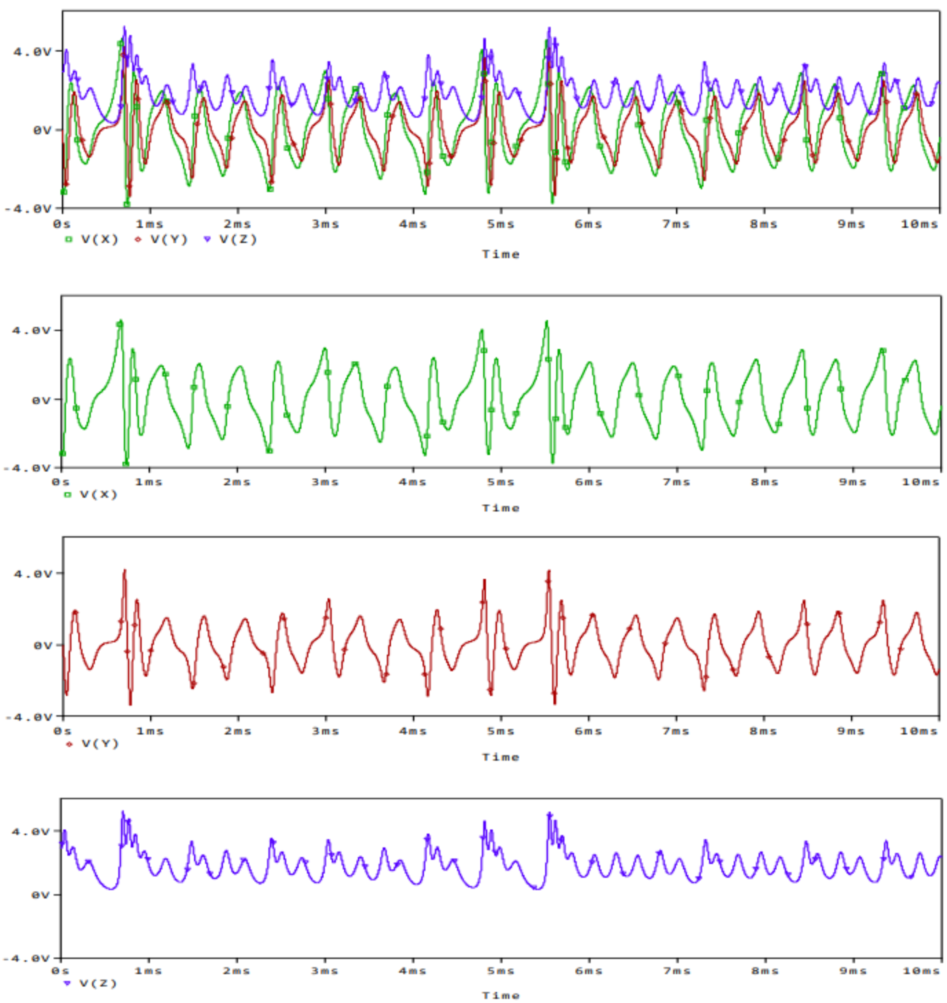


Figure 6. x-y-z signals from the PSpice simulation of the Lu-Chen oscillator

4.2. **Real World Application.** After the simulation of the electronic circuit of the modeled Lu - Chen - oscillator in Figure 5 in the OrCAD - PSpice program, the real electronic circuit was created. The results of the x-y, x-z, and y-z phase portraits obtained on the oscilloscope screen as a result of the application in the real environment are shown in Figures 7 to 9.

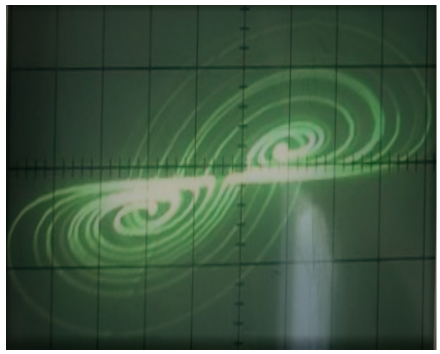


FIGURE 7. x-y phase portrait: CH1(X) Volts/Div: 1V, CH2(Y) Volts/Div: 2V

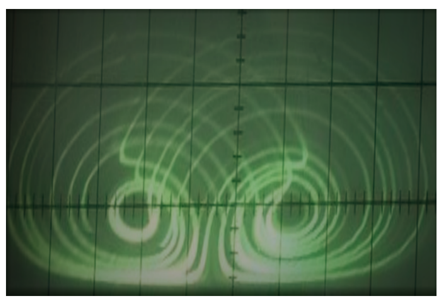


FIGURE 8. x-z phase portrait: CH1(X) Volts/Div: 1V, CH2(Z) Volts/Div: 2V

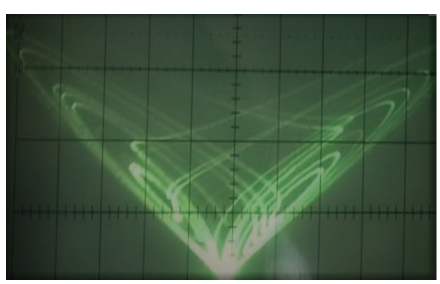


FIGURE 9. y-z phase portrait: CH1(Y) Volts/Div: 0.5V, CH2(Z) Volts/Div: 1V

5. Conclusion

Scientists, engineers and researchers in the fields of physics, mathematics, electrics and electronics may need to model these equations and build electronic circuits to create new chaotic systems with complex and different dynamic behaviours. The physical realization of electronic circuits of some chaotic systems can be relatively difficult and complex. For example, in electronic circuit simulations of chaotic systems output amplitude values are not a problem, but in real circuit applications, the values that the state variables can assume should the supply voltage values of the operational amplifier or similar operating element (e.g. +15 V, -15 V).

In this study, a multiscroll chaotic Lu-Chen system was scaled to be an example of systems that require scale surgery with differential equations. The comparative simulation and oscilloscope outputs of the chaotic multiscroll-scaled Lu-Chen system show that a successful scale operation and an electronic circuit design were performed.

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