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Research Article

An implementation of chaotic circuits with Multisim-LabVIEW

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ABSTRACT

In last decades, chaos phenomenon and chaotic systems are defined as a nonlinear behavior have received a plenty of attention. In many areas, a chaotic system is used due to chaotic signals depend very sensitively on initial conditions, have unpredictable features and noise like wideband spread spectrum. In literature as well as the basic chaotic systems, there are many hybrid chaotic systems. In this paper, Sprott case A chaotic system is formed by using OP-AMPS and other appropriate circuit components on Multisim environment. This model is being constructed for each chaotic system, so the results of mathematical simulations of these chaotic differential equations can be seen. Convenient chaotic behavior is observed, circuit simulation is conducted via co-simulation between Multisim and LabVIEW. The simulation results show similar behavior when it is compared with the theoretical chaotic system.

1. Introduction

Chaos word, which is the subject of academic studies, can be defined as the arrangements in non-linearity of non-linear systems. Chaotic systems can be described as systems that are very sensitive to initial conditions, exhibit non-periodic behaviors, and have complexity which cannot be measured. In addition to sensitivity to initial conditions, chaotic systems have a broadband noise-like and periodic structure

The term chaos was first used by Henri Poincaré during the dissolution of three-body problem raised in 1889. [1] Ed Lorenz who is an American mathematician and meteorologists expressed chaotic behaviour with differential equations for the first time [2]. In practice, the first real physical dynamic system similar to the Lorenz system was created by Chua [3]. The Chua's circuit is a simple autonomous third level circuit that exhibits dynamic behavior. Following these studies, scientists such as Chen, Rössler, Sprott, Van Der Pol, Rucklidge, Lü formed their own chaotic systems [4-9]. After these studies, many chaotic novels and hyper-chaotic systems which display different dynamical behaviours have took place in literature [10-16].

Chaos theory and chaotic systems have attracted the interest of academic community in the fields of theoretical research and practical application. It has been used in applications ranging from weather prediction to computer science, economics, geology, robotics, physics etc. [17]. Chaotic systems have many applications. Examples of application areas of chaotic systems in daily life include oscillation control of chemical reactions, measurement of heart rhythm, examination of brain waves, biomedical and medical applications, secure communication using chaotic signals, internet banking, increase of laser power, power electronics, image compression and transmission, turbulence controversy, chaotic masking, weather forecasts, chaotic modulation, pattern recognition, random number generators, population projection studies, polymer production, protein production of bacterial colonies, etc [18].

In this study, Sprott case A, case B and case C chaotic system is created with using OP-AMPS and appropriate circuit opponents in Multisim environment. Then the systems are designed with LabVIEW control&simulation toolbox. Chaotic behaviour is observed and real-time circuit simulation is conducted via Multisim-LabVIEW platform simulation. The results are compared with theoretical Sprott system and observed similar behaviour.

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2. Method

2.1 Sprott Chaotic System

J.C Sprott, introduced nineteen simple systems with a few terms which show similar dynamical behaviour to the traditional Lorenz, Rossler and Chua systems [19-20]. Among these systems, while equations A to E have 5 terms in total, F-S equations have 6 terms.

$$\dot{X} = a + \sum_{i=1}^{3} b_i + X_i + \sum_{i=1}^{3}\sum_{j=1}^{3} c_{ij} X_i X_j \tag{1}$$

Sprott accepted that the second-order nonlinear three-dimensional ordinary differential equations are in the form given in (1). Here, X = (x, y, z) is the real three-dimensional state variables, and a, b, and c are real three-dimensional coefficients.

A	B	C	D	E	F
$\dot{x}=y$	$\dot{x}=yz$	$\dot{x}=yz$	$\dot{x}=-y$	$\dot{x}=yz$	$\dot{x}=y+z$
$\dot{y}=-x+yz$	$\dot{y}=x-y$	$\dot{y}=x-y$	$\dot{y}=x+z$	$\dot{y}=x^2-y$	$\dot{y}=-x+0.5y$
$\dot{z}=1-y^2$	$\dot{z}=1-xy$	$\dot{z}=1-x^2$	$\dot{z}=xz+3y^2$	$\dot{z}=1-4x$	$\dot{z}=x^2-z$
G	**H**	**I**	**J**	**K**	**L**
$\dot{x}=0.4x+z$	$\dot{x}=-y+z^2$	$\dot{x}=-0.2y$	$\dot{x}=2z$	$\dot{x}=xy-z$	$\dot{x}=y+3.9z$
$\dot{y}=xz-y$	$\dot{y}=x+0.5y$	$\dot{y}=x+z$	$\dot{y}=-2y+z$	$\dot{y}=x-y$	$\dot{y}=0.9x^2-y$
$\dot{z}=-x+y$	$\dot{z}=x-z$	$\dot{z}=x+y^2-z$	$\dot{z}=-x+y+y^2$	$\dot{z}=x+0.3z$	$\dot{z}=1-x$
M	**N**	**O**	**P**	**Q**	
$\dot{x}=-z$	$\dot{x}=-2y$	$\dot{x}=y$	$\dot{x}=2.7y+z$	$\dot{x}=-z$	
$\dot{y}=-x^2-y$	$\dot{y}=x+z^2$	$\dot{y}=x-z$	$\dot{y}=-x+y^2$	$\dot{y}=x-y$	
$\dot{z}=1.7+1.7x+y$	$\dot{z}=1+y-2z$	$\dot{z}=x+xz+2.7y$	$\dot{z}=x+y$	$\dot{z}=3.1x+y^2+0.5z$	
R	**S**				
$\dot{x}=0.9-y$	$\dot{x}=-x-4y$				
$\dot{y}=0.4+z$	$\dot{y}=x+z^2$				
$\dot{z}=xy-z$	$\dot{z}=1+x$				

Figure 1. Sprott System Equations[21]

Chaotic results are obtained when X_0=0.05, Y_0=0.05, Z_0=0.05 are taken as the initial condition for the equations except for the equation A. The initial conditions for the case A are X_0=0, Y_0=0.5, Z_0=0 .If the Sprott chaotic system is examined, it appears that there are separate attractors for each equation case. Change of state variables over time and chaotic attractors for Sprott A, and B systems are shown in Fig.2, 3, 4, 5 [21].

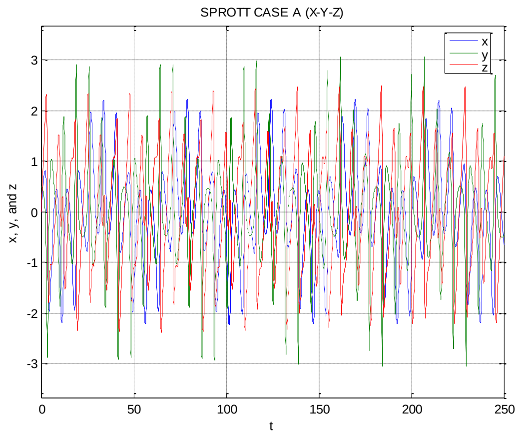

Figure 2. Sprott Case A(nose-hoover system)

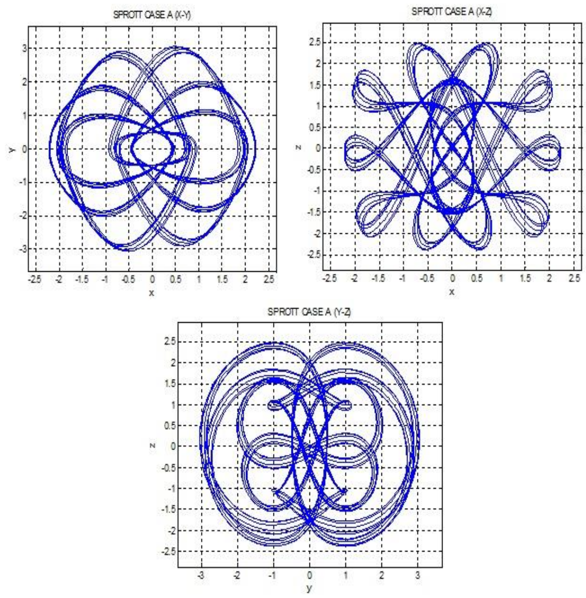

Figure 3. Sprott Case A Chaotic Attractors

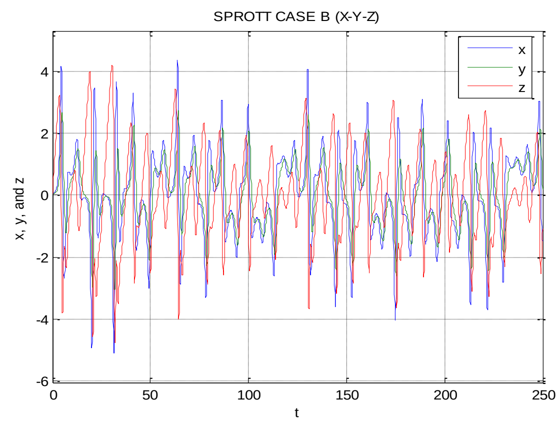

Figure 4. Sprott Case B

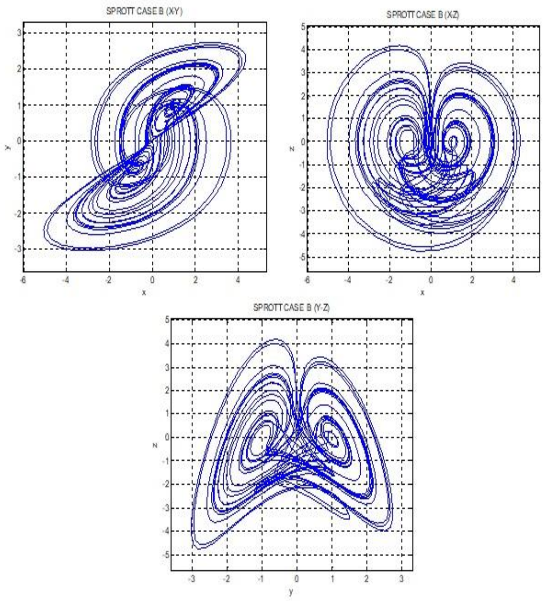

Figure 5. Sprott Case B Chaotic Attrattors

2.2 *Circuit Simulation*

The chaotic circuit for the Sprott case A system established in the Multisim program using functional elements to provide chaotic system's simulation. Sprott case B and case C chaotic systems simulated using via Labview. Initial parameters for all chaotic systems except case A , X_0, Y_0, Z_0 parameters were taken 0,05, 0.05, 0,05.The initial conditions of the case A taken as 0, 0.05, 0 [22]. It is expected that the simulation circuit which established in the Multisim and Labview environment will be similar to the theoretical system outputs. Case A, B, C chaotic system equations are given in equations (2-4).

<u>Sprott Case A:</u>

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

<u>Sprott Case B:</u>

$$\dot{x} = yz$$
$$\dot{y} = x - y \qquad (3)$$
$$\dot{z} = 1 - xy$$

<u>Sprott Case C:</u>

$$\dot{x} = yz$$
$$\dot{y} = x - y \qquad (4)$$
$$\dot{z} = 1 - x^2$$

Sprott case A chaotic system is established with using simple OP-AMP's and other appropriate components. Then system is designed with using Multisim program. Fig 6 shows Multisim design of Sprott model.

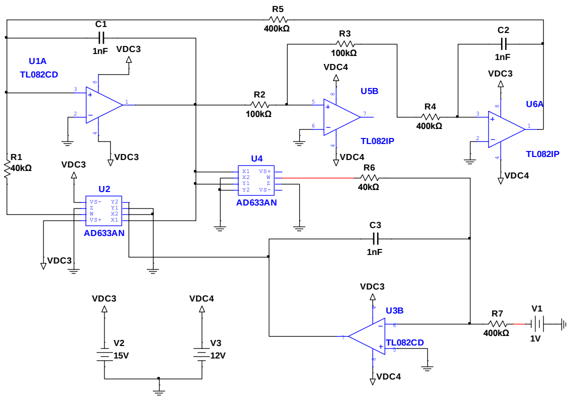

Figure 6. Multisim Design of Sprott Model

Fig. 7 and fig. 8 illustrate Sprott Case A and C chaotic models of LabVIEW. LabVIEW is a graphics-based software platform. The usage of program is increasing in engineering applications day by day[23-24]. It ensures a visual platform for the development of algorithms.

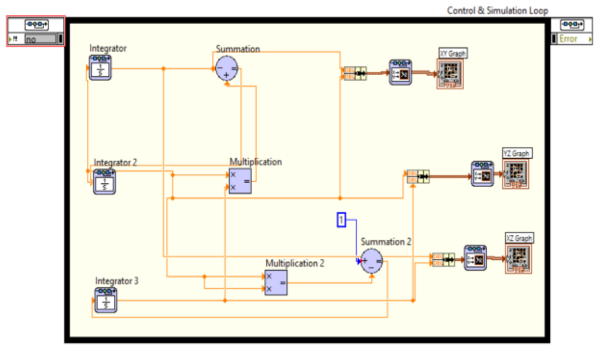

Figure 7. LabVIEW Design of Sprott Case A Chaotic Attractors

The operations required to model differential equations can be summarized by adding, multiplying, multiplying by a fixed number, analog multiplication, taking an integral, taking a derivative etc. The generated block diagrams can be modeled and simulated with electronic circuit programs using analog operational elements.

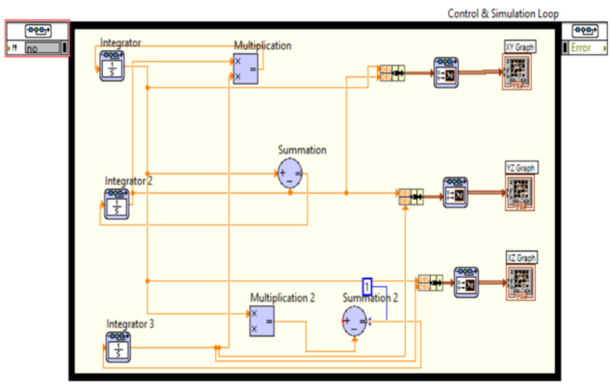

Figure 8. LabVIEW Design of Sprott Case C Chaotic Attractors

The same simulation results can also be obtained by establishing the actual electrical circuit of the systems which has also the digital modeling and simulation.

Models are created using control& simulation toolbox in LabVIEW. Sprott model's differential equations are given before section. Their LabVIEW designs are showed.

3. Results

Sprott Systems using functional elements, chaotic for state A circuits are installed in the Multisim program to provide chaotic circuit implementations. The systems are designed with the system parameters which is in the literature. For case A, initial conditions taken as $X_0 = 0$, $Y_0 = 0.5$, $Z_0 = 0$. Fig. 9 shows Sprott Case A chaotic attractors x-y, y-z and x-z phase.

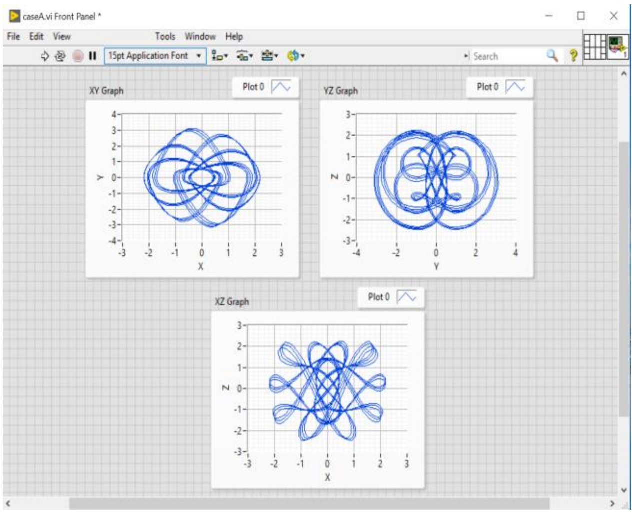

Figure 9. LabVIEW Design of Sprott Case A Chaotic Attractors

The second Sprott model Case B is also designed in the LabVIEW program to provide its chaotic behaviour. The system parameters are used as in literature. For B condition is taken as X0 = 0.05, Y0 = 0.05, Z0 = 0.05. Fig. 10 shows Sprott Case B chaotic attractor results in x-y, y-z and x-z phase.

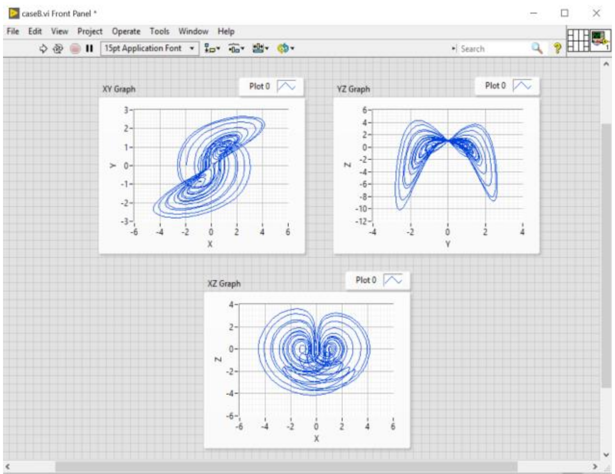

Figure 10. LabVIEW Design of Sprott Case B Chaotic Attractors

The other chaotic model is C. For C condition initial parameters are taken as $X_0 = 0.05$, $Y_0 = 0.05$, $Z_0 = 0.05$. Fig. 11 shows Sprott Case C chaotic attractors results x-y, y-z and x-z phase.

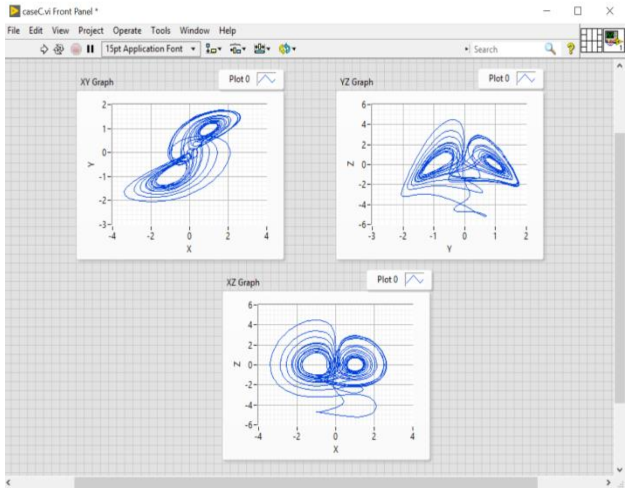

Figure 11. Sprott Case C Chaotic Attractors

Sprott chaotic system's 3D phase portrait for case A is also shown in fig. 12.

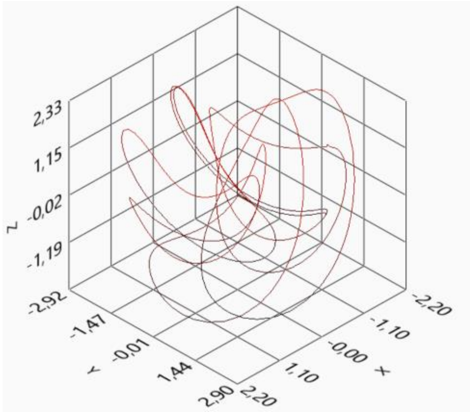

Figure 12. Sprott Chaotic Systems 3D Phase Portrait

4. Conclusion

Research on engineering related to nonlinear dynamics and chaos is generally theoretical and simulation based, and experimental studies include a single circuit model whose results are reported in the literature. In this study Sprott case A, B and C chaotic models designed with using Multisim circuit program and LabVIEW control& simulation toolbox. As a result, the simulation results of the digital model with block diagrams and electronic circuit programs and the results of the oscilloscope output of the actual electronic circuit can be the same.

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