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# Circuit simulation on control and synchronization of fractional order switching chaotic system

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**Abstract**

In view of obtaining a larger key space and thus improve the level of security attainable in chaotic communication, this paper examines the dynamics of a switched, fractional-order chaotic system. Taking the fractional-order Chen system as a starting point, the dynamics of a modified version of that system is examined, and the composed system is hereafter realized by allowing switching between the two different subsystems. Our work first demonstrates how fractional-order chaotic systems can be realized physically. For the fractional-order switching chaotic system, a linear feedback controller and a number of synchronization schemes are designed. Our simulations show that control and synchronization of the individual subsystems can be achieved with the same feedback and synchronization controller.


*Keywords:* Fractional order; Switching chaotic system; Control and synchronization; Circuit simulation

## 1. Introduction

Application of chaotic oscillations in connection with secure communication has attracted significant interest since Pecora and Carroll [17] suggested the possibility of chaos synchronization. Wu and Chua [25] established a unified framework for the control and synchronization of nonlinear dynamic systems, Rulkov [21] presented experimental results with chaos synchronization in electronic systems, and Kolumban et al. [13] discussed the role of synchronization in digital communication. Alexander et al. [2] described the unusual forms that the basin of attraction for a synchronized chaotic state can attain, and Heagy et al. [8] established the necessary and sufficient conditions for the stability of a synchronized state for identical chaotic oscillators.

In the subsequent years, fractional-order chaotic models started to attract significant interest in a variety of different fields. Jia et al. [12], for instance, developed a circuit implementation of the fractional-order Lorenz system. Wang and He [24] demonstrated the so-called projective synchronization of fractional-order chaotic systems based on linear

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separation. Wu et al. [26] discussed chaos and chaos synchronization in a unified fractional-order system. Compared with integer order models, fractional-order models can better reflect the behavior of systems that display different forms of complex dynamics. In particular, fractional-order chaotic systems have a larger so-called key space and may thus provide additional safety to applications of secure communication.

Switching processes play an important role in many situations [15]. A significant number of biological and social systems display different modes of operation depending on the external conditions. Examples are the characteristic changes in the electrical activity of the brain between different phases of sleep and the change in the rhythm of the heartbeat that a person experiences between sleep and awakeness. Due to their simplicity in design and small parameter drift, switching control is extensively used in technical control systems. Well-known examples are heaters, refrigerators, systems for water level control, and different forms of power electronic converter systems [20]: it is also known that various forms of complex nonlinear dynamic phenomena may arise in switching systems [30].

In the present paper our interest in switching systems derives from the fact that switching chaotic systems may display better pseudo-random behavior and more complicated forms of dynamics in general than individual chaotic systems. Switched chaotic systems may, therefore, effectively enhance the safety performance of secure communication systems, and exploitation of this possibility has already attracted considerable attention [3,5,6,22]. Hespanha [9] has studied the uniform stability of switched linear systems in order to extend LaSalle's invariance principle. Sun and Ge [23] have studied the analysis and synthesis of switched linear control systems. Yu et al. [27] generated grid multiwing chaotic attractors by constructing heteroclinic loops into switching systems. Appropriate control strategies for particular switching systems have been suggested by Fan et al. [7]. Liu et al. [16] studied a four-dimensional, hyperchaotic switching system, and Zhou et al. [29] studied correlation of chaotic systems and their synchronization. Kousaka et al. [14] researched the bifurcation of switched nonlinear dynamic systems. But these researches mainly focused on the integer order chaotic system. Radwan et al. [19] reported on the fractional order chaotic system. In view of obtaining a larger key space and thus improve the level of security attainable in chaotic communication, this paper examines the dynamics of a switched, fractional-order chaotic system. Taking the fractional-order Chen system as a starting point, the dynamics of a modified version of that system is examined, and the composed system is hereafter realized by allowing switching between the two different subsystems. Our work first demonstrates how fractional-order chaotic systems can be realized physically. For the fractional-order switching chaotic system, a linear feedback controller and a number of synchronization schemes are designed. Our simulations show that control and synchronization of the individual subsystems can be achieved with the same feedback and synchronization controller.

This paper is organized as follows. After this introduction, we give in Section 2 the dynamics of a switched, fractional-order chaotic Chen system and the dynamics of a modified version of that system is examined. In Section 3, we deal with design and simulation of fractional order switching circuit. In Section 4, we design a linear feedback controller for fractional order switching chaotic system. In Section 5, we achieve a number of synchronization schemes of the individual subsystems with the same feedback and synchronization controller. Conclusion is given in the last section.

## 2. Principle

The dynamic equation of a fractional order Chen system can be expressed as

$$\begin{cases} \dfrac{d^q x}{dt^q} = a\,(y - x) \\ \dfrac{d^q y}{dt^q} = (c - a)\,x - xz + cy \\ \dfrac{d^q z}{dt^q} = xy - bz \end{cases} \tag{1}$$

where $a = 35$, $b = 3$, $c = 28$. The system given by Eq. (1) will be called the system 1.

Following Zhang and Yang [28], simulation is performed by means of a predictor–corrector method for $q = 0.9$. The chaotic behavior of the system 1 is shown in Fig. 1.