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Dynamical behavior and application in Josephson Junction coupled by memristor

Ge Zhang[a], Jun Ma[a,c,*], Ahmed Alsaedi[b], Bashir Ahmad[b], Faris Alzahrani[b]

[a] Department of Physics, Lanzhou University of Technology, Lanzhou 730050 China
[b] NAAM-Research Group, Department of Mathematics, Faculty of Science, King Abdulaziz University, Jeddah 21589, Saudi Arabia
[c] College of Electrical and Information Engineering, Lanzhou University of Technology, Lanzhou 730050, China

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ABSTRACT

The memristor has drawn a considerable interest when the nanoscale memristor is regarded as the critical element of novel ultra-high density and low-power non-volatile memories. The nonlinearity of electric circuit is enhanced and the dynamical behavior becomes more complex when memristor is used in circuits because it memductance is dependent on the inputs current. Josephson Junction (JJ) coupled resonator also present complex dynamical behaviors in nonlinear circuit because JJ is used as sensitive inductive component. The Josephson Junction circuit employing memristor is designed in this paper. Firstly, dynamical properties about this model are discussed by numerically calculating phase portraits, Lyapunov exponents and bifurcation diagram. It is found that appropriate parameters setting can induce distinct chaotic and periodical states by analyzing the output series. The dynamical response and potential mechanism for behavior selection is discussed. Interestingly, the chaos encryption based on Josephson junction circuit coupled by memristor is investigated as well.

1. Introduction

With the burst of a Wanna decryptor [1] in the middle of 2017, secure communication within a network [2] has again triggered the considerable attention. Meanwhile, many feasible methods have been proposed to enhance the data security and it is also involved with chaotic encryption, which is one of the important branch of the chaos theory. Come what may, it is necessary to investigate the dynamical system with chaotic features [3–8]. Therefore, these topics are related to the systems with hidden attractor, multi-scroll attractor, attractor without equilibrium points, and infinite equilibrium points [9–20], the main contribution of these topics could be associated with chaos. Interestingly, chaotic behaviors can also be generated in the system mapped from the nonlinear circuit composed of the Josephson Junction [21–23]. The effect of Josephson Junction in superconductors [24–26] has, since its discovery in the 1960s, been the focus of great interest both due to its implications for fundamental questions in physics and electronics, particularly, where it promised significant increase in device speed and sensitivity. The most of the distinct effect of Josephson Junction has been an attempt to develop Josephson Junctions as high-speed (picosecond) switches for digital applications [27]. The emphasis is now shifting to analog applications and devices [28], such as the voltage standard, squid magnetometers, millimeter, submillimeter mixers. It did focus on mathematical techniques for obtaining analytical results by using various models of the Josephson Junction [29].

* Corresponding author at: Department of Physics, Lanzhou University of Technology, Lanzhou 730050 China.
E-mail addresses: hyperchaos@163.com, hyperchaos@lut.cn (J. Ma).

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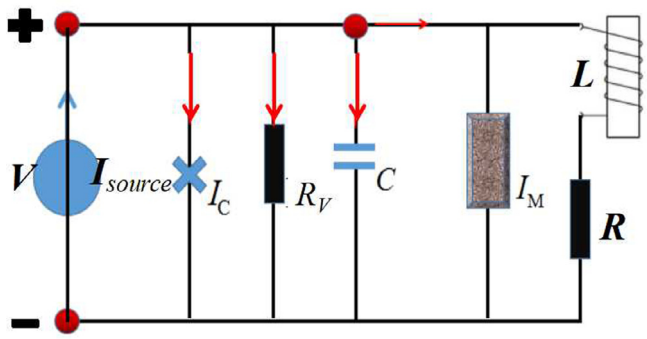

Fig. 1. The scheme diagram for memristor-coupled circuit.

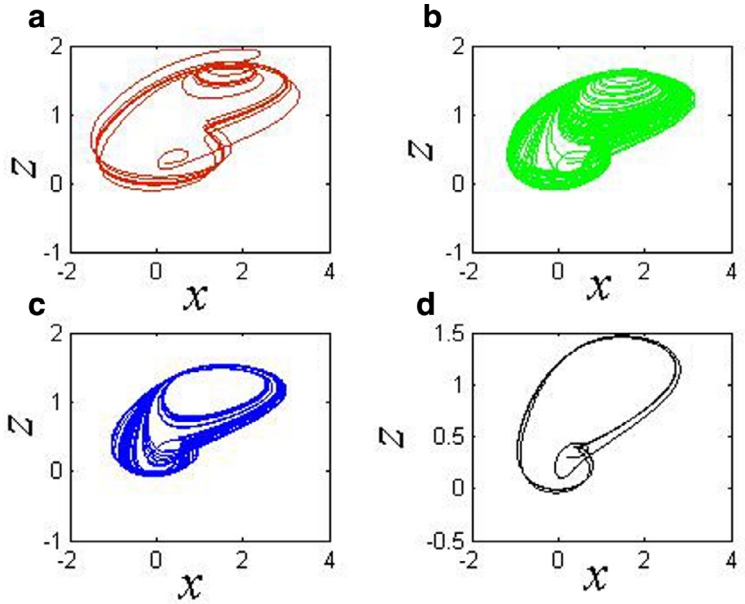

Fig. 2. Attractors are calculated by setting different gain k_0 at fixed parameters $k_1 = 0.1$, $k_2 = 0.2$, $\alpha = 0.2$, $\beta = 0.2$, for (a) $k_0 = -0.3$; (b)$k_0 = -0.1$; (c)$k_0 = 0.1$; (d)$k_0 = 0.3$.

This approach is nicely supplemented by graphs from computer simulations and circuit approach. The Josephson Junction consists of superconductors on both sides and in the middle of the insulator being supplied. Indeed, Cho [30] presented a review on the development prospect of the high-temperature superconductor in China. Furthermore, the superconductivity at different high-temperature in iron-based X-doped has been reported extensively [31]. As a result, the nonlinear electronic component associated with Josephson Junction formed from the kinds of superconductor can play important role in electric-switch application [32].

Another important nonlinear electronic component is memristor [33] that is proposed by Chua based on symmetry arguments [34]. Generally, the resistor, capacitor and inductor have been used to describe the inter-relation of current-voltage, voltage-charge and current-magnet flux, respectively. Using memristor component, however, is set up a connection between charge and magnet flux. Although this kind of memristor had been found and predicted in theory, it seemed to show no importance to the application in scientific and engineering domains. Researchers began to discern the significance of memristor until the realization of its nano-size electrical device had been reported at HP lab in 2008 [35]. The memristor, with the ability of memory and low-power feature, may make a distinct candidate for the artificial intelligence [36–38], regarded as the synapses [39] in the link with neurons and gliocyte or the electrical element component in the integrated circuit of chaos. In the neurodynamics, improved neuron model coupled by memristor can be built and the different modes of electrical activities can be detected to be consistent with biological experiments [40,41]. For example, Wu et al. [42] imposed phase noise on the improved neuron, and a time-varying electromagnetic field is induced to trigger different modes of electrical activities, and coherence resonance behavior can be observed. It is believed that memristor coupling can describe the effect of memory, and bridge the output voltage and magnetic flux by generating induction current. It could be very