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Chaos propagation in Ladder Chaotic Circuits by Switching Coupling Strength

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1. Introduction

Recently, chaos propagation has attracted much attention. In this study, chaos propagation is researched by switching the coupling strength based on the difference of the voltages of the neighboring circuits.

2. System Model

The chaotic circuit is shown in Fig. 1. The system model is shown in Fig. 2. In this system, the circuit in the one end of the system generates chaotic attractor and the other circuits generate three-periodic attractors. Ten chaotic circuits next to each other are coupled together with resistors.

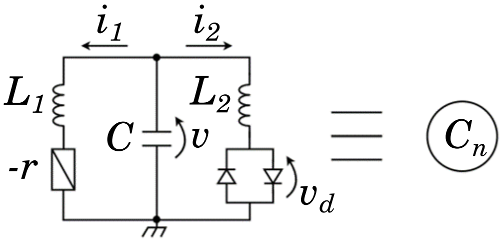

Figure 1: Circuit model.

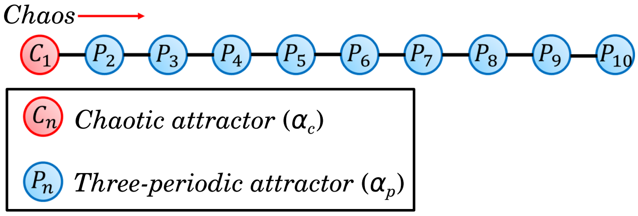

Figure 2: System model.

The normalized circuit equations are described as follows:

$$\begin{cases} \dot{x_n} = \alpha x_n - z_n \\ \dot{y_n} = z_n - f(y_n) \\ \dot{z_k} = -x_n - \beta y_n - \gamma_{n,n-1}(z_n - z_{n-1}) \\ \qquad - \gamma_{n,n+1}(z_n - z_{n+1}) \\ (n = 1, 2, \cdots, N) \end{cases} \tag{1}$$

where

$$\gamma_{1,0} = \gamma_{N,N+1} = 0$$

$$f(y_n) = \frac{\delta}{2}\left(\left|y_n + \frac{1}{\delta}\right| - \left|y_n - \frac{1}{\delta}\right|\right).$$

For the computer simulations, we calculate Eq. (1) using the fourth-order Runge-Kutta method with step size h = 0.005. We set the parameters of this circuit model as follows; α_c =0.460, α_p = 0.413, β = 3.0 and δ = 470.0.

3. Results

The chaos propagation is changed by switching the coupling strength with the difference of x_n and x_{n+1} as a threshold. The first method is to switch all the couplings simultaneously, and the second method is to switch each coupling at a certain intervals. How to switch the coupling strength is shown in Fig. 3.

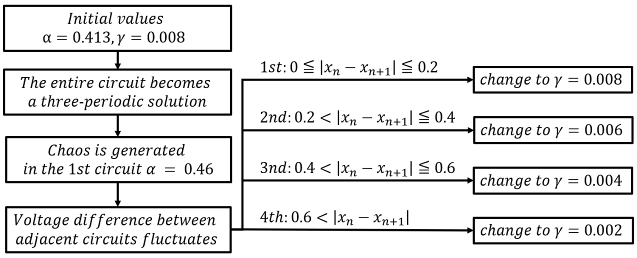

Figure 3: The algorithm for controlling chaotic propagation by coupling strength.(the threshold widths are all 0.2)

The horizontal axis is the value of x_n representing the current flowing in L_1, and the vertical axis shows the value of z_n representing the voltage applied to C.

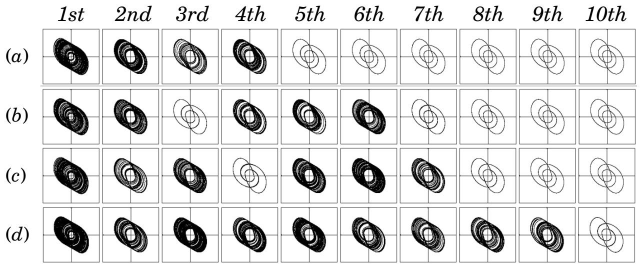

Figure 4: Four patterns of chaos propagation.

When all coupling strength is switched at the same time, the maximum number of circuits to propagate is 4 or 5. However, when the coupling strength is switched for each coupling, propagation can be classified into four patterns as shown in the Fig. 4. When the first threshold width is $0 \leq |x_n$ - $x_{n+1}| \leq 0.1$, the chaos propagation can be suppressed as shown in the Fig. 4(a). When the voltage difference is less than 0.6 and the respective threshold widths are 0.1, 0.2, and 0.3 regardless of the order, the propagation state is the same as in Fig. 4(b). Using the value of the threshold width in Fig.3, the propagation can be seen in Fig. 4(c). As shown in Fig. 4(d), when the first or second threshold width is 0.4, the propagation spreads out greatly.

4. Conclusion

In this study, chaos propagation by switching the coupling strength was considered. It was found that there may be a regularity of propagation depending on the threshold of the coupling strength. As our future works, it will be confirmed whether the observed regularity holds when the bifurcation parameter of chaos, the time to generate chaos, and the time to continue coupling are changed.