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Synchronization Phenomenon of Chaotic Circuits Cross-Coupled via Indoctors

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1 Introduction

Synchronization phenomena in complex systems are good models to describe various higher-dimensional nonlinear phenomena in the field of natural science. Studies on synchronization phenomena of coupled chaotic circuits are extensively carried out in various fields.

In this study, two Shinriki-Mori chaotic circuits cross-coupled by inductors are investigated. We observe the generation of interesting state transition phenomenon.

2 Circuit Model

Figure 1 shows the circuit model. In the circuit, two Shinriki-Mori chaotic circuits are cross-coupled via inductors L_2.

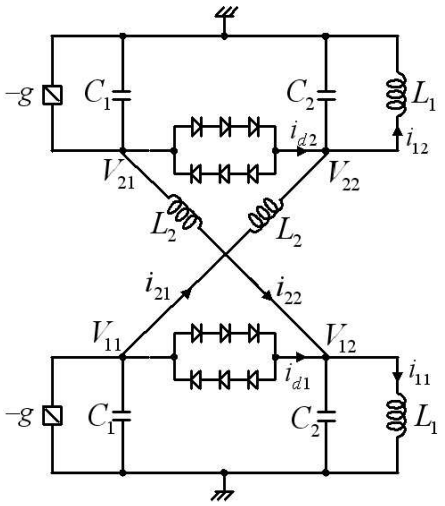

Figure 1: Circuit model.

By using the following variables and the parameters,

$$\begin{cases} i_{k1} = \sqrt{\dfrac{C_2}{L_1}}\, V x_k, \quad i_{k2} = \sqrt{\dfrac{C_2}{L_1}}\, V w_k, \\ v_{k1} = V y_k, \quad v_{k2} = V z_k, \\ \alpha = \dfrac{C_2}{C_1}, \quad \beta = \sqrt{\dfrac{L_1}{C_2}}\, G, \quad \gamma = \sqrt{\dfrac{L_1}{C_2}}\, g, \\ \delta = \dfrac{L_1}{L_2}, \quad t = \sqrt{L_1 C_2}\, \tau, \quad \text{“}\cdot\text{”} = \dfrac{d}{d\tau} \qquad (k = 1, 2) \end{cases} \tag{1}$$

the normalized circuit equations are given as follows.

$$\begin{cases} \dot{x}_k = z_k \\ \dot{y}_k = \alpha\{\gamma y_k - w_k - \beta f\,(y_k - z_k)\} \\ \dot{z}_k = \beta\, f(y_k - z_k) + w_{k+1} - x_k \\ \dot{w}_k = \delta(y_k - z_{k+1}) \\ (k = 1, 2), \end{cases} \tag{2}$$

where f are nonlinear functions corresponding to the $v - i$ characteristics of the nonlinear resistors and are described as follows.

$$f(y_k - z_k) = \begin{cases} y_k - z_k - 1 & (y_k - z_k > 1) \\ 0 & (|y_k - z_k| \le 1) \\ y_k - z_k + 1 & (y_k - z_k < -1) \\ (k = 1, 2). \end{cases} \tag{3}$$

3 State Transition Phenomenon

From the circuit in Fig. 1, we can observe interesting state transition phenomenon shown in Fig. 2.

The two circuits exhibit chaos but almost synchronized in in-phase. When one circuit switches to/from the positive region to the negative region, the other follows the transition after a while. The sojourn time between state transitions becomes longer as the coupling parameter δ decreases.

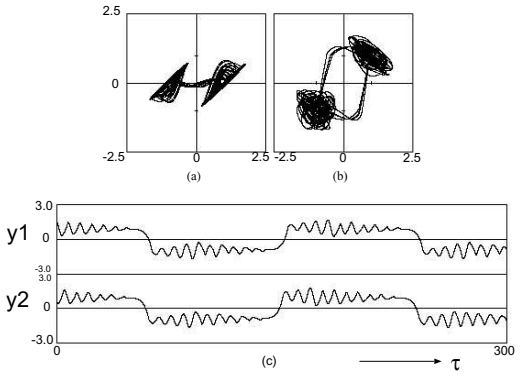

Figure 2: State transition phenomenon around in-phase synchronization (computer calculated result). $\alpha = 1.5$, $\beta = 5.0$, $\gamma = 0.2$, and $\delta = 0.005$. (a) Attractor on $y_1 - z_1$ plane. (b) Attractor on $y_1 - y_2$ plane. (c) Time waveform.

It is very interesting that we can also confirm the generation of the state transition around the anti-phase synchronization for different set of parameter values.

Also, the circuit experimental results show the similar phenomenon to the computer calculated results.

4 Conclusions

In this study, we have investigated interesting state transition phenomenon observed from two Shinriki-Mori chaotic circuits cross-coupled via inductors.

Investigating the coexistence of the states and the generation mechanism of the observed phenomena are our important future work.

References

[1] P. Ashwin, J. Buescu and I. Stewart, “Bubbling of Attractors and Synchronization of Chaotic Oscillators,” Phys. Lett. A, 193, pp. 126-139, 1994.