1-8 Synchronization Phenomena of Chaotic System by Using Mutual Coupling

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1. Introduction

In this study, we investigate synchronization phenomena observed in two coupled chaotic circuits. In addition, one of chaotic circuits is mutually coupled with van der Pol oscillator. We investigate synchronization phenomena by changing the value of mutual inductance. Also, we observe the phase difference between the both circuits by using computer simulations.

2. Circuit model

Figure 1 shows the circuit model. This circuit model is made based on Inaba circuit and van der Pol oscillator.

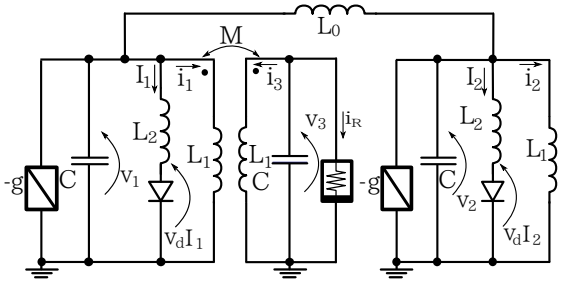


Figure 1: Circuit model.

We can consider the following equations when all circuits are coupled with the others.

$$\begin{cases} \dot{x}_k &= \beta x_k - \eta_1 - z_k + \delta(y_{k-1} - 2\eta_1 y_1 + y_{k+1}) \\ \dot{x}_3 &= \eta_3 x_3(1 - \frac{1}{3}x_3^2) - y_3 \\ \dot{y}_1 &= x_1 + \eta_2 x_3 \\ \dot{y}_2 &= x_2 \\ \dot{y}_3 &= -\eta_2 x_1 + x_3 \\ \dot{z}_k &= \alpha(x_k - f(z_k)) \end{cases} \quad (1)$$

$$(k = 1, 2)$$

where $y_0 = y_2$, $y_{2+1} = y_1$ and

$$f(z_k) = \begin{cases} \gamma z_k \cdots (z_k \leq 1/\gamma) \\ 1 \quad \cdots (z_k > 1/\gamma) \end{cases} \quad (2)$$

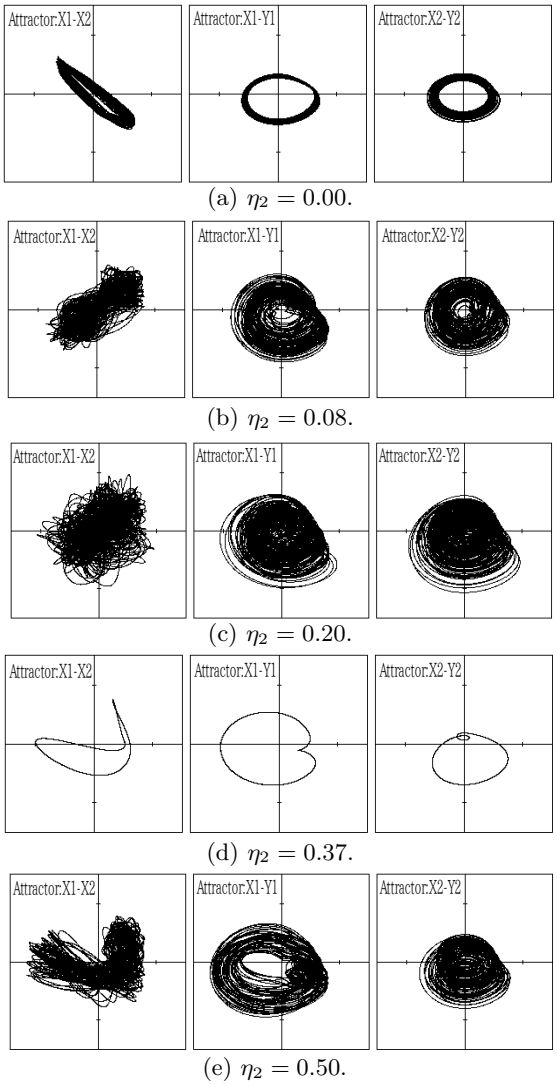
the parameter η_2 represents the coupling coefficient.

$$\begin{cases} \eta_2 = M/L_1 \\ \eta_1 = 1/(1 - \eta_2^2) \end{cases} \quad (3)$$

The value of M denotes the mutual inductance between the L_1 shown in Fig. 2. In this study, we change the value of η_2 by using computer simulations to observe the phase differences.

3. Simulation results

We carry out the simulation in $\eta_2 = 0.00 \sim 0.50$. In this simulation, the values of α, β, γ, δ and η_3 are fixed ($\alpha = 6.00$, $\beta = 0.16$, $\gamma = 100.00$, $\delta = 0.30$, $\eta_3 = 0.10$). We obtain the simulation results as shown in Fig. 2. Fig. 2 (a) is shown that the phase difference is anti-phase when η_2 is 0.00. The phase difference becomes in-phase from anti-phase when the value of η_2 is 0.08 (Fig. 2 (b)). However, when increasing η_2, the phase difference becomes asynchronous (Fig. 2 (c)). After that, the phase difference becomes periodic solution when the value of η_2 is 0.37 (Fig. 2 (d)). When η_2 is 0.50, the phase difference becomes asynchronous (Fig. 2 (e)).



(a) $\eta_2 = 0.00$.

(b) $\eta_2 = 0.08$.

(c) $\eta_2 = 0.20$.

(d) $\eta_2 = 0.37$.

(e) $\eta_2 = 0.50$.

Figure 2: Simulation result.

4. Conclusions

In this study, we have investigated the synchronization phenomena in coupled chaotic circuits system by using mutual coupling with van der Pol oscillator. We confirmed that synchronization phenomena is influenced by the mutual inductance. In future work, we would like to investigate synchronization phenomena when the number of chaotic circuits are increased.