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Synchronization Phenomena in Ladder-Coupled Chaotic Circuits Including Ring Structure

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1. Introduction

In this study, we investigate synchronization phenomena in ladder-coupled chaotic circuits including ring structure. In the proposed model, all chaotic circuits are coupled by resistors. We set the parameters that generate periodic solutions or chaotic solutions at these chaotic circuits. Moreover, we change the network structure, and we research the influence of synchronization phenomena.

2. System Model

The chaotic circuit model is shown in Fig. 1. This is called Nishio-Inaba circuit. In this study, we propose five network models coupled by resistors in ladder-coupled chaotic circuits including ring structure. These networks are shown in Fig. 2. These circuits generate three periodic solutions. Then we investigate the synchronization phenomena.

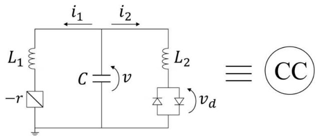
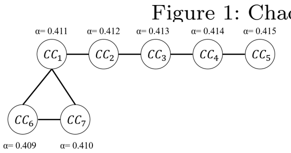
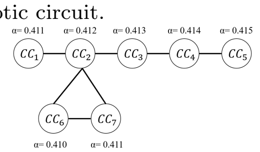


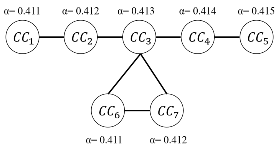
Figure 1: Chaotic circuit.



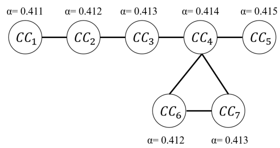
(a) CC_1 ring.



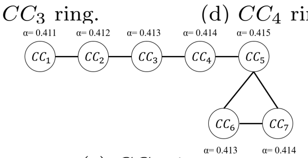
(b) CC_2 ring.



(c) CC_3 ring.



(d) CC_4 ring.



(e) CC_5 ring.

Figure 2: Network models

The normalized circuit equations of this circuit equations are given by the following equations.

$$\begin{cases} \dfrac{dx_i}{d\tau} = \alpha x_i + z_i \\ \dfrac{dy_i}{d\tau} = z_i - f(y) \\ \dfrac{dz_i}{d\tau} = -x_i - \beta y_i - \displaystyle\sum_{i,j=1}^{N} \gamma_{ij}(z_i - z_j) \\ \qquad\qquad (i, j = 1, 2, \cdots, N). \end{cases} \quad (1)$$

where $N = 1, 2, 3, ..., 7$. The parameter γ corresponds the coupling strength between the circuits. $f(y)$ is described as follows :

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

3. Simulation results

We set the parameters of the system as $\beta = 3.0$, $\delta = 470.0$ and $\gamma = 0.008$. The parameter α increases from 0.409 to 0.415 in increments of 0.001. Figures 3 and 4 show the simulation result. In this case, we couple ring structure to CC_1. Attractors those we couple in ladder become chaotic attractors. And we observe chaotic synchronization or synchronization. Figures 5 and 6 shows the simulation result. We couple ring structure to CC_2. In this case, all circuits generate three periodic solutions, and we observe synchronization. Furthermore, these results are same at Figs. 5 and 6 when we couple ring structure to CC_3, CC_4 and CC_5.

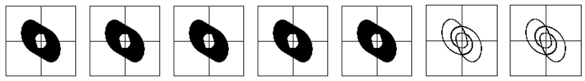


Figure 3: Attractors(CC_1 ring).

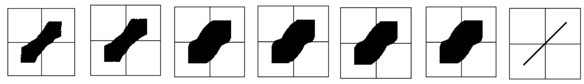


Figure 4: Lissajous figure(CC_1 ring).

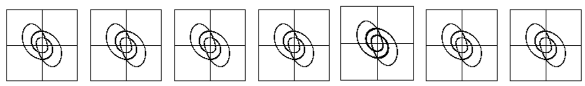


Figure 5: Attractors(CC_2 ring).

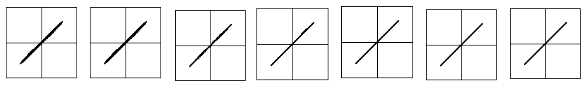


Figure 6: Lissajous figure(CC_2 ring).

4. Conclusion

In this study, we have proposed network models, and we have investigated the synchronization phenomena. We have confirmed that when we change the part that we couple ring sturucture, we can observe various chaotic synchronization or synchronization. In our future works, we would like to investigate the syncronization phenomena in more complex network.