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Synchronization Phenomena in Coupled Chaotic Circuit with Delay Signal Transfer

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1. Introduction

In this study, we investigate two chaotic circuits coupled via resistor containing time delay coupling. Interesting synchronization phenomena can be confirmed by computer simulations and circuit experiments.

2. Circuit model

Figure 1 shows the circuit model. In the circuit, two Nishio-Inaba circuits are coupled via resistors R and switches SW. The circuit consists of a negative resistance, a nonlinear resistance consisting of two diodes, capacitor and two inductors.

The normalized circuit equations are given as follows,

$$\begin{cases} \dot{x_n} = \alpha x_n + z_n \\ \dot{y_n} = z_n - f(y_n) \\ \dot{z_1} = -x_1 - \beta y_n - \gamma(z_2(\tau - \tau_{d2}) - z_1) \\ \dot{z_2} = -x_2 - \beta y_n + \gamma(z_1(\tau - \tau_{d1}) - z_2) \end{cases} \quad (1)$$

$$(n = 1, 2).$$

The nonlinear function $f(y_n)$ corresponds to the $I - V$ characteristics of the nonlinear resistors consisting of the diodes and are assumed to be described as follows;

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

$$(n = 1, 2).$$

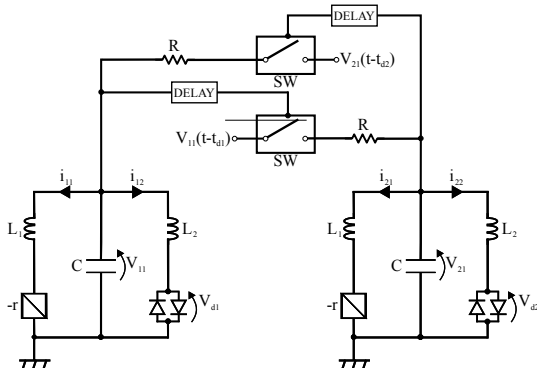


Figure 1: Circuit model.

Figure 2 shows the switching operation. SW is controlled by the amplitude, switch is connected to the R in the case of amplitude is larger than the threshold V_{th}, and connect time is represented by T_c. Also, this switching operation is included delay, and delay time is represented by T_d. Furthermore, the voltage of the time T_c is input to R.

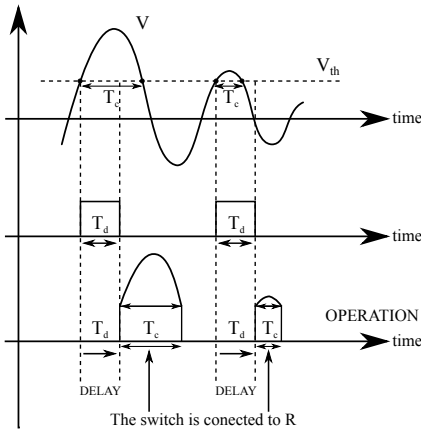
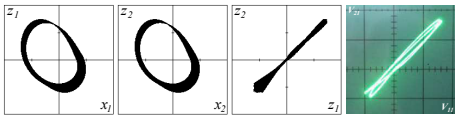


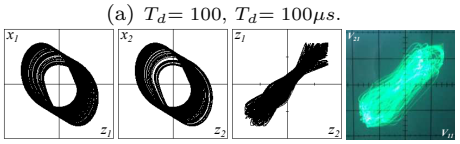
Figure 2: Switching operation.

3. Synchronization Phenomena

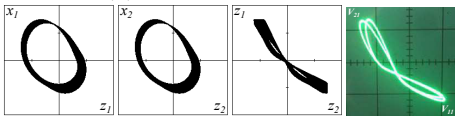
Figures 5 shows computer simulations results and circuit experiments results. We confirmed nonlinearity of the two circuits vary and the phase difference switches in in-phase and anti-phase synchronization depending on T_d. We can say that this phenomenon can be observed from both computer simulations and circuit experiments.



(a) T_d= 100, T_d= 100μs.



(b) T_d= 200, T_d= 200μs.



(c) T_d= 700, T_d= 214μs.

Figure 3: Three figures from the left are computer simulation results. The right figure is circuit experimental result.

4. Conclusions

In this study, we have confirmed the interesting synchronization phenomena observed from coupled chaotic circuits containing time delay coupling.