Synchronization Phenomena of Two Coupled Chaotic Circuits Using Stochastic Coupling

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Abstract— **In this research, synchronization phenomena in stochastic coupling are investigated using two chaotic circuits. As a result, new synchronization patterns are observed by switching resistors with reference to the positive value and the negative value of the chaotic circuit.**

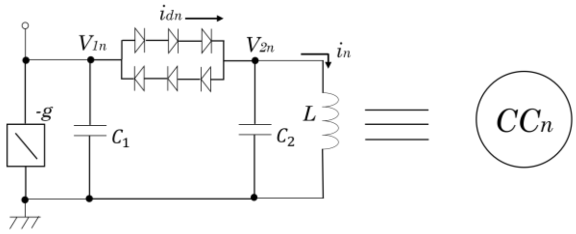
Keywords; Synchronization; Stochastic; Chaotic circuit

I. INTRODUCTION

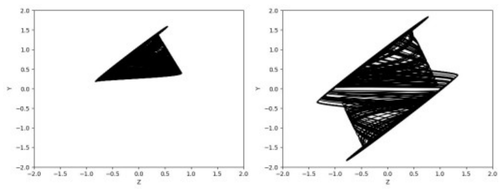
Synchronization phenomena are phenomena in which two or more oscillating bodies behave in the same way by influencing each other and can be observed in many situations in everyday life [1]. The observation and analysis of phenomena using electrical circuits are also one of the most effective tools because they can be applied to real physical systems. Investigating synchronization phenomena in chaotic circuits is very important, therefore, for future engineering applications. Synchronization phenomena in chaotic circuits are mostly investigated in statically coupled chaotic circuit networks, and fewer in dynamically varied coupling chaotic circuit networks [2]. For these reasons, in this research, synchronization phenomena of chaotic circuits in dynamically varying resistors coupled chaotic circuits (stochastic coupling) are investigated [3].

II. SYSTEM MODEL

The chaotic circuit used in this research is shown in Fig. 1(a). The attractor of this chaotic circuit is shown in Fig. 1(b) and (c). The chaotic circuit is called as the Mori-Shinriki circuit and consists of a negative resistor, an inductor, two capacitors and dual-directional diodes. In this research, two Mori-Shinriki chaotic circuits are used to connect two resistors *Ra* and *Rb*. *Ra* and *Rb* are then varied stochastically to construct a system model. The system model is shown in Fig. 2. The circuit equation is described as Eq. (1).



(a) Chaotic circuit.



(b) Attractor(γ = 0.5). (c) Attractor(γ = 0.65).

Figure 1. Circuit model.

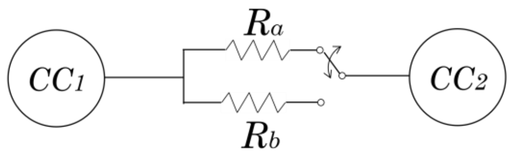


Figure 2. System model.

$$\begin{cases} L\dfrac{di_1}{dt} = V_{2n}, \\ C_1\dfrac{dV_{1n}}{dt} = gV_{1n} - i_{dn} - \dfrac{1}{R}\displaystyle\sum_{k\in C_n} V_{1n} - V_{1k}, \\ C_2\dfrac{dV_{2n}}{dt} = i_{dn} - i_n. \\ \qquad (n = 1,2) \end{cases} \quad (1)$$

Normalized resistor R is set as the coupled strength δ. The normalized equation of this circuit is given as follows:

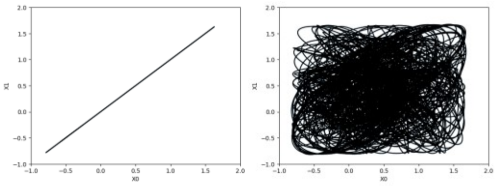
$$
\begin{cases}
\dfrac{dx}{d\tau} = z_n, \\
\dfrac{dy}{d\tau} = \alpha\gamma y_n - \alpha\beta f(y_n - z_n) - \alpha\delta \displaystyle\sum_{k \in S_n} (y_n - y_k), \\
\dfrac{dz}{d\tau} = \beta f(y_n - z_n) - x_n. \\
\qquad\qquad\qquad (n = 1,2)
\end{cases}
\tag{2}
$$

The nonlinear function f() corresponds to the i-v characteristics of the nonlinear resistor consisting of the diodes and are described as follows:

$$
f(y_n - z_n) = \begin{cases}
\beta(y_n - z_n - 1) & (y_n - z_n > 1), \\
0 & (|y_n - z_n| < 1), \\
\beta(y_n - z_n + 1) & (y_n - z_n < 1).
\end{cases}
\tag{3}
$$

III. SETTING THE COUPLED STRENGTH

The normalized coupling strength of Ra and Rb is set to δa and δb. In this research, the coupling strength is switched between the in-phase state for δa and the asynchronous state for δb.



(a) In-phase state ($\delta a = 0.22$). (b) Asynchronous state ($\delta b = 0.01$).

Figure 3. The coupling strength.

The positive value and the negative value of the waveform of y in the Mori-Shinriki circuit (γ = 0.65) are also used as standards for switching the coupling strength and are shown in Fig. 4. Switching is performed with δa for time the positive value and δb for time the negative value.

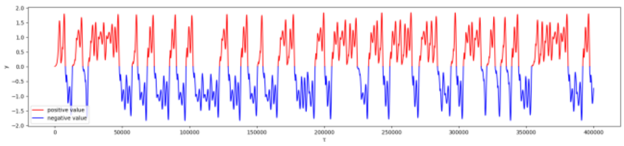
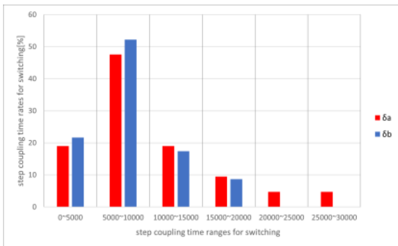


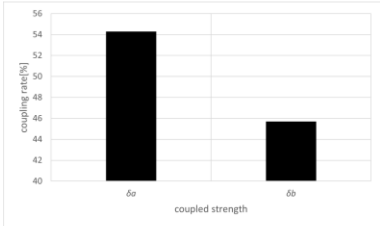
Figure 4. The standard waveforms for switching the coupling strength.

IV. RESULTS

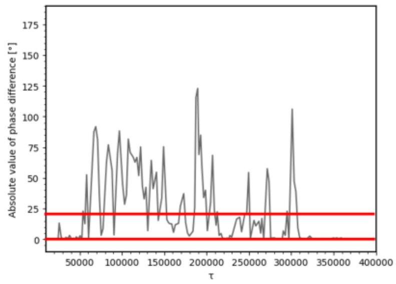
In this research, the time interval is set to (τ = 400,000, step = 0.005τ) using numerical simulation. The synchronization rate is investigated by considering phase differences within 20 degrees to be in-phase states. Results are shown in Fig. 5. It is showed coupling step time rates of δa and δb for switching, classified by 5,000 in Fig. 5(a). It is also showed the overall δa and δb coupling time rate for switching in Fig. 5(b), and phase differences in Fig. 5(c). These show that in-phase and asynchronous states are repeated. The synchronization rate is 68.9 [%]. It is also considered that the coupling step times of δa more than 20,000 are relatively in-phase state.



(a) Coupling step time rates of δa and δb for switching.



(b) The overall δa and δb coupling time rate for switching.



(c) Phase differences.

Figure 5. Simulation results.

V. CONCLUSIONS

This research investigated synchronization phenomena of chaotic circuits in coupled chaotic circuits with dynamically varying resistors (stochastic coupling). The results of dynamically switching the coupling strength with reference to the positive value and the negative value of the chaotic circuit showed new synchronization phenomena. As a future work, we would like to carry out circuit experiments and compare the results with numerical simulations.

VI. REFERENCES

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