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Synchronization Phenomena of Two Chaotic Circuits Using Four RC Circuits

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1. Introduction

In our previous study, a simple chaotic oscillator using two RC circuits were proposed [1].

In this study, we investigate two coupled chaotic oscillators composed of RC circuits. Two chaotic oscillators coupled by one resistor. By computer calculation and circuit experiment, we confirm that the synchronization state changes according to the coupling strength.

2. Circuit model

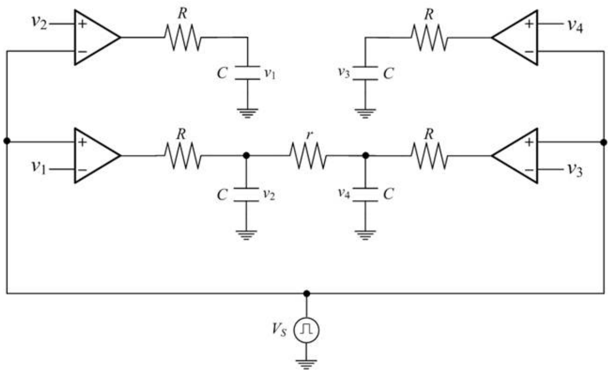

Figure 1: Circuit model.

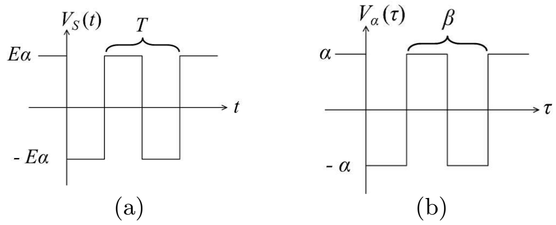

Figure 2: Rectangular voltage waveform.

Figure 1 shows the circuit model. In this figure two chaotic oscillators, which was proposed in [1], are coupled via one resistor r. An independent rectangular voltage source is connected to four comparators. Figure 2(a) shows the rectangular voltage waveform $V_S(t)$. $E\alpha$ is the amplitude of the rectangular voltage and T is the period of the waveform. E is the output voltage of the comparators, namely the DC supply voltage of the operational amplifiers. By using the following variables and the parameters,

$$v_l = Ex_l,\ t = RC\tau,\ T = RC\beta,\ \frac{R}{r} = \gamma$$

$$(l = 1, 2, 3, 4)$$

we obtain the normalized circuit equations. Because the circuit equation is linear in each region, the exact solutions can be derived as follows:

$$x_m = \begin{cases} (x_{m0} - 1)e^{-\tau} + 1 & (x_{m+1} > V_\alpha) \\ (x_{m0} + 1)e^{-\tau} - 1 & (x_{m+1} < V_\alpha) \\ \qquad (m = 1, 3) & \end{cases}$$

$$x_n = \begin{cases} \left(\frac{x_{20}+x_{40}}{2} + 1\right)e^{-a\tau} \\ \quad + \left(\frac{x_{20}-x_{40}}{2}\right)e^{-(1+2\gamma)a\tau} - 1 \ (x_{n-1} > V_\alpha) \\ \left(\frac{x_{20}+x_{40}}{2} - 1\right)e^{-a\tau} \\ \quad + \left(\frac{x_{20}-x_{40}}{2}\right)e^{-(1+2\gamma)a\tau} + 1 \ (x_{n-1} < V_\alpha) \\ \qquad (n = 2, 4) \end{cases}$$

where V_α corresponds to V_S and is shown in Fig. 2(b), and x_{10}, x_{20}, x_{30} and x_{40} are initial values. a is introduced to give a frequency error, in order to set up similar condition to the circuit experiment. We carry out computer calculation with $a = 1$ for $n = 2$ and $a = 1.0005$ for $n = 4$.

3. Synchronization phenomena

Figures 3(a) and (b) show the results of computer calculations. Figures 3(c) and (d) show circuit experimental results for $C = 49.0 \pm 10\%$[nF] and $R = 1.2 \pm 5\%$[kΩ]. From Figs. 3(a) and (c), we observe perfect in-phase synchronization. Moreover, when the value of coupling strength is small, we can observe asynchronous state. We obtain the same result from computer calculation and circuit experiment.

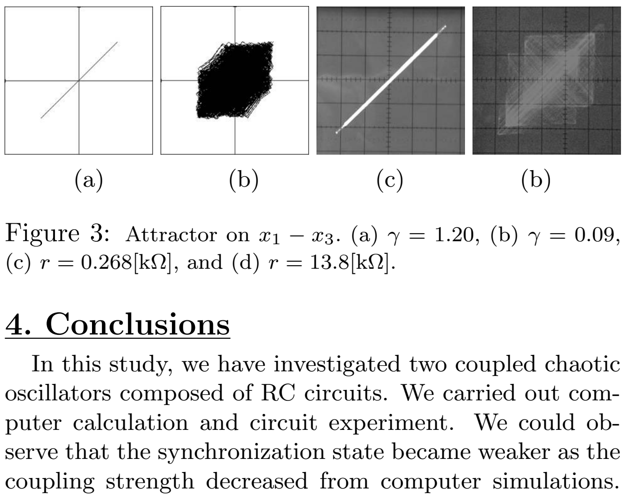

Figure 3: Attractor on $x_1 - x_3$. (a) $\gamma = 1.20$, (b) $\gamma = 0.09$, (c) $r = 0.268$[kΩ], and (d) $r = 13.8$[kΩ].

4. Conclusions

In this study, we have investigated two coupled chaotic oscillators composed of RC circuits. We carried out computer calculation and circuit experiment. We could observe that the synchronization state became weaker as the coupling strength decreased from computer simulations. We also obtained the same synchronization phenomena from the circuit experiment.

References

[1] S. Masuda, Y. Uchitani and Y. Nishio, "Simple Chaotic Oscillator Using Two RC Circuits," Proc. of NCSP'09, pp. 89-92, 2009.