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Synchronization in Triangular Oscillatory Networks

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1. Introduction

In this study, we investigate synchronization phenomena observed from the circuit system which is two coupled triangular oscillatory networks via negative resistors.

2. Circuit Model

The circuit model of two coupled triangular oscillatory networks sharing the branch is shown in Fig. 1. Composed oscillators are coupled by the negative resistors.

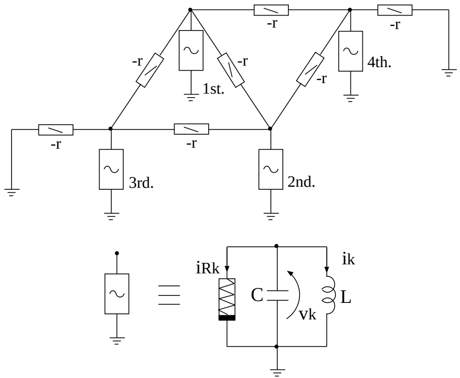

Figure 1: Circuit model.

We assume that the $v_k - i_{Rk}$ characteristics of the nonlinear resistor in each oscillator is given by the following third order polynomial equation,

$$i_{Rk} = -g_1 v_k + g_3 {v_k}^3 \quad (g_1, g_3 > 0), \qquad (1)$$

$$(k = 1, 2, 3, 4).$$

The normalized circuit equations governing the circuit in Fig. are expressed as following equation.

$$\begin{cases} \dfrac{dx_k}{d\tau} = \varepsilon\left(1 - \dfrac{1}{3}{x_k}^2\right)x_k - y_k \\ \qquad - \dfrac{\gamma}{3}(x_{k+1} + x_{k+2} + x_{k+3} - 3x_k) \\ \dfrac{dy_1}{d\tau} = x_k \end{cases} \qquad (2)$$

where

$$t = \sqrt{LC}\tau, \quad v_k = \sqrt{\frac{g_1}{3g_3}}x_k, \quad i_k = \sqrt{\frac{g_1}{3g_3}}\sqrt{\frac{C}{L}}y_k,$$

$$\varepsilon = g_1\sqrt{\frac{L}{C}}, \quad \gamma = \frac{1}{r}\sqrt{\frac{C}{L}},$$

$$(k = 1, 2, 3, 4).$$

In this equations, γ is the coupling strength and ε denotes the nonlinearity of the oscillators.

3. Synchronization

The computer simulation results of synchronization state are summarized in Tab. 1. We can see that the 1st and 2nd oscillators are synchronized at in-phase state and the other combination oscillators synchronize with anti-phase.

Table 1: Synchronization states.

combination of osc.	synchro. state
1-2	in-phase
2-3, 3-1, 1-4, 2-4	anti-phase

Next, we investigate the synchronization state when the coupling strength between the 1st and the 2nd oscillators are changed. The new parameter β is introduced to change the coupling strength. Figure 2 shows the phase difference of coupled oscillators. The phase difference between the 1st and the 2nd oscillators increase with β. The whole oscillators are synchronized with three-phase state when the β is 1.77. If β is larger than 3.0, the graph of the phase difference becomes to oscillate.

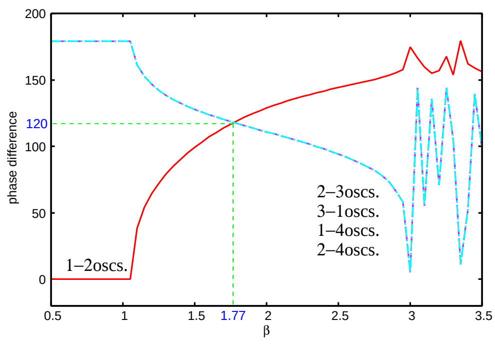

Figure 2: Phase difference by changing β.

4. Conclusions

In this study, we have investigated synchronization phenomena in two coupled triangular oscillatory networks sharing the branch. The negative resistors are fixed as the coupling term for composed oscillators.

In order to make clear the mechanism of such synchronization, to discuss a power consumption of the negative resistors is our future works.