Synchronization of Two Chaotic Circuits
Coupled via Mutual Inductance

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1. Introduction
Synchronization phenomenon is one of the fundamental phenomena in nature. Especially, chaos synchronization phenomena in nonlinear circuits have been studied in many fields. Thus, it is thought that investigations of the synchronization phenomena will be important in the future.

In this study, we investigate synchronization phenomena in two coupled chaotic circuits via mutual inductance. We observe some interesting synchronization phenomena. In many fields, thus, it is thought that investigations of the synchronization phenomena will be important in the future.

2. Circuit model

\begin{equation}
    v_d(i_k) = \sqrt{r_d} \cdot \text{characteristics of the diode}
\end{equation}

By changing the variables and parameters,

\begin{equation}
    I_k = a = \sqrt{L_1/L_2} \cdot \beta = \sqrt{C/L_1}, \quad \gamma = \frac{M}{L_1}, \quad t = \sqrt{L_1C} \cdot \text{"a","} = \frac{d}{dt}\tau,
\end{equation}

the circuit equations are normalized as

\begin{align}
    x_1 &= \frac{1}{1 - \gamma^2} \{ \beta(x_1 + y_1) - z_1 \} \\
    y_1 &= \alpha \{ \beta(x_1 + y_1) - z_1 - f(y_1) \} \\
    z_1 &= x_1 + y_1 \\
    x_2 &= \frac{1}{1 - \gamma^2} \{ \beta(x_2 + y_2) - z_2 \} \\
    y_2 &= \alpha \{ \beta(x_2 + y_2) - z_2 - f(y_2) \} \\
    z_2 &= x_2 + y_2
\end{align}

3. Simulation Results
We carry out computer calculations for the two chaotic circuits coupled via mutual inductance. We observe various synchronization phenomena. Figure 2 shows the observed attractors, phase differences and time waveform for the parameters (a): $\alpha = 24.0, \beta = 0.20$ and $\gamma = 0.60$. (b): $\alpha = 24.0, \beta = 0.30$ and $\gamma = 0.05$. In Fig. 2(a), the two chaotic circuits are synchronized at the opposite-phase. Whereas, the two chaotic circuits are synchronized at the in-phase as shown in Fig. 2(b). In the coupled circuits, the two circuits are synchronized at the opposite-phase when $\beta$, which determines chaotic characteristics of each circuit, is small. While, the two circuits are synchronized at the in-phase when $\beta$ is large.

4. Conclusions
In this study, we investigated the synchronization phenomena in chaotic circuits coupled via mutual inductance. By carrying out computer calculations for the circuits, we confirmed various kinds of synchronization phenomena. In-phase synchronization and opposite-phase synchronization can be observed for different parameters.

References