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Inhibiting Chaos by Noisy Parametric Excitation

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1. Introduction

Chaos is termed nonperiodic oscillation made by deterministic system. In some situations, chaos may not be wanted because it has irregular oscillation. In this study, we focused on chaos generated in van der Pol oscillator under parametric excitation. We investigate inhibiting effect on chaos by noise in van der Pol oscillator under parametric excitation.

2. van der Pol Oscillator under Parametric Excitation

The circuit model used in this study is shown in Fig 1.

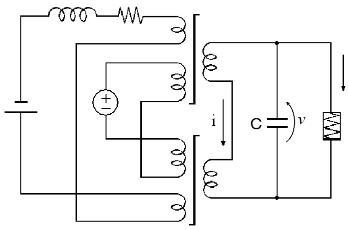

Figure 1: van der Pol oscillator under parametric excitation.

In our system, the circuit includes a time-varying inductor L whose characteristics are given as the following equation.

$$L = L_0 \gamma(t). \tag{1}$$

$\gamma(\tau)$ is expressed in a rectangular wave as shown in Fig. 2, and its amplitude and angular frequency are termed α and ω.

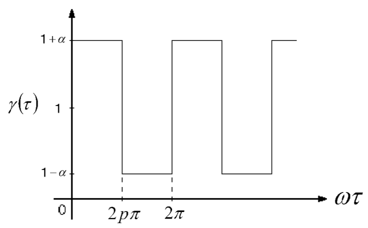

Figure 2: rectangular wave.

The $v-i$ characteristics of the nonlinear resistor are approximated by the following equation.

$$i_d = -g_1 v + g_3 v. \tag{2}$$

By changing the variables and the parameters,

$$t = \sqrt{L_0 C}\tau, \quad v = \sqrt{\frac{g_1}{g_3}}x, \quad \omega = \omega_0\sqrt{L_0 C},$$
$$i = \sqrt{\frac{g_1}{g_3}}\sqrt{\frac{C}{L_0}}y, \quad \varepsilon = g_1\sqrt{\frac{L_0}{C}}, \tag{3}$$

the normalized circuit equations are given by the following equations.

$$\begin{cases} \dfrac{dx}{d\tau} = \varepsilon(x - x^3) - y \\ \dfrac{dy}{d\tau} = \dfrac{1}{\gamma(\tau)}x. \end{cases} \tag{4}$$

ε corresponds to the nonlinearity of van der Pol oscillator. The behavior of van der Pol oscillator changes by only ε. When we change ε, the bifurcation diagram is obtained as shown in Fig. 3. Periodic, quasi-periodic and chaotic behaviors are confirmed.

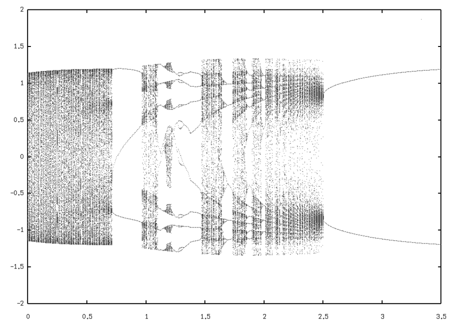

Figure 3: $x-\varepsilon$ bifurcation diagram. $\alpha = 0.75$ and $\omega = 1.50$.

In this study, we add noise to $\gamma(\tau)$, and we investigate observed phenomena.

3. Inhibiting Chaos by Noise

First, the noise used in this study takes alternative values $+\zeta$ and $-\zeta$ in random order. We call this noise "binary noise". In this section, we add the binary noise to the duty ratio of $\gamma(\tau)$. When we change ζ, the bifurcation diagram is obtained as shown in Fig. 4.

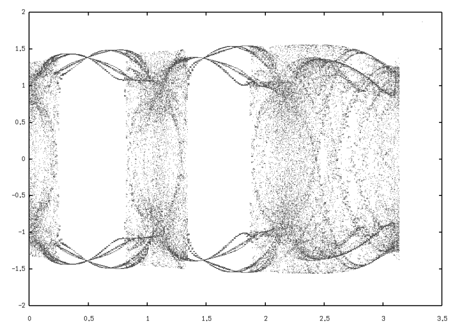

Figure 4: $x-\zeta$ bifurcation diagram. $\alpha = 0.75$, $\omega = 1.50$ and $\varepsilon = 1.50$.

The behavior of van der Pol oscillator under noisy parametric excitation changes by the amplitude ζ of the noise. Almost periodic attractors are obtained between about $\zeta = 0.25$ and about $\zeta = 0.75$. Namely, chaos is inhibited by the binary noise. However, chaotic attractors appear again if ζincleases further. We obtained interesting phenomenon that chaotic behaviors appear or are cleared by the binary noise amplitude.

4. Conclusions

In this study, we investigated inhibiting effect of chaos by noise in van der Pol oscillator under parametric excitation. We proposed binary noise taking alternative value $+\zeta$ and $-\zeta$ in random. Chaotic behavior was inhibited by the binary noise when it was added to the duty ratio. Additionally, we observed a phenomenon that there is the range of the noise amplitude that can inhibit chaotic behavior or cannot inhibit chaotic behavior.