Dynamical analysis and control of chaos in Vilnius chaotic oscillator circuit

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Summary. In this paper, Vilnius chaotic oscillator circuit is realized. Electronic circuit implementation of the Vilnius chaotic oscillator was realized using Multisim®. Also, the state equations of Vilnius chaotic oscillator are obtained by circuit theory. Dynamical analysis of Vilnius chaotic circuit is investigated by using dynamic state equations. The mathematical model of oscillator is constructed using MATLAB®. In addition, control of chaos in Vilnius chaotic oscillator is determined by using time delay feedback theory. Time delay feedback controllers are designed to eliminate chaos from system trajectories and stabilize the system at its equilibrium point. Numerical simulations results confirming the analytical analysis are shown and MATLAB® simulations are also performed to confirm the efficiency of the proposed control scheme.

1 Introduction

Chaos has not a general definition in literature but there are some properties of chaotic systems. The chaotic systems are very sensitivity to initial conditions. In order that any nonlinear system is able to behave chaotic, the system must be at least three dimensional for an autonomous system or two dimensional for non-autonomous system in the continuous system [1]. In chaos, Lyapunov exponents must be determined to identify whether the system behaves chaotic or not [2]. In the 3D system, one of the lyapunov exponents of the system must be positive, the second one negative and third one zero, respectively. So, in a third order dynamical system, the sign of the Lyapunov exponent could be positive, negative and zero for chaotic behavior [3]. In oscillator circuit, in order to can show chaotic behavior, autonomous circuit designed by resistor, capacitor and inductor elements must contain:

- one or more nonlinear elements
- one or more locally active resistors
- three or more energy storage elements [4].

Many chaotic oscillator circuits are developed. Vilnius oscillator which has a simple circuit scheme is developed for educational purpose by A. Tamasevicius in 2005 [5].

2 Vilnius chaotic oscillator and its dynamical analysis

In this section, Vilnius chaotic oscillator circuit is shown in Fig. 1.

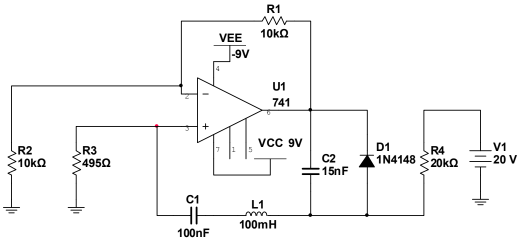

Fig. 1 Vilnius chaotic oscillator circuit

This circuit is constructed in Multisim program. By changing the R_3 resistor, dynamic analysis of circuit is analyzed using Multisim and simulation results are given in Fig. 2

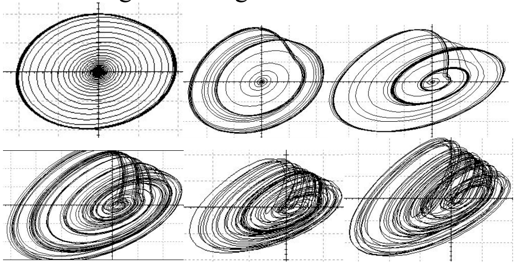

Fig. 2 Phase portraits of Vilnius circuit *R=100, 220, 350, 400, 495, 600 ohm*

Using KCL and KVL circuit theory, state equations of Vilnius chaotic oscillator circuit are obtained as shown in Eq. 1.

$$
\begin{aligned}
C_1 \frac{dV_{C1}(t)}{dt} &= I_L \\
L_1 \frac{dI_{L1}(t)}{dt} &= (k-1)R_3 I_{L1} - V_{C_2} - V_{C_1} \\
C_2 \frac{dV_{C2}(t)}{dt} &= I_{R4} + I_{L1} - I_D
\end{aligned}
\qquad (1)
$$

By using some transformations, dimensionless state equations may be obtained in Eq. 2.

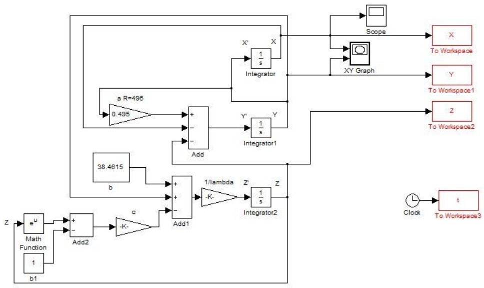

Fig. 3 Matlab-Simulink model of circuit via state equations

$$\begin{aligned} \dot{x} &= y \\ \dot{y} &= \frac{(k-1)R_3}{\rho} y - x - z \\ \dot{z} &= \frac{1}{\varepsilon}(b + y - c(e^z - 1)) \end{aligned} \qquad (2)$$

where, $\rho = \sqrt{\frac{L_1}{C_1}}$, $\varepsilon = \frac{C_2}{C_1}$, $k = 1 + \frac{R_1}{R_2}$, $b = \frac{\rho I_{R4}}{V_T}$,

$$c = \frac{\rho I_S}{V_T}$$

Using Simulink model, phase portraits of circuit are obtained as shown in Fig. 4.

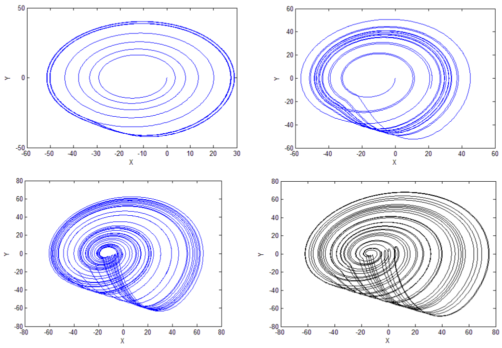

Fig. 4 Phase portraits of circuit *R=100, 220, 350, 600 ohm using Matlab*

Also, electronic circuit implementation of vilnius chaotic oscillator is realized and phase portrait of circuit are obtained by oscilloscope.

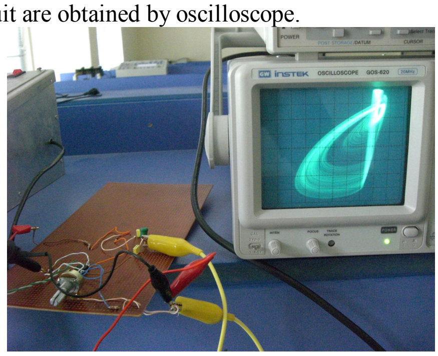

Fig.5 Electronic circuit experiment

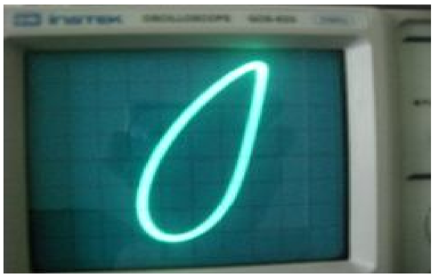

Fig.6. Phase portrait of system R=100 ohm- Limit cycle

3 Time delay feedback control of chaos in Vilnius chaotic oscillator

In this section, control of chaos in Vilnius oscillator is realized by using time delay feedback control theory. The controller [6] is designed based on time delay feedback control scheme in Eq 3.

$$u = K(x(t) - x(t-\tau)) \qquad (3)$$

Time delay feedback controller is applied to the Vilnius system as shown in Eq. 4

$$\begin{aligned} \dot{x} &= y + K(x(t) - x(t-\tau)) \\ \dot{y} &= \frac{(k-1)R_3}{\rho} y - x - z \\ \dot{z} &= \frac{1}{\varepsilon}(b + y - c(e^z - 1)) \end{aligned} \qquad (4)$$

Finally, phase portraits of controlled Vilnius circuit will be obtained.

References

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