CHAOS IN A NON-AUTONOMOUS INDUCTORLESS ACTIVE-RC CIRCUIT

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Chaotic performance of a simple inductorless active-RC non-autonomous electronic circuit is reported. The circuit uses two operational amplifiers, an operational transconductance amplifier, a diode, two resistors, and one capacitor only. No discrete inductors are involved.

INTRODUCTION

At present, there is a growing interest in studying non-autonomous electronic circuits exhibiting chaotic behavior [1–6]. A circuit is said to be non-autonomous if it is driven by an ac source. The circuit reported by Matsumoto et al. [1] is the simplest non-autonomous circuit that can become chaotic. It is formed of a linear resistor, a linear inductor and a non-linear capacitor. It appears, therefore, that use of an inductor is inevitable to obtain chaotic behavior in a non-linear electronic circuit.

On the other hand, inductance simulations using operational-amplifier-based active-RC realizations are very attractive for monolithic realization. This raises the question of whether it is feasible to obtain chaotic behavior from active-RC realizations using operational amplifiers and/or operational transconductance amplifiers, capacitors, and resistors only.

It is the objective of this paper to report experimental results showing that chaotic behavior can occur in an inductorless active-RC circuit.

PROPOSED CIRCUIT

The proposed circuit is shown in Fig. 1. A breadboard of the circuit was constructed using off-the-shelf components. The phase trajectory of V_B versus V_A was measured with an oscilloscope in the X-Y mode. The results, obtained with the component values shown in Fig. 1, are shown in Fig. 2. The circuit of Fig. 1 was derived by a 3300A Hewlett-Packard function generator with an output impedance of 600Ω . Fig. 2(a) shows the phase trajectory obtained with a square-wave input, Fig. 2(b) shows the phase trajectory obtained with a sinusoidal input, and Fig. 2(c) shows the phase trajectory obtained with a triangular input.

These observations confirm that the proposed inductorless active-RC circuit of Fig. 1 can provide chaotic performance by careful adjustment of the values of the resistances. It must be mentioned here that the two dc sources are simultaneously

FIGURE 1 Proposed inductorless nonautonomous chaotic circuit $R_1 = 2K$, $R_2 = 5K$, $R = 15\Omega$, $C = 1$ nF IC1 and IC2: 741 OA, IC3: 3080 OTA

used to supply the two operational amplifiers, as well as the operational transconductance amplifier.

In an attempt to explore the similarity between the proposed circuit of Fig. 1 and the Matsumoto et al. circuit [1], let the operational amplifiers and the operational transconductance amplifier be ideal. Routine analysis, assuming that $g_m R_1 = 1$, where g_m is the transconductance of the operational transconductance amplifier, shows that the input impedance between points X and Y of the circuit shown in Fig. 3 can be expressed as [7]

$$Z_{inp} = \frac{j\omega CR_1 R_2}{1 + j\omega CR_2} \quad (1)$$

This is equivalent to the impedance of a parallel $R_{eq} - L_{eq}$ circuit with

$$L_{eq} = CR_1 R_2 \quad (2)$$

and

$$R_{eq} = R_1 \quad (3)$$

Thus, the equivalent circuit of the proposed circuit of Fig. 1 can be represented by the circuit shown in Fig. 4. From Fig. 4 it appears that the similarity between the proposed circuit of Fig. 1 and Matsumoto et al. circuit [1] is very close.

CONCLUSION

In this paper, the experimental observations of the chaotic performance of an inductorless active-RC electronic circuit have been reported. This is probably the first attempt to obtain chaotic performance from a non-autonomous circuit without

FIGURE 2 Phase trajectories with (a) square wave input (b) sinusoidal input and (c) triangular input

FIGURE 3 Circuit used for inductor simulation $g_m R_1 = 1$.

FIGURE 4 Equivalent circuit of the proposed circuit shown in Fig. 1.

using discrete inductors. The similarity between the proposed circuit of Fig. 1 and the Matsumoto et al. [1] circuit has been illustrated assuming ideal models for the operational amplifiers and the operational transconductance amplifier.

Finally, it is worth mentioning that since the proposed circuit of Fig. 1 does not use any externally connected inductors, then its implementation in an integrated circuit form is feasible. This may be a useful step towards the integration of chaos-generating circuits in VLSI systems.

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