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Electrical implementation of a complete synchronization dynamic system

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Abstract: This work presents an electrical implementation of a complete synchronization system, proposing a master/slave synchronization of two identical particle-in-a-box electronic circuits, exhibiting a rich chaotic behavior. This behavior was experimentally observed, and also emulated. Just a few works in literature describe experimental measurements of chaotic systems.
keywords: Synchronization, chaotic circuit, particle-in-a-box circuit, phase synchronization.

1. INTRODUCTION

Synchronization between dynamical systems are being extensively explored in electronic circuits [1, 2].

There are many types of circuits with potential applications to generate chaotic signals, like Chua´s circuit [3], Lorenz-based chaotic circuit [4] and Pecora-Carroll synchronization and error-feedback synchronization [5].

Complete or full synchronization occurs when there is coincidence of states of two interacting subsystems, as:

$$x_d(t) = x_r(t) \qquad (1)$$

Although the great interest in chaotic systems, just a few works in the literature show also experimental realization of these systems [1]. The great advantage of this work is to employ simple chaotic and identical systems, exhibiting a rich chaotic behavior.

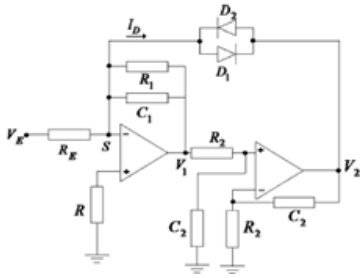
2. PURPOSE

The aim of this work is to realize a electrical implementation of a synchronization dynamic system, by using two identical dynamic subsystems, using a drive-response scheme proposed by Pecora-Carroll [5], analyzing its behavior, and comparing the experimental results with data simulation.

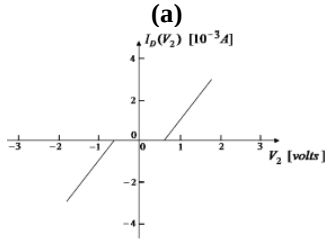
3. METHODS

The electronic circuit proposed emulates a particle-in-a-box mechanical system, described in [6].

The particle-in-a-box circuit is described on Figure 1(a). The key devices of this circuit are the anti-parallel diodes D_1 e D_2. They emulate the nonlinearity of this circuit The curve of current versus voltage of the anti-parallel diodes D_1 and D_2 is shown on Figure 1(b).



(a)



(b)

Figure 1 (a)– Particle-in-a-box circuit. The component values are: resistors ($k\Omega; R_1 = 47; R = R_E = R_2 = 10$), capacitors ($nF; C_1 = C_2 = 12$), diodes $D_1 = D_2 : 2N4148$, operational amplifiers 741 or equivalents; (b) current versus voltage curve of the anti-parallel diodes D_1 and D_2.

The particle-in-a-box electronic circuit has a sinusoidal input $V_E = V_{\max}\sin(\omega t)$, and the contribution of the currents in the point S, shown in Figure 1, results in the differential equation:

$$R_2 C_1 C_2 \frac{d^2 V_2}{dt^2} + \frac{R_2 C_2}{C_1}\frac{dV_2}{dt} + I_D(V_2) = -\frac{V_E}{R_E} \qquad (4)$$

The key devices of this circuit are the anti-parallel diodes D_1 and D_2. A master-slave configuration was proposed by using two identical systems according to the open-loop error feedback technique described in [5].

4. RESULTS

Experimental results of measurements taken from a particle-in-a-box circuit are shown. The periodic chaotic behavior can be obtained by the variation of the parameter frequency of the sinusoidal signal

$V_E = V_{\max}\sin(\omega t)$. Phase diagrams are shown on Figure 2.

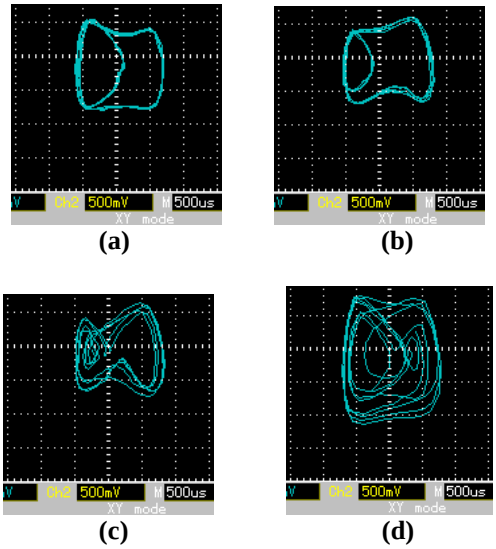


Figure 2–Phase diagrams of the particle-in-a-box circuit for the fixed amplitude 2V, and variable frequency as bifurcation parameter: (a)Period 1- $f = 958Hz$; (b) Period 2- $f = 963Hz$;(c) Period 4- $f = 965Hz$;(d) Chaos- $f = 1096Hz$, scale: 500mV/div, time scale:500µs.

The chaotic output signals V_2 were taken from a digital oscilloscope and then analyzed. It was observed complete synchronism analyzing data between output signals of drive and response subsystems as shown on Figure 3.

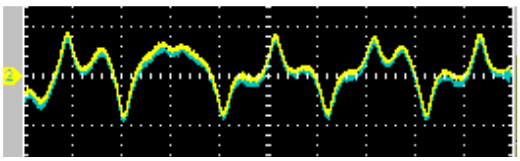


Figure 3– Complete synchronism exhibited between output signals of drive and response subsystems. scale: 1V/div, time scale:500µs.

As shown on Figure 4, the phase diagram of output signals exhibits a identity, as described by equation (1).

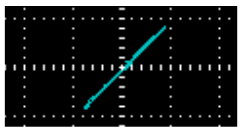


Figure 4– Phase diagram exhibited between output signals of drive and response subsystems; scale: 1V/div, time scale:500µs

Simulated results of synchronization between chaotic drive and response subsystems using similar parameters of experimental conditions are shown in this section. Figure 5 exhibits the results obtained from numerical simulation of the complete synchronization regime between output signals of drive and response subsystems.

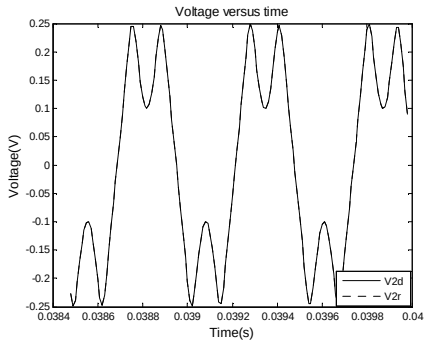


Figure 5– Numerical simulation of synchronism between output signals of drive and response subsystems.

5. DISCUSSION

Experimental results demonstrate the chaotic behavior of the system in complete synchronization regime. Figure 2 shows phase diagrams of the particle-in-a-box circuit for the fixed amplitude 2V, and variable frequency as bifurcation parameter. Figures 3 and 4 show complete synchronism regime exhibited by the system. Numerical results are in agreement with experimental results, as shown on Figure 5.

6. CONCLUSION

It may be concluded that numerical simulation results show agreement with experimental results. As shown, complete synchronization regime is observed.

ACKNOWLEDGMENTS

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