SIMPLE CHAOS GENERATOR WITH ROBUST OPERATION

Victor Cojocaru[1], Horia-Nicolai Teodorescu[2]
[1]D. Ghitu Institute of the Electronic Engineering and Nanotechnologies of the Academy of Sciences of Moldova, Chisinau, Moldova
[2] Faculty of Electronics, Telecommunications and Information Technology,
'Gheorghe Asachi' Technical University of Iasi, Romania
Institute of Computer Science of the Romanian Academy, Iasi, Romania
vcojocaru@nano.asm.md, hteodor@etti.tuiasi.ro

Abstract. *We describe a simple chaos generator circuit build based on the LM555 timer. This simple circuit can be assembled on a test board shortly. The circuit can be used for studying the processes related to nonlinear dynamics and to perform various measurements.*

Keywords: *Chaos, electronic circuit, nonlinearity, 555 timer* .

I. Introduction

The chaotic dynamics is the complex non-periodic movement being generated by the non-linear systems. This kind of movement can occur in the absence of the external noise and is completely determined by the properties of the dynamic deterministic systems [1-3]. In this paper, we study a simple chaotic dynamic generator realized using the E555 timer [4] and low tolerance components.

A good instrument used to characterize the chaotic regime is the phase portrait which consists in the graphical representation of the internal state of a system towards another. The phase diagram is easy interpretable applying the signals at X respectively Y inputs of the oscilloscope. The phase diagram method is a graphical-analytical method used to study the dynamic systems with the equations having the form:

$$\frac{dx}{dt} = P(x,y), \ \frac{dy}{dt} = Q(x,y),$$

where x and y are the system variables, $P(x,y)$, $Q(x,y)$ and – functions that meet the conditions of existence of the solutions, t – the time, as independent variable [5, 6].

The systems behavior can be represented on a rectangular plan in Cartesian coordinates. In this representation each state of a dynamic system corresponds to a point of the x and y coordinates plan and reverse, for each point of the plan corresponds to a state of the studied system. The $Q(x,y)$ is named phase plane. The change of the studied system state is displayed on the phase plan through displacement of a point, named phase point. The point movement trajectory is named phase trajectory, the direction and the velocity are determined by the phase vector. Is essential that each point from the phase plan is a phase trajectory only. The phase trajectories set is named portrait phase of the system and display all the combinations and the types of the possible system movements. In the phase plane are usually three types of the phase trajectories: singular points or equilibrium position determined by solving the equations system.

$$P(x,y)=0 \quad Q(x,y)=0$$

Closed isolated trajectories corresponding to periodic movement in the system, separated, that divided the phase plan in zones with different types of trajectories. The phase plan method is used to build a phase portrait of the system and to analyze later this portrait. The method is proper to determine the number, the types and the nature of the singular points, the closed and isolated orbits of the points, and make possible viewing all the movements set that occur in a dynamic system for all initial possible conditions. The singular points are classified function by the nature of the phase trajectories in their vicinity. The isolated closed trajectories (limited cycles) are classified function by the nature of their stability [7-10].

II. Circuit

The diagram of the circuit is shown in Fig. 1. The circuits consist in two tightly coupled oscillators based on the venerable 555 [4]. The couplings are nonlinear and consist in the diodes D1 and D2 and one of the couplings a first inter filter. One of the couplings relates in a nonlinear manner the two periods through the diode D_1, while the other emphasizes the higher frequencies through the circuit R_1C_1. The value of the capacitance C_1 is important in providing the right frequency coupling of the output of IC_1 to the charging circuit of IC_2 thus favoring the chaotic behavior.

The two outputs are not alike, as illustrated in Fig. 2 and Fig. 3, left panel. A typical graphical tool for characterizing the chaotic regime is the phase plot, which consists in the graphical representation of one internal state of the system with respect to another one. In the phase plot diagram, the time is suppressed, as one state evolution is a function of the other state evolution during time.

Here, the two states are chosen to be the outputs of the two 555 timers, denoted by O_1 ands O_2 in Fig. 1. Subsequently, the phase plot corresponds to the output O_2 as a function of the output

O_1. The phase plot is easily displayed as the XY view on an oscilloscope, assigning to the oscilloscope inputs $X = O_2, Y = O_1$.

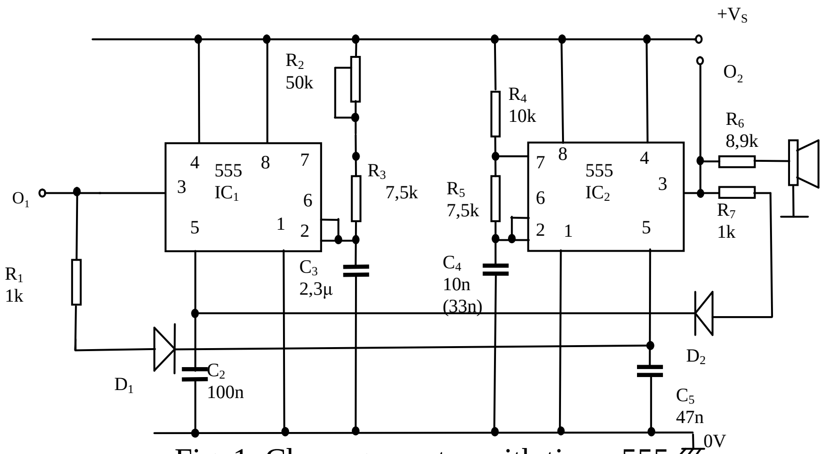

Fig. 1. Chaos generator with timer 555.

Examples of phase plots are shown in Fig. 3 (right panel), for $V_{cc} = 15V$, in Fig. 4 (right), for $V_{cc} = 16V$, and in Fig. 5 (right), for $V_{cc} = 18{,}5V$, for the circuit in Fig. 1. These plots demonstrate that the circuit behavior is strongly influenced by the power supply voltage. At $V_{cc} < 13V$, the behavior correspondents to a periodic oscillator. The interesting operation V_{cc}-region is between $13V$ and $18V$.

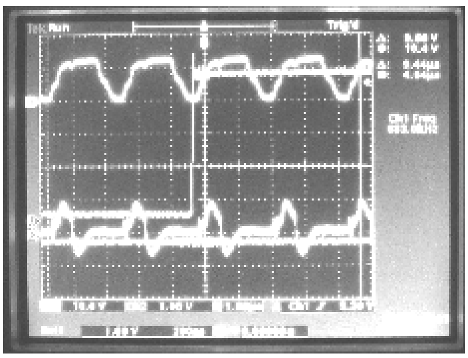

Fig. 2. Signals O_1 and O_2, for $V_{cc} = 13.5V$, with the values of the components shown in. Fig. 1

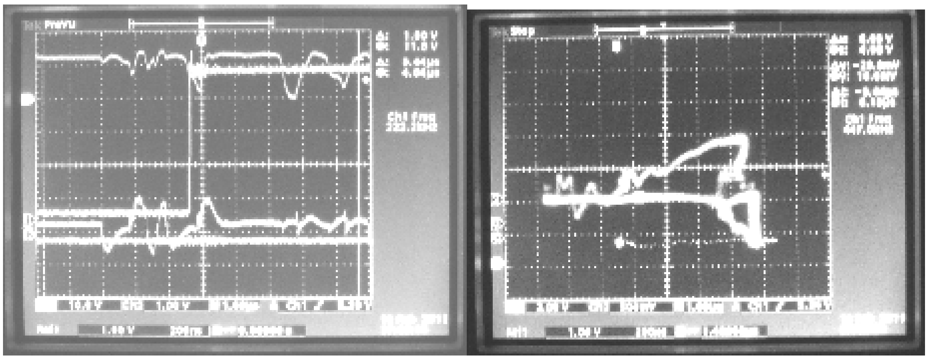

Fig. 3. Signals O_1 and O_2, for $V_{cc} = 15V$, (left), and the corresponding phase plot (right)

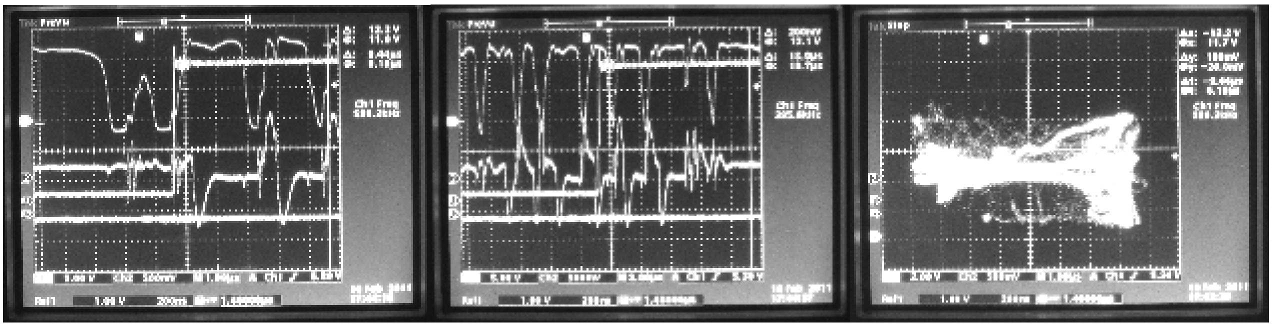

Fig. 4. Two screenshots with the outputs O_1 and O_2 (left and middle) and phase plot (right), for $V_{cc} = 16V$

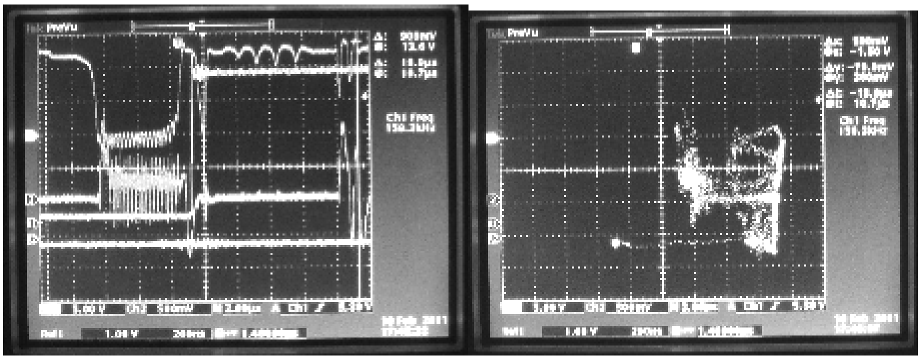

Fig. 5. Signals O_1 and O_2 (left) and phase plot (right), for $V_{cc} = 18.5V$

III. Conclusion

The circuit constitutes an easy to build example of chaotic system based on relaxation circuit and can be assembled in class by students in less than 10 minutes on a breadboard. The operation is stable because this circuit is less plagued, as many chaotic circuits are, by high sensitivity to the component tolerances. Thus, the circuit is a good choice for introducing chaotic circuits operation, chaotic behavior and methods of chaos characterization to students, even for vividly immersing K12 students into chaos and nonlinear dynamics concepts, through teaching by investigation, experimenting and active engagement. The circuit can be also used in a variety of applications, including audio noise effects.

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Authors' contributions

The circuit was proposed by the second author who also carried out the planning of the work and the method of analysis and implementation. The first author implemented and simulated the circuits under the supervision and with the support of the first author.

IV. References

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