High frequency chaotic behavior in non-ideal operational amplifiers

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Abstract. The possibility of designing electronic circuits to intentionally produce a chaotic behavior is a well-known topic in nonlinear dynamics. It is also well-known that non-ideal electronic devices display unmodelled nonlinear dynamic behaviors due to intrinsic imperfections linked to the manufacturing processes, leading to parasitic dynamics. In this paper, we explore the non-ideal behavior of integrated operational amplifiers which produces an high frequency chaotic flow whose characteristic can be tuned by means of a single variable resistor, acting as bifurcation parameter.

Introduction

The simplest ideal electronic systems capable of generating chaos must encompass three memory element and a nonlinear device. The nonlinear device can be a diode, and the nonlinearity of the parasitic capacitance of the diode determines the occurrence of chaos [1]. A consideration can be performed on the basis of this standard example: chaotic behaviour and nonlinear dynamics arise thanks to an imperfection in the diode manufacturing process. Therefore, if on the one hand, parasitic nonlinearities represent an element of deterioration for the device, on the other it enhances its characteristics, enriching its dynamics and manifesting behaviours that would otherwise not be observable.

In the following, we want to examine a simple electronic circuit made with a single high-speed voltage comparator, in which imperfections, with respect to the ideal model of this component, allow to manifest an high frequency chaotic behaviour.

Results and discussion

A voltage comparator is an electronic circuit that compares two input voltages and identifies the greater. A voltage comparator can be realized by using standard off-the-shelf operational amplifiers. The chaotic circuit proposed in this contribution is realized by designing a voltage comparator circuit using a LM311p high speed differential comparator. The circuit used for our experiment is shown in Fig. 1(a). It consists, besides the integrated device, only in standard resistors and a single variable resistor. The supply voltage is fixed at the values $V_{cc}^{+} = 9.98$V and $V_{cc}^{-} = -3.99$V.

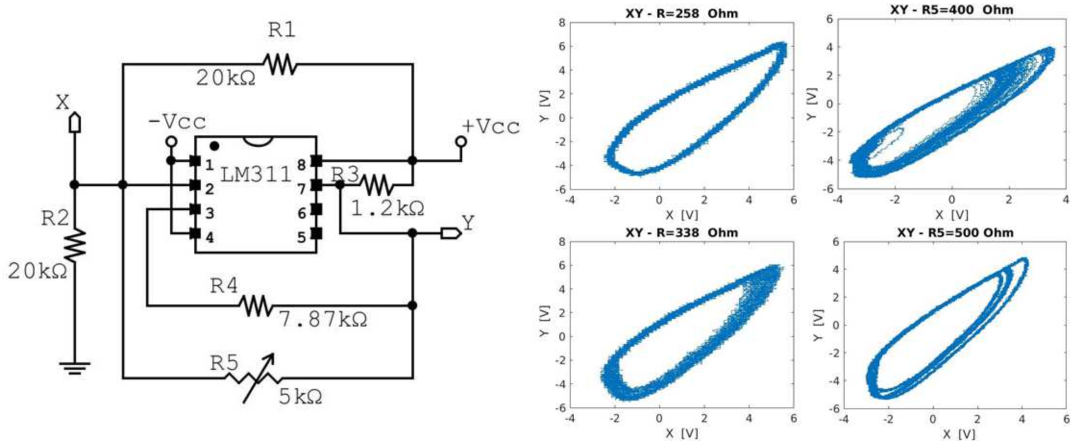

Figure 1: Schematic the electronic circuit based on a high speed voltage comparator LM311p (left). Nonlinear dynamical behaviors observed for different values of $R5$ (right).

Nonlinear dynamical behaviors are investigated varying the value of $R5$. We acquired the temporal evolution of the voltages in the points labeled in Fig. 1(a) by using a digital storage oscilloscope at a sampling frequency of $1MHz$. Typical examples of the chaotic behaviors of examined circuit are displayed in Fig. 1(b).

The graphical results immediately highlight the emergence of chaotic dynamics in the circuit as the value of $R5$ changes. The fundamental conceptual difference of the circuit under consideration with respect to other simple chaos generators must still be underlined, in fact in our circuit the complex dynamics emerge from the imperfections of the active device. It is these imperfections that bring out dynamics that would otherwise remain latent, enriching the collection of possible behaviours.

References

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[2] Yim, G.S., Ryu, J.W., Park, Y.J., Rim, S., Lee, S.Y., Kye, W.H. and Kim, C.M., 2004. Chaotic behaviors of operational amplifiers. Physical Review E, 69(4), p.045201.