2008 International Symposium on Nonlinear Theory and its Applications
NOLTA'08, Budapest, Hungary, September 7-10, 2008

A Fully-Differential Multi-Hysteresis Two-Port VCCS Chaotic Oscillator Integrated Circuit

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Abstract—We propose a chaotic oscillator based on multi-hysteresis two-port voltage-controlled current sources (2P-VCCSs). In particular, we propose a novel method to obtain a multi-hysteresis VCCS with multiple switching points in its hysteresis characteristic. The proposed chaotic oscillator can have a complex chaotic attractors with many switching points. Moreover, we propose a fully-differential integrated circuit technique that implements the proposed multi-hysteresis VCCS. We also implement a fully-differential 2P-VCCS chaotic oscillator circuit using the multi-hysteresis VCCS circuits. With these circuits, we can obtain a variety of chaotic dynamics by modifying hysteresis characteristics through the external control voltages. We make a prototype integrated circuit for the proposed chaotic oscillator with TSMC 0.35 μm CMOS semiconductor process. Through SPICE simulations and measurements on the prototype chip, we confirm a variety of dynamics from the proposed circuit.

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1. Introduction

A chaotic oscillator based on two-port voltage-controlled-current-sources (2P-VCCSs) has been proposed, and rigorously analyzed with a piecewise-linear technique [1]–[4]. The circuit is suitable for an implementation as an integrated circuit, because it includes no bulky inductors. On the other hand, multi-hysteresis chaotic circuits have been proposed [5, 6].

We have proposed a hysteresis 2P-VCCS chaotic integrated circuit [7, 8]. We then extended the proposed circuit to a compact fully-differential configuration, which has advantages over its single-ended counterpart such as a large dynamic range, low common-mode noise, and less even-oder harmonic distortions [9]. We have fabricated prototype chips for theses circuits with TSMC 0.35 μm CMOS semiconductor process [8, 9]. We have observed a variety of interesting dynamics including a quad-screw attractor from the prototype chip.

In this paper, we further extend the original 2P-VCCS chaotic oscillator to have a multi-hysteresis characteristic.

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2. Multi-Hysteresis VCCS Circuit

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Figure 1: (a) A configuration of a multi-hysteresis VCCS circuit, and (b) the v_{id}-i_{Oi} characteristic of constituent single-hysteresis VCCS circuits (E_i: threshold voltages, I_i: saturation currents, and $1 \leq i \leq n$).

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Figure 2: (a) Three constituent single-hysteresis VCCS characteristics, and (b) the resulting multi-hysteresis VCCS characteristic.

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3. Multi-Hysteresis 2P-VCCS Chaotic Oscillator

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Figure 3: The multi-hysteresis 2P-VCCS chaotic oscillator. The single-ended configuration is shown for simplicity.

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Figure 4: The horizontal screw attractor when we use the multi-hysteresis characteristic of Fig. 2. ($\pm E_1 = \pm 0.1$, $\pm E_2 = \pm 0.7$, $\pm E_3 = \pm 1$, $\pm I_1 = \pm 0.2$, $\pm I_2 = \pm 0.6$, $\pm I_3 = \pm 0.2$).

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Figure 5: (a) The fully-differential multi-hysteresis VCCS circuit, and (b) the single-hysteresis circuit used in (a).

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Figure 6: The fully-differential linear VCCS circuit.

4. Integrated Circuit for Multi-Hysteresis 2P-VCCS Chaotic Oscillator

We implement the circuit in Fig. 3 into a fully-differential integrated circuit form using the technique proposed in [9].

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The prototype integrated circuit was fabricated through TSMC 0.35 μm CMOS semiconductor process with power supply voltages of $V_{DD} = 2.5$ V and $V_{SS} = -2.5$. The

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Figure 7: The schematic of the fully-differential multi-hysteresis 2P-VCCS chaotic oscillator implemented in the prototype chip.

photomicrograph of the prototype chip is shown in Fig. 8. The size of the circuit is 460 μm $\times$ 820 μm where the two capacitors take most of the chip area.

5. Simulation and Experimental Results

The SPICE simulation and experimental results for the multi-hysteresis characteristics, when we set V_{he1}=0.9 V, V_{he2}=1.3 V, V_{he3}=1.3 V, and V_{hi}=1.2 V in Fig. 5, are shown in Fig. 9.

Furthermore, circuit simulation and experimental results on the prototype chip for sextuple-screw attractors are compared in Fig. 10.

6. Conclusions

We have proposed the multi-hysteresis VCCS circuit which can have many switching points and routes in its hysteresis characteristic. Furthermore, we have proposed the multi-hysteresis 2P-VCCS chaotic oscillator circuit, and its fully-differential integrated circuit implementation. The prototype chip has been fabricated through TSMC 0.35 μm CMOS semiconductor process. As a result, we experimentally observed hysteresis characteristics and chaotic attrac-

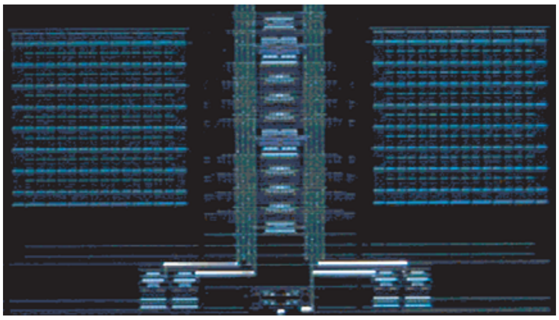

Figure 8: The photomicrograph of the prototype chip.

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Figure 9: The i_o-v_{id} characteristics of the multi-hysteresis VCCS circuit obtained from (a) SPICE simulation, and (b) measurement on the prototype chip.

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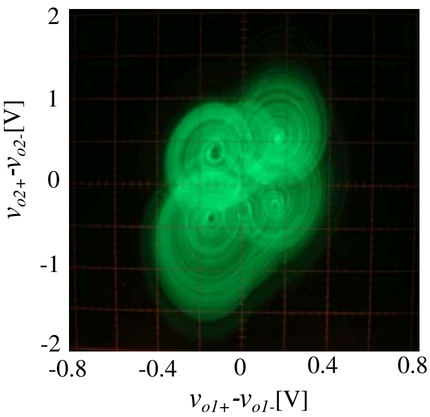
(a)



(b)

Figure 10: Sextuple-screw attractors obtained from (a) SPICE simulation, and (b) measurement on the prototype chip.

tors compatible to those obtained from the SPICE simulations.

Acknowledgments

This work was supported in part by Grant-in-Aid no. 20300085 from the Ministry of Education, Culture, Sports, Science and Technology, Japan. This work was also supported by VLSI Design and Education Center (VDEC), the University of Tokyo with the collaboration with Cadence Corporation.

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