INDUCTORLESS REALISATION OF MIXED-MODE CHAOTIC CIRCUIT

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ABSTRACT

Central to this study is inductorless realisation of mixed-mode chaotic circuit using FTFN-based inductance simulator. FTFN-based topology used in this realisation enables to simulate of ideal floating and grounded inductance in the mixed-mode chaotic circuit. This modification provides an alternative solution to integration problem of not only mixed-mode chaotic circuit but also other chaotic circuits in the literature using CMOS VLSI technologies.

I. INTRODUCTION

Up to now, a variety of autonomous and nonautonomous chaotic circuits which can be effectively used in chaotic secure communication systems have been designed and described in the literature; see for example [1-5] and references therein. Chaotic circuits for use in chaotic secure communication systems must not only have a simple design but also a structure that is able to provide greater reliability in the form of a wide range of parameter variations and extra security keys. Mixed-mode chaotic circuit [6] has such a chaotic circuit structure. Mixed-mode chaotic circuit exhibits both autonomous and nonautonomous chaotic dynamics via switching method. This circuit's structure is extremely simple and it contains only one nonlinear resistor. In addition to the wide range of autonomous and nonautonomous chaotic circuit parameters, the switching method, which changes the chaotic dynamics of the circuit from autonomous to nonautonomous mode, can be used an extra security key in chaotic communication systems. Details of such an application of mixed-mode chaotic circuit to chaotic communications for transmission of analog signals can be found in [7].

Inductorless realisation of chaotic circuits greatly facilities the experimental studies based on these circuits. This also enables the implementation of low cost, reliable, accurate and compact chaotic systems as integrated circuits. Such integrated circuits could be readily used in many chaos-based secure communication systems. Recently, several inductor-free realisations of chaotic circuits have been proposed [8-10]. These studies especially deals with the inductorless realisation of autonomous Chua's circuit [11]. Instead of inductor element, active inductance simulators have been used in these circuit structures and in generally as active element, Op-Amp and OTA-based building blocks are preferred.

On the other hand, the four terminal floating nullor (FTFN) has been also receiving considerable attention recently as it has been shown that an FTFN is very flexible and versatile building block in active network synthesis [12]. This leads to growing attention in design of amplifiers, gyrators, inductance simulators, oscillators and filters which use FTFN as an active element [13-15].

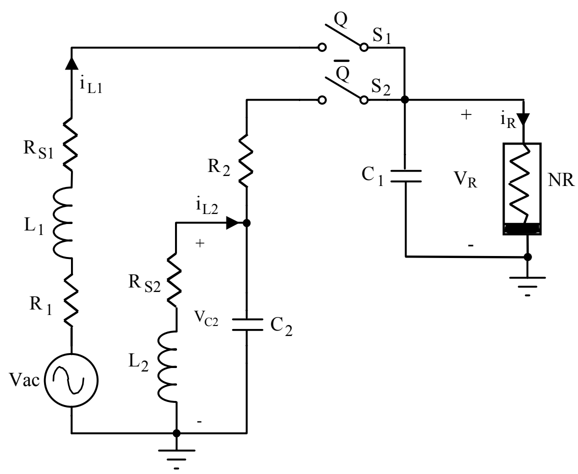


Fig.1 Mixed-mode chaotic circuit.

In this work, the considered major improvement was the inductorless realisation of mixed-mode chaotic circuit. For this purpose, instead of inductor elements in mixed-mode chaotic circuit, FTFN –based inductance simulators have been used. This FTFN-based topology enables to simulate of ideal floating inductance and ideal grounded inductance in mixed-mode chaotic circuit. This improvement provides an alternative solution to integration problem of not only mixed-mode chaotic circuit but also other chaotic circuits in the literature using CMOS VLSI technologies.

II. CIRCUIT DESCRIPTION OF INDUCTORLESS MIXED-MODE CHAOTIC CIRCUIT

Original mixed-mode chaotic circuit is shown in Fig.1. Mixed-mode chaotic circuit exhibits both autonomous and nonautonomous chaotic circuit dynamics. In design of mixed-mode chaotic circuit, common dynamics of autonomous Chua's circuit [11] and a nonautonomous MLC circuit [16] were combined using a switching method [6]. In this way depending on the states of the switches, mixed-mode chaotic circuit operates either in the chaotic regime determined by autonomous circuit part or in the chaotic regime determined by nonautonomous circuit part.

When the states of switches are S1-ON and S2-OFF, we have the standard nonutonomous chaotic circuit described in [16] exhibiting a double-scroll chaotic attractor. In this case, the circuit is represented by the following set of two first-order nonautonomous differential equations:

$$C_1 \frac{dV_R}{dt} = i_{L1} - f\,(V_R) \tag{1}$$

$$L_1 \frac{di_{L1}}{dt} = -i_{L1}\,(R_1 + R_{S1}) - V_R + A \sin\,(wt) \tag{2}$$

where (A) is the amplitude and (w) is the angular frequency of the external periodic force V_{ac} in Fig.1. The amplitude of the external forcing source can be used as the bifurcation parameter. By increasing the amplitude (A) from zero upwards, the circuit exhibits the complex dynamics of bifurcation and chaos.

When the states of switches are S1-OFF and S2-ON, we have the standard autonomous Chua's circuit [11] exhibiting a double-scroll Chua's chaotic attractor. In this case, the circuit is described the following set of three first-order autonomous differential equations:

$$L_2 \frac{di_{L2}}{dt} = -V_{C2} - i_{L2} \cdot R_{S2} \tag{3}$$

$$C_2 \frac{dV_{C2}}{dt} = i_{L2} - \frac{1}{R_2}\,(V_{C2} - V_R) \tag{4}$$

$$C_1 \frac{dV_R}{dt} = \frac{1}{R_2}(V_{C2} - V_R) - f\,(V_R) \tag{5}$$

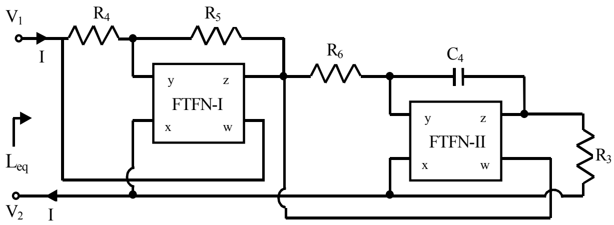


Fig.2 FTFN-based inductance simulator.

By reducing the variable resistor R_2 in Fig.1 from 2000 Ω towards zero, the circuit exhibits the autonomous complex dynamics of bifurcation and chaos. In the original structure of mixed-mode chaotic circuit, the circuit realisation in [17] was used for nonlinear resistor and its i-v characteristic is follow:

$$i_R = f\,(V_R) = G_b V_R + 0.5 \cdot (G_a - G_b) \times \left(\left| V_R + B_p \right| - \left| V_R - B_p \right|\right) \tag{6}$$

where the actual values of G_a , G_b and B_p are -0.76 mS, -0.41 mS and 1.0 V, respectively.

In the new realisation of mixed-mode chaotic circuit, as a major improvement, FTFN-based inductance simulators are used instead of flaoting inductance L_1 and grounded inductance L_2 in Fig.1. FTFN-based floating inductance simulator is shown in Figure 2. Routine analysis yields equalivent inductance between terminals 1 and 2 as;

$$L_{eq} = \frac{C_4 R_3 R_4 R_6}{R_5} \tag{7}$$

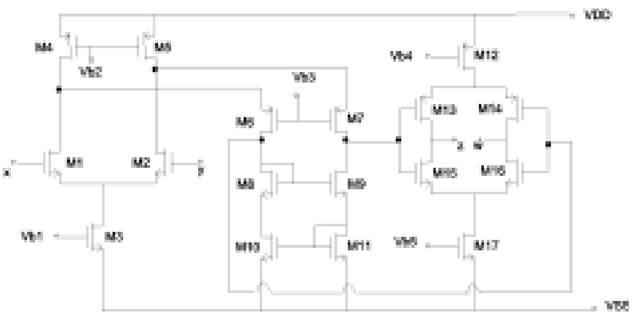
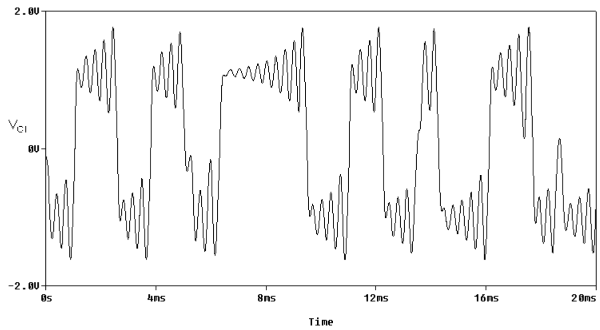


Fig.3 A CMOS realisation of the FTFN.

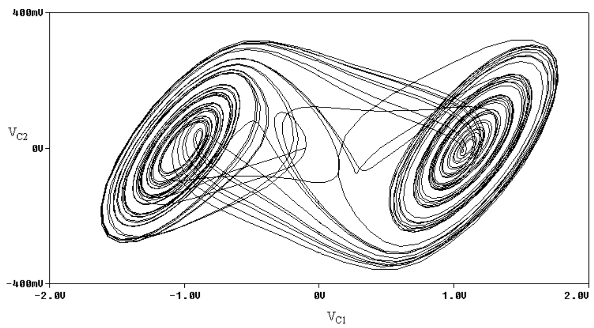
In Figure 2, the following element values are chosen: R_3=R_4=R_5=R_6=1KΩ, C_4=18nF to simulate L_1=L_2=18mH. Floating inductance is also used as grounded inductor by connecting one port of the floating inductance to ground for simplicity. The PSpice simulations were performed using a CMOS realisation of FTFN, shown in Fig.3, in literature with same parameters [15].

III. SIMULATION RESULTS

For the PSpice simulations, in addition to above arrangement of FTFN-based inductance simulator for ideal floating inductance L_1 (18 mH) and ideal grounded inductance L_2 (18 mH) , we fixed the other circuit parameters in Fig.1 as C_1=10 nF, C_2=100 nF, R_1=1340 Ω, R_2=1700 Ω, R_{S1}=12.5 Ω, R_{S2}=12.5 Ω, A=0.1V and frequency of the external forcing source is 8890 Hz for which the circuit exhibit double-scroll chaotic behaviour.



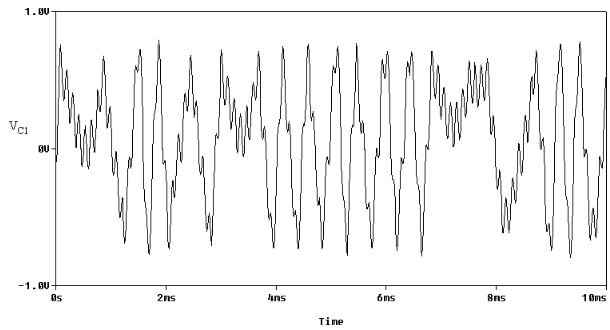
(a)



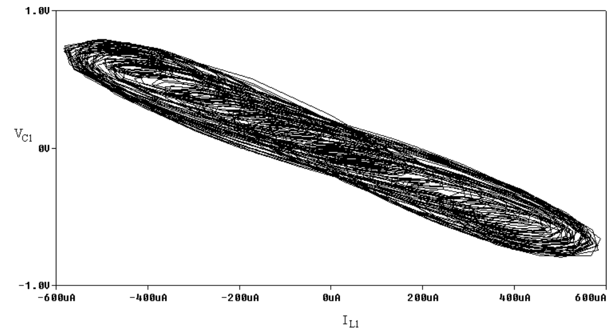
(b)

Fig.4 When inductorless mixed-mode chaotic circuit oscillates in autonomous mode (S1-Off, S2-On), (a) the chaotic waveform of the voltage across capacitor C_1 in Fig.1, and (b) double-scroll chaotic attractor.

While inductorless mixed-mode chaotic circuit's autonomous (S1-OFF, S2-ON) chaotic waveform and double-scroll attractor are illustrated in Fig.4, inductorless mixed-mode chaotic circuit's nonautonomous (S1-ON, S2-OFF) chaotic waveform and double-scroll attractor are illustrated in Fig.5.



(a)



(b)

Fig.5 When inductorless mixed-mode chaotic circuit oscillates in nonautonomous mode (S1-On, S2-Off), (a) the chaotic waveform of the voltage across capacitor C_1 in Fig.1, and (b) double-scroll chaotic attractor.

IV.CONCLUSION

Inductorless realisation of mixed-mode chaotic circuit using FTFN-based inductance simulator has been introduced. The simulation results indicate that inductorless mixed-mode chaotic circuit using FTFN topology exhibit its original chaotic behaviors. The CMOS implementation of mixed-mode chaotic circuit using FTFN-based inductance simulators provides new possibilities to the designer for the integrated circuit realisation of chaotic communication systems.

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