Chaos Control
in The Smallest Transistor-Based Chaotic Circuit

التحكم بالفوضى في أصغر دائرة ترانزستور فوضوية

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Abstract:-

In this paper, the so-called smallest nonautonomous chaotic circuit introduced by Lindberg-Murali-Tamasevicius (LMT) [1], is considered. Basically it is containing a single transistor, two resistors, and two capacitors. This circuit exhibits different dynamics behaviour (different period limit cycles, period-doubling bifurcation route to chaos, chaos). The possibility of controlling of chaos by adding a further sinusoidal signal generator is demonstrated. Measurements and Orcad-SPICE simulation are presented.

I. Introduction

Chaos originates from nonlinear interactions in a system and it is very sensitive to the system configuration and initial conditions. Tiny variations of these parameters result in great changes in chaotic signals [2,3]. A great deal of research, both theoretical and experimental, has been performed on nonlinear electronic circuits. This is because; nonlinear electric circuits provide a convenient framework for undertaking a systematic exploration of mechanisms underlying the onset of chaos. Nonlinear oscillators and electronic circuits subjected to periodic forcing can produce different behaviours like periodicity and period-doubling bifurcation route to chaos[4-6].

From a practical point of view, it is often desired to control chaotic circuits tosome intended periodic oscillations. One of the most surprising applications of chaos theory is the possibility of mastering the dynamics of nonlinear systems from chaos to order (chaos control), or reversely from order to chaos (chaos anticontrol). Chaos in control systems and controlling chaos in dynamical systems have both attracted increasing attention recent years.The effect of an additional periodic forcing on such chaotic oscillators and circuits results in variety of dynamical behaviour including the possibility of controlling chaos [7-11].

In this paper, The smallest nonautomous Lindberg-Murali-Tamasevicius (LMT) chaotic circuit is considered. Orcad-SPICE simulation and experimental verification show that circuit exhibits period- doubling route to chaos which is interspersed with periodicity. Experimental results have shown that the chaotic attractor can be controlled to periodic oscillation by introducing an additional sinusoidal signal. It has been observed that the chaotic dynamics is considerably suppressed or enhanced with the amplitude and the frequency of the additional sinusoidal signal.

The paper is organized as follows. In section II, the dynamics of the LMT circuit with the help of Orcad-SPICE simulation and experiments are identified. Experimental observations of controlling chaos by introducing additional sinusoidal signal are described in section III. The conclusion is given in section IV.

II. Rout to Chaos

Fig.1, shows the scheme of the LMT chaotic circuit of a single transistor. Here R1, R2, C1, and C2 are all linear passive components. The nonlinearity is provided by a single transistor. In this paper, an additional sinusoidal signal $f(t)$ is included in series with the existing sinusoidal source V_s, as shown in Fig.1. In the absence of the additional signal ($f(t)$=0), the mechanism of operation is referred as the disturbance of charging of a capacitor or "disturbance of integration". The capacitor C2 is charged through R2. The large value of R2 allows to keep constant charging current into C2. When the base voltage V_b of the transistor Q reach approximately 0.65V the transistor switches ON, the collector current becomes large positive, and it causes a short circuit on the capacitor C2. The disturbance of integration occurs because of the oscillation at the collector terminal of the transistor that is connected to the R1C1 series circuit and the sinusoidal source V_s [1,12].

Fig. 2(a-d) reports the Orcad-SPICE simulation results for the given parameter values, the data have been plotted by using Matlab. The temporal waveforms of the collector current and the collector voltage $V_c$are shown in Fig.2(a) and (b), respectively. Notice that, in the selected time range, the collector current is negative and the base voltage is increasing

regularly. When the base voltage reaches approximately 0.65 V, the transistor switches ON and the collector current becomes a large positive and then assumes a large negative value. Fig.2(c) and (d) show the phase portrait of the collector voltage V_c with respect to the collector current and the base voltageV_b, respectively.

In the experimental setup, the LMT circuit shown in Fig.1 has been employed. The circuit is implemented by using discrete component boards. The values of circuit elements are R1=10kΩ, R2=1MΩ, C1=C2=1.1nF, and V_s=6.4sin(2πf t). The dynamics behaviour of LMT circuit is observed by choosing the frequency f as the control parameter for controlling the transition from periodicity to chaos at a fixed amplitude.The circuit exhibits different dynamics oscillations (periodic or chaotic) by an appropriate selection of f. Fig.3(a-h), depict the bifurcation sequence with respect to the frequency f, thephase portraits of the collector voltage V_c versus the base voltage V_b are observed experimentally. Periodic orbits with different periods and chaotic attractors are observed. Note that from these oscilloscope pictures there is a period–doubling routeto chaos. The oscillation becomes period-1 for the value of frequency$f$ = 0.9 kHz as shown in Fig.3(a), while Fig. 3(b)

and (c) show the period-2 (f =1.4 kHz) and period-4 (f =1.7 kHz), respectively.

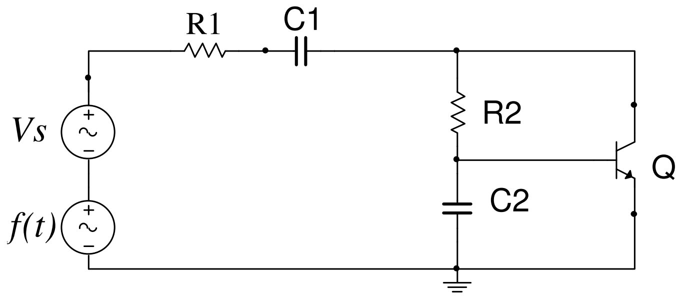
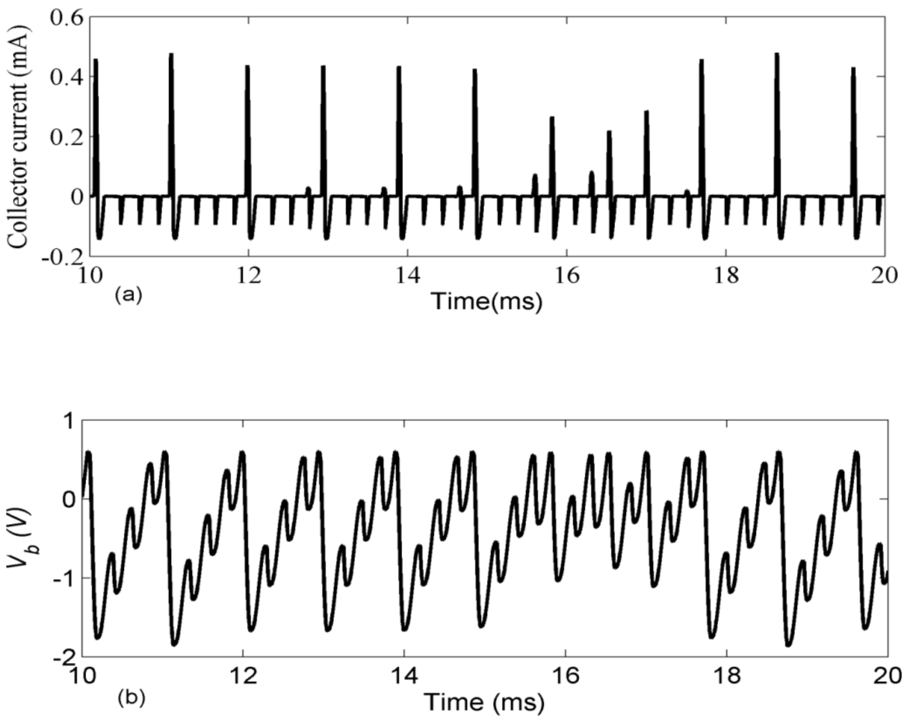


Fig. 1. Schematic diagram of the LMT chaotic circuit supplemented with additional sinusoidal signal $f(t)$. Q is a 2N2222 transistor.



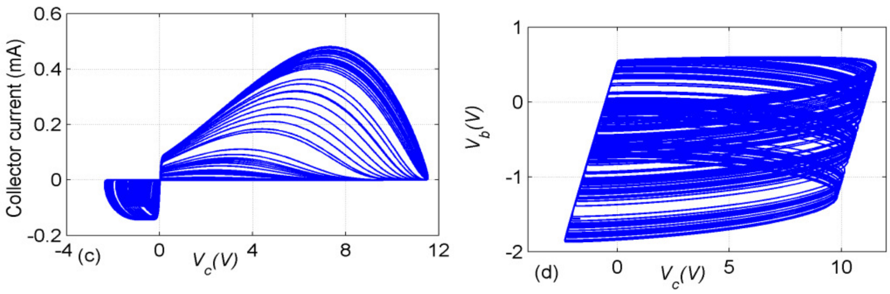


Fig. 2.SPICE simulation results. (a) and (b) temporal waveforms of the collector current and the base voltage V_b of the transistor, respectively. (c) and (d)phase portrait of the collector voltage V_c versus the collector current and V_b, respectively. R1=1 kΩ, R2=1 MΩ, C1=C2= 1.1 nF, and V_s=6.4sin(2πf t): f=4.2 kHz.

The transition from periodicity tochaos, mainly, follows period-doubling bifurcation, the chaotic attractors is observed near the value of frequency f=2.2 kHz as shown in Fig.3(d).

The periodic oscillations interspersed the chaotic oscillations,therefore the transition reversal from chaos to periodicity is observed when slowly increasing the value of frequency f. Fig.3(e)-(g) reveal that the period–three doubling bifurcation route to chaos, period-3 and period-6 oscillations appear at f = 2.79 kHz and f =3.2 kHz as shown in Fig.3(e) and (f), respectively. The further increasing of the value of the frequency f, leads to chaotic oscillations observed at f=4.2 kHz as shown in Fig.3(g). Moreover, Fig.3(h) depicts the period-3 limit cycle obtained at the value of f = 8 .2 kHz. Notice that the circuit shows the chaotic oscillations but with intermediate periodic oscillations.

III. CHAOS CONTROL

The method under consideration to control of chaos in LMT circuit is based on introducing of additional sinusoidal signal $f(t) = Fsin(2\pi v\, t)$ in series with original source. The applied of harmonic perturbation is used to control chaos. The additional sinusoidal signal acts as a control signal that has a different amplitude and frequency from the original signal. Initially, the amplitude and the frequency of original source are fixed at the values 6.4V and f=5 kHz, respectively. For such choice of the parameters, in the absence of the additional

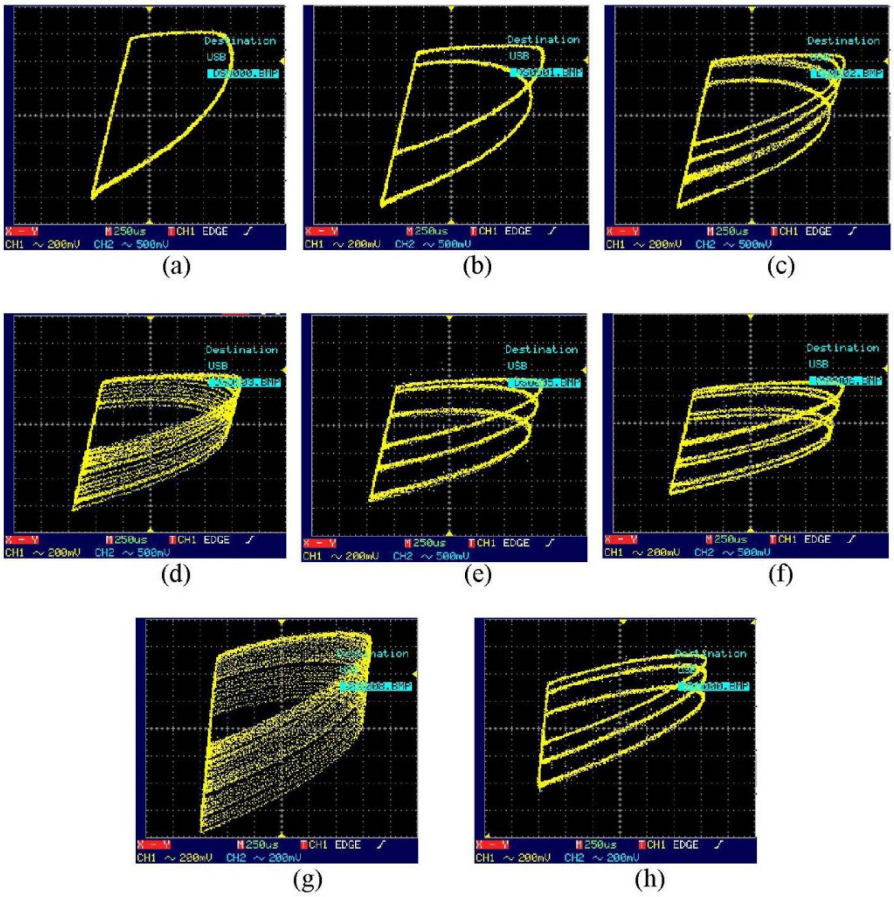


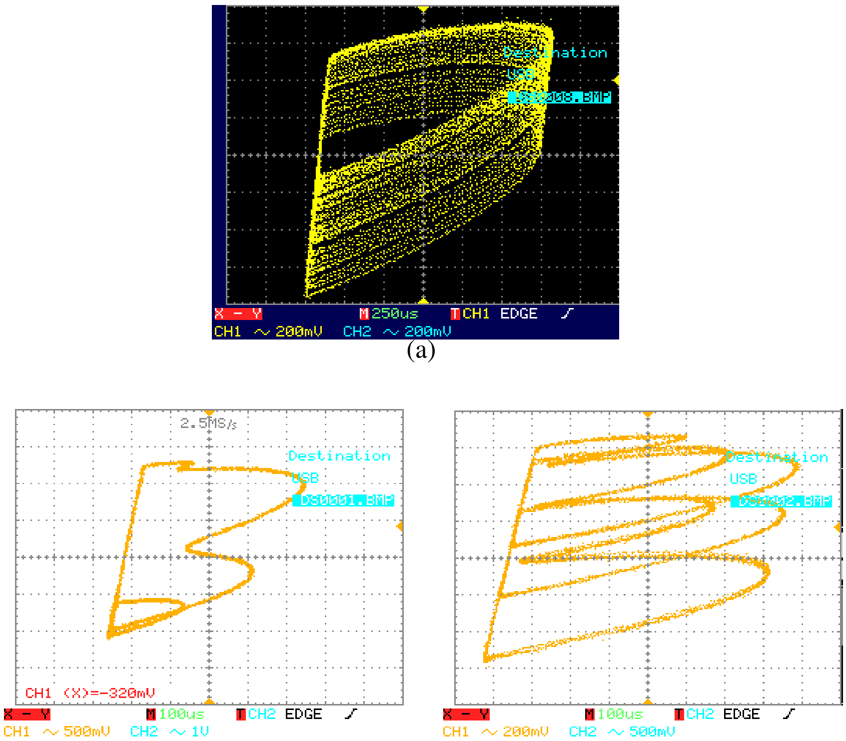
Fig. 3.Experimental results: Phase portrait of $V_c$versus V_b. Period-two doubling route to chaos [a-d]: Period-1 (*F=0.9 kHz)*, period-2 (*F=1.4 kHz)*, period-4 (*F=1.7 kHz)*, chaotic attractor (*F=2.2kHz).* Period-three doubling [e-h]: Period-3 (*F=2.79 kHz),* period -6 (*F=3.2 kHz),* chaotic attractor (*F=4.2 kHz),* period-3 (*F=8.2kHz).*

sinusoidal signal (*F=0*) the circuit shows a chaotic attractor.

as shown in Fig.4(a). The additional signal amplitude fixed to $F = 1.85\,\mathrm{V}$ with small frequency. Then, due to the slowly increase of the frequency to the value near $\upsilon = 1.25\,\mathrm{kHz}$, the chaotic attractor stabilizes to a period -3 limit cycle as shown in Fig.4(b). Fig.4(c) shows the influence of a further increasing in the frequency of the additional signal on the dynamical behaviour of the circuit, a period-6 limit cycle is obtained at the frequency values near $\upsilon = 2.78\,\mathrm{kHz}$.

IV. CONCLUSION

In this paper, the chaotic dynamics of the Lindbreg-Murali-Tamasevicius (LMT) circuit is studied. The chaotic behaviour is obtained from the smallest nonautonomouscircui based on.



(a)

(b) (c)

Fig. 4. Experimental results: Phase portrait of :V_c versus V_b:(a) Chaotic attractor for $F = 0$. (b) Controlling to period-3 limit cycle. (c) Controlling to period-6 limit cycle.

two capacitors, two resistors, and a single transistor. The rich dynamics of the circuit are found to besensitive to the frequency of the sinusoidal source. Period-two doubling bifurcation, period-three doubling, and chaos are observed. The possibility of altering the circuit dynamics with small perturbation signal has been investigated in the paper. Theopen loop technique has been shown suitable for chaos control. The frequency of additional signal plays a key role in the determination of dynamical behaviour of the circuit. The chaotic attractor can be stabilized to periodic limit cycles for suitable tuning of the frequency values.

الخلاصة:ـ

التحكم بالفوضى في أصغر دائرة ترانزستور فوضوية

في هـــذا البحـــث, تم اعتمـــاد اصـــغر دائـــرة فوضـــوية غـــير ذاتيـــة (nonautonomous) chaotic circuit . تتكـون الـدائرة المُعتمـدة مـن ترانزســـتور منفـــرد، متســـعتين، ومقـــاومتين. دائـــرة -Murali-(LMT) Tamasevicius Lindberg، باستخدام التجربة و المحاكاة ببرنامج SPICE، أظهـرت سـلوكيات ديناميكيـة متنوعـة مثـل الحلقـات المقيـدة (limit cycles) لـدورات متنوعـة، التشـعب المـؤدي للفوضـى ذو تضـاعف الـدورة (-period doubling) bifurcation route to chaos, chaos) والفوضـى). إضـافة إلى ذلك، تم أثبات أن عملية التحكم بالفوضى (chaos control) يمكـن أن تتـأثر بإضافة مصدر إشارة دوري آخر.

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