Inductorless Realization of Chua's Circuit

Shiji Shajahan, A. Vasuki.A

Abstract: Nonlinear systems may produce many types of complex behaviour such as chaos. Simple electronic circuits may exhibit chaotic behavior. Among such electronic circuits, the Chua's circuit is mostly used since it is quite simple and can easily be realized in the laboratory using standard electronic components. Experimentally Chaos can be observed using a simple circuit named Chua's circuit and it is the first physical implemented system. Several alternative realizations are possible for Chua's circuit. Inductors are used in most of the chaotic signal generators, which is inconvenient for various reasons. An Inductorlessrealisation of Chua's circuit, which exhibits chaotic behaviour is presented in various circuits. This new realization consists of the Wien bridge circuit or op amp based circuit, which is in parallel with the nonlinear resistor. In this paper an Inductorless realization of Chua's Circuit is presented using op-amps. Simulated results for two synthetic values of inductance L=18mH and L= 8.2mH is presented.

Key Words: Chua's Circuit, Inductorless, Chaos

I. INTRODUCTION

Chaotic systems create widely diverging outcomes for small changes in initial conditions, and future predictions are not possible. It means that initial conditions are used to determine their future behaviour, with no random elements involved. This behaviour is known as chaos[1]. Chaotic behavior of weather was discovered by E. Lorenz. Chua's Circuit was rigorously proved to be chaotic. The presence of chaos theory is in almost every interdisciplinary science fields and even in weather, finance, economics and in nanotechnology. L.O.Chua in 1984 has first physically implemented the concept of Chaos using an electronic circuit called Chua's circuit. Experimentally Chaos can be produced using a circuit named Chua's circuit. Most of the chaotic signal generators proposed in literature contains inductors, which is inconvenient for various reasons. Inductorlessrealisationof circuit is easy to design, due to the absence of inductor.Simulaion can be performed using software's such as Multisim, Pspice, Matlab, Simulink etc. Multisim is an electronic schematic capture and simulation program. Electronics Workbench company originally created Multisim, which is now a division of National instruments. Multisim is widely used for electronic schematic design,circuit's education and SPICE simulation in academia and industry. An introduction to Chua's circuit and Inductor less Chua's circuit is covered in section I. The Literature Review are covered in Section II. Chua's circuit description, Chua's Diode, I-V Characteristics of Chua's circuit and Chua's diode is covered in section III. Inductor less Chua's Circuit is explained in section IV.

Section V includes Results and discussions. Section VI Concludes the work.

II. LITERATURE REVIEW

The concepts chaos theory and chua's circuit are well explained in [1]-[9] and concepts of Inductorless Chua's Circuit and various realization techniques are covered in [10]-[16]. Chaos theory is mainly studied in physics, mathematics, economics and philosophy, studying the system behaviour that is highly depending on initial conditions.This effect is known as butterfly effect.

Chaos typically means a state lacking order or predictability. The weather pattern is not produced as predicted is studied by Lorenz. By using his twelve variable computer he has produced divergent weather patterns, by making minute variations in initial conditions. Thisinitial conditions dependence is known as butterfly effect. Lorenz created a simple set of equations which produce complicated dynamical object known as Lorenz attractor. Various Inductor freechua's circuit was available and the simple one is using Resistor- Capacitor network instead of Inductor. Active- RC sinusoidal oscillator is used to replace L-C (inductor-capacitor) tank circuit in Chua's circuit. Morgulet. al. realized the first successful implementation of Inductorlesschua's circuit. In Morgul's implementation, wien bridge based circuit topology is used to replace the LC resonator of the circuit.

III. CHUA'S CIRCUIT

A. Chua's Circuit Description

Experimentally chaos was first produced by Chua's Circuit..For many chaos related areas this electronic chaotic circuit has been used. It exhibits various chaotic behaviour exhibited by more complex circuits, which makes it popular. In 1984 first Chua's circuit was proposed.

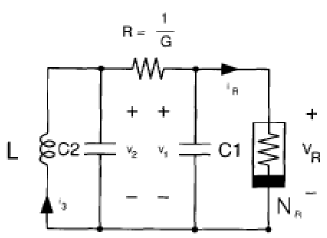

Fig.1. Chua's Circuit

Circuit consist of three energy-storing elements. Three energy storing elements are two passive capacitors C1, C2 and inductor L.

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These components are available off the shelf. Circuit has a simple energy-dissipating device, passive resistor R. For obtaining chaos in different ways a variable resistor or potentiometer can be used whose values can be varied by user.

Chaotic behavior can be observed by tuning it. Most important requirement is a locally active nonlinear device such as Chua's diode and it's a negative resistor. It is built using battery, integrated chips and some passive resistors. It is represented by the symbol N_R. The oscillatory behavior is shown by the v_{C1} and v_{C2} and by i_L .

The following set of equations are used to describe the Chua's Circuit dynamics[1]

$$C_1 \frac{dv_1}{dt} = G(v_2 - v_1) - f(v_1)\,, \qquad (1)$$

$$C_2 \frac{dv_2}{dt} = G(v_1 - v_2) + i_3\,, \qquad (2)$$

$$L\frac{di_3}{dt} = -v_2 \qquad (3)$$

Where voltage across capacitor C1 isv_1, voltage across capacitor C_2 is v_2, current across inductor L is i_L and f(v_R) nonlinear function defined by [1]

$$i_R = f(v_R) = G_b\, v_R + 0.5*((G_a - G_b)\,\{|v_R + B_p| - vR - Bp \qquad (4)$$

where BP denotes the breakpoint and segment slopes are denoted by Ga and Gb. Computer simulations or by physical electronic implementations are used to study Chua's equation Chaotic behavior can be improved by using a resistor in series to inductor. By the use of larger energy storage elements can slow down chaotic oscillations [1].

B. Chua's Diode

At least one non-linear element is required to exhibit chaos by the circuit. Chua's diode is used as the non-linear element. Chua diode can be realized using off-the-shelf components and using batteries. C_1, C_2, L, R and the nonlinear characteristics function g (.) are the parameters used to find behavior of the Chua's Circuit. Two Operational amplifier and resistors are used in first electronics realization of Chua's circuit[1].

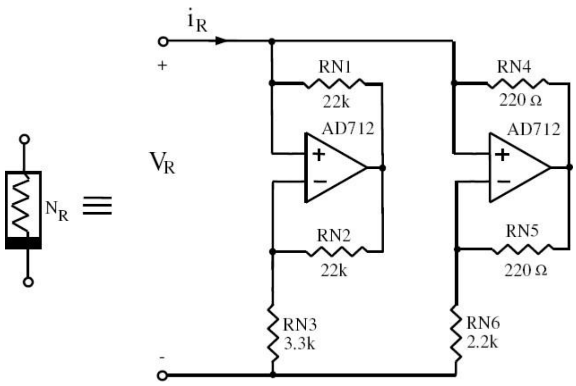

Fig.2. Chua Diode Implementation

C. V-I Characteristics of Chua's Circuit

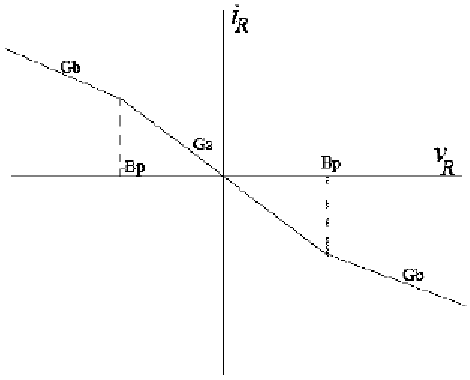

Fig.3. V-I Characteristics of Chua's Circuit

Voltage nonlinear function i_R = f (v_R) whose slope is negative on the curve is a locally active resistor. Chua circuit gives piecewise three segment odd linear- symmetric characteristic. This characteristic is defined by[1]

$$i_R = f(v_R) = G_b\, v_R + 0.5*((G_a - G_b)\,\{|v_R + B_p| - vR - Bp$$

$$= G_b\, v_R + (G_b - G_a)B_p\,, v_R < -B_p$$

$$G_a\, v_R, -B_p \le v_R \le B_p$$

$$G_b\, v_R + (G_a - G_b)B_p\,, v_R > B_p \qquad (5)$$

IV. INDUCTORLESS CHUA'S CIRCUIT

Simple nonlinear circuits may exhibit such chaotic behavior, the analysis and design of electronic circuits which generate chaotic signals has received a great importance in recent years. Most of the chaotic signal generators proposed in the literature contain inductors, which is inconvenient for various reasons. Inductors are prepared separately in most applications. Compared to other circuit elements they are not ideal and they are bigger in size, unless the inductance is rather small. An Inductorless design is also used for VLSI implementation. The circuit which contain capacitors instead of inductors are more convenient in this sense; however, most of such chaotic circuits proposed in the literature are rather complex.

An op-amp based Inductorless realization of Chua'scircuit is shown in fig 4 and fig 5. Realization is performed for two values of inductance, L=18mH and L= 8.2mH

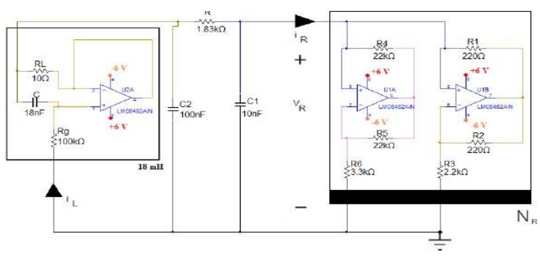

Fig.4.Simulated schematic for 18mH version

Figure 4 shows aInductor free Chua's Circuit. LMC6482 from National Semiconductor is used as op-amp. LMC6482 in the circuit is replaced with the TL082 and the AD822AN.

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Bifurcation and chaos phenomenon is displayed by both the TL082 and the AD822AN circuits. LMC6482, TL082 and AD822AN can be used as op-amps in this circuit. 9V supply is used to give as power for TL082 and AD822AN. In this circuit single op-amp synthetic inductor is used to replace 18mH inductor. Kennedy's robust two op-amp implementation is used for Chua diode.

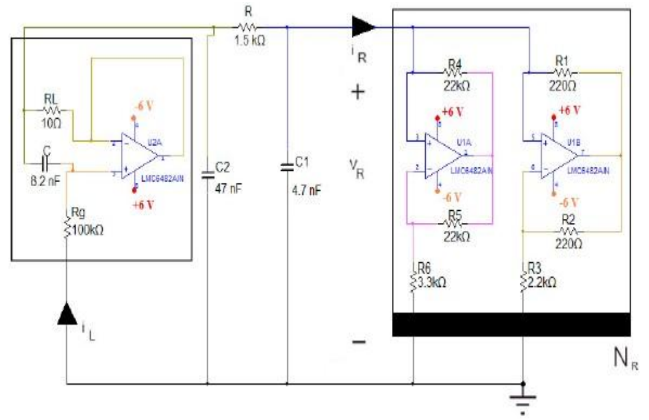

Fig.5. Schematic for 8.2 mH version

Fig 5 consists of circuit with component values L=8.2mH, C2=55nF, R=1.33kΩ, C1=5.5nF. The synthetic inductor capacitor has been changed to C=8.2nF to implement the 8.2mH inductor, this is to examine the robustness of Inductorfree Circuit[13].

V. RESULTS AND DISCUSSION

The following figures shows the circuit variables v_{C1}, v_{C2}, i_L and a double-scroll attractor simulated using Multisim for Chua's circuit with 18mH version.

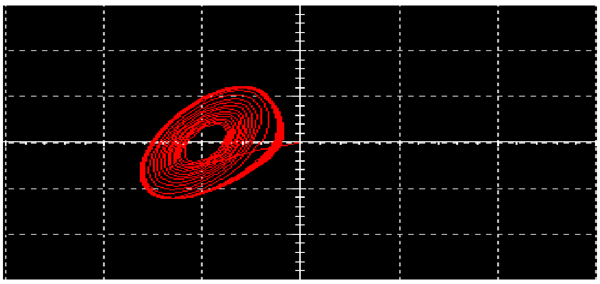

Fig.6.Simulated Double Scroll for the 10.7nF version

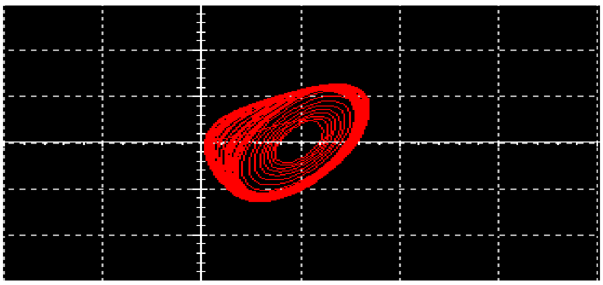

Fig.7. Simulated Double Scroll for the 10.4nF version

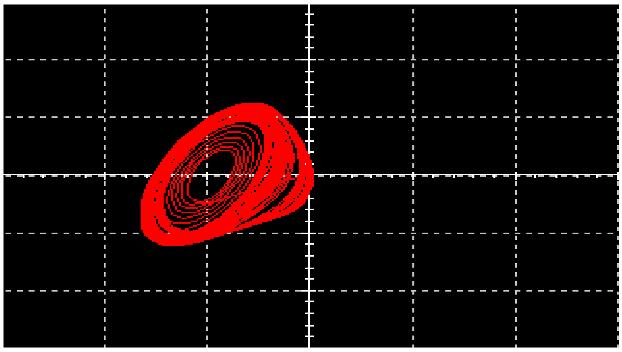

Fig.8. Simulated Double Scroll for the 10.3nF version

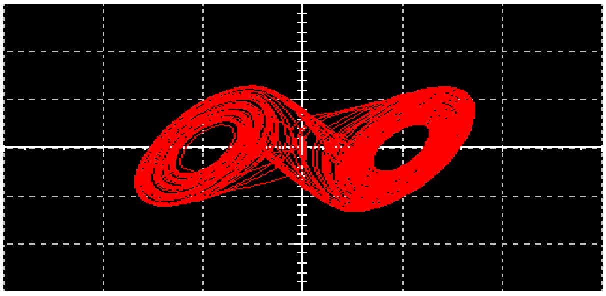

Fig.9. Simulated Double Scroll for the 9.8nF version

Simulated attractors from MultiSim with component values R_L = 10Ω, Rg = 100KΩ ,C = 18 nF ,C_2 = 100 nF ,R = 1.83 KΩ. By using different values to C_1 can show the period-doubling route to chaos. v_{C1} is Horizontal axis and v_{C2} is the vertical axis.

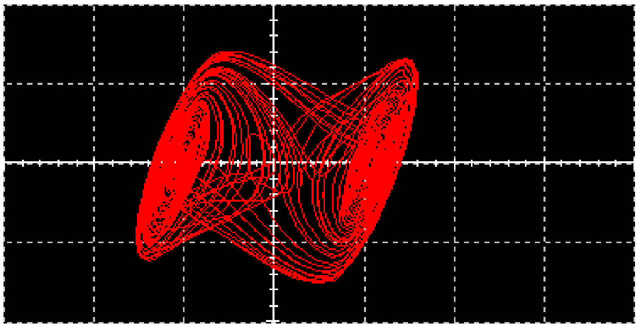

Fig.10. Simulated Double Scroll for Chua's circuit for 18mH version

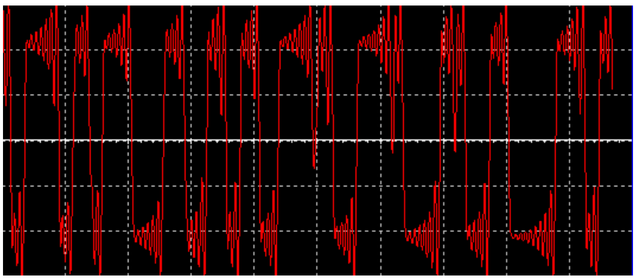

Fig.11. Vc_1 versus Time graph for L= 18mH version of Chua's circuit

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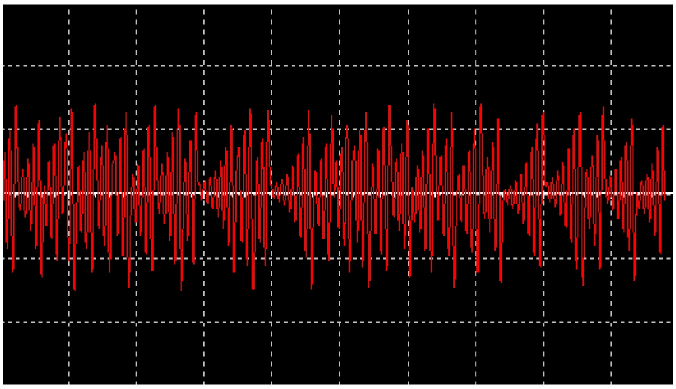

Fig.12. Vc_2 versus Time graph for L= 18mH version of Chua's circuit

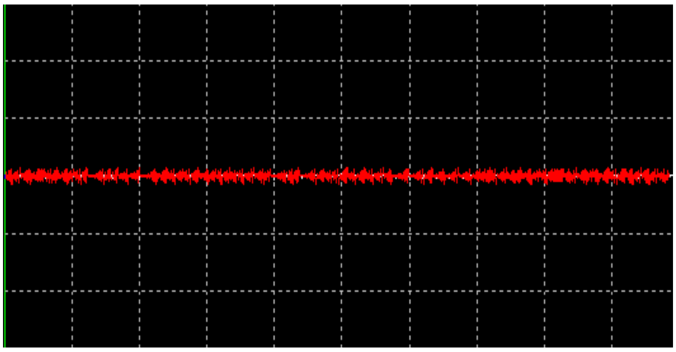

Fig.13.i_L versus Time graph for L= 18mH version

Simulated double scroll Vc_1, Vc_2 and i_L versus Time graph for L=8.2mH is shown in below figures.

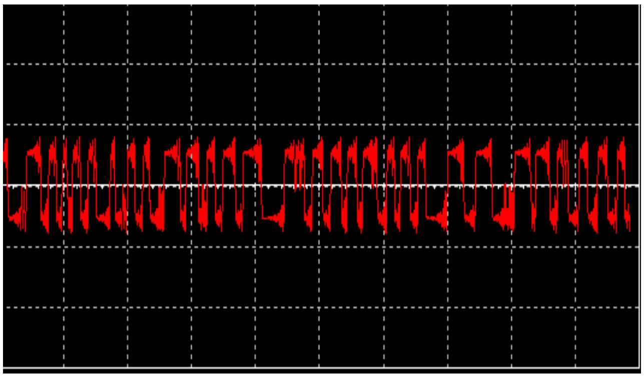

Fig.14. Vc_1 versus Time graph for L= 8.2mH version

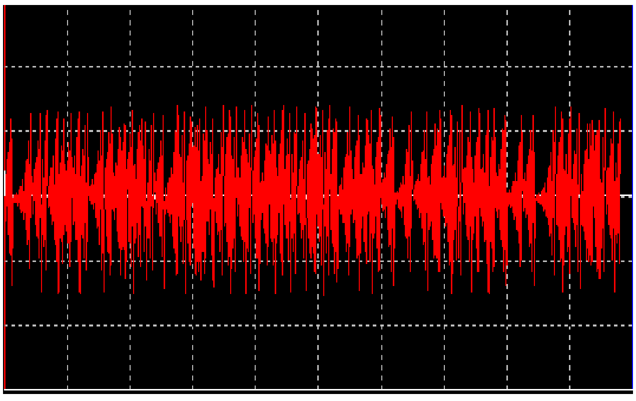

Fig.15. Vc_2 versus Time graph for L= 8.2mH version

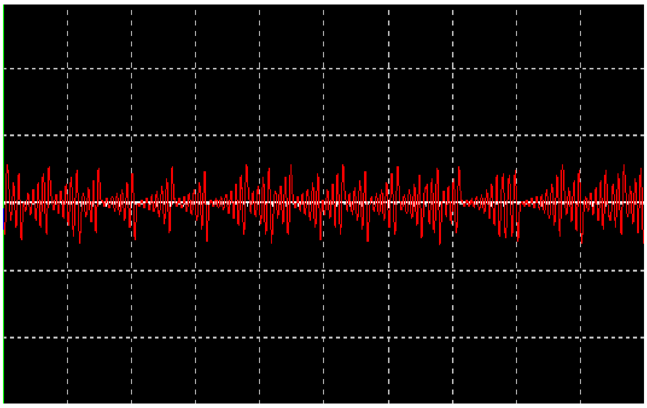

Fig.16.i_L versus Time graph for L= 8.2mH version

Main advantages of Inductorless realization of Chua's Circuit is easy to design. Inductors are quite bulky and most of the cases they are prepared separately [1]. Inductorless design is also used for VLSI implementation since inductors are not ideal. Inductorless implementation of Chua's Circuit increases chaotic electronic circuit practical studies,to implement compact, reliable, low cost and accurate chaotic systems.

VI. CONCLUSION

In this paper an Inductorless realization of Chua's circuit was designed using op-amp. Simulated results for two synthetic values of inductance L=18mH and L= 8.2mH is presented. This circuit is most suitable for integrated circuit applications because its practical realization will occupy less volume.

Different chaotic behaviors can be obtained by varying parameters in the circuit. The experimental results are similar to the theory, indicating that the simulated inductor solution is feasible and easy to obtain.Since this circuit has more parameters which could be used for chaos tuning, it may be useful for various practical applications.

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