Chua's Oscillator Using CCTA

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Abstract- **This paper presents a Chaotic oscillator/Chua's circuit, which has been realized using a current mode building block i.e. current conveyor trans-conductance amplifier (CCTA). The proposed circuit also consists of some other passive components such as resistor, capacitor and active inductor. Chua's diode/negative resistance (NR) defines the chaotic phenomenon of the Chua's oscillator. Chua's diode as well as the active inductor is realized using the block CCTA in the proposed paper.**

Index Terms- **Current conveyor trans-conductance amplifier CCTA; Chua's diode using CCTA; CCTA based Chaotic oscillator; Max435, AD844.**

1. INTRODUCTION

The research on the 'Chaos theory' is already being carried out since an entire century and still it has various aspects that motivate the society of researchers to discover further. The chaotic signal is best produced by an electronic circuit known as Chua's oscillator due to the robustness, stability and ease of implementation of the circuit [3-8]. Chua's oscillator has already been implemented in various ways in literature using voltage [6, 7, 11-15] as well as current mode [1,3-5, 9,10]. The various advantages of the current mode building block such as high bandwidth, high slew rate, high dynamic range over voltage mode building block, makes the current mode building block based circuits more preferable. The disadvantages of fabrication of passive inductor in the integrated circuits have brought forward the need to develop and use an active inductor. This paper presents Chua's circuit in which the inductor used is an active inductor realized using the block CCTA.

Chua's circuit is the first successful physical implementation that can exhibit a variety of chaos, hyper-chaos, bifurcation phenomena and variety of attractors. Few application areas of the Chaotic signal produced by the Chua's circuit include, secured communication, control of lasers, Heart-rhythm analysis, control of tachometer oscillations, neural network, compression of information and storage techniques, washing machine and control of chaos in robotics [2]. Moreover, this theory has also proven its presence in the non-technical fields like finance and economics.

The schematic representation of the Chua's circuit is given in Fig. 1, which contains one piecewise linear NR, two capacitors, one resistor and one active inductor.

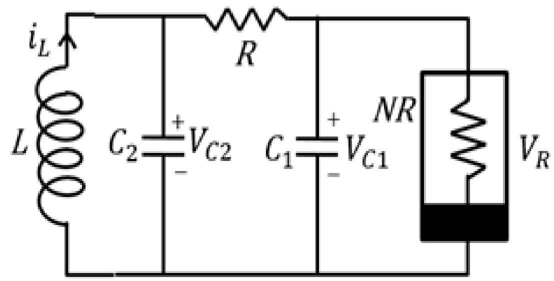


Fig. 1 Chua's circuit

As stated earlier, the very existence of chaotic phenomenon depends on the functionality of the negative resistance (NR). V-I characteristics of a three segment piecewise linear NR, which defines the nature and functionality of the Chua's oscillator, is illustrated in Fig. 2.

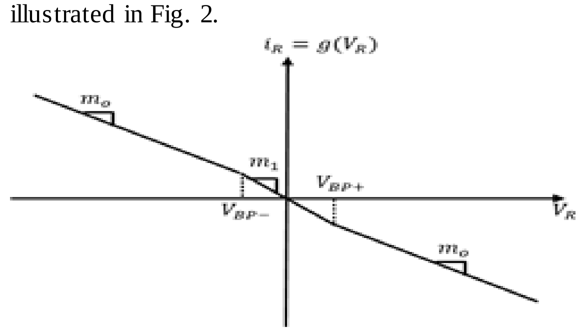


Fig. 2 V-I Characteristics of NR

There are certain standardized equations, which govern the dynamics of this circuit. These equations are stated as follows:

$$RC_1\frac{dV_{C1}}{dt} = (V_{C1} - V_{C2}) - Rg(V_R) \quad (1)$$

$$RC_2\frac{dV_{C2}}{dt} = (V_{C1} - V_{C2}) + Ri_L \quad (2)$$

$$L\frac{di_L}{dt} = (-V_{C2}) \quad (3)$$

$$g(V_R) = m_0V_R + 0.5(m_1 - m_0) \times [|V_R + B_P| - |V_R - B_P|] \quad (4)$$

The voltages across the capacitors C_1 and C_2 are denoted by V_{C1} and V_{C2} respectively, while the current across the inductor L is shown by i_L. The slopes of the outer and inner regions are m_0 and m_1 respectively and V_{BP} denotes the breakpoints as shown in Fig. 2 for a three segment linear piecewise NR in Chua's circuit. The characteristic equation of the Chua's circuit is given by the following equation:

$$s^3 + s^2\left[\frac{G}{C_2} + \frac{G+m_i}{C_1}\right] + s\left[\frac{1}{LC_2} + \frac{Gm_i}{C_1C_2}\right] + \left[\frac{G+m_i}{LC_1C_2}\right] = 0 \quad (5)$$

The condition of oscillation and frequency of oscillation can be obtained by the equations (6) and (7) respectively:

$$R = -\frac{Lm_i(C_1+C_2)}{C_i^2 + LC_2m_i^2} \quad \text{And} \quad \left|\frac{Lm_i}{C_1R}\right| < 1 \quad (6)$$

$$f = \frac{1}{2\pi\sqrt{LC_2}}\sqrt{\left(1 + \frac{Lm_i}{C_1R}\right)}\ ; i = 0,1 \quad (7)$$

2. THE BLOCK CCTA

The Chua's circuit proposed in this paper has been designed using the block CCTA. Fig. 3 shows the block representation of CCTA. CCTA is based on second generation current conveyor (CCII) and operational trans conductance amplifier (OTA). CCTA has the combined advantages of both CCII and OTA. It has low input impedance current mode terminal (X), high input impedance terminal (Y). Port ±Z is the high impedance auxiliary port and port ±O is the high impedance output terminal [16].

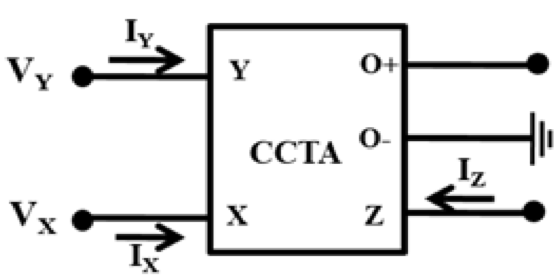


Fig. 3 Block diagram of the block CCTA

The input-output port relationship of the CCTA can be described by the following equations:

$I_Y=0$, $V_X=V_Y$, $I_{\pm Z}=\pm I_X$, $I_{\pm O}=\pm g_mV_Z$ (8)

The block CCTA is implemented using the integrated circuits AD844 and MAX435 [18,19] as illustrated in Fig. 6.

IC AD844 and MAX435 is depicted in Fig. 4 and Fig. 5 respectively.

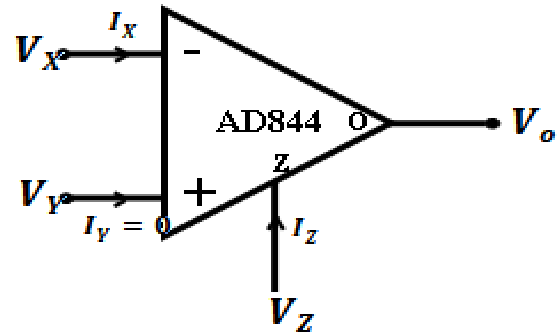


Fig. 4 Block diagram of IC AD844

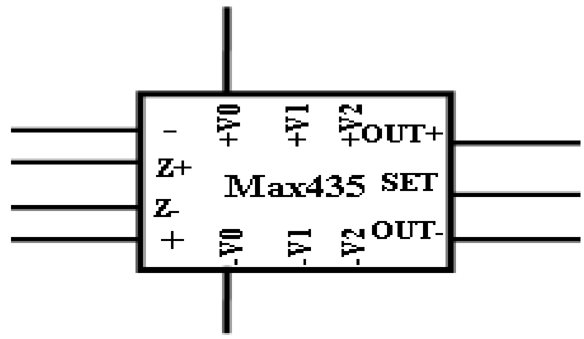


Fig. 5 Block diagram of IC Max435

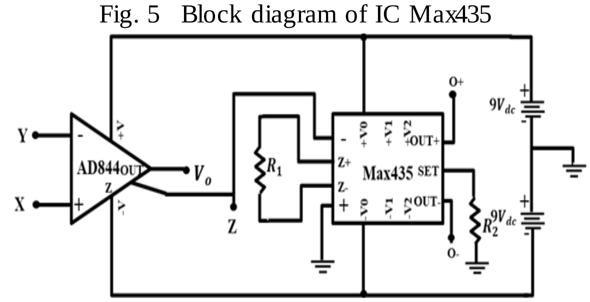


Fig. 6 Implementation of the block CCTA using the ICs AD844 and MAX435

Value of components used in the block CCTA is shown in Table.1.

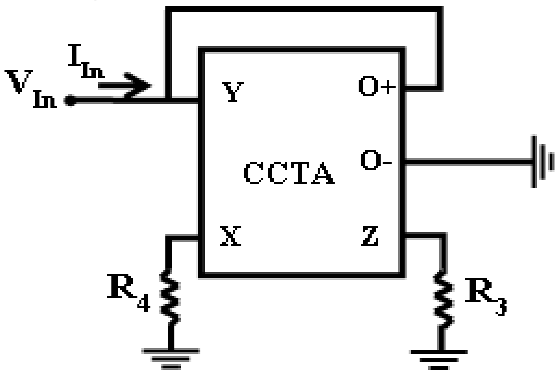
Passive component	Value (kΩ)
R_1	4
R_2	20

Table.1 Values of components used in the block CCTA

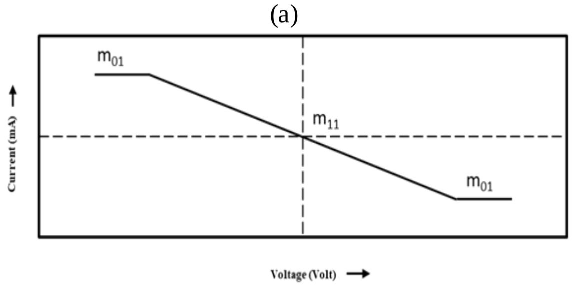
3. PROPOSED ACTIVE PIECEWISE THREE SEGMENT LINEAR NEGATIVE RESISTOR

The proposed Chua diode or active piecewise three segment linear NR is made up of two linear negative resistors NR_1 and NR2, which are parallel-connected. The negative resistors NR_1 and NR_2 along with their generalized V-I characteristics are illustrated in Fig. 7 and Fig. 8 respectively while the three segment linear NR is depicted in Fig. 9

i. Design of proposed NR_1



(a)



(b)

Fig. 7 (a) Negative resistance NR_1, (b) generalized V-I characteristics of NR_1

The analysis of NR_1 shown in Fig. 7 (a) results in the following equation:

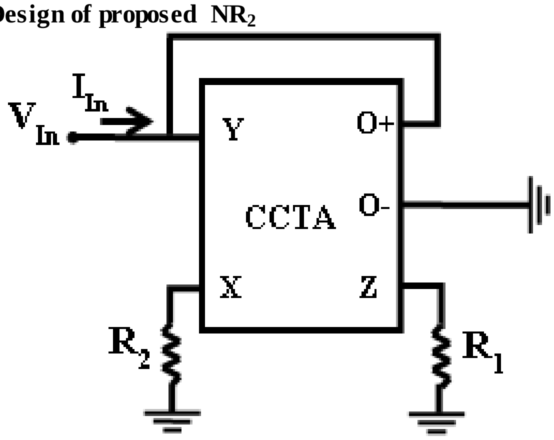
$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{-R_4}{g_{mR_3}} \quad (9)$$

The theoretical value of slopes are:

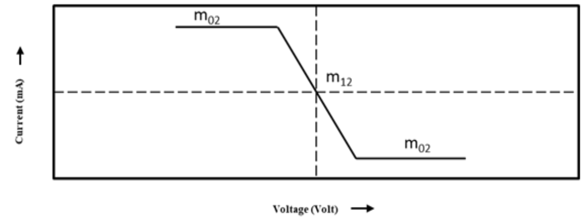
$m_{11} = -g_{m1} = -515.9\mu s$ and

$$m_{01} = \frac{1}{R_1} = \frac{1}{250} = 4ms \quad (10)$$

Design of proposed NR_2



(a)



(b)

Fig. 8 (a) Negative resistance NR_2, (b) generalized V-I characteristics of NR_2

The analysis of NR_1 shown in Fig. 8 (a) results in the following equation:

$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{-R_2}{g_{mR_1}} \quad (11)$$

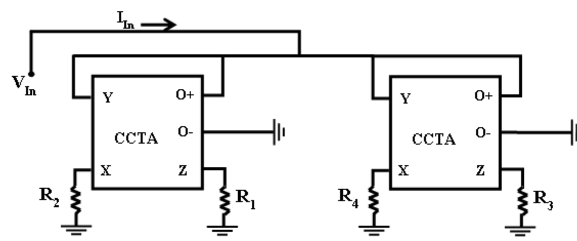
The theoretical value of slopes are:

$m_{12} = -g_{m1} = -342.7\mu s$ and

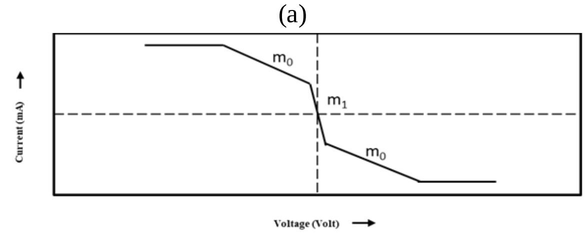
$$m_{01} = \frac{1}{R_1} = \frac{1}{22K} = 45\mu s \quad (12)$$

i. Parallel connection of NR_1 and NR_2

The piecewise linear three segment NR is made up of two parallel connected three segment linear negative resistors NR_1 and NR_2. The schematic of NR and its generalized V-I characteristic curve is illustrated in the figure 9:



(a)



(b)

Fig. 9 (a) Three segment linear NR. (b) Generalized V-I characteristics of NR

The slopes m_0 and m_1 can be obtained by the following equations:

$m_{11} + m_{02} = m_0$,

$m_{11} + m_{12} = m_1$ (13)

The theoretical values of the slopes m_0 and m_1 are -0.5ms and -0.8ms respectively.

4.PROPOSED CHUA'S CIRCUIT USING CCTA

The proposed Chua's circuit designed using the block CCTA is illustrated in Fig.10. The following schematic of Chua's circuit clearly depicts the grounded inductor L on the left side of the circuit, while on the right the proposed active piecewise three segment linear NR designed using CCTA can be seen.

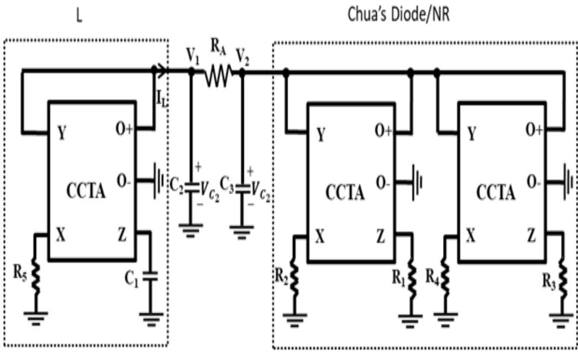


Fig. 10 Proposed Chua's Circuit

The value of components used in the proposed circuit is given in Table. 2.

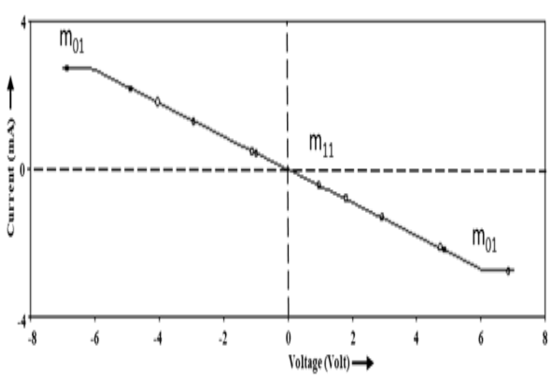
Passive components	Value(kΩ)	Passive components	Value
R_1	22	R_A	variable
R_2	3.3	C_1	18nF
R_3	0.250	C_2	100nF
R_5	2.2	C_3	10nF

Table.2 Values of components used in the proposed Chua's circuit.

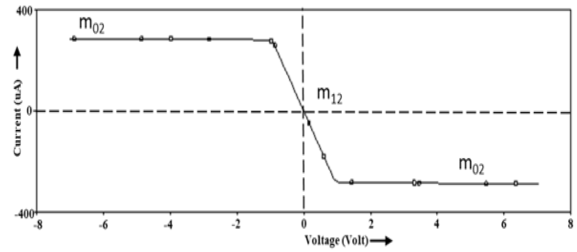
1. Experimental Results:

The workability of the proposed Chua's circuit is studied and tested by the simulations done in ORCAD PSPICE software.

The V-I characteristics of negative resistance NR_1 and NR_2 as obtained by the simulations are shown in Fig. 11(a) and 11(b) respectively.



(a)



(b)

Fig. 11 (a) V-I characteristics of Negative resistance NR_1, (b) V-I characteristics of Negative resistance NR_2

The values of slopes as verified by the simulations are:

m_{01} = 4ms, m_{11} = -515.926µs, m_{12} = -342.78µs, m_{02} = 45µs,

$m_0 = m_{11} + m_{02}$ = -515.926µs+45µs ~ -5ms and

$m_1 = m_{11} + m_{12}$ = -512.926µs-342.78µs = -8ms

The V-I characteristics of proposed three segment piecewise linear negative resistance NR i.e. parallel connection of NR_1 and NR_2 is shown in Fig. 12.

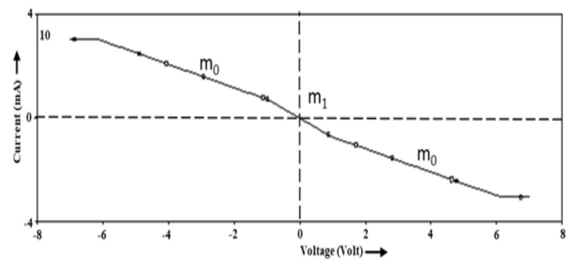


Fig. 12 V-I characteristics of proposed NR.

The simulated chaotic oscillations produced by the designed Chua's circuit at the outputs V1 and V2 is shown in Fig. 14

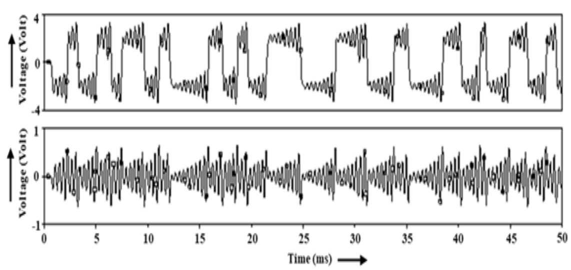


Fig. 14 Chaotic oscillations produced at outputs V1 and V2.

The various attractors formed by the impact of different resistor values of RA is shown in Fig. 15. It is a 3-dimensional representation of the plot of output voltage V1 verses output voltage V2.

Equations (1), (2) and (3) along with some specified parameters such as slopes m0 and m1 have three equilibria known as 'the origin', 'centre of the upper hole' and the 'centre of the lower hole'. The plot of V1 verses V2 forms a typical trajectory in the attractor that rotates around one of the equilibria.

The trajectory gets away from the equilibrium after each rotation until a certain time after which it either goes back to a position closer to the equilibrium or instead of going closer to the equilibrium it starts descending in a spiral path. The number of rotations made by the trajectory around the equilibrium is random and the path followed by the trajectory in each rotation is unique [17].

By varying the values of RA, a sequence of bifurcation can be obtained as shown in Fig. 15.

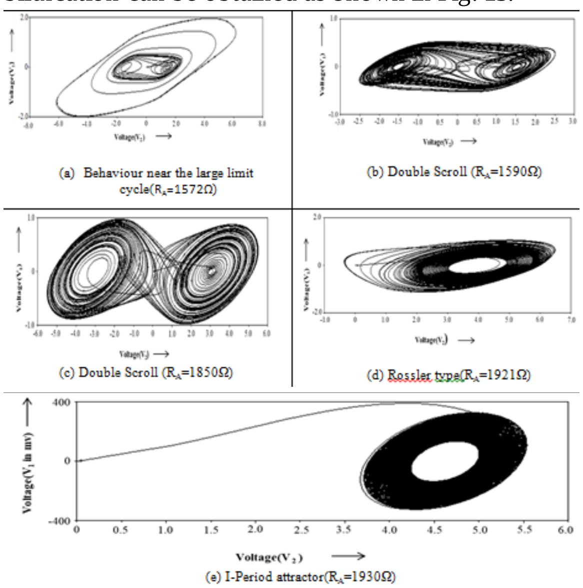


Fig. 15 Various attractors produced by the Chua's circuit for different values of RA.

5. CONCLUSION

A new implementation of Chua's circuit has been proposed using current mode building block CCTA which offers several advantages of current mode building block in terms of slew rate, bandwidth and dynamic range. Implementation of the block CCTA has been done using IC AD844 and MAX435 and the proposed circuit has been simulated using ORCAD PSPICE software.

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