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Realization of Chaotic Oscillator using Miller Integrators

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Abstract - *This paper introduces peculiarly a dignified simple chaotic oscillator which has been derived from the jerk equations constituting the third derivative of position or a scaler variable. In this approach, the major part providing the nonlinear characteristic is an impedance convertor circuit and hence results in the generation of different chaotic waveforms. We describe the experimental results demonstrating the dynamical behavior of the circuit. Further, we provide the numerical simulations of the proposed oscillator which are performed in Multisim and verifies the desired outcome.*

Key Words: **Oscillators, Miller Integrator, Ordinary Differential Equations (ODE), Non-Linear Element (NLE), Chaos, Jerk Function (J).**

1. INTRODUCTION

The way in which variation in processes occur in time is generally sketched by using differential equations. Such complex systems where tiny changes in the starting conditions can lead to large variations over time are called non-linear systems. In mathematics, it signifies that the equations expressing non-linear systems are extremely sensitive to initial inputs [1].

In earlier studies it has been reported that as an output chaos can occur in the systems of autonomous ordinary differential equations (ODE) constituting various quadratic nonlinearities [2].

The Chua circuit, which is a chaotically oscillating circuit was introduced in 1983 along with its many variants [3-4]. This circuit is implemented by third order differential equation which is represented by $\dddot{x} = J(\ddot{x}, \dot{x}, x)$ where J is the non-linear function known as 'jerk' which is described by third derivative of x [5-6]. The simplest ordinary differential equation with quadratic nonlinearity whose solutions are chaotic in nature is given by [7]

$$\dddot{x} + A\ddot{x} + x \pm \dot{x}^2 = 0 \qquad (1)$$

which is a jerk equation $J = -A\ddot{x} - x \mp \dot{x}^2$ with where A is the bifurcation parameter leading to most of the narrow range of chaos, 2.0168 . . . < A < 2.0577.

Meanwhile, more studies on 'jerk' function and its behavior results in more simplified conclusions and experimental proofs. The equation (1) can be generalized to

$$\dddot{x} + \ddot{x} + x + f(\dot{x}) = 0 \qquad (2)$$

in which chaos occurs for a wide variety of non-linear functions, $f(\dot{x}) = a^2 \exp(\dot{x}/a)$ with a < 0.27 [8].

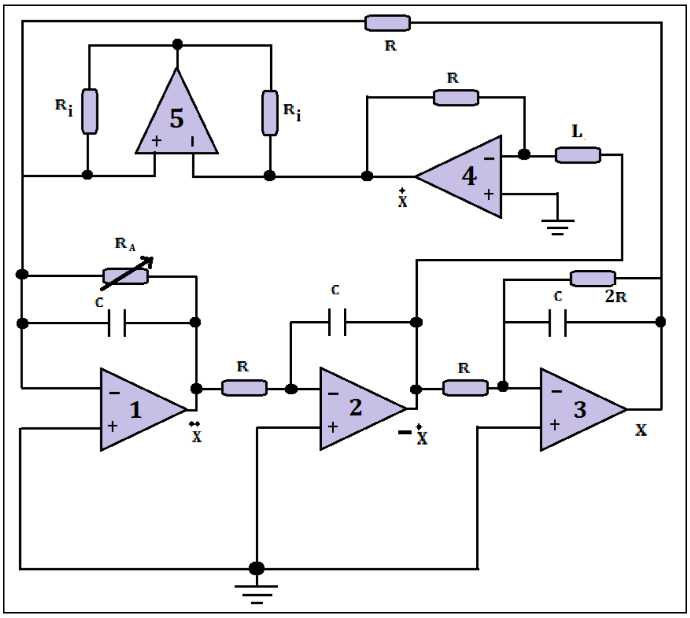

Fig 1.1: Chaotic Oscillator Circuit Schematic

2. CIRCUIT REALIZATION

The electronic implementation of equation (2) is shown in figure 1.1. The circuit consists of three consecutive miller integrators (OpAmp 1, OpAmp 2 and OpAmp 3 respectively) from which two of them are followed by a feedback loop. The feedback from OpAmp 2 consists of an invertor (OpAmp 4) followed by a Negative Impedance Convertor (NIC) which acts as a non-linear element (NLE) and therefore providing the non-linear characteristic to the circuit. The output of OpAmp 2 is connected through an inductor to the inverting input terminal of OpAmp 4. The output of invertor is connected to the NIC whose circuitary is constructed by using two 10kΩ resistors connected on negative and positive feedback of OpAmp 5 respectively. The feedback from OpAmp 3 consist only a resistor. Both the feedbacks (i.e. feedback loop1 and feedback loop 2) are provided at the inverting input of OpAmp 1 as shown in Fig 4.2.1. A variable resistance (R_a) is placed between inverting input and output of first miller integrator (OpAmp 1).

While there are many ways to build a standard chaotic circuit along with many variations on the standards. So, for simplicity and better analysis the proposed circuit is designed using Resistors, Capacitors and Operational Amplifiers. The arbitrary values of all components are shown below in table 2.1.

COMPONENT	QUANTITY		SPECIFICATION
TL082CP IC	3		Low Power Consumption High Slew Rate: 13V/μs
RESISTORS 10% Tolerance	R	5	1KΩ
	R_i	2	10KΩ
	R_A	1	1-10KΩ Range
CAPACITORS 10% Tolerance	C_1	1	1μF
	C_2	1	1μF
	C_3	1	1μF
INDUCTOR	L	1	100mH

Table 2.1: Component Parameters

The circuit was constructed on the breadboard in college premises which is shown in figure 2.2.

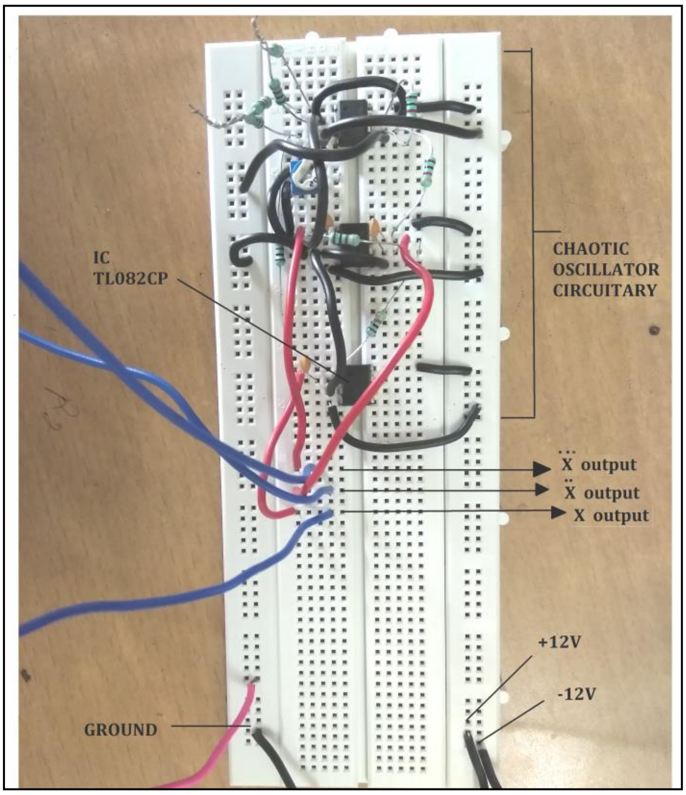

Fig 2.2: Hardware Implementation on Breadboard

The output of the chaotic oscillator was observed on the Cathode Ray Oscilloscope (CRO) screen so as to verify the simulation results. The CRO observation is shown in fig 2.3 in which channel A is provided with ‘X Output’ (i.e. output from OpAmp 3) and channel B is provided with ‘ $\ddot{X}$ Output’ (i.e. output from OpAmp 1).

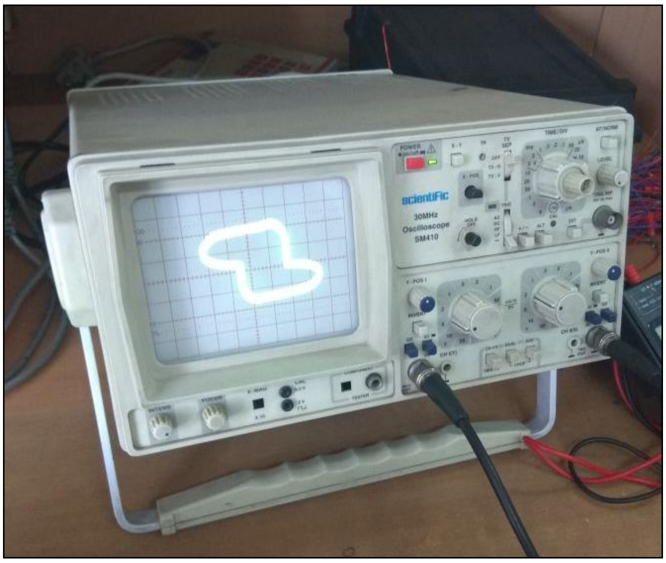

Fig 2.3: Hardware Output Waveform on CRO screen

The pattern shown in Fig 2.3 represents a chaotic attractor that may be sort of attractor (i.e. an attracting set of states) during a complicated resurgent system's space that shows sensitivity to initial conditions. As a result of this property, as shortly because the system is on the attractor nearby states diverge exponentially quick from one another. Hence, minute noises get amplified. Once sufficiently amplified the noise determines the system's large-scale behavior and therefore the system is then unpredictable.

3. SOFTWARE SIMULATION RESULTS

The software simulations were performed in Multisim 14.1 software. Multisim is an electronic schematic capture and simulation program that is a component of a set of circuit design programs that are used to employ the original Berkeley SPICE primarily based software simulation. For PCB Layout designing Proteus Design Suite v8.3 is being used.

The software schematic of the proposed chaotic oscillator circuit is shown in Fig 3.1. At the X output a frequency counter is placed to record varying frequency of the circuitary. Fig 3.2 represents the alternating output waveforms with respect to time. The numerically calculated phase space plots of the proposed chaotic oscillator circuit are shown in Fig 3.3 and Fig 3.4.

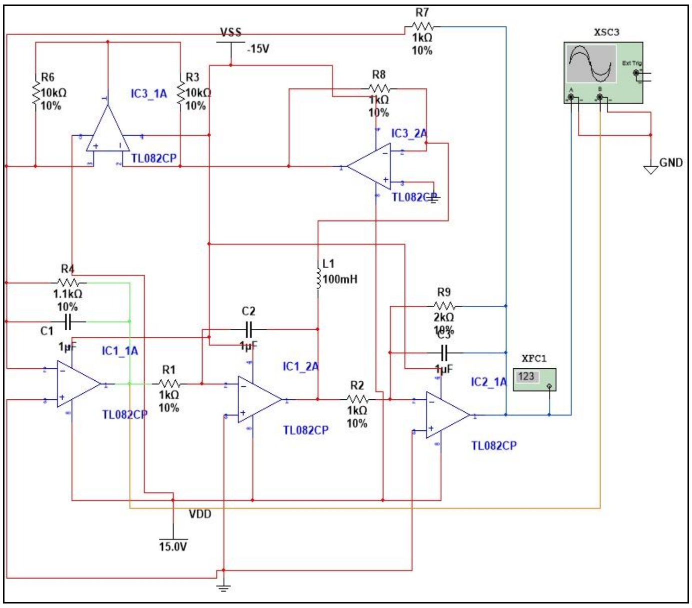

Fig 3.1: Schematic of Chaotic Oscillator in Multisim 14.1

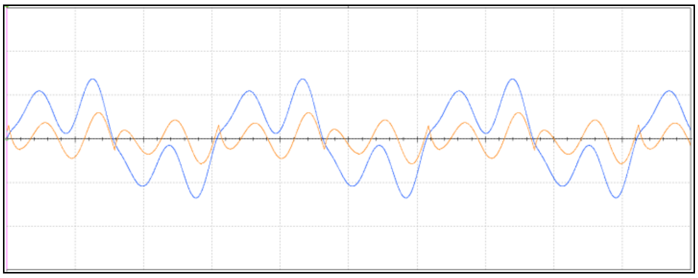

Fig 3.2: Waveforms with respect to time. Output from OpAmp 1 (Orange) and Output from OpAmp 3 (Blue) at 2V/div.

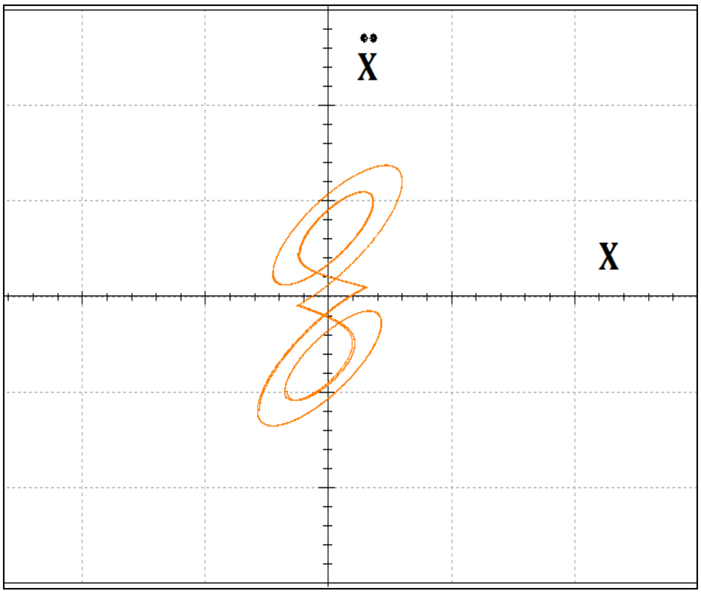

Fig 3.3: Numerically calculated Phase Space Plot at 2V/div where x-axis and y-axis represents 'X' output and 'd²/dt(X)' output respectively.

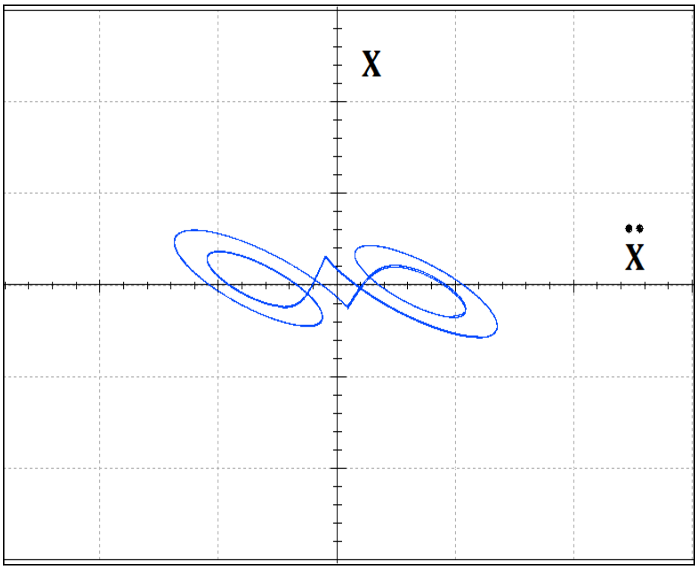

Fig 3.4: Numerically calculated Phase Space Plot at 2V/div where x-axis and y-axis represents 'd²/dt(X)' output and 'X' output respectively.

4. BLOCK DIAGRAMS

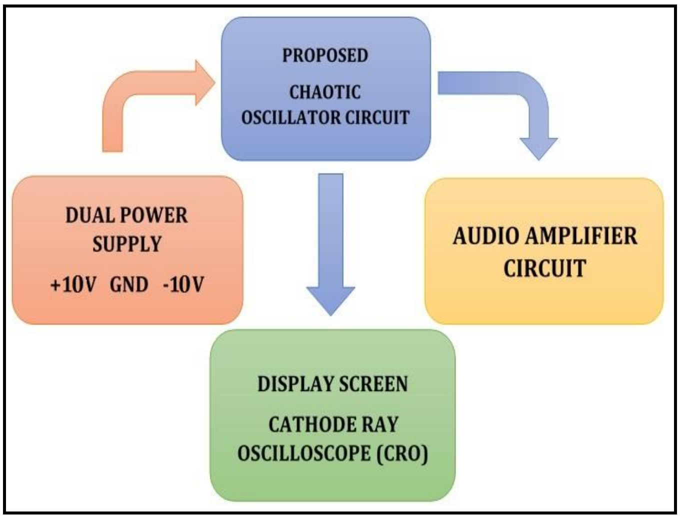

Fig 4: Block Diagram of the System

The power to the proposed chaotic oscillator circuit is provided by the dual power supply circuitary of around 10V. For further evidence of chaos, the X output is connected to an audio amplifier circuit and hence generating sound of varying frequency. To visualize the behavior LEDs can be used at the output.

4.1 DUAL POWER SUPPLY BLOCK DIAGRAM

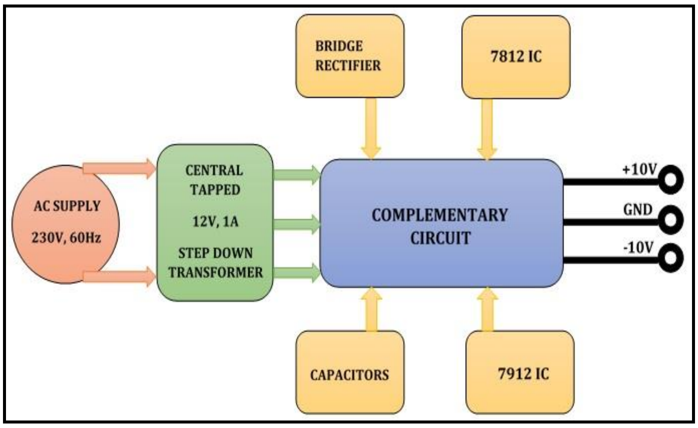

Fig 4.1.1: Dual Power Supply of output approx. 9v

4.2 CHAOTIC OSCILLATOR CIRCUIT BLOCK DIAGRAM

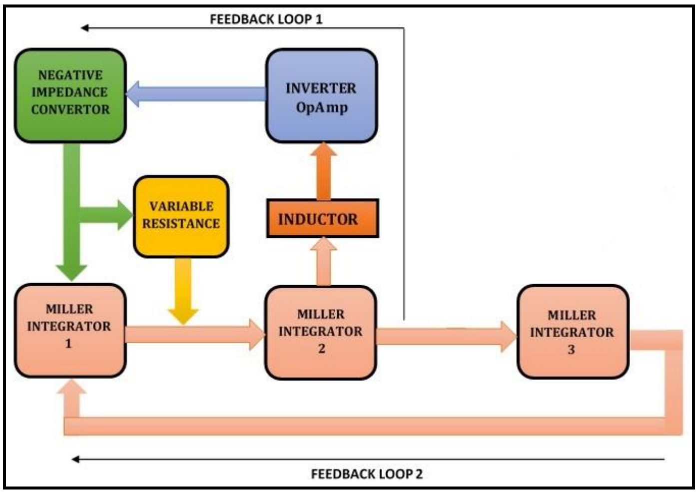

Fig 4.2.1: Chaotic Oscillator Circuit Block Representation

4.3 AUDIO AMPLIFIER CIRCUIT BLOCK DIAGRAM

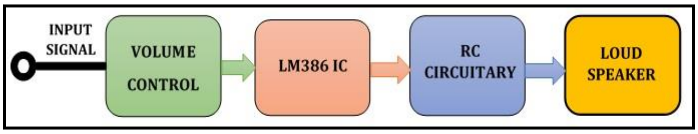

Fig 4.3.1: Audio Amplifier

5. CONCLUSION

The Block Diagram Fig 4 represents a modular approach towards execution of this project. The benefit of such approach is that it provides tidiness to the work done and further enhancement in the blocks (if any) can be made easily without effecting the other connections. Figures Fig 4.1.1, 4.2.1 and 4.3.1 shows the block representation of internal circuitary of Dual Power Supply, Proposed Chaotic Oscillator and Audio Amplifier respectively.

A new chaotic oscillator circuit has been realized using three cascaded miller integrators, which was encouraged and well predicted by a variant of the simplest differential equation whose solutions are chaotic. The circuit requires no special components and can be scaled over a wide range of frequencies. Also, it requires no careful tuning, and is strongly chaotic. The reactive components are three identical capacitors and an inductor, and the only nonlinear element is the negative impedance converter (NIC) whose characteristics are not critical. The circuit is enough responsive to numerical and theoretical analysis. It is thus an attractive candidate for all applications of chaotic circuits. Further circuit simplifications and orders might be possible.

6. ACKNOWLEDGEMENT

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