International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 10 | Oct -2017 www.irjet.net p-ISSN: 2395-0072

Generation Of Chaotic Signal and Time Division Multiplexing Based Multiple Synchronized Chaotic Signal

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ABSTRACT: *Chaotic signals comprise a wide range of spectrum with infinite bandwidth and are sensitive to initial conditions. These signals are generated using Chua's circuit. The signals are transmitted through a single channel using TDM. This is what we are going to show. TDM is a process of combining two or more signals and transmitting them over a single transmission channel using time slots. At the receiver end, de-multiplexing (reverse of TDM) is carried out to get back the original transmitted signals.*

Key Words: **Chaotic, Signals, TDM, Synchronization, Multiplexing, Chua's Circuit, Butterfly Effect.**

1. INTRODUCTION:

Multiple synchronized Chaotic signals are transmitted via single channel based on time-division multiplexing. Both the sampling and holding modes are used alternately during the transmission process so that multiple chaotic signals can be transmitted by sharing the single physical channel. The proposed method is implemented with an electronic circuit, and then is applied to solve simultaneous synchronization of multi-pair chaotic systems using a single channel. Chaotic signals comprise a wide range of spectrum with infinite bandwidth and are sensitive to initial conditions. By synchronizing a pair of master–slave chaotic signals, one can recover the message generated by the master system from the signal of the slave system. The combination of synchronization and unpredictability has led to novel non-traditional applications, such as observers for anti-control of chaos and secure communication. Usually, if only one signal is transmitted between a pair of master–slave chaotic systems, a single channel is needed to implement synchronization. However, in some cases, two or more signals are required for the synchronization, then two or more transmission channels may be required, which would lead to a high cost of establishing transmitting and receiving devices, especially when the master and slave systems are far apart in geographic location. Multiplexing is the process of combining two or more signals and transmitting them over a single transmission channel. To deliver multiple unrelated analogue signals using a single channel based on time division multiplexing (TDM) results in efficient use of the communication link. The basic idea is to employ a zero-order holder followed by the signals to be transmitted. Both the sampling and holding modes are used during the transmission process. One of the signals is transmitted over the sampling state while other signals are transmitted over the holding period.

2. CHAOS THEORY:

Chaos theory is one of the field of mathematics but also has vast scopes in other disciplines like meteorology, physics, etc. A very eccentric response is seen in the behavior of dynamical systems that are highly sensitive to initial conditions, this response is referred to as butterfly effect and chaos theory helps to study such behavior. It is observed that by rounding the values in numerical computation in initial condition yield widely diverging outcomes for dynamical systems which renders long-term prediction difficult in general. This kind of eccentric behavior is known as deterministic chaos, or simply chaos. But there is some amount of time for which the behavior of a chaotic system can be effectively predicted. This depends on three things: How much uncertainty we are willing to tolerate in the forecast; how accurately we are able to measure its current state; and a time scale depending on the dynamics of the system.

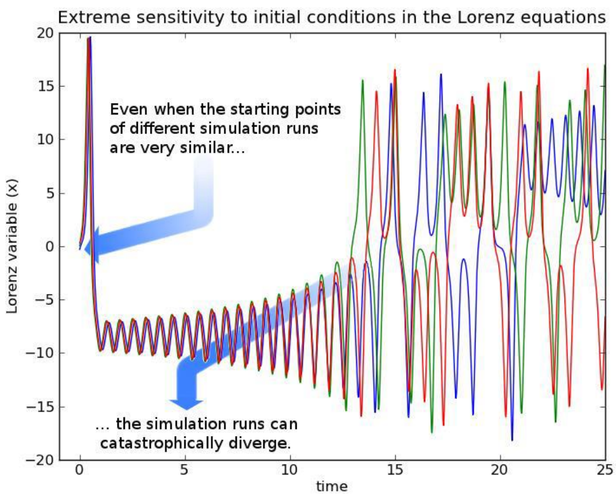

Figure 1:

3. BUTTERFLY EFFECT:

In terms of chaos theory, the sensitivity in the initial conditions in which a slight change in one state of a deterministic nonlinear system can result in large differences in a later state is known as butterfly effect. Edward Lorenz discovered the effect. He observed that runs of his Computational weather model which he left with initial condition data with rounded values in a seemingly inconsequential manner would fail to reproduce the same results of runs with the unrounded initial condition data. A very small change in initial conditions had created a significantly different outcome.

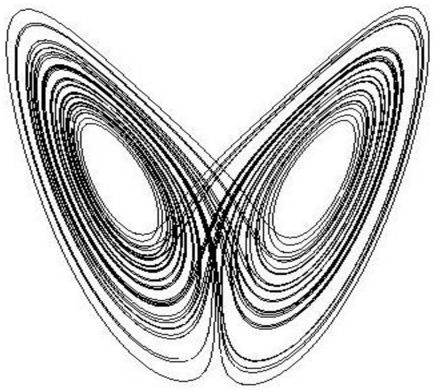

Figure 2: Butterfly Effect

4. CHAOS COMMUNICATION:

Being an application of chaos theory it provides secure communication. The content of the message is inaccessible to eavesdroppers. Usually, a basic scheme of a communications device (Cuomo and Oppenheim 1993) is made by two identical chaotic oscillators for chaos communication. Identical synchronization is achieved between the two oscillators. In this way, the message transmitted is masked by the chaotic signal. Coupling of two or more dissipative chaotic signals is known as synchronization of chaos signals. Because of sensitivity to initial conditions, two trajectories emerging from two different closely initial conditions separate exponentially in the course of the time. As a result, chaotic systems defy synchronization. There exist several types of synchronization including complete synchronization, lag synchronization, generalized synchronization, frequency synchronization, phase synchronization, Q-S synchronization, time scale synchronization, and impulsive synchronization. The reader is referred to for a list of references that cover these different techniques.

5. TUNNEL DIODE:

A tunnel diode or Esaki diode is a highly doped semi-conductor device and is used mainly for low voltage high frequency switching application. Using quantum mechanical effect- tunneling, it is capable of very fast operation especially into microwave frequency region. These diodes have a heavily doped p-n junction only some 10nm wide. For a charged particle in order to cross an energy barrier should possess energy at least equal to the energy barrier. Hence the particle will cross the energy barrier if its energy is greater than the barrier and cannot cross the barrier if its energy is less than the energy barrier. There exists non-zero probability that a particle which has energy less than the energy barrier will cross the barrier as if it is tunneling across it. This is called as Tunneling effect. The probability increases with the decreasing barrier energy.

5.1 Forward bias operation: Under normal condition forward bias operation as voltage begins to increase, electrons are first tunneled through the very narrow PN junction barrier because filled electron states in the conduction band on the n side become aligned with empty valence band hold states on the p side of the pn junction. These states become misaligned with the increase in voltage and the current starts to drop. This is called negative resistance. Yet with further increase the diode begins to operate as a normal diode (electrons travel by conduction across the PN junction and no longer by tunneling through the PN junction barrier). Negative resistance region is the most important operating region of tunnel diode.

5.2 Reverse bias operation: When we operate it in reverse direction, tunnel diodes are called backward diodes. They can act as fast rectifiers with zero offset voltage and extreme linearity for power signals (having an accurate square law characteristic in the reverse direction). Under reverse bias, filled states on the p-side become increasingly aligned with empty states on the n-side and the electrons now tunnel through the p-n junction barrier in reverse direction.

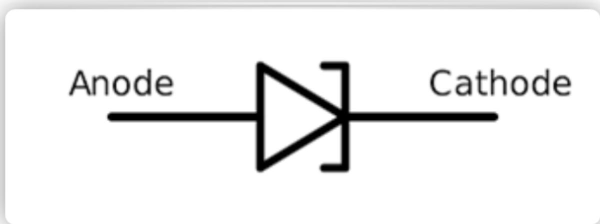

Figure 3: Schematic symbol of Tunnel Diode

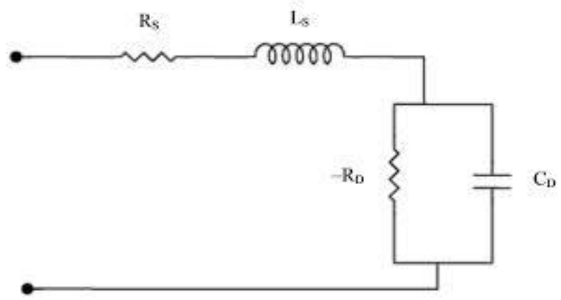

Figure 4: Equivalent circuit of Tunnel Diode

5.3 I-V Characteristics: As forward biased is applied, significant current is produced. After continuous increase of voltage, the current achieves its minimum value called as value current. The region in which the current shows continuous decrease is called negative differential region. After further increase in voltage, the current start increasing as ordinary diode. The reverse I-V characteristic is similar to zener diode. The zener diode in which the reverse bias characteristic of almost a constant voltage regardless of the current flowing through the diode.

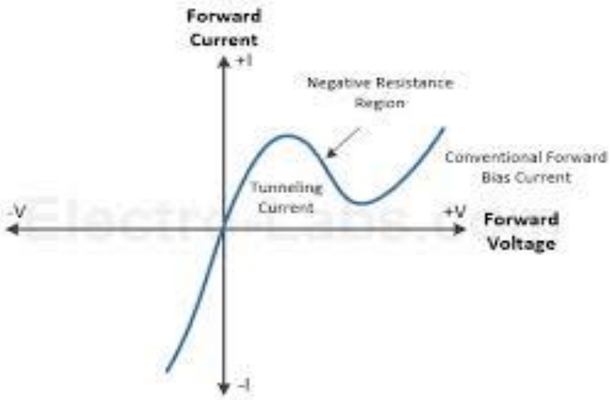

Figure 5: I-V Graph

6. GENERATION OF CHAOTIC SIGNAL:

SOFTWARE USED: MULTISIM

Chaotic signal is generated using Chua's Circuit. Classic chaos theory behavior is exhibited by Chua's circuit (also known as a Chua circuit) and it is one of the simplest electronic circuit. This means roughly that it is a "non-periodic oscillator"; it produces an oscillating waveform that, unlike an ordinary electronic oscillator, never "repeats". Three criteria's that must be met by an autonomous circuit made from standard components (resistors, capacitors, inductors) before it can display chaotic behavior are:

1. One or more nonlinear elements
2. One or more locally active resistors
3. Three or more energy-storage elements.

One of the simplest electronic circuit meeting all this requirement is Chua's circuit. The energy storage elements are two capacitors (labeled C1 and C2) and an inductor (labeled L1). A device that has negative resistance is called "locally active resistor" and is said to be active as it provides power to generate oscillating current. We use tunnel diode as locally active resistor because it has negative resistance.

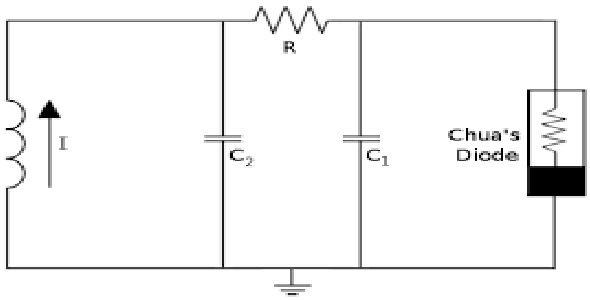

Figure 6: Chua's Circuit

A general sinusoidal oscillator is coupled to a voltage-controlled nonlinear resistor via a passive RC network. Since there should exist at least one energy source in the configuration, at least one of these two blocks must be active. A simple LC tank resonator (passive sinusoidal oscillator) is used since oscillations which start due to subjective initial conditions can be sustained only if an external energy source is present. Therefore, the classical LC-R sinusoidal oscillator is obtained by adding a negative resistor to the tank circuit.

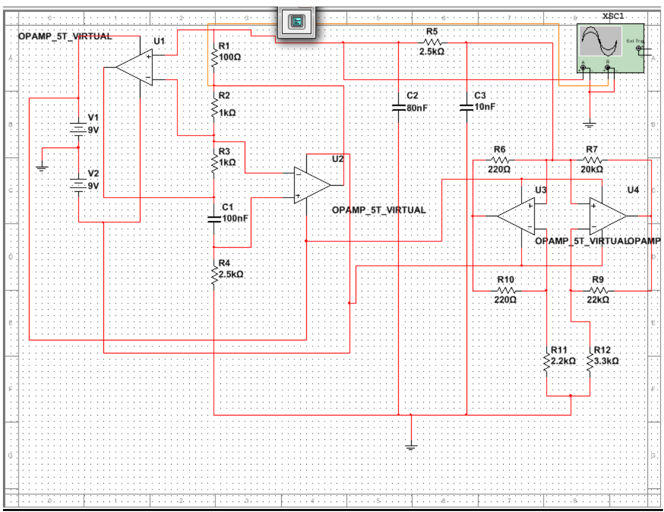

Figure 7: Circuit 1 for Chaotic Signal Generation

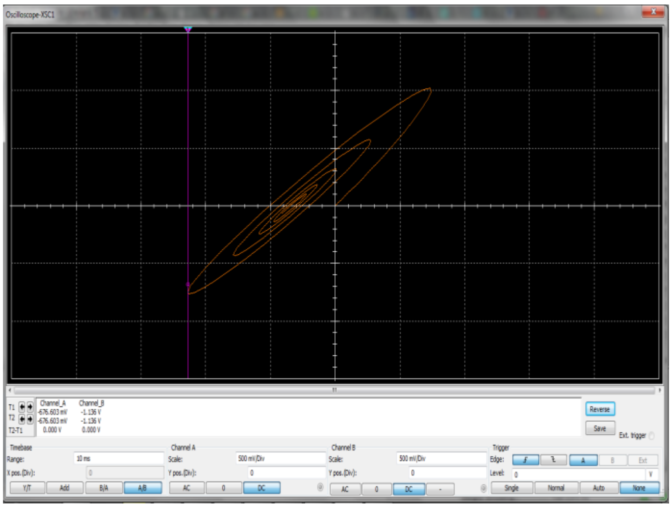

Figure 8: Chaotic Signal Output for Circuit 1

There are many variations on how to build Chua's circuit, but figure 7 shows the basic design. This is the standard Chua's circuit used in research and a number of experiments, but there are many different ways to realize the full circuit. However, when building Chua's circuit at home, even a very slight variation can cause large effects or even failure of the entire circuit. A loose connection or uneven voltages will dramatically affect the output. Building Chua's circuit on a breadboard can be a frustrating endeavor if care is not taken. Even a slight bump can slacken the connections enough to wildly change the output. Also, the quality of the output from a breadboard will be quite less than that of a soldered circuit board. As no one manufacture the Chua's diode, it must be manufactured. There are numerous ways to create a Chua's diode. Chua's diode is a non-linear resistor In Circuit 1 we can see Chua's diode made from only resistors and op-amps. Both designs equally satisfy the circuit, but Circuit 1 is easier to make. We can replace the inductor and accurately simulated with an additional circuit called a gyrator out of the same components. This is also one of the effective way of generating chaotic signals for transmission. Thus, with this inductor simulator, a fully realized circuit can be built from only resistors, capacitors and op-amps (as seen in Circuit 1).

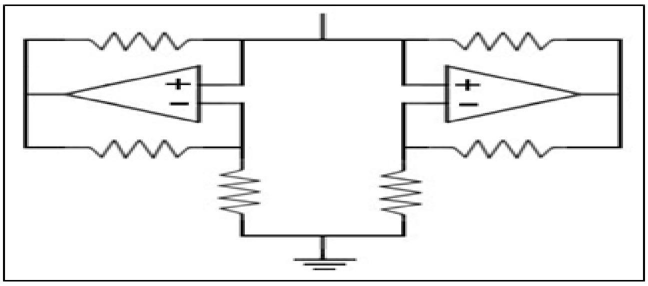

Figure 9: Chua's Circuit

Changing the value of components, we generate two chaotic signals:

Sr.No	Value of C_2	Value of C_3	Value of R
1.	80nF	10nF	1kohm
2.	100nF	10nF	4kohm

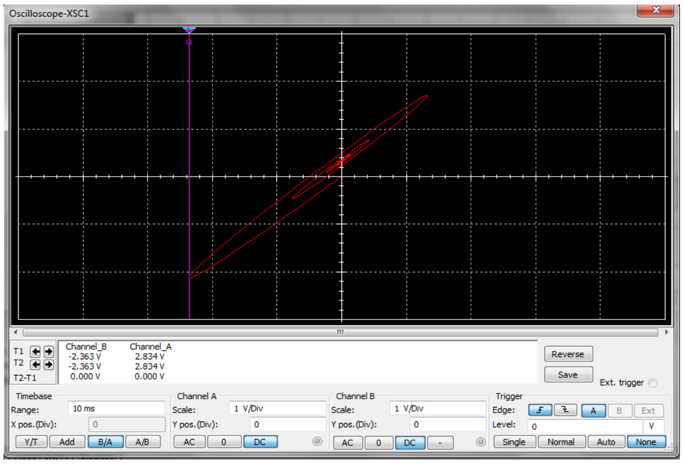

Figure 10: Output 2 for Circuit 1

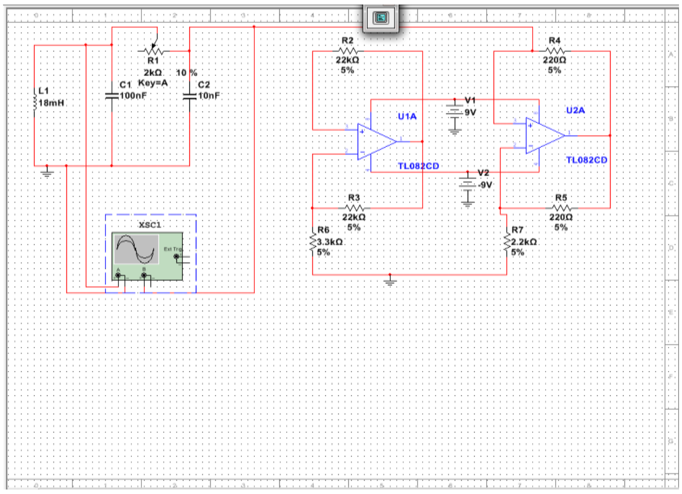

Figure 11: Circuit 2 for Chaos Signal Generation

This is another method of designing Chua's circuit for chaotic signal generation. It consists of simple electronic components resistors, inductor, capacitors and operational amplifiers. The L1 inductor and C2 capacitor build a resonant circuit (CIRCUIT 2), whereas their values determine the basic oscillation frequency. Two

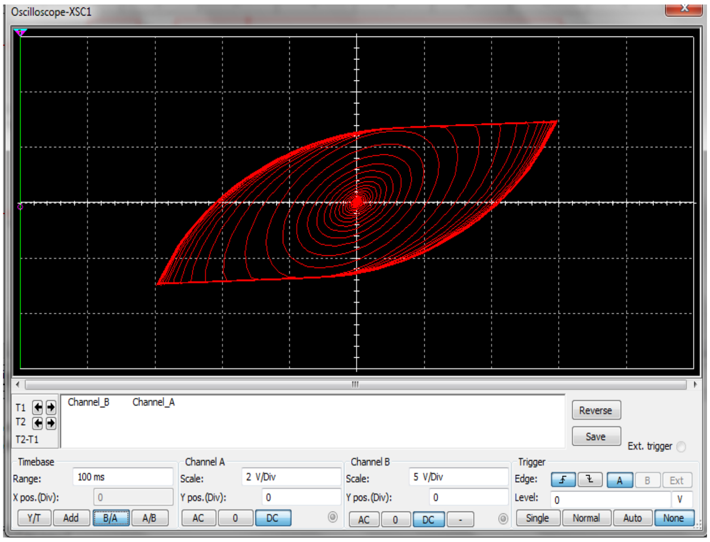

Figure 12: Output of Circuit 2

TL082CD operational amplifiers is used for realization of the nonlinear resistor which is the key factor for the circuit to behave in a chaotic order.

7. TIME DIVISION MULTIPLEXING OF MULTIPLE CHAOTIC SIGNALS:

Chaotic signals comprise a wide range of spectrum with infinite bandwidth and are sensitive to initial conditions. By synchronizing a pair of master–slave chaotic signals, one can recover the message generated by the master system from the signal of the slave system. However, in some cases, two or more signals are required for the synchronization, then two or more transmission channels may be required, which would lead to a high cost of establishing transmitting and receiving devices, especially when the master and slave systems are far apart in geographic location. Multiplexing is the process of combining two or more signals and transmitting them over a single transmission channel. To deliver multiple unrelated analogue signals using a single channel based on time division multiplexing (TDM) results in efficient use of the communication link. Based on our previous research, we propose a TDM based method for transmitting multiple synchronized chaotic signals via a single channel. The basic idea is to employ a zero-order holder followed by the signals to be transmitted. Both the sampling and holding modes are used during the transmission process. One of the signals is transmitted over the sampling state while other signals are transmitted over the holding period.

The synchronization of a master slave chaotic scheme could be achieved connection the capacitor C1 of the master circuit with the capacitor C3 of the slave circuit. The realization of this synchronization technique is presented at fig. 2. In fig. 11 circuit, the right hand side represents the master circuit (transmitter). The circuit is operating in a chaotic behavior giving a double scrolled attractor as it can be seen in (fig. 12). The receiver which is presented in the left hand side, it is identical with the transmitter ones. There we have a pair of the Chua's circuit presented in circuit 2. We have connected the

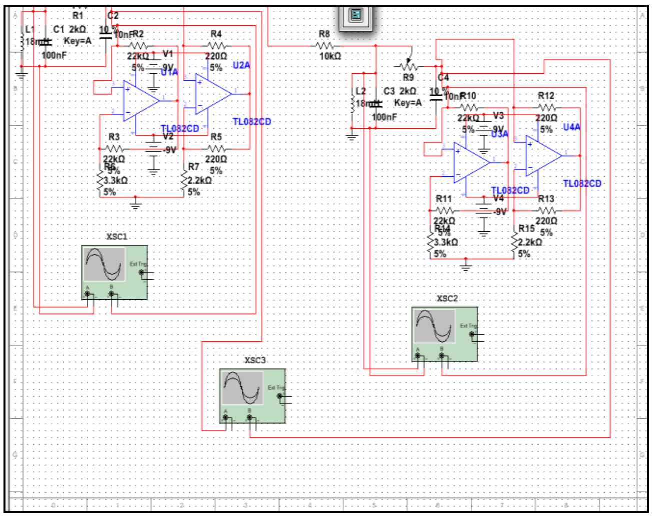

Figure 13: Synchronization Circuit of Chaotic Signals

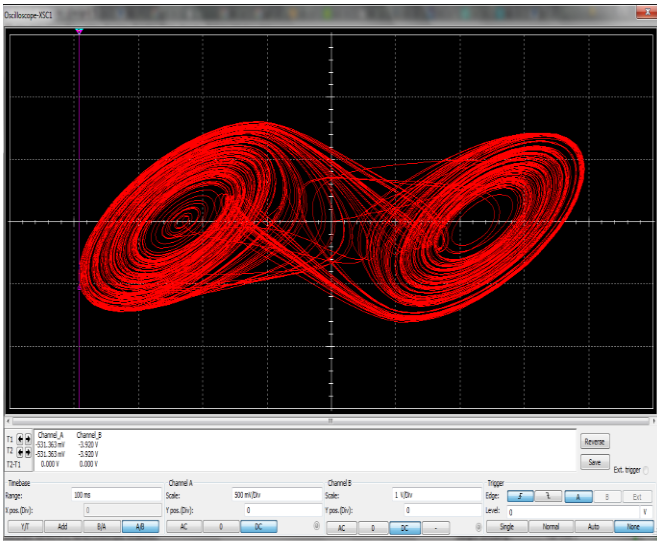

Figure 14: Chaotic Attractor (transmitter v2 Vs receiver v2)

capacitors with a resistance free line. As it is expected from theory and verified from the simulation (fig. 13) we can achieve a perfect synchronization. Here the v2 (t) at the transmitter is identical with v2*(t) at the receiver. As a result in the scope we see a y=x line. In fig. 12 the attractor presented in the right figure is presenting the double scroll attractor of the receiver.

Comparing the chaotic attractors generated at this deferent condition we do not notice any deference in the characteristics of the chaotic attractor.

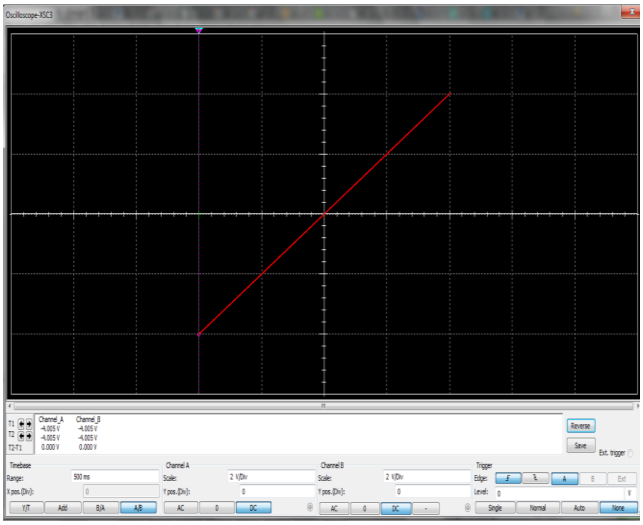

Figure 14: Perfect Synchronization of Chaotic Signal

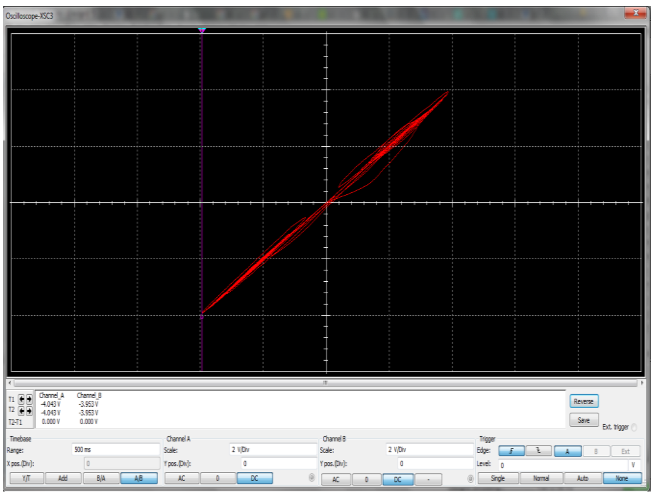

Figure 16: Partial Synchronization of Chaotic Signal

A partial synchronization can be seen after increasing the resistance of the line at 3.5KΩ. According to our simulation (FIG. 15), we can notice a partial synchronization. This could be explained from the difference between the transmitted signal and the received one. After a couple of second we receive a perfect synchronization which could last for a long time. In fig. 15 at the right hand side is presented the v2 (t) at the transmitter versus the v2*(t) at the receiver and at the left hand side is presented the chaotic attractor.

Now, increasing the resistance from 3.5k ohm to 10k ohm, we can see that for resistance above 3.5k ohm we are not able to have a synchronized system which can be observed from figure 16.

This could reduce the distance between the transmitter and receiver, since the larger the distance the bigger the resistance. With the use of amplification through the line, this problem could be solved while designing a chaotic encryption scheme..

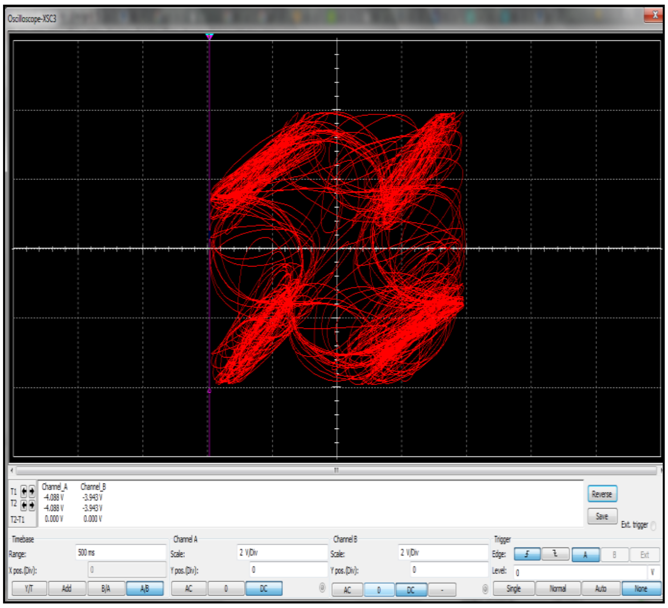

Figure 17: No Synchronized System at 10k ohm

8. CONCLUSION:

In this, we have presented an implementation of synchronization of Chua's chaotic circuit. The motivation for synchronization of a chaotic circuit is from the fact that this circuit could be used for encryption. Digital models of chaotic can be included in any sort of cryptosystems. We have used the Multisim, an electronic circuit simulation software, well known for it's close to real results. After simulating a master – slave coupled chaotic transition scheme we figured out that increasing the resistance of the synchronization line more than 3.5kΩ we are not able to have a synchronized system. This could reduce the distance between the transmitter and receiver, since the larger the distance the bigger the resistance. This problem could be solved with the use of amplifications through the line in the design of a chaotic encryption scheme. Transmission coefficient is modulated with the information bearing waveform and then the chaotic signal is transmitted. The chaos synchronization is done to receive synchronized signal at the receiver. The parameters can be changed to produce different signals. A TDM based single channel for transmitting multiple synchronized signal. The basic idea is to employ a zero order holder followed by the signals to be transmitted. Both sampling and holding modes are used for transmission process. One of the signals is transmitted over the sampling state while other signal is transmitted over the holding period.

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