Audio Signal Encryption and Decryption using Chaos Generating Circuits

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INTRODUCTION

This experiment explores the use of chaotic systems, specifically the Chua circuit, to encrypt analog audio signals for secure communication. The Chua circuit produces chaotic, noise-like signals highly sensitive to initial conditions, making them ideal for masking audio data and difficult for unintended recipients to decode.

An audio signal is combined with the Chua Diodes' chaotic output to create an encrypted signal. This chaotic carrier obscures the original audio, which can only be recovered by a synchronized Chua circuit at the receiver. This setup demonstrates how chaos-based encryption can secure audio transmissions over unsecured channels. The experiment evaluates the effectiveness of Chua circuit encryption by assessing the quality and security of the recovered signal and examining the circuit's sensitivity to parameter variations during encryption and decryption.

USING CHUA CIRCUITS FOR THE EXPERIMENT

• Chua Diodes

Chua Diode helps in generating chaotic Potential V(x) or V(y) and current I(Z) (shown in Fig1.) whose state is dependent on the values of Capacitor C_1, C_2, Inductor L_1 and Resistor R_6 as they set the initial values of the system. A microscopic change in the values of components results in a larger difference in chaotic behavior and hence Chua Circuit is useful as it generates chaos using simple circuit components.

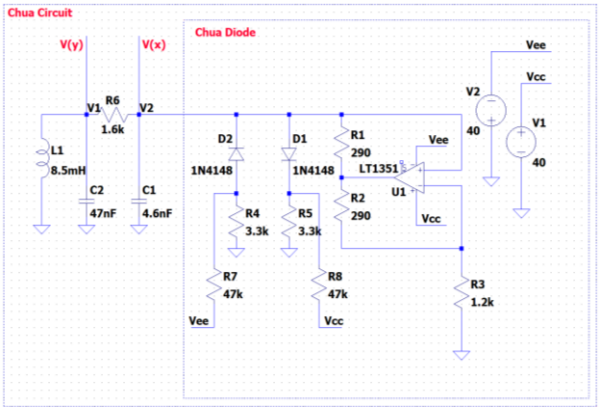


Fig. 1. Chua Circuit used with all the units in SI Unit.

For Encryption and Decryption of the audio signals, we require two exactly same Chua circuits so as to operate on synchronized circuits.

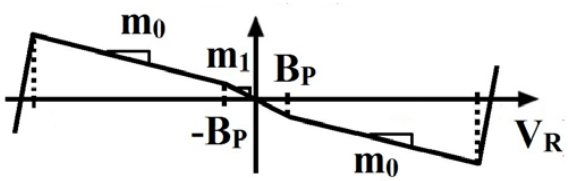


Fig. 2. I-V Characteristics of Chua Circuit.

$$f(X) = m_0 X + 0.5(m_1 - m_0)\left(|X + B_p| - |X - B_p|\right)$$

X: Voltage across capacitor C_1 Y: Voltage across capacitor C_2
Z: Current through the inductor L_1 G: Conductance resistor R_6
f(X): Nonlinear function describing the Chua diode's voltage-current characteristic
Bp: is the breakpoint voltage for the piecewise linear function.

• Differential Equations for Chua Circuit

The dynamics of the Chua circuit are governed by the following equations:

$$\frac{dX}{dt} = \frac{1}{C_1}\left(G(Y - X) - f(X)\right)$$

$$\frac{dY}{dt} = \frac{1}{C_2}\left(G(X - Y) + Z\right)$$

$$\frac{dZ}{dt} = -\frac{1}{L}Y$$

• Observables in Chua Circuit

The Circuit generates chaotic voltage at X and Y terminals and Chaotic current Z.

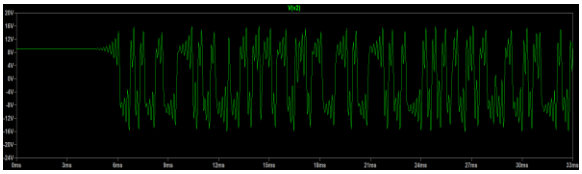


Fig. 3a, Voltage across C_1 (X) against time

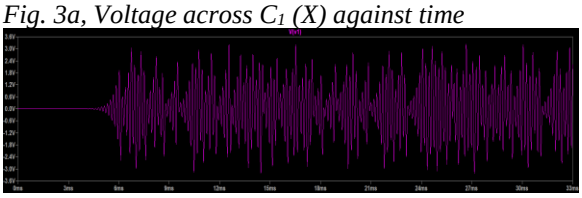


Fig. 3b, Voltage across C_2 (Y) against time

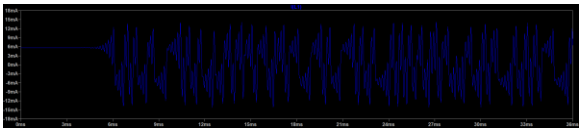


Fig. 3c, Current through L_1 (Z) against time

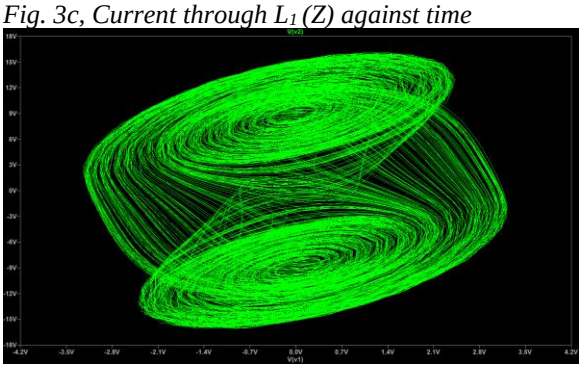


Fig. 3d, $V(C_1)$ or X against $V(C_2)$ or Y.

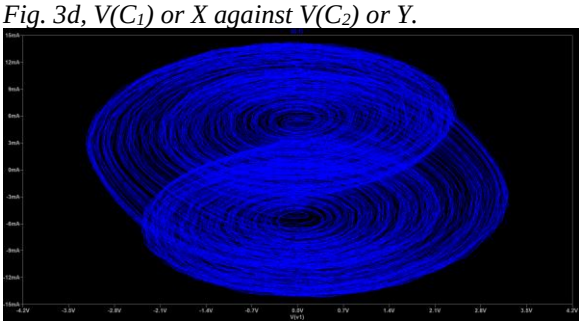


Fig. 3e, $I(L_1)$ or Z against $V(C_2)$ or Y.

Here X, is flipping its values with time and has a higher amplitude. So we use X(t) as the encrypting input.

III. Experiment

The chaotic voltage *X(t)* generated by the circuit is used as an Input voltage (through a decoupler to ensure full signal retention) to an adder circuit to superimpose with the analog audio signal say *A(t)*.

The signal is then passed through an Inverting Amplifier to ensure the polarity retention of the waveform and can be sent as an encrypted signal.

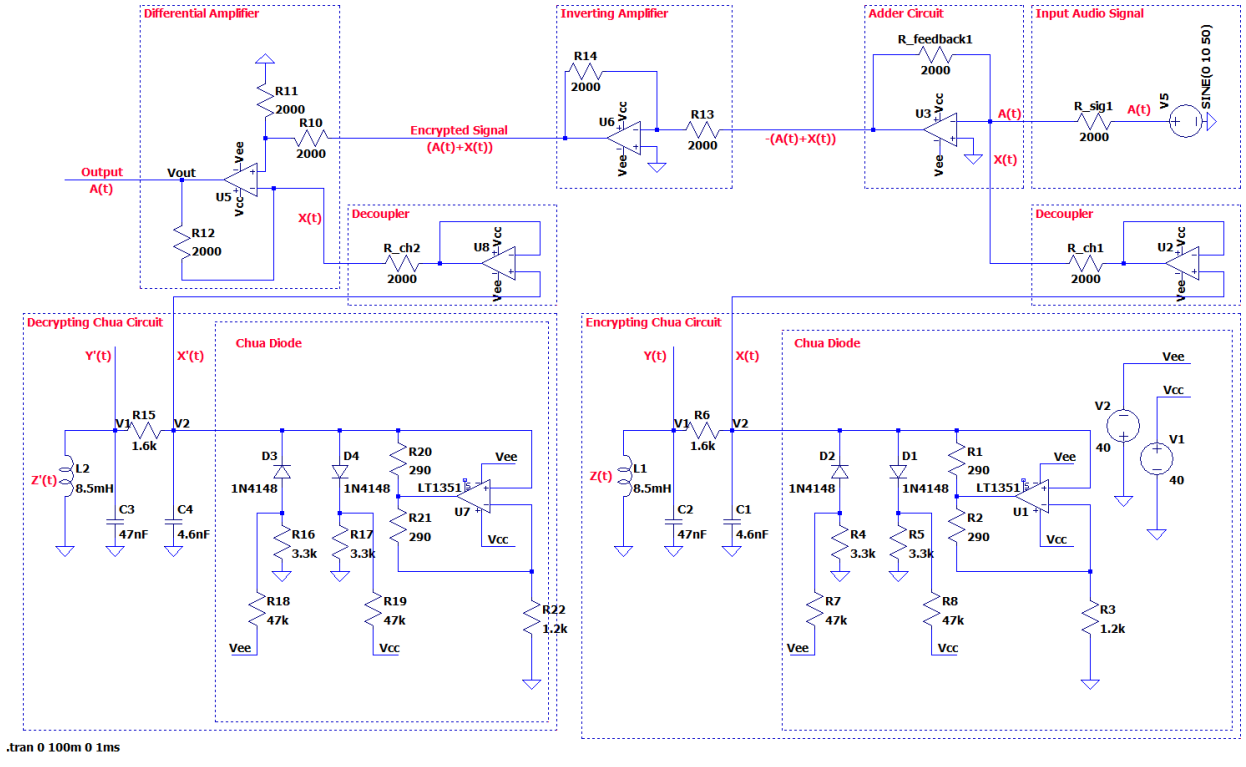
Now, another synchronized Chua circuit (exactly the same configuration as the one used at the point of encryption) is used to decrypt the signal at the receivers end while using a differential amplifier to cancel out the superposition of the initial chaos.

IV. DISCUSSION

Since the fine tuning for the synchronization of two Chua circuits is dependent on very minor factors like the length of wires used (observed during the making of the circuits), a digital implementation of the circuit is quite more of a practical approach as in to store the encrypted voltage signal sent from the source and then decrypting it during using the same conditions for the decrypting Chua (will be demonstrated during presentation).

V. CONCLUSIONS

Irrespective of the synchronization problem, Chua circuit can be used due to its simpler components to encrypt data and can be the used to decrypt at receivers end through same initial condition. It can also be implemented in many other encryptions like image encryption through normalization of the bit values and then using the circuit.



ACKNOWLEDGMENTS

We extend our sincere gratitude to **Dr. Rajeev Gupta** for their invaluable guidance and feedback, which greatly supported the completion of this experiment. We also thank the lab staff **Dr. Upendra Kumar Parashar and Mr. Ramesh Prasad** for providing resources and a safe, organized environment.
Finally, We appreciate **Indian Institute of Technology, Kanpur** for fostering an atmosphere of learning and exploration. This experience has enhanced our understanding and strengthened practical skills, which will benefit our academic journey.

APPENDIX

Using dual Chua circuit as an advancement of the experiment: http://surl.li/nxejwu

REFRENCES

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