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Design and Implementation of a Secured Communication System Using Chau's Circuit

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Abstract

The Chua circuit is one of the most basic nonlinear circuits that exhibits the most complicated dynamical behavior, including chaos, which exhibits a variety of bifurcation occurrences and attractors. Proteus software was used to develop and simulate the Chua masking communication circuits in this paper. The transmitter and receiver sections of the electronic circuit oscilloscope outputs of the realized Chua system are also shown. The accuracy of the intended and implemented Chua chaotic oscillator circuits is demonstrated using simulation and oscilloscope outputs. The Chua system is designed for chaotic communication circuits with masking. The acquired data is utilized to demonstrate the Chua chaotic system's usefulness in secure communication applications .The results were compared with previous studies on circuit implementation and experimental results that indicate the double-pass attractor, in addition to the advantages of this technique over others in the fields of communication, image coding, and simulation of neural systems.

Keywords: Chua; chaos; secure communications.

1. Introduction

The word "chaotic" is frequently interchanged with the word "complex." The latter type of system would have a vast number of components interacting in a complex manner, and it could be chaotic. However, if the main purpose is to achieve chaotic behavior, there is no underlying law that requires us to build an extremely complex circuit. Interest in nonlinear dynamics and chaos has increased rapidly since Lorenz published his monumental work on a simplified model of convection for weather prediction [1]. The chaotic behavior of a dynamic system has a very large (possibly infinite) number of attractors and is sensitive to initial conditions [2]. Thus, an arbitrarily small perturbation of the current trajectory may lead to significantly different future behavior [3]. Leon Chua invented his electrical circuit in 1983 in response to two unfulfilled endeavors by many researchers on chaos, and that was about the required aspects of Lorenz's equations [4]. Chua's brilliance was in realizing that a simple circuit may display chaos that it contains all the necessary elements as well as all the measurement components needed to control chaotic attractors [5]. Chaotic signals, like broadband spectrum sensing, are very responsive to initial circumstances and have unexpected characteristics and noise. As a result of its noise-masking and immunizing properties, it can be used in a variety of communication applications. Because they can spread the spectrum of information signals while simultaneously encrypting them with chaotic circuitry that is simple and inexpensive, destruction-encrypted communication technologies have been a feasible alternative to typical wideband systems [6]. To exhibit chaotic behavior, a system must have at least three components: a nonlinear element or elements, a locally resistor or elements, and three or more energy storage elements [7, 8]. These autonomous dynamical systems are defined as systems that evolve naturally without any external signal injection into the circuit [9]. There are numerous applications of chaos and chaotic processes.

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Secure communication is one of the most commonly used practical applications. In recent years, the synchronization of chaotic systems and chaos-based secure telecommunication have become prominent study areas [10, 11]. The Chua circuit has become a universal paradigm for chaos due to its rich repertoire of nonlinear dynamical phenomena [12].

2. Literature Review

The Chua circuit was the subject of extensive research. Only ten years after that last circuit's conception [10]. The early efforts focus on the raceway characteristics. Studying chaotic behavior experimentally and numerically is dependent on control factors, the various forms of attractors that can occur, or the development of discrete maps to explain the various properties of the solutions. Many early studies are starting to show alternate layouts of the Chua circuit; between 1984 and 1986, efforts were made to reduce its complexity to clarify the device, but it was also expressly incorporated into the theoretical model [13]. Several pieces of information became available. Try to change the op-amp to improve the circuit's efficiency during high-frequency vibrations or to examine the circuit's behavior with finer non-linearity. Although the first issue was empirically avoided, there is a strong case for limiting the second instance to the piecewise-linear situation, as previous research has shown that no general qualitative occurrences emerge [6]. The project's purpose is to create and build a robust messaging system for Chaotic Systems Chua's transmitter and receiver. A current-voltage polynomial model is used to behaviorally characterize the circuit topology, current-voltage characteristics, and its application as a Chua diode in a Chua circuit. The model's conclusions are then corroborated by experimental instrumentation [14]. A Chua-based model was used in [15] to build a simulation of neurons that contributes to building neuron systems and computer technologies. In [16], Chua technology was used to design a secure communication system based on artificial neural networks (ANN), which can be used in the future to encode images and sounds.

3. Materials and Methods

Chua's design is a simple oscillator with several perturbation theories and chaos. Three basic power generation devices (an oscillator and two capacitors), a regular resistor, and a solitary nonlinear resistor (NR) are used in the system. The Chua system is characterized by three differential equations using Kirchoff's law [17].

$$C_1 \frac{dv_{C1}}{dt} = G(v_{C2} - v_{C1}) - g v_{C1} \qquad (1)$$

$$C_2 \frac{dv_{C2}}{dt} = G(v_{C1} - v_{C2}) + i_L \qquad (2)$$

$$L \frac{di_L}{dt} = -v_{C2} \qquad (3)$$

Where **C** represents the capacitor, **L** represents the induction, **G** represents the linear resistor, $\boldsymbol{vC1}$ represents the potential across the capacitors **C_1**, $\boldsymbol{vC2}$ represents the voltage across the capacitor **C_2**, $\boldsymbol{i_L}$ represents the current that flows through the inductor, and $\boldsymbol{g(vC1)}$ is the nonlinear voltage-current characteristic of a nonlinear resistor which can be written as:

$$g(v_{C1}) = g(v_R) = m_0 + \frac{1}{2}(m_1 - m_2)[|v_R + B_P| - |v_R - B_P|] \qquad (4)$$

The gradients in the inlet and outlet areas are $\boldsymbol{m_1}$ and $\boldsymbol{m_0}$, respectively, and the thresholds are $\pm \boldsymbol{Bp}$. The resistor **R** acts as a variable, allowing the arpeggiator to be tuned over a wide range of catastrophic values. The parameters of the two capacitors, inductor, and resistor are set based on Proteus' computer models [12]. Two negative resistors are placed in parallel to make the nonlinear resistor. In this study was chosen 220**Ω** which is sufficient enough to hold the op- amp from being overloaded, perhaps approximately. **R_2** is selected to be identical to **R_1** in order to simplify the analysis. The breaking points are chosen so that the destination (the final state of the system) stays in the negative resistance zone which Provides a detailed design for the nonlinear resistor [10, 18]. It's simple to calculate the constants **m_o**, **m_1**, and **B_p**:

$$\left(m_1 - \frac{R_2}{R_1 R_3}\frac{R_5}{R_1 R_6} \dots\right) = \frac{R_2}{R_1 R_3} + \frac{1}{R_4}, B_{P1} = \frac{R_3}{R_2 + R_3} E_{sat} B_{P2} = \frac{R_6}{R_5 + R_6} E_{sat} \qquad (5)$$

The values of **R_1, R_2, R_3, R_4, R_5** and **R_6** are 220 **Ω**, 220 **Ω**, 220 **Ω**, 2.2 **KΩ**, 22**KΩ** and 3.3 **KΩ** respectively. The values of capacitors **C_1** and **C_2** are 10 **nF** and 100 **nF** respectively. The inductor **L** is 18**mH**, **R** varied **E_{sat}** is 9**V**. The OP-AMP type is TL082CD.

3.1 Design of a secure communications network simulation

The full execution of Chua's electronic circuit using Proteus software is shown in Figure 1. These mechanisms were created with great care. The transmitter and receiver are the same. In order to execute chaotic masking communication, it is important to ensure that the transmitter and receiver characteristics are equal. A low-level message signal is added to the driving chaotic signal in this masking approach in order to reconstruct a clean driving signal at the receiver.

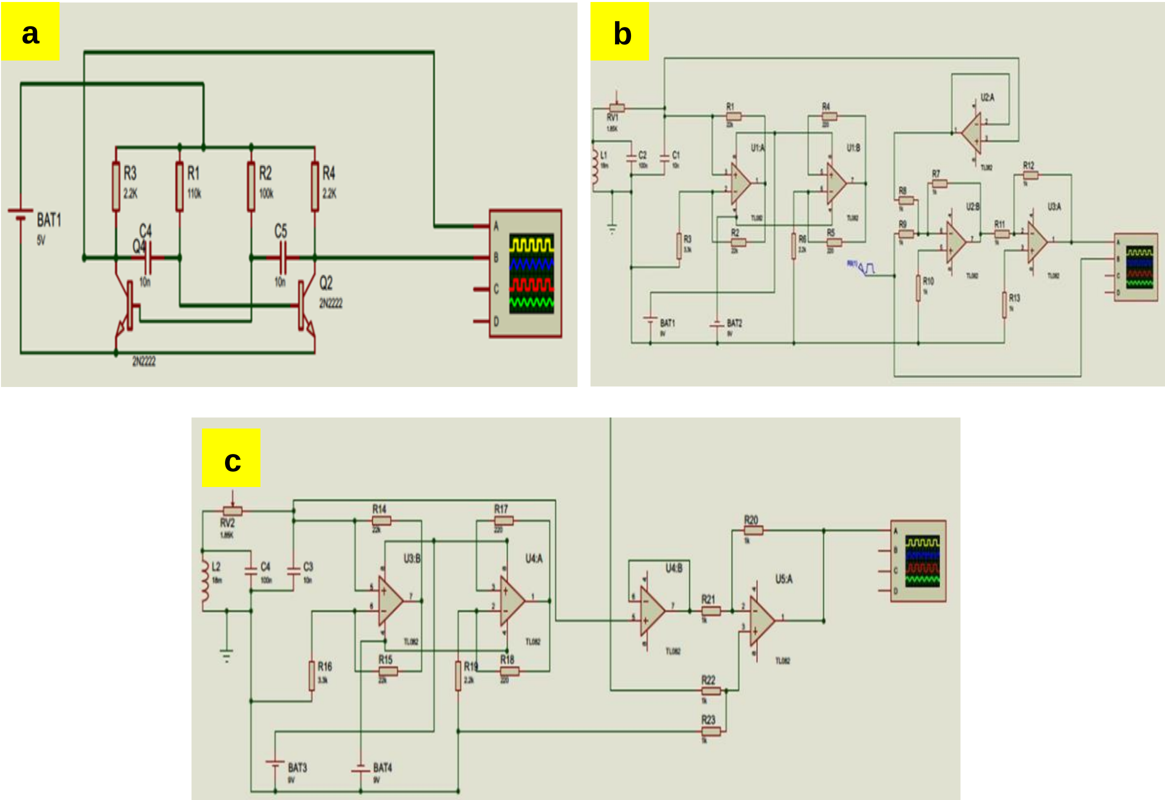

Fig. 1. (a) Chua's massage signal circuit is being implemented utilizing the proteus model; (b) transmitter proteus circuit; (c) receiver proteus circuit.

The experimental electronic circuit hardware realization of the Chua's circuit is shown in Figure 2. It consists of a linear inductor **L**, two capacitors **C_1** and **C_2**, a linear resistor **R** and a nonlinear resistor **N_R** often referred to as Chua's diode. The experimental component values that used in the circuit are illustrated in table 1.

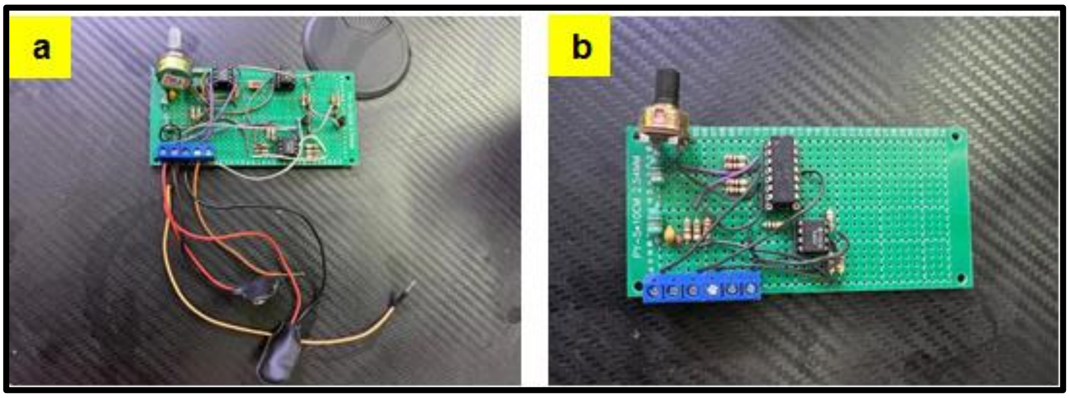

Fig. 2. Chua's circuit hardware: (a) transmitter circuit; (b) receiver circuit.

Table 1 The Chua circuit parameters

Element	Description	Value
R1	Resistor	220 Ω
R2	Resistor	220 Ω
R3	Resistor	2.2 kΩ
R4	Resistor	22 kΩ
R5	Resistor	22 kΩ
R6	Resistor	3.3 kΩ
C1	Capacitor	10 nF
C2	Capacitor	100 nF
L	Inductor	0.730 H
R	Variable resistor	0-1.5 kΩ
Op-Amp	TL082CD	

4. Results and Discussion

4.1 Results of simulation secure communication system design

A numerical simulation to illustrate the dynamical behavior of Chua's circuit system is presented. Figure 3 shows the obtained results. $S(t) = x + i(t)$ is fed into the receiver after the square wave signal is merged with theproduced chaotic x signal. If x = xR, the chaotic **x** pattern is produced, enabling a single subtraction to extract the transmitted data, $[x + i(t)] - xR = i'(t)$.

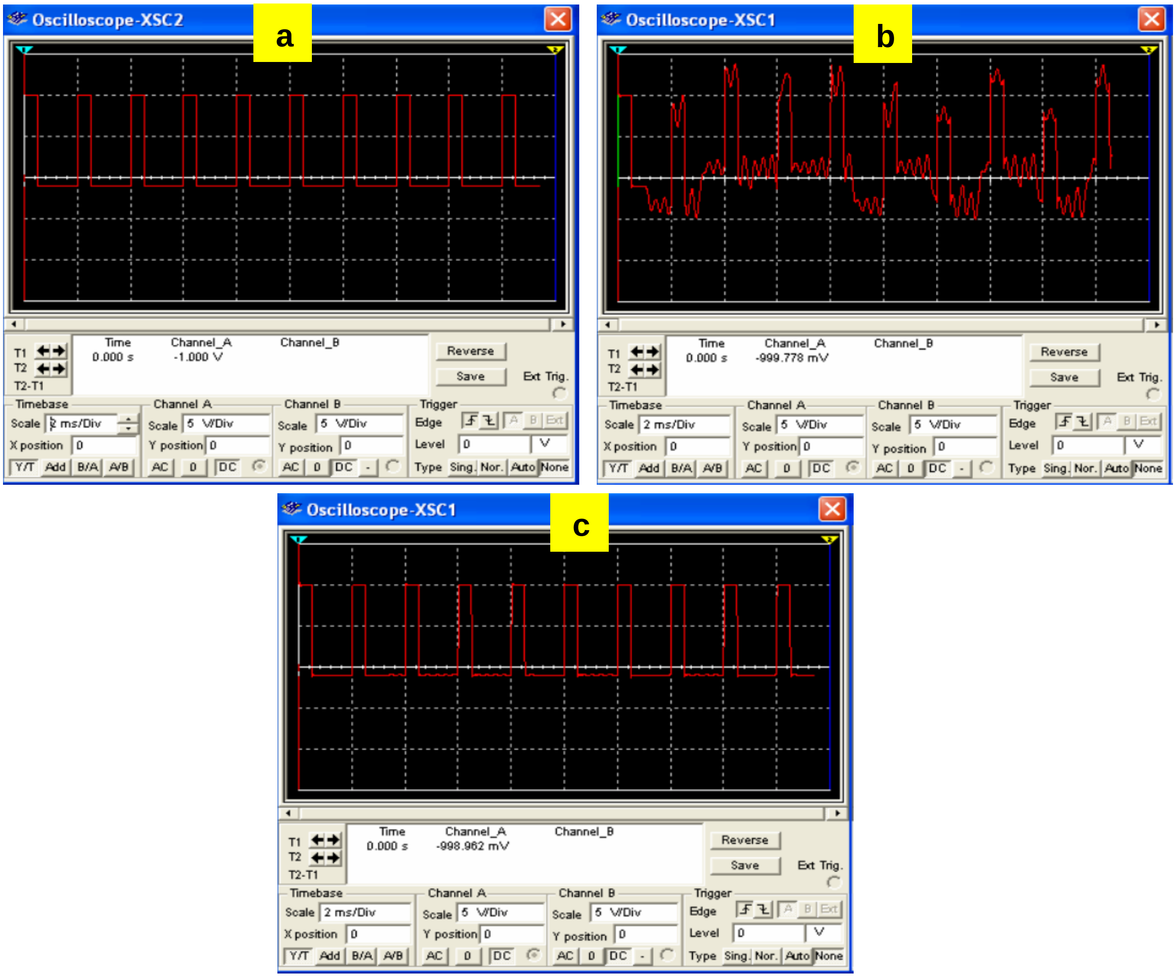

Fig. 3. (a) the proteos simulation of the chaotic time series shows the outputs of information signal i(t); (b) outputs of chaotic masking transmitted signal S(t). (c) the dynamics of the system Chua's system change are achieved by accessing the parameter set given as a fixed parameter (and R as a varied parameter).

The phase profile of the investigated signal is shown in the proteus simulation findings. It was discovered that the output signal may restore the input signal, implying that secure communication in a chaotic system is achievable. The use of chaos in secure communication systems is proposed and attributed to the prevalence of a chaotic signal between transmission and reception.

4.2 Practical results of the designed system

The numerical results can be compared to earlier laboratory research using the same parameter set. Figure 4 shows the practical results of Chua's circuit time series using oscilloscope outputs.

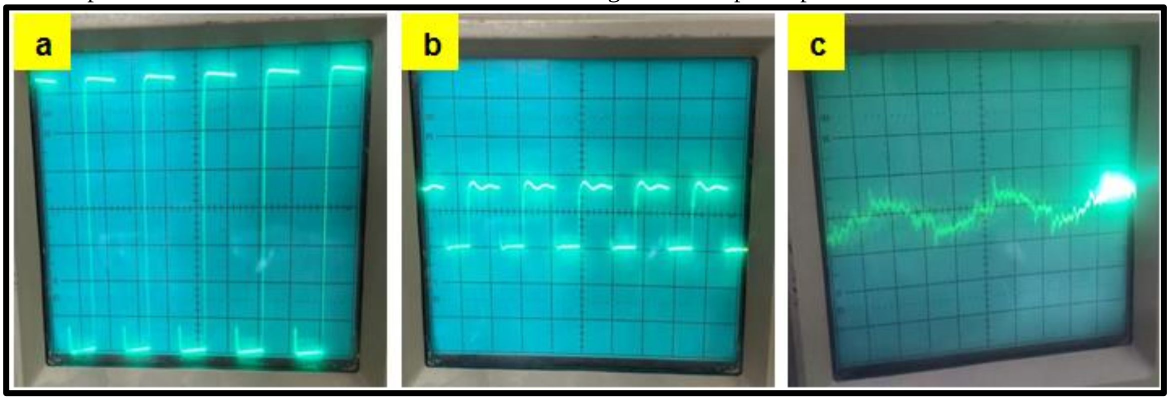

Fig. 4. oscilloscope outputs: (a) massage signal; (b) transmitter signal; (c) recovered signal.

Using the signal masking technique and Chua's behavior, the information was perfectly retrieved. Multiple studies investigating Chua circuits using various software, such as Mutasim [19], revealed a strong correlation by lowering **R** (the variable resistor). In Chua's chaotic system, double scroll attractors indicated that although the system might not be sensitive to certain system parameters, it was highly responsive to others. Through the results of the chaotic Chua system, it was noted that it is possible to use the dynamics in the encryption process because of the wide range (bandwidth) of frequencies as compared with the Ressler chaotic system [20**].**

5. Conclusions

The topic of this paper is the chaotic oscillation circuit of the Chua attractor and its applications in signal-masking communications. Chua's chaotic circuit system is investigated in depth in this work by fundamentally changing the control parameter **R**. The system exhibits a wide range of chaotic dynamic phenomena. The chaotic system that evolves was not only numerically proven, but also generated by electronic circuit simulation and experimentally verified in the laboratory, with very strong self-consistent with the simulation results. As we demonstrated in simulations, chaos camouflage modeling was generated using Proteus software, then applied to a real circuit and tested with a scope. This technology can be used to secure communications as well as encrypt images and simulate nervous systems.

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