Design and Simulation of a Simple Two-Transistor Single-Supply Resistor-Capacitor Chaotic Oscillator

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Abstract

This paper presents the design, operation, and analysis of a simple two-transistor single-supply resistor-capacitor (RC) chaotic oscillator, a fundamental nonlinear circuit capable of generating chaotic signals. The oscillator employs a minimal configuration of two bipolar junction transistors (BJTs), resistors, and capacitors to achieve nonlinear dynamics under a single DC supply. Unlike conventional oscillators that produce periodic waveforms, the circuit exhibits sensitive dependence on initial conditions, leading to irregular yet deterministic chaotic behavior. Through simulations carried out in eSim software, the study demonstrates the transition from stable oscillations to chaotic regimes as component values and biasing conditions are varied. The results highlight the influence of RC time constants and transistor nonlinearities on the onset of chaos, confirming the potential of such compact circuits in applications including secure communications, random number generation, and nonlinear system studies. This emphasizes the significance of simple transistor-based chaotic oscillators as low-cost and accessible platforms for exploring complex dynamical phenomena.

Keywords: Chaotic oscillator, Two-transistor circuit, Single-supply design, RC network, Nonlinear dynamics, eSim simulation

I. INTRODUCTION

Chaotic oscillators are nonlinear electronic circuits capable of generating aperiodic and unpredictable waveforms that exhibit deterministic chaos. Unlike conventional oscillators, which produce regular sinusoidal or periodic signals, chaotic oscillators demonstrate sensitive dependence on initial conditions, leading to complex yet deterministic output behavior. These properties make chaotic systems attractive for applications in secure communication, random number generation, cryptography, and the modeling of nonlinear dynamical systems.

Among various chaotic oscillator designs, transistor-based circuits offer the advantages of simplicity, low cost, and ease of implementation. In particular, a two-transistor configuration with resistor-capacitor (RC) networks provides a minimal yet effective approach to realizing chaotic behavior using a single DC supply. The nonlinear characteristics of the transistors, combined with the time constants of the RC components, introduce feedback and nonlinearity essential for chaotic dynamics. This work focuses on the design, simulation, and analysis of a simple two-transistor single-supply RC chaotic oscillator using eSim software.

II. PURPOSE OF CHAOTIC OSCILLATORS

- Secure Communications: Chaotic waveforms can mask information signals to improve transmission security.
- Random Number Generation: The unpredictability of chaotic signals makes them suitable for cryptographic applications.
- Nonlinear Dynamics Study: Provides a simple platform for analyzing chaos theory and dynamical systems.
- Educational Demonstration: Useful in labs for teaching chaos and nonlinear electronics.

III. WORKING PRINCIPLE

The working principle of the two-transistor single-supply RC chaotic oscillator relies on nonlinear transistor characteristics and RC feedback. The two BJTs introduce nonlinearity through their exponential I–V behavior, while the resistors and capacitors establish time constants that control energy storage and release. Together, these create nonlinear feedback loops that transform regular oscillations into chaotic waveforms.

The two-transistor single-supply RC chaotic oscillator works on the principle of nonlinear feedback and energy exchange between the resistor-capacitor (RC) network and the active transistor pair.

Non-linearity through transistors

1. The two bipolar junction transistors (BJTs) introduce nonlinear amplification and switching behavior.
2. Their input-output relationship is nonlinear (due to exponential I–V characteristics), which is essential for generating chaos.

Feedback through RC networks

3. The capacitors store and release energy, while the resistors control charging/discharging rates.
4. This interaction forms time delays and feedback paths.
5. Small changes in voltage/current get fed back into the circuit, altering transistor operation.

Single-supply operation

6. With only one DC supply, the biasing network ensures both transistors operate in active/nonlinear regions.

7. The RC feedback combined with the transistor nonlinearity produces oscillations without needing dual supplies.

Onset of chaos

8. At certain resistor and capacitor values, the system transitions from stable oscillations → periodic oscillations → chaotic oscillations.

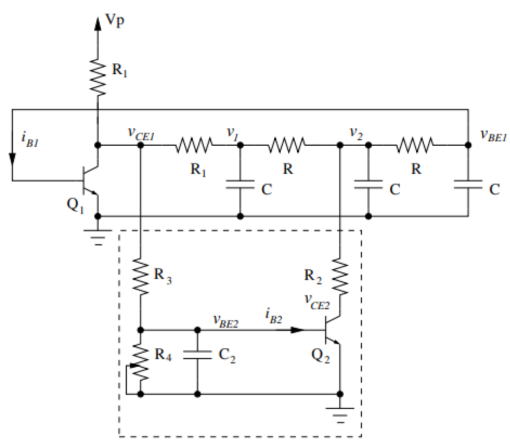
9. This occurs because the nonlinear feedback amplifies small variations, making the output highly sensitive to initial conditions.

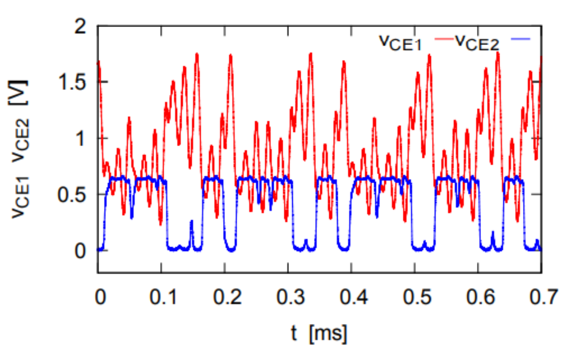
Resulting output

10. The output waveform is aperiodic and irregular but deterministic (chaotic).

This makes it useful for applications like secure communication (masking signals), random number generation, and nonlinear system modeling.

Circuit diagram





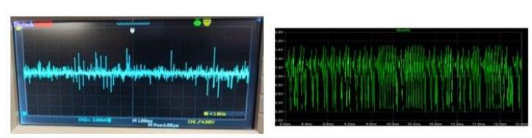


Figure 7. Mode 1; right – in-situ oscilloscope display (voltage vs. time); left – in-silico voltage vs. time plot

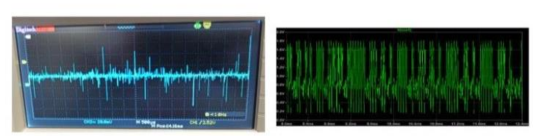
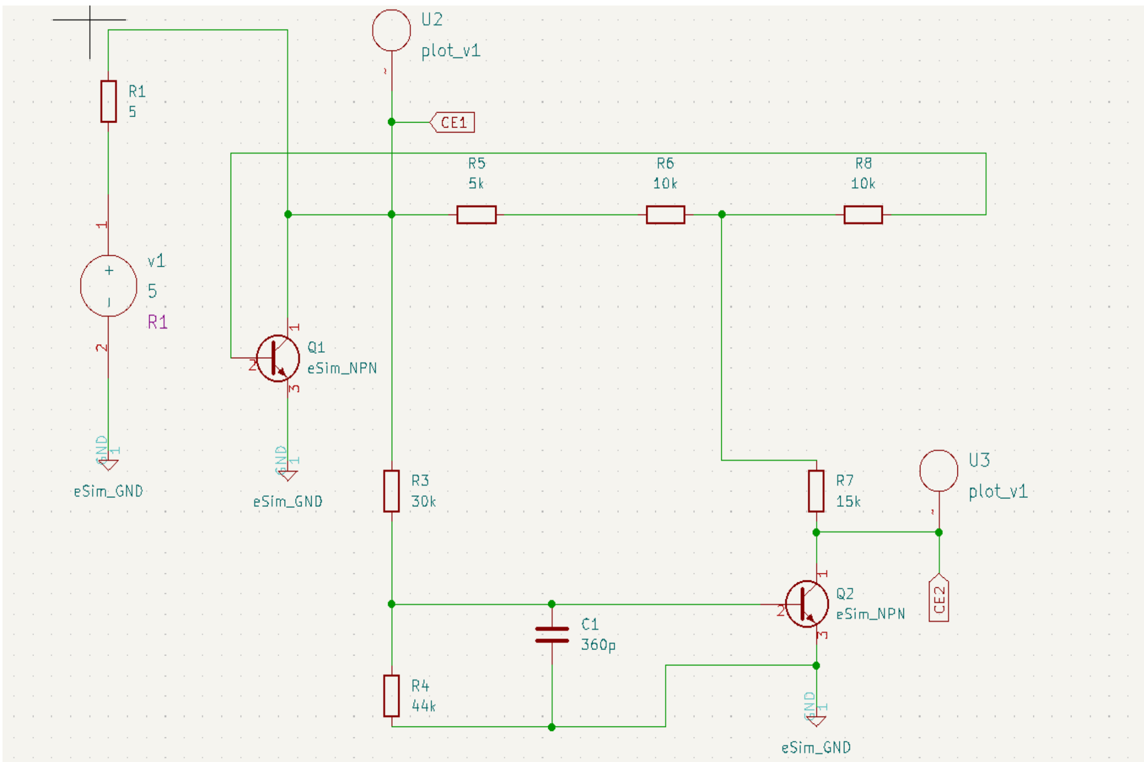


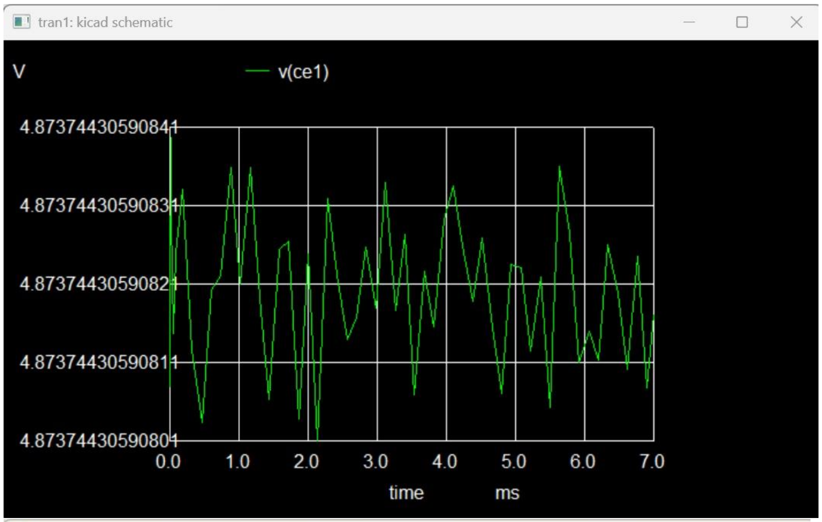
Figure 8. Mode 2; right – in-situ oscilloscope display (voltage vs. time); left – in-silico voltage vs. time plot

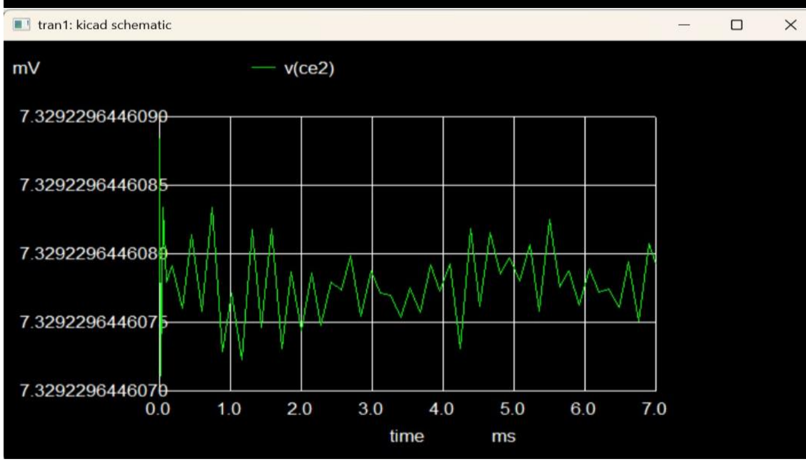
IV. PROPOSED SYSTEM

The proposed system introduces a two-transistor single-supply RC chaotic oscillator implemented in eSim software. The circuit demonstrates how simple active and passive components can generate complex chaotic signals. By adjusting resistor and capacitor values, different chaotic regimes can be observed, making it a useful platform for applications in secure communication, signal masking, and nonlinear dynamics research.

eSIM CIRCUIT







V. APPLICATIONS OF CHAOTIC OSCILLATORS

1. Secure Communications: Encryption and masking of transmitted signals.
2. Random Number Generation: Used in hardware-based cryptographic systems.
3. Radar and Imaging Systems: Enhances stealth and anti-jamming properties.
4. Nonlinear Dynamics Research: Serves as a simple testbed for chaos theory studies.
5. Educational Tools: Demonstrates nonlinear and chaotic behavior to students in laboratories.

VI. CONCLUSION

In conclusion, the design and simulation of a simple two-transistor single-supply RC chaotic oscillator in eSim highlight the fundamental principles of nonlinear dynamics and chaos. The results confirm that with minimal components, complex and aperiodic signals can be generated, offering significant potential in applications such as secure communication, cryptography, and nonlinear system analysis. This study emphasizes the value of compact, low-cost transistor-based chaotic oscillators for both practical applications and educational purposes.

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