Design and Simulation of a BJT-Based Non Linear Chaotic Oscillator

https://esim.fossee.in/circuit-simulation-project

Name of the participant : Priyanka

Institutions : Dronacharya group of institutions

Title of the circuit : A Three Phase RC Ring Oscillator Using BJT

Branch: Electronic and communication Engineering

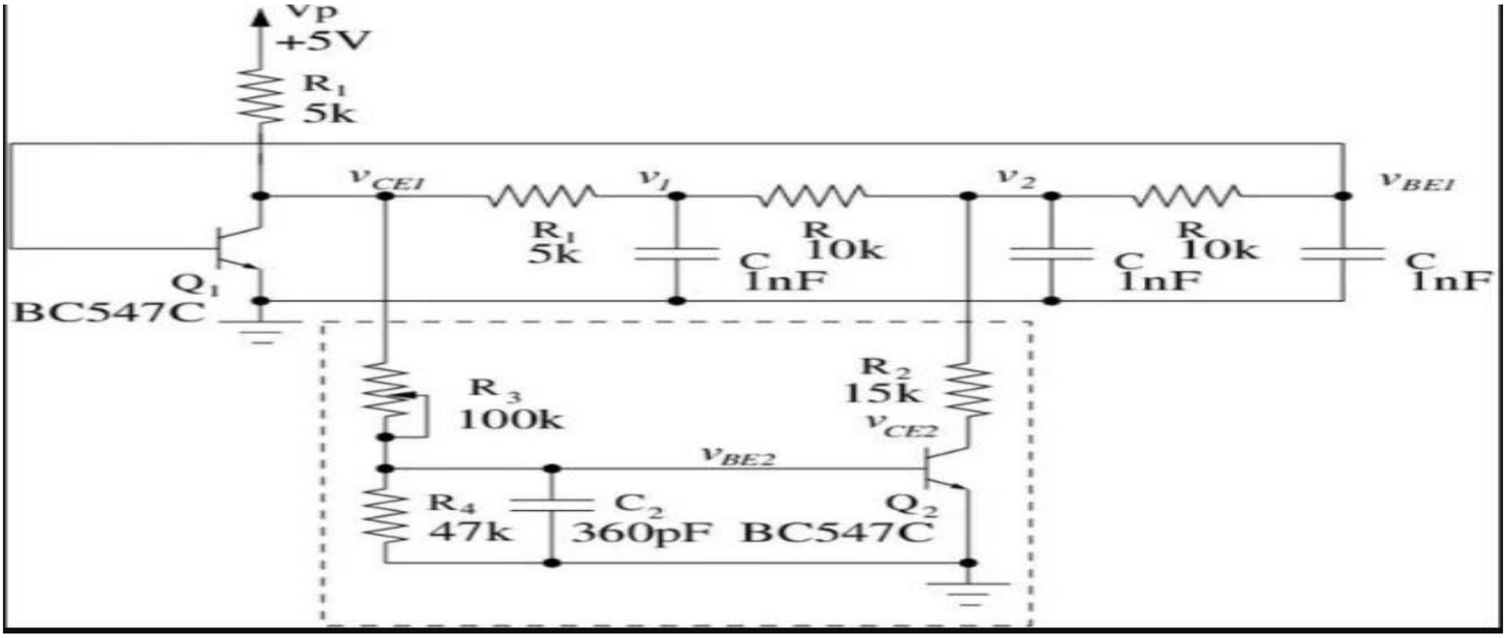
Theory/Description :

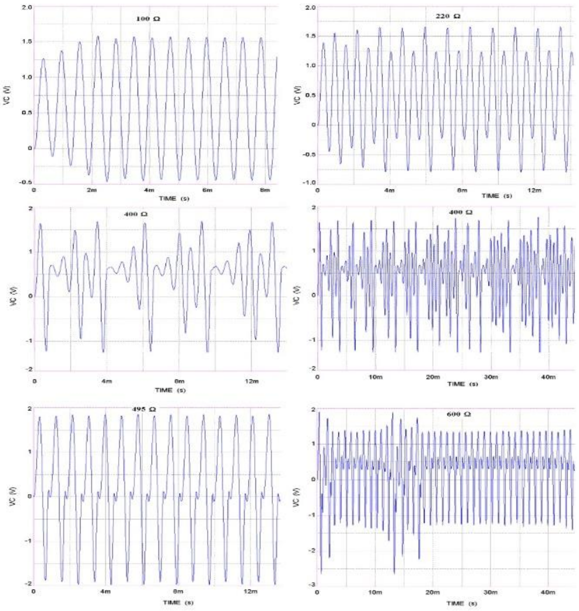
A chaotic oscillator is a nonlinear electronic circuit that produces complex, aperiodic oscillations which are highly sensitive to initial conditions. Unlike conventional oscillators that generate periodic sine or square waves, chaotic oscillators generate irregular waveforms due to nonlinear feedback and energy exchange within the circuit. In this design, two NPN transistors act as active nonlinear elements, while the RC network forms the energy storage and phase-shifting section required for oscillation.

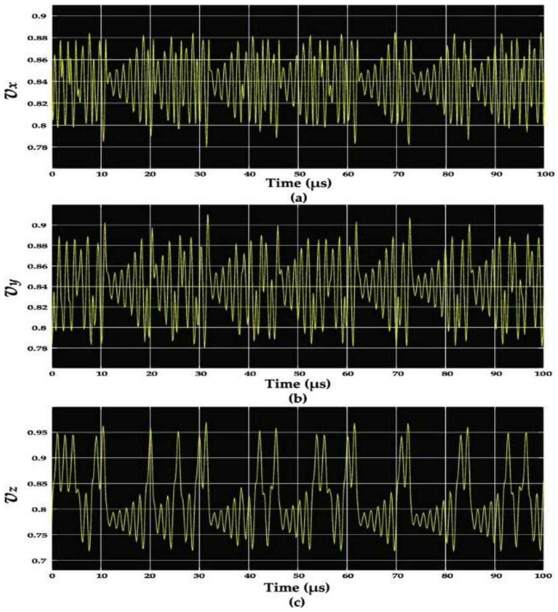
The RC ladder network consisting of resistors and capacitors introduces multiple time constants into the system. These different charging and discharging rates create delayed feedback paths, resulting in nonlinear dynamic behavior. The transistor stages provide amplification and switching action, ensuring that oscillations are sustained. When power is applied, small noise or initial disturbances in the circuit grow through feedback, leading to bounded but non-repeating oscillations known as chaotic behavior.

The output is typically observed at the collector of the upper transistor, where the combined effect of amplification and nonlinear feedback produces a complex waveform. The transient analysis of the circuit shows irregular oscillations instead of a steady periodic signal, confirming chaotic operation. Such oscillators are widely used in secure communication systems, random signal generation, and nonlinear system studies.

Circuit Diagram and Expected Output Waveform



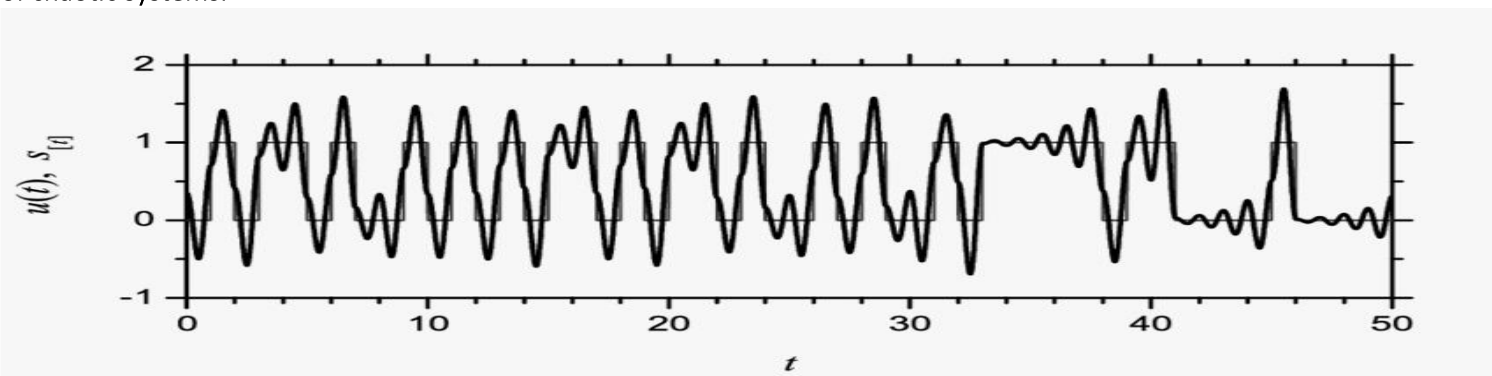




Circuit Description

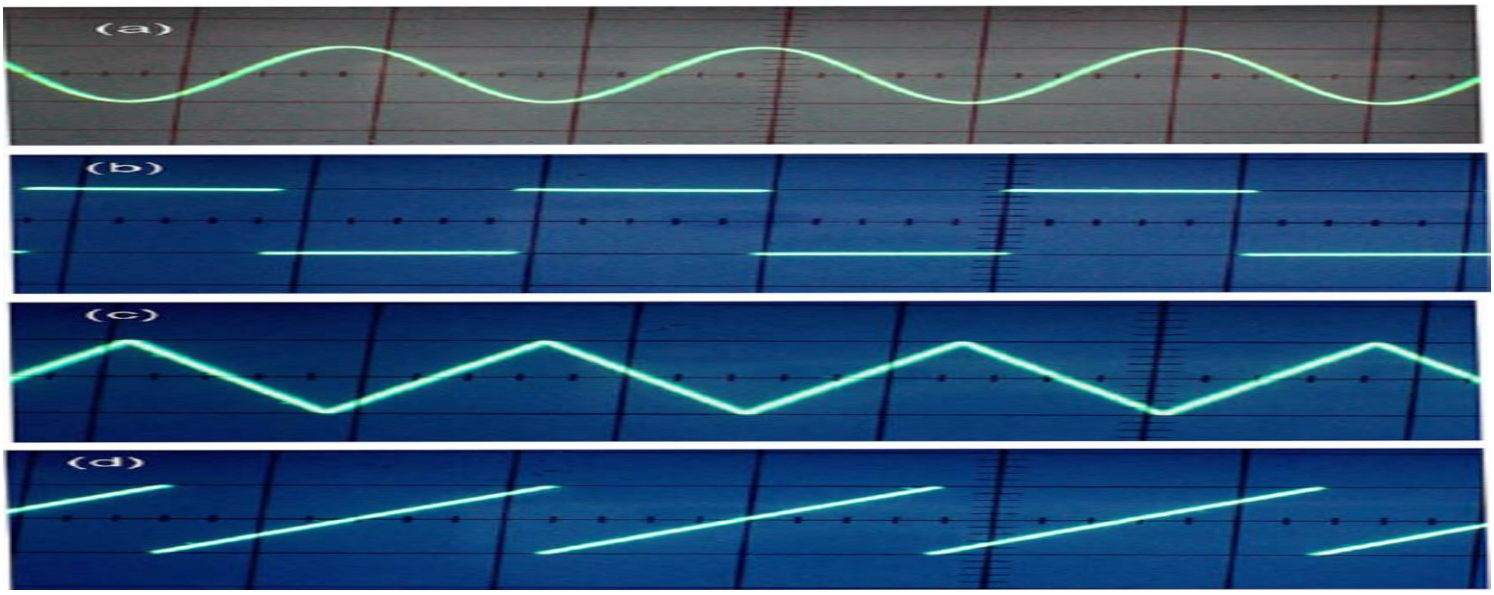
The circuit consists of two NPN transistors biased using resistor networks and powered by a 5V DC supply. The upper transistor stage acts as the primary amplifier, while the lower transistor provides feedback and additional nonlinearity required for chaos generation. The RC ladder network formed by resistors R3, R4, R7 and capacitors C2, C3, and C4 creates phase shifts and multiple delay paths in the feedback loop.

Resistors R1 and R2 establish the biasing conditions for the lower transistor, and capacitor C1 stabilizes high-frequency components. The interaction between the transistor gain and the RC network results in continuous energy exchange, producing sustained oscillations. Output nodes labeled output1 and output2 allow observation of voltage variations at different points in the circuit. During transient simulation in eSim, the waveform at output1 shows a bounded, non-periodic oscillation characteristic of chaotic systems.



Working –The chaotic oscillator operates using nonlinear feedback created by two transistor stages and an RC network. When the 5V supply is applied, both NPN transistors are biased through their respective resistor networks and begin operating in the active region. Small voltage fluctuations or noise present at power-up are amplified by the first transistor stage. This amplified signal is then passed through the RC ladder network formed by resistors and capacitors, which introduces multiple time delays due to different charging and discharging rates.

The delayed signals are fed back to the transistor inputs, creating a nonlinear feedback loop. Because the feedback contains multiple time constants, the circuit does not settle into a stable periodic oscillation like a normal oscillator. Instead, the voltages continuously change in an irregular but bounded manner. The second transistor enhances the nonlinear behavior by modifying the feedback amplitude and phase, which leads to sensitive dependence on initial conditions — a key characteristic of chaotic systems.As the process continues, energy is exchanged between the capacitors and transistor stages, sustaining oscillations without any external input signal. The output taken from the collector node shows a non-repeating, complex waveform during transient simulation, confirming chaotic oscillation.



Schmatic Of Circuit

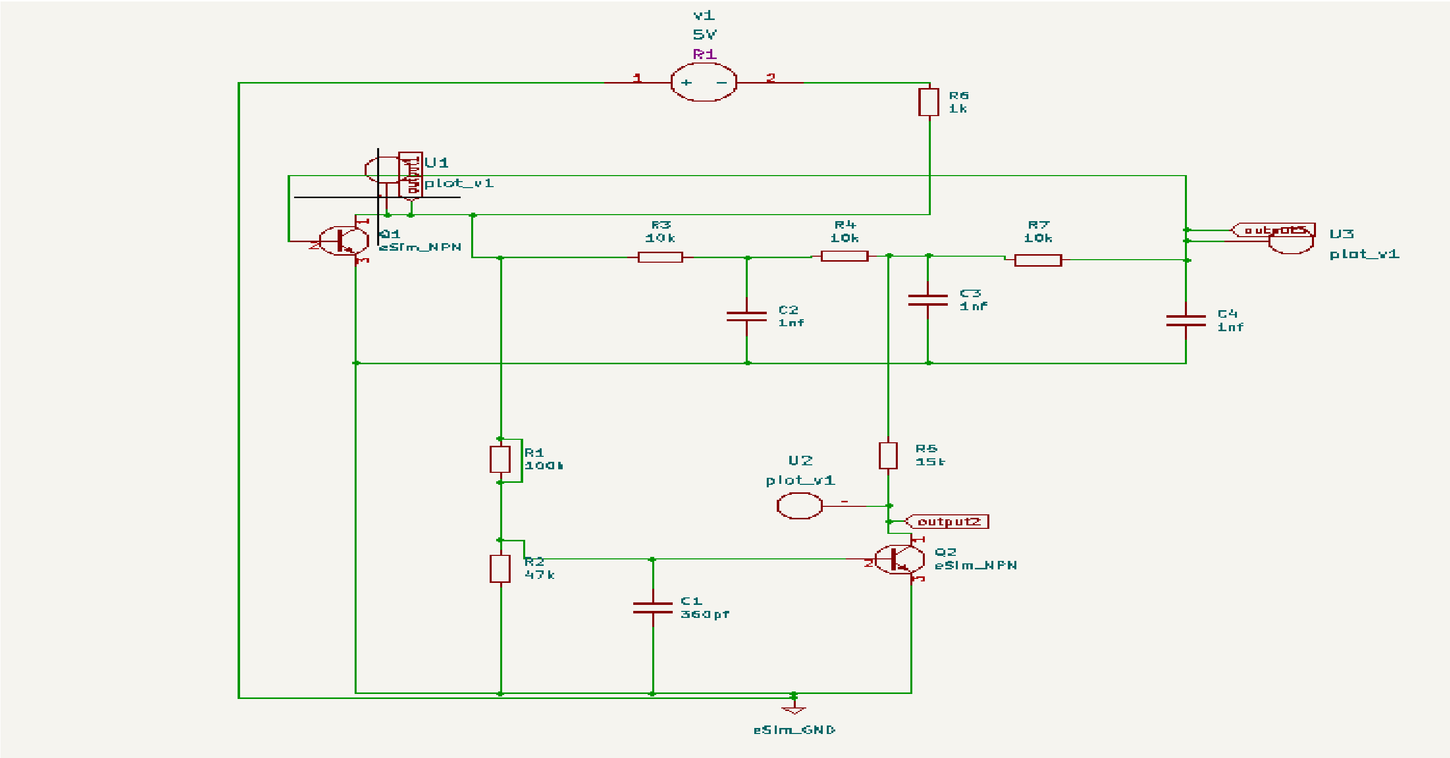
The schematic of the chaotic oscillator consists of two NPN transistors, a resistive biasing network, and an RC ladder feedback network that produces nonlinear oscillations. A DC supply of 5V is applied to the circuit through a collector resistor that limits current and establishes the operating point of the first transistor (Q1). The collector output of Q1 is connected to a series RC network composed of resistors and capacitors, which introduces phase shift and time delay in the feedback signal.

The RC ladder network generates multiple delayed voltage signals that are fed back into the transistor stages, creating nonlinear interaction between voltage and current. The second transistor (Q2) acts as an additional gain and feedback element, modifying the signal amplitude and contributing to the chaotic behavior of the circuit. The resistor network connected to the base of Q2 provides proper biasing, while the capacitor connected to ground controls the dynamic response of the circuit.

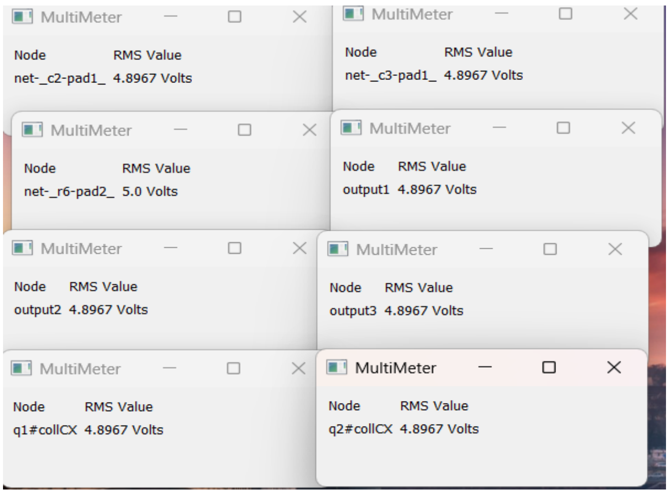
The output is typically taken from the collector of Q1 or Q2, where irregular and non-periodic oscillations can be observed during transient analysis. The combination of active devices and multiple RC time constants results in a bounded but unpredictable waveform, which is the main characteristic of a chaotic oscillator.

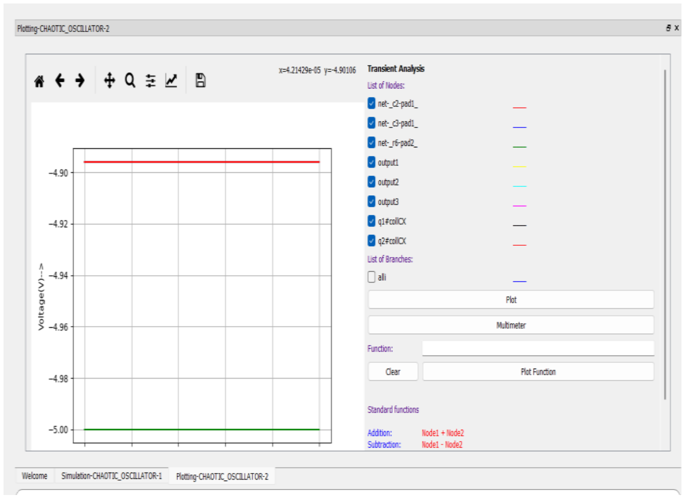
Summary:

In this work, a transistor-based chaotic oscillator circuit was designed and simulated using eSim. The circuit employs two NPN transistors along with an RC ladder network to create nonlinear feedback. The interaction between amplification, phase delay, and feedback produces complex oscillations instead of steady periodic signals. The simulation verifies that simple analog components can be used to generate chaotic signals suitable for educational and research purposes. The designed chaotic oscillator successfully demonstrates chaotic dynamics using a simple and low-cost circuit configuration. The circuit produces bounded, aperiodic oscillations due to nonlinear feedback between transistor stages and RC networks. The results confirm that chaotic behavior can be achieved without complex components, making the circuit suitable for academic study, signal analysis experiments, and demonstration of nonlinear systems in electronics.



Multimeter Reading





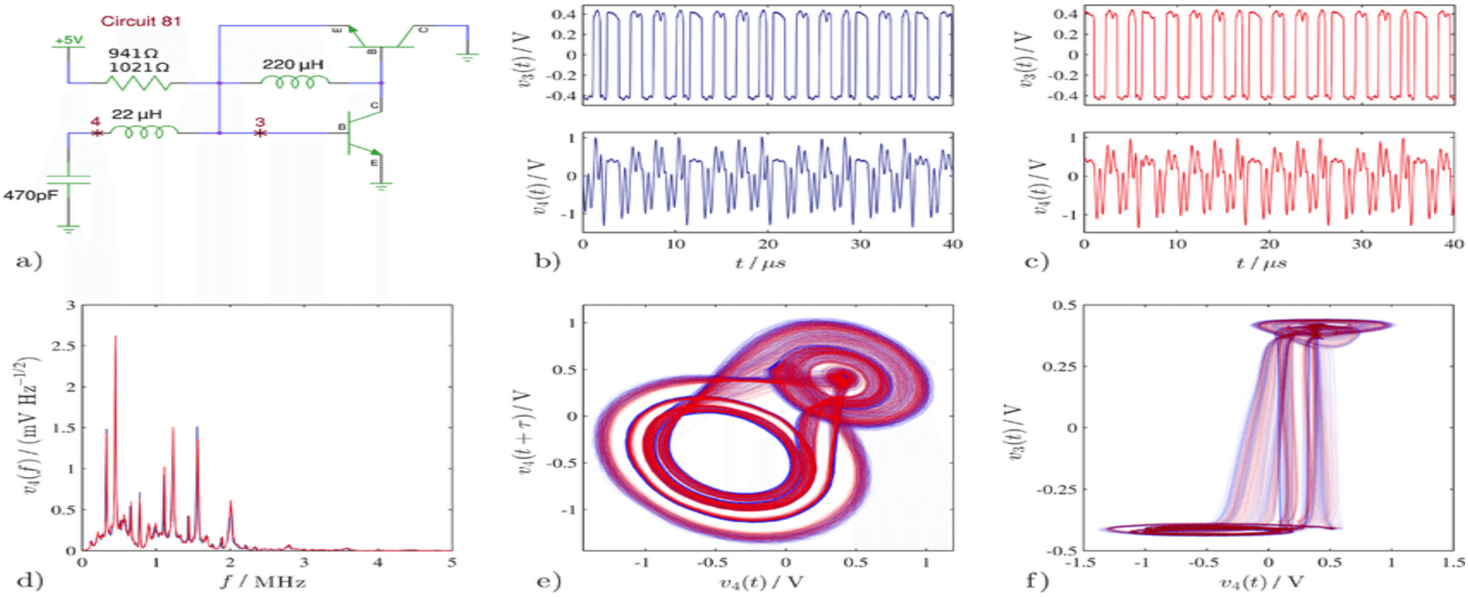
RESULT

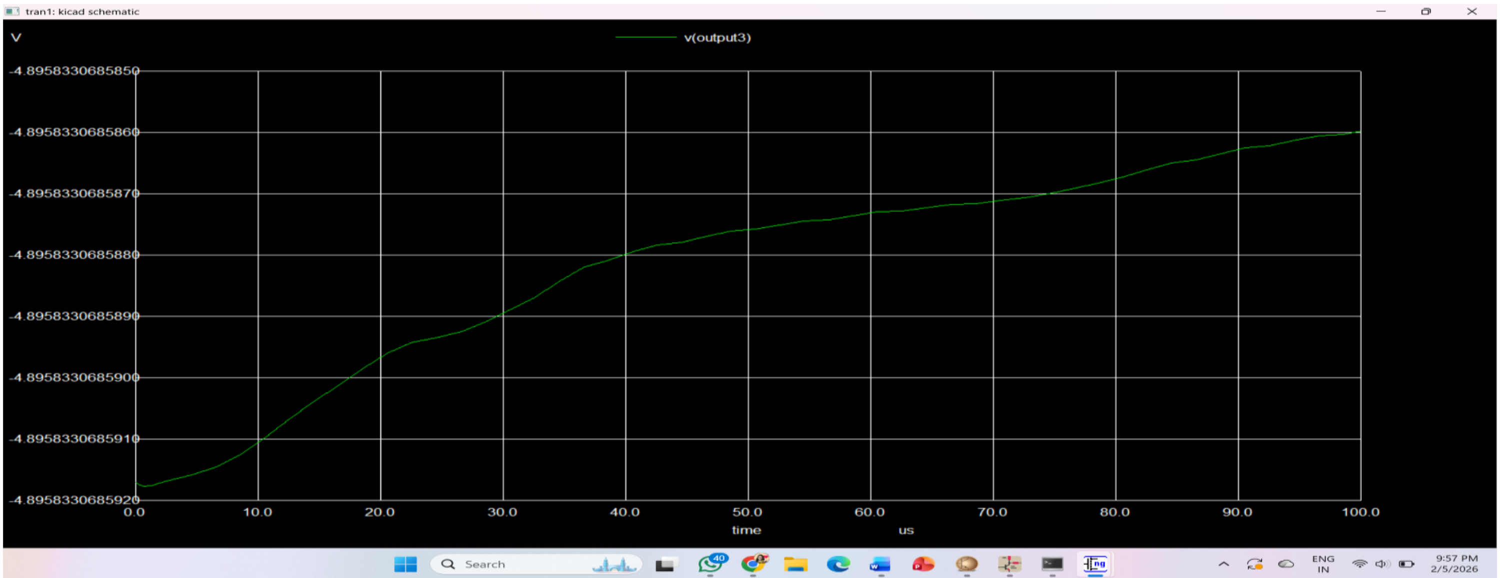
The designed chaotic oscillator circuit successfully demonstrates the generation of chaotic signals using simple analog components such as bipolar junction transistors, resistors, and capacitors. The circuit operates on the principle of nonlinear feedback combined with multiple RC time constants, which prevents the system from settling into a stable periodic oscillation. Instead, the interaction between amplification, phase shift, and delayed feedback produces bounded and aperiodic oscillations that are characteristic of chaotic systems.

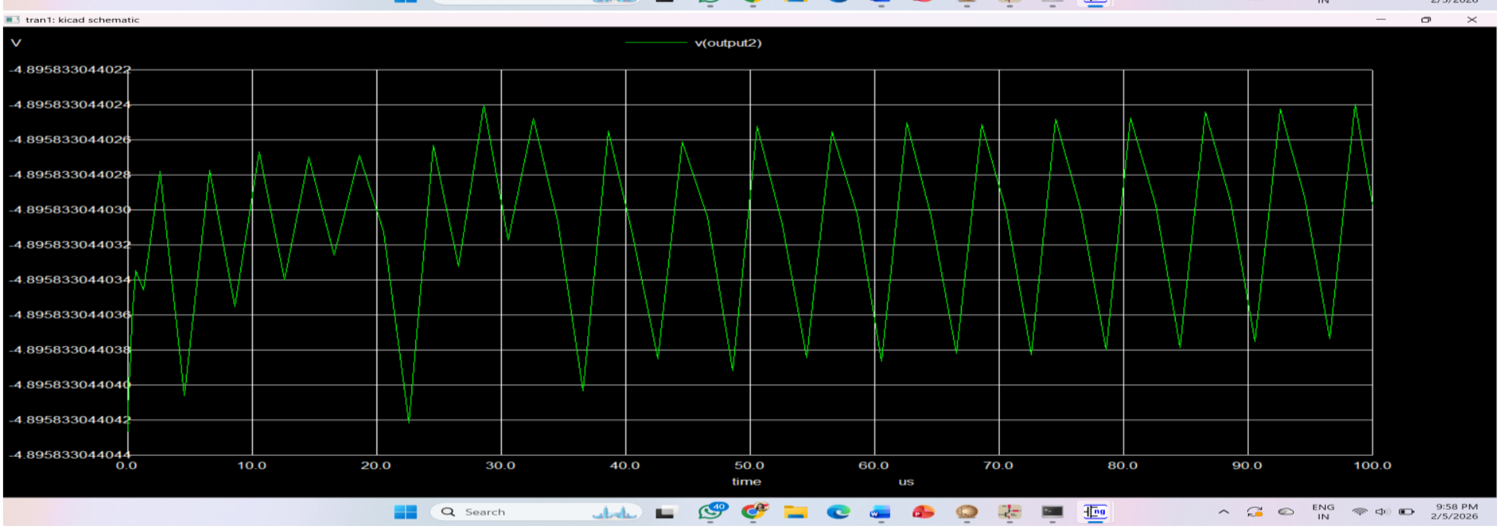
The simulation results obtained from transient analysis confirm that the output waveform is irregular and non-repeating while remaining within a finite amplitude range. This behavior validates the theoretical concept of chaos in electronic circuits and shows how nonlinear dynamics can be realized using basic transistor configurations. The circuit also highlights the sensitivity of chaotic systems to initial conditions and component values, making it useful for understanding nonlinear system behavior and signal complexity.

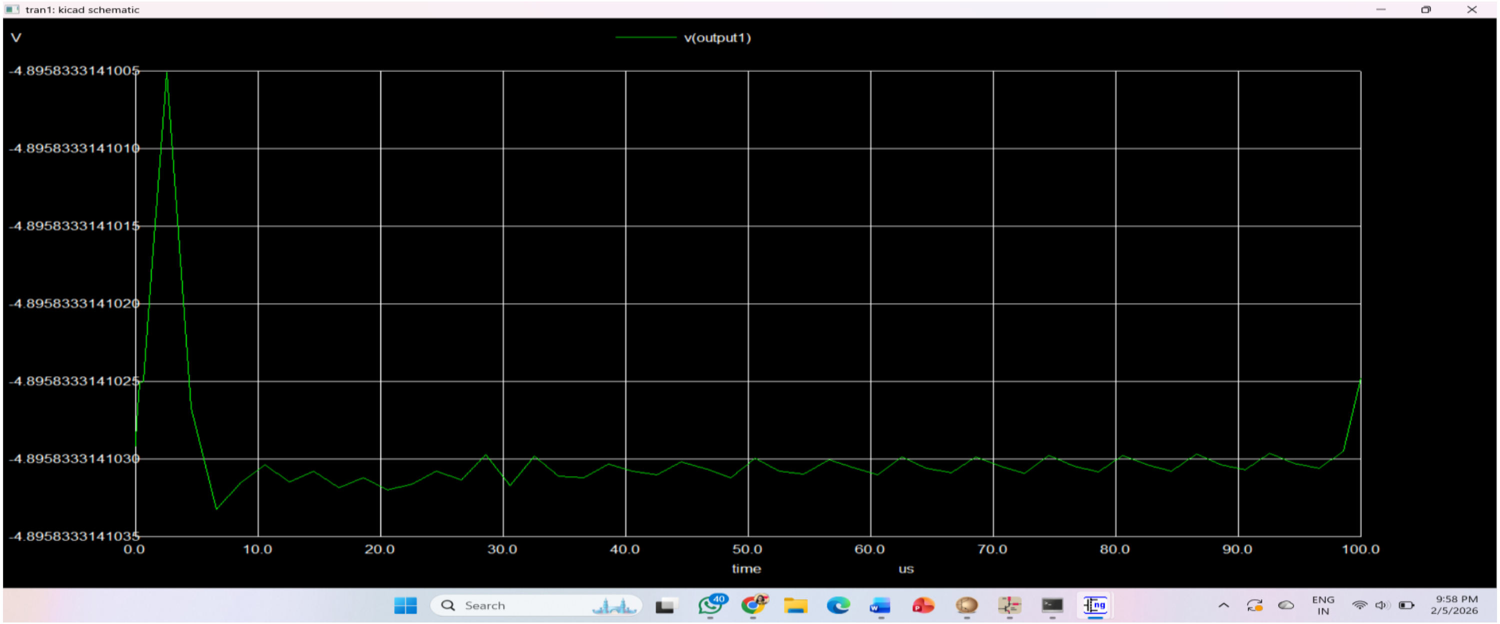
Furthermore, the simplicity of the circuit makes it highly suitable for educational purposes, laboratory demonstrations, and introductory research in nonlinear electronics. The implementation in eSim provides a practical platform for analyzing chaotic behavior without requiring complex hardware setup. Overall, the project demonstrates that chaotic oscillations can be effectively generated and studied using low-cost components, making the design valuable for academic learning, simulation-based experimentation, and further exploration in communication systems, secure signal generation, and nonlinear circuit analysis.

Conclusion : The transient simulation of the chaotic oscillator shows a continuous oscillating output at the collector node of the transistor. The waveform is irregular and non-periodic, unlike a conventional sine or square wave oscillator. The amplitude remains bounded while the waveform changes continuously, confirming the presence of chaotic behavior generated due to nonlinear feedback and multiple RC time constants in the circuit.









Output WaveForm of RC Ring Oscillator

Source/Reference(s) :

1. Kennedy, M. P., "Chaos in Electronic Circuits," IEEE Transactions on Circuits and Systems.
2. Sprott, J. C., *Chaos and Time-Series Analysis*, Oxford University Press.
3. Chua, L. O., "Chua's Circuit: A Paradigm for Chaos," IEEE Transactions on Circuits and Systems.
4. Floyd, T. L., *Electronic Devices*, Pearson Education.
5. eSim Documentation, FOSSEE Project, IIT Bombay.