
The Research Migration Project is an initiative of FOSSEE, IIT Bombay that promotes the use of eSim for reproducing published research circuits originally implemented using proprietary simulation tools. The objective is to migrate these validated designs to eSim to build an open source resource database.

Name of the participant : Priyanka

Branch : Electronics and communication engineering
Affiliation / Institution : Dronacharya group of institutions

Title of the circuit : A Three Phase RC Ring Oscilator Using BJT
Theory/Description :

A ring oscillator is a basic electronic circuit used for generating periodic signals and clock pulses, consisting of an odd number of inverting stages connected in a closed feedback loop. In this project, a three-stage RC ring oscillator is designed and simulated using bipolar junction transistors and resistor–capacitor delay networks. Each stage operates as an inverter and introduces a propagation delay, while the output of one stage is connected to the input of the next, and the final stage feeds back to the first, forming a closed loop with an overall phase shift of 360 degrees. Due to the odd number of inversions, the circuit satisfies the condition for sustained oscillations without requiring an external clock source. The oscillation frequency is primarily determined by the RC time constants and the switching characteristics of the transistors. The three outputs obtained from the individual stages are phase-shifted with respect to each other, resulting in a three-phase oscillatory waveform. The circuit is simulated using the eSim open-source platform, and LEDs are used to visually indicate the oscillatory behavior, demonstrating the practical working and applications of ring oscillators in clock generation, timing circuits, and integrated system design.

Reason to reproduce with eSim :

The proposed ring oscillator circuit is highly suitable for simulation and reproduction using eSim due to its open-source nature and strong compatibility with Ngspice. eSim provides an integrated environment for schematic design, transient analysis, and waveform visualization, which allows clear observation of oscillatory behavior and phase-shifted outputs at each stage of the circuit.This circuit has significant educational value, as it helps in understanding fundamental concepts such as inverter action, feedback, propagation delay, and waveform generation. By reproducing the circuit in eSim, the theoretical operation of a ring oscillator can be easily verified through time-domain simulations, enabling direct comparison between expected and simulated results.Additionally, eSim allows easy placement of voltage probes at collector nodes, making it convenient to analyze output waveforms and validate oscillation conditions. Since eSim is freely available and widely used in academic institutions, reproducing this circuit using eSim promotes accessibility, reproducibility, and further modification or improvement of the design without dependency on proprietary tools.

Expected Outcome/outputs :

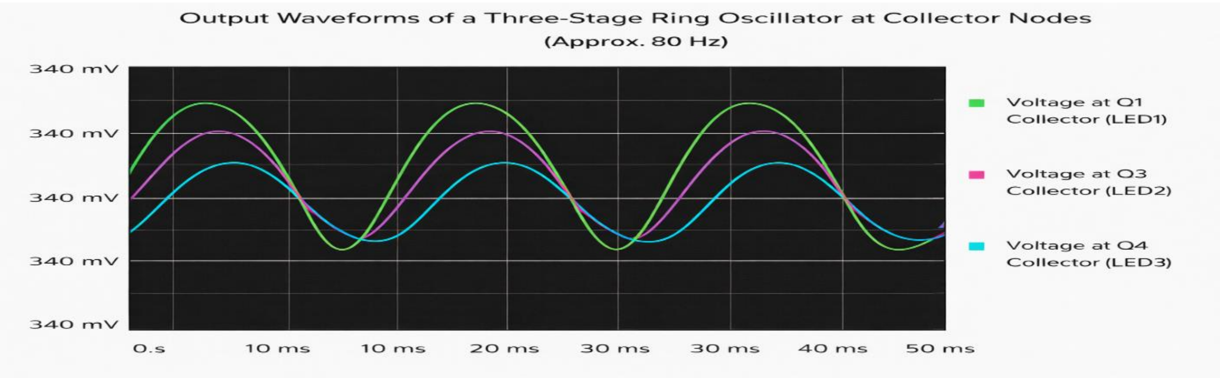
When the proposed ring oscillator circuit is simulated or implemented, it is expected to generate continuous oscillations without any external input signal. The output taken from the collector terminals of each transistor stage will produce periodic waveforms due to the inverter action and feedback provided by the RC network.

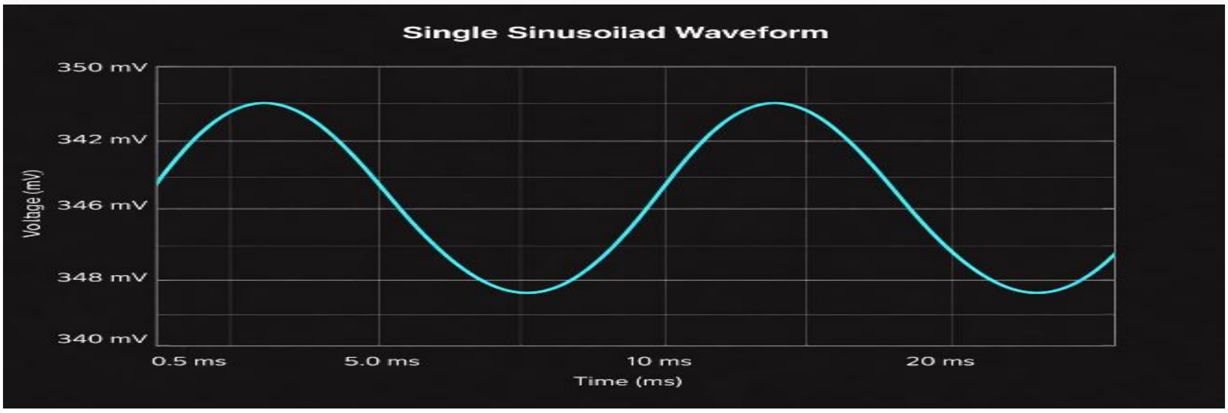
The output waveforms will be phase-shifted with respect to each other, demonstrating the characteristic behavior of a multi-stage ring oscillator. The oscillation frequency will depend on the values of the resistors and capacitors used in the circuit, and it can be measured using transient analysis in eSim.

The performance of the circuit can be validated by:

- Observing stable oscillations in the time-domain waveform plots
- Measuring the oscillation period and frequency
- Verifying phase shift between successive stages
- Confirming consistent waveform amplitude at the collector outputs

Successful simulation results will confirm correct circuit operation and validate the theoretical principles of ring oscillators such as feedback, delay, and oscillation conditions.





Circuit Diagram(s) :

The proposed circuit is a three-stage ring oscillator implemented using NPN bipolar junction transistors (2N3904) operating in common-emitter configuration. Each stage of the circuit acts as an inverting amplifier and is connected in a closed loop to form a feedback path necessary for sustained oscillations.

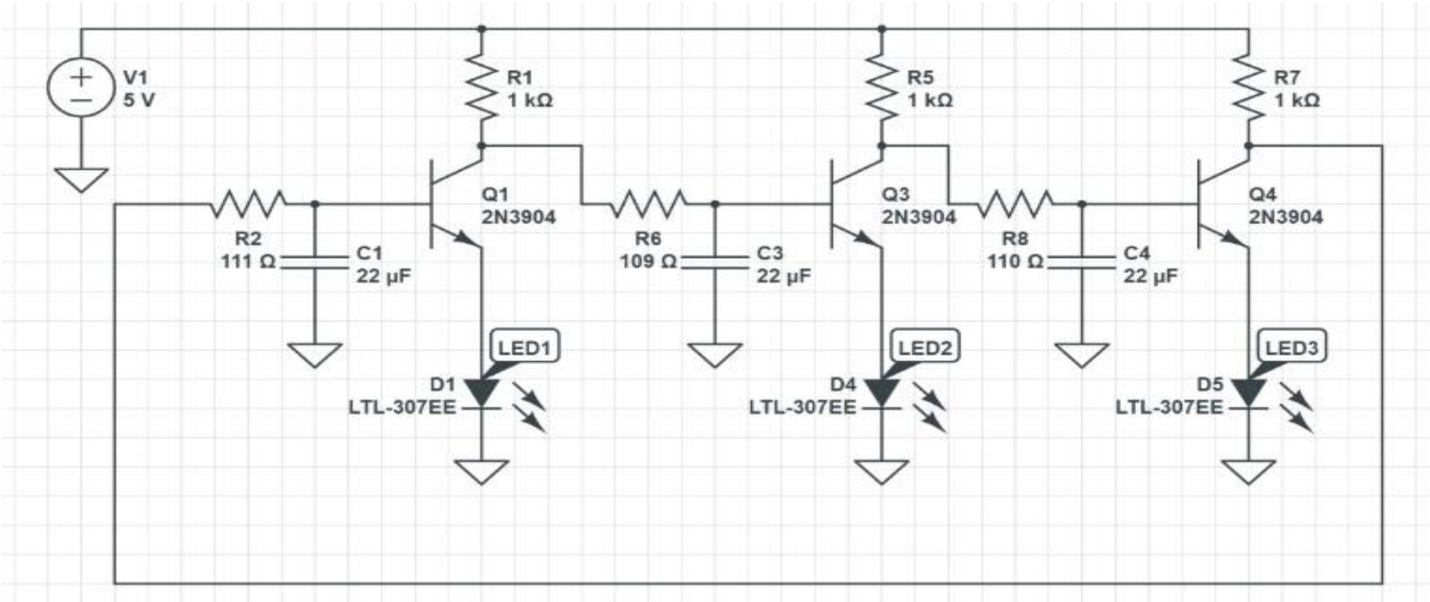
The collector of each transistor is connected to the supply voltage through a load resistor (1 kΩ), which converts collector current variations into output voltage signals. The base of each transistor receives feedback from the previous stage through a series resistor and capacitor (RC network). This

RC network introduces a time delay and phase shift, which is essential for meeting the oscillation condition of the ring oscillator.

The emitter terminals of the transistors are connected to ground through LEDs, which serve as visual indicators of oscillation and switching activity in each stage. The LEDs glow sequentially, indicating phase-shifted operation of the circuit.

A DC supply voltage of 5 V is used to power the circuit. Due to the odd number of inverter stages (three), the total phase shift around the loop satisfies the Barkhausen criterion, resulting in continuous oscillations. The outputs are taken from the collector nodes, where periodic waveforms are observed during transient simulation

A three-stage RC ring oscillator was designed and simulated using BJTs in the eSim platform. The circuit generates sustained oscillations using an odd number of inverting stages with RC delay networks, producing three phase-shifted outputs. The oscillation frequency depends on the RC time constants, and LEDs visually confirm the oscillatory behavior. This project demonstrates the practical application of ring oscillators in timing and clock generation circuits.

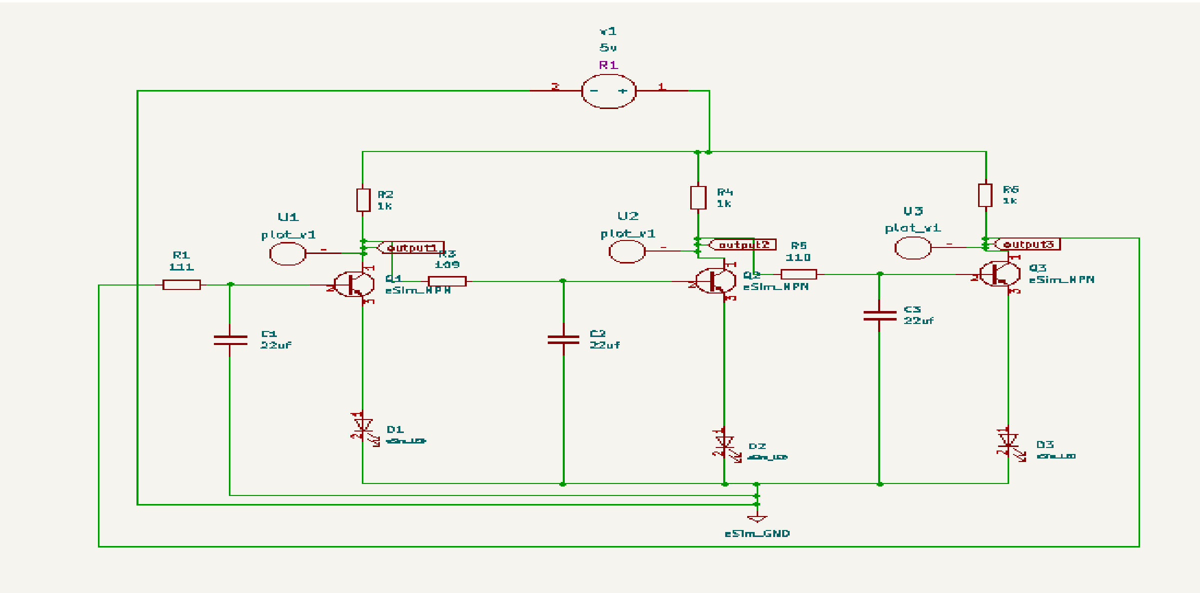


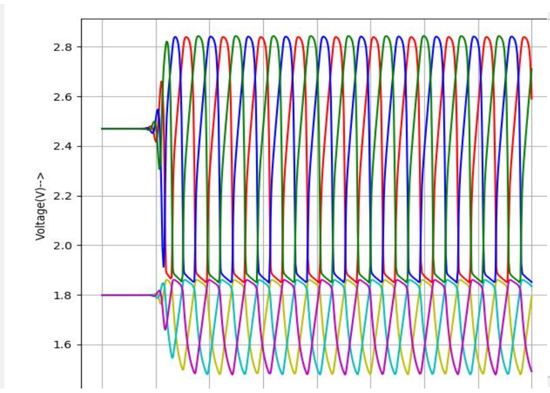
Block Diagram (s) :

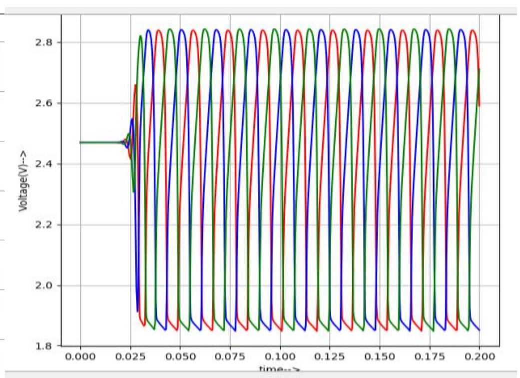
The circuit operates as a three-stage RC ring oscillator powered by a 5 V DC supply. Each stage consists of an NPN transistor configured as an inverter along with a resistor–capacitor (RC) network that introduces a time delay. When power is applied, due to small variations and noise, one of the transistors begins to conduct slightly. This causes its collector voltage to fall, which is then coupled to the base of the next transistor through the RC network. As the capacitor in the RC network charges or discharges, it controls the base voltage of the next transistor, introducing a propagation delay. When the base voltage reaches the threshold level, the transistor switches ON or OFF, causing an inverted voltage change at its collector. This inverted output is passed to the subsequent stage, and the same process repeats through all three stages.The output of the third stage is fed back to the input of the first stage, forming a closed feedback loop. Since the circuit contains an odd number of inverting stages, the total phase shift around the loop becomes 360 degrees, satisfying the condition required for oscillation. The continuous charging and discharging of the capacitors ensure that the transistors keep switching states, resulting in sustained oscillations without the need for an external input signal.The frequency of oscillation is determined by the RC time constants of the delay networks and the switching speed of the transistors. The outputs taken from each stage are phase-shifted with respect to one another by approximately 120 degrees, producing a three-phase oscillatory output. Light-emitting diodes connected at each stage provide a visual indication of the oscillation by blinking sequentially, confirming the proper operation of the ring oscillator.

Schmatic Of Circuit and output made in esim

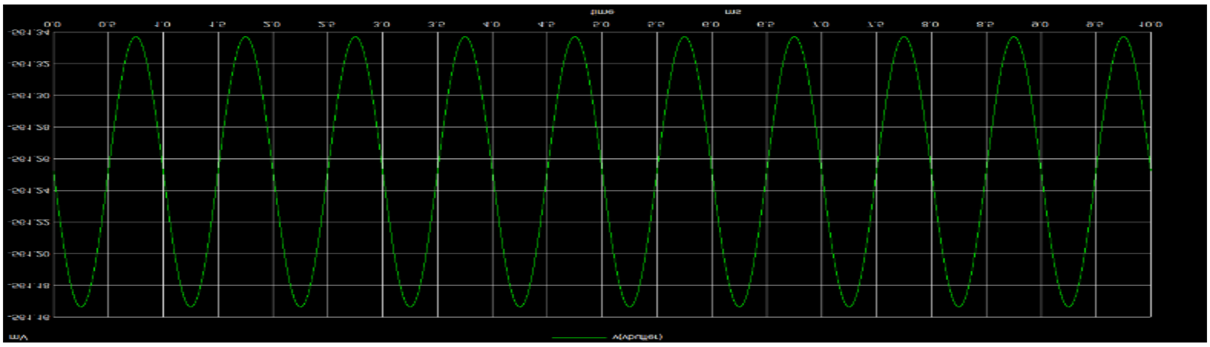
The schematic consists of three identical transistor-based inverter stages connected in a ring configuration. Each stage includes an NPN transistor with a collector load resistor and an RC network at the base to introduce delay. The output of each stage is connected to the input of the next, while the final stage output is fed back to the first stage, forming a closed loop. A 5 V DC supply powers the circuit, and LEDs are included at each stage for visual indication of oscillation. This project presents the design and simulation of a three-stage RC ring oscillator using bipolar junction transistors in the eSim platform. The circuit consists of three inverting stages connected in a closed feedback loop with RC delay networks, resulting in sustained oscillations without an external clock source. The outputs obtained from each stage are phase-shifted by approximately 120 degrees, confirming three-phase operation. The simulation results validate the theoretical behavior and demonstrate the effectiveness of the design for timing and clock generation applications.

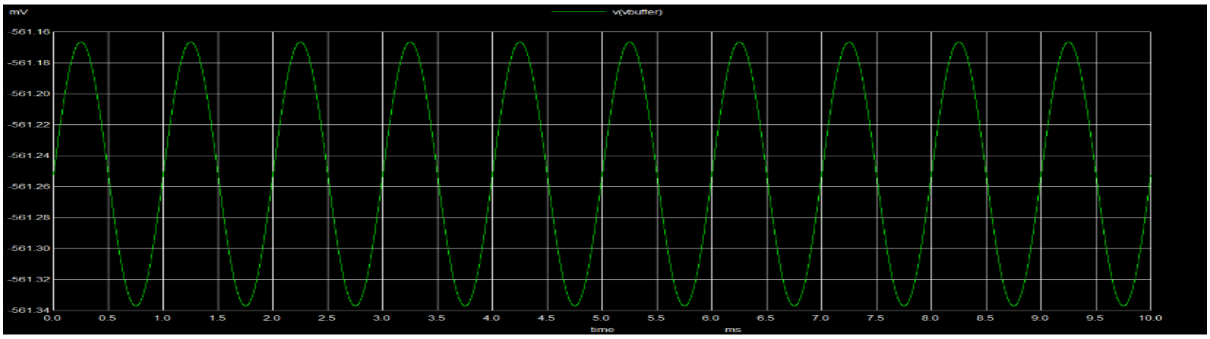


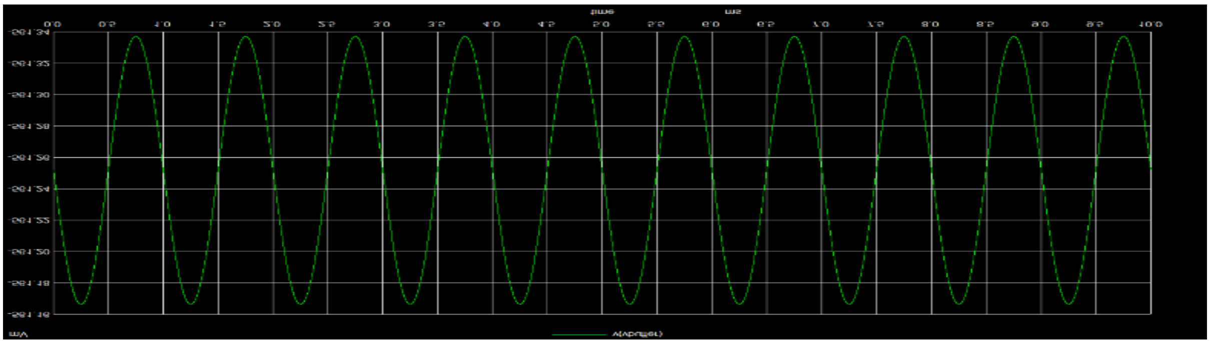


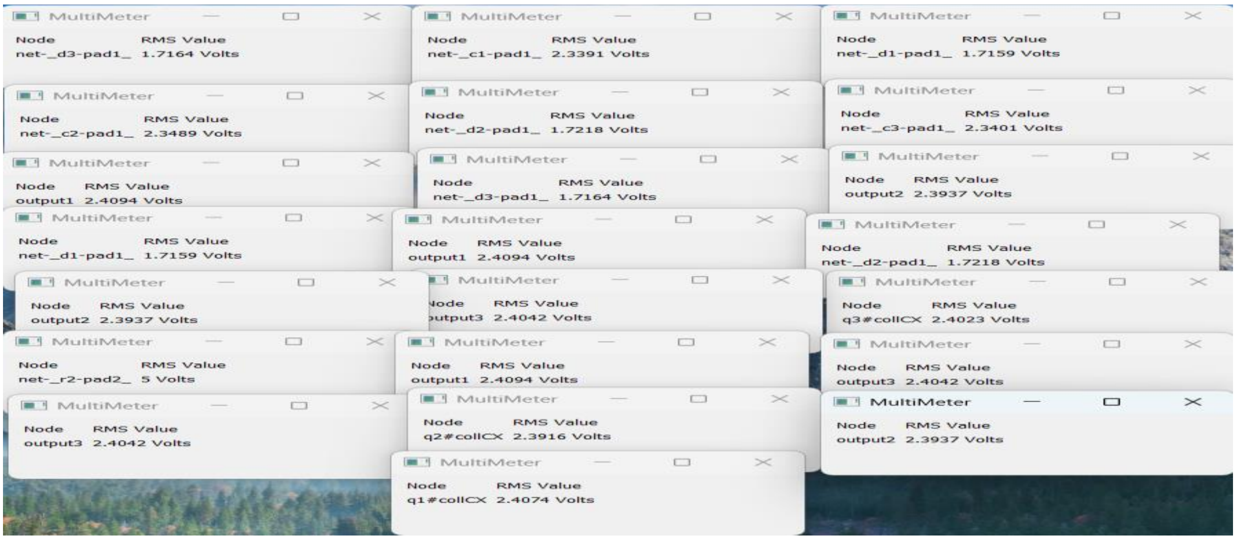


Expected Results (Input, Output waveforms and/or Multimeter readings) : The transient simulation results of the three-stage RC ring oscillator show continuous and stable oscillations at the collector outputs of all three transistor stages. Each output waveform is inverted relative to the preceding stage, which is a result of the inverting behavior of the transistor configuration. The gradual rising and falling edges of the waveforms indicate the charging and discharging action of the RC delay networks, which introduce the necessary propagation delay for oscillation. A distinct phase difference of approximately 120 degrees is observed between the waveforms of successive stages, confirming the three-phase nature of the oscillator. The measured oscillation frequency obtained from the time-domain plots closely aligns with the theoretical frequency calculated using the RC time constants, with minor variations attributed to transistor switching delays and component tolerances. The uniform amplitude and consistent periodicity of the waveforms demonstrate stable circuit operation, while the sequential LED indications further validate the correct phase relationship and proper functioning of the designed ring oscillator.









Research Paper/Journal/etc. :

Title: ***Ring oscillators: Characteristics and applications***
Author: Mrinal Kanti Mandal, Bishnu Charan Sarkar
Journal: ***Indian Journal of Pure & Applied Physics***
Volume/Issue/Year: Vol. 48, No. 2, February 2010
Pages: 136–145
Link:https://www.researchgate.net/publication/234046858_Ring_oscillators_Characteristics_and_applications

Source/Reference(s) :

[1] X. Lei, Z. Wang, and L. Shen, “Design and analysis of a three-stage voltage-controlled ring oscillator,” J. Semiconductors, vol. 34, no. 11, 2013.

[2] N. Ramanjaneyulu et al., “Design of a Three Stage Ring VCO in 0.18 µm CMOS under PVT Variations,” Int. J. Comput. Appl., vol. 170, no. 8, 2017.

[3] “Three stage RC inverter ring oscillator,” CircuitLab, 2012.

[4] “Ring Oscillator” entry on Wikipedia — explains basic theory (not formal but useful)

[5]eSim / NGSpice user manuals for running transient analysis

[6]Application notes from electronic manufacturers about oscillators (e.g., TI, Analog Devices)