

# Design and Analysis of a CMOS-Based Colpitts Oscillator Using Operational Amplifier

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## ABSTRACT

The Colpitts oscillator is a simple LC oscillator that uses two capacitors (C1 and C2) and an inductor (L) to form a tank circuit in order to produce sinusoidal signals. A capacitive divider is used to provide feedback. The circuit is stable, requires little power, and is simple to integrate into contemporary integrated circuits when configured using a CMOS op-amp. Since the LC network determines the oscillation frequency by its equation  $f = 1 / (2\pi \sqrt{L \cdot (C1 \cdot C2 / (C1 + C2))})$ , an op-amp is used to supply the gain. The design meets the Barkhausen criterion, which requires not only phase to be  $0^\circ$  or a multiplication of  $360^\circ$  as well as loop gain equal to or greater than unity for an oscillation. The circuit is designed using esim software for cost-effective and localized oscillator structure (such as the Colpitts oscillator with CMOS op-amp) is popularly utilized for RF/microwave circuits, communication systems and signal generation purposes, because of its ease to be implemented and good stability with frequency characteristic.

**Keywords:** Colpitts Oscillator, CMOS Technology, Operational Amplifier, LC Circuit, eSim, Signal Generation, Frequency Stability

## I. Introduction:

Oscillators are active devices which produce continuous periodic signal and they find their application in communication system, signal processing, and electronics. The Colpitts oscillator is one of a number of designs for LC oscillators, electronic oscillators that use a combination of inductors (L) and capacitors (C) to produce an oscillation at a certain frequency. All the circuit is low power and compact as it can be easily modified on the modern electronic devices by using CMOS op-amp. The Op- amp gives the required factor and meets the Barkhausen criterion for sustained oscillations. Here, the Colpitts oscillator is simulated and designed using eSim software has presented simple, stable and low-cost signal generation application.

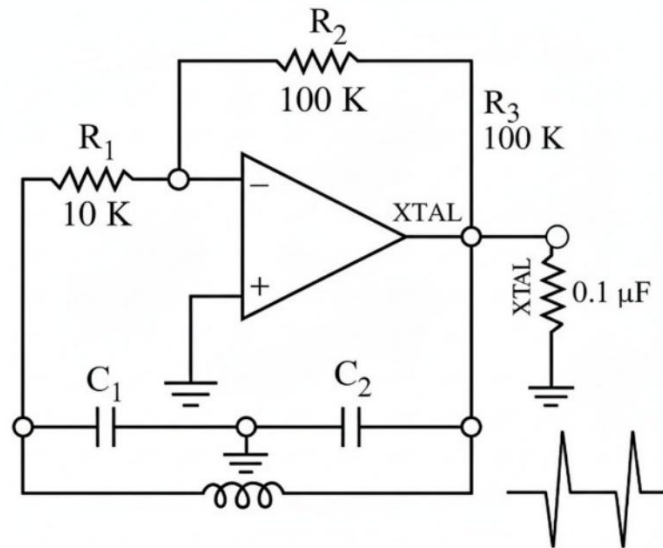
## II. Purpose of Crystal oscillator

The purpose of the Colpitts oscillator using a CMOS op-amp is to generate a stable sinusoidal waveform at a desired frequency for use in electronic and communication systems. The circuit employs an LC tank network with a capacitive divider to determine the oscillation frequency, while the op-amp provides the necessary gain to sustain continuous oscillations. Implementing the design with CMOS technology ensures low power consumption, high efficiency, and ease of integration into modern ICs. This makes the circuit highly suitable for RF applications, signal generation, wireless communication, and other analog system designs where stable and reliable oscillations are required.

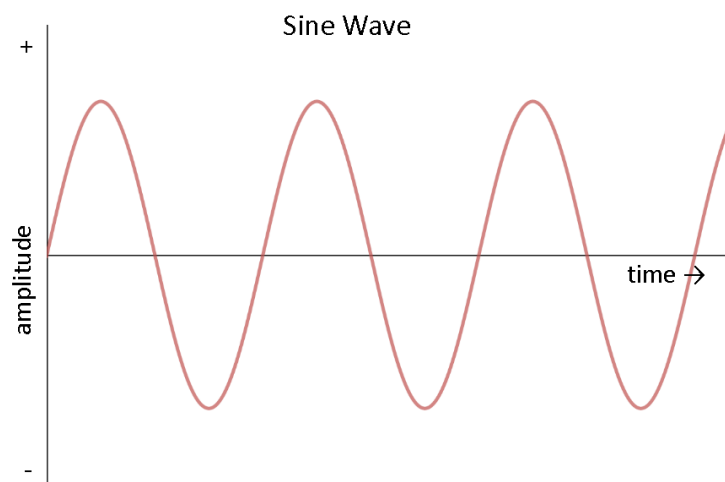
## III. Working principle:

The Colpitts oscillator keep oscillating using a combination of one inductor (L) and two capacitors (C1, and C2) connected as a tank circuit to produce continuously a sine wave. The capacitors constitute a voltage divider and supply part of the output signal back to the input, thus perpetuating the oscillation. Analog signal amplification is achieved by a CMOS operational amplifier with desired gain to ensure that the signal remains stable and clean. The output frequency is determined by i.e inductor and capacitors, and low power is obtained by CMOS technology small size, and easy integration into modern electronic circuits.

#### IV. Circuit diagram:



**Fig 1: Colpitts oscillator using operation amplifier (CMOS)**



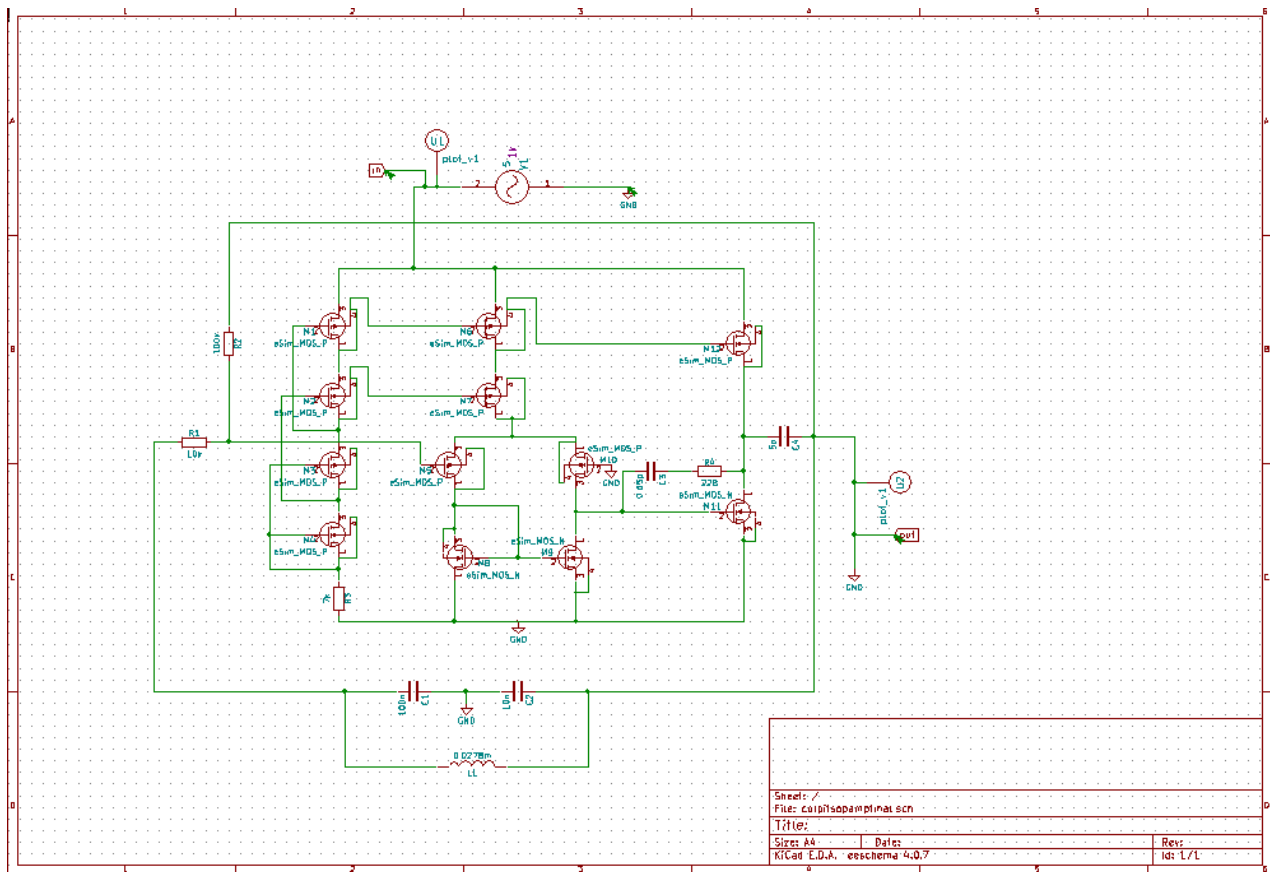
**Fig 2: Sample Output**

The Colpitts oscillator circuit uses a CMOS op-amp, an inductor (L), and two capacitors (C1 and C2) to generate a sinusoidal output. The inductor and capacitors form a tank circuit that decides the frequency of the signal, while the capacitors also act as a feedback network to keep the oscillations going. The op-amp gives the required amplification, and the resistors (R1, R2, R3) help set the bias and stability of the circuit. The result is a smooth sine wave output at a fixed frequency. Because of its simple design, low power use, and stable output, this oscillator is useful in communication circuits, RF systems, and signal generators.

## V. Proposed System

The proposed system implements a Colpitts oscillator using eSim software. It employs a CMOS operational amplifier along with an LC tank circuit consisting of an inductor and two capacitors to generate a stable sinusoidal output. The capacitive divider provides the necessary feedback, while the op-amp ensures sufficient gain to sustain oscillations. The simulation in eSim validates the circuit's frequency stability, power efficiency, and suitability for RF and communication applications.

## eSim circuit:



**Fig 3: Colpitts Oscillator in eSim Software**

The circuit diagram of a Colpitts oscillator implemented using eSim software. The circuit employs a CMOS-based operational amplifier along with an LC tank network consisting of an inductor and two capacitors. The capacitive divider formed by the two capacitors provides the required feedback, while the op-amp ensures sufficient gain to sustain oscillations. Biasing resistors stabilize the operation and control the feedback path, guaranteeing startup of the oscillator. The inductor and capacitors determine the frequency of oscillation, and the output is obtained as a sinusoidal waveform. This layout ensures low power dissipation, stable frequency generation, and suitability for RF and communication applications.

Output Waveform:

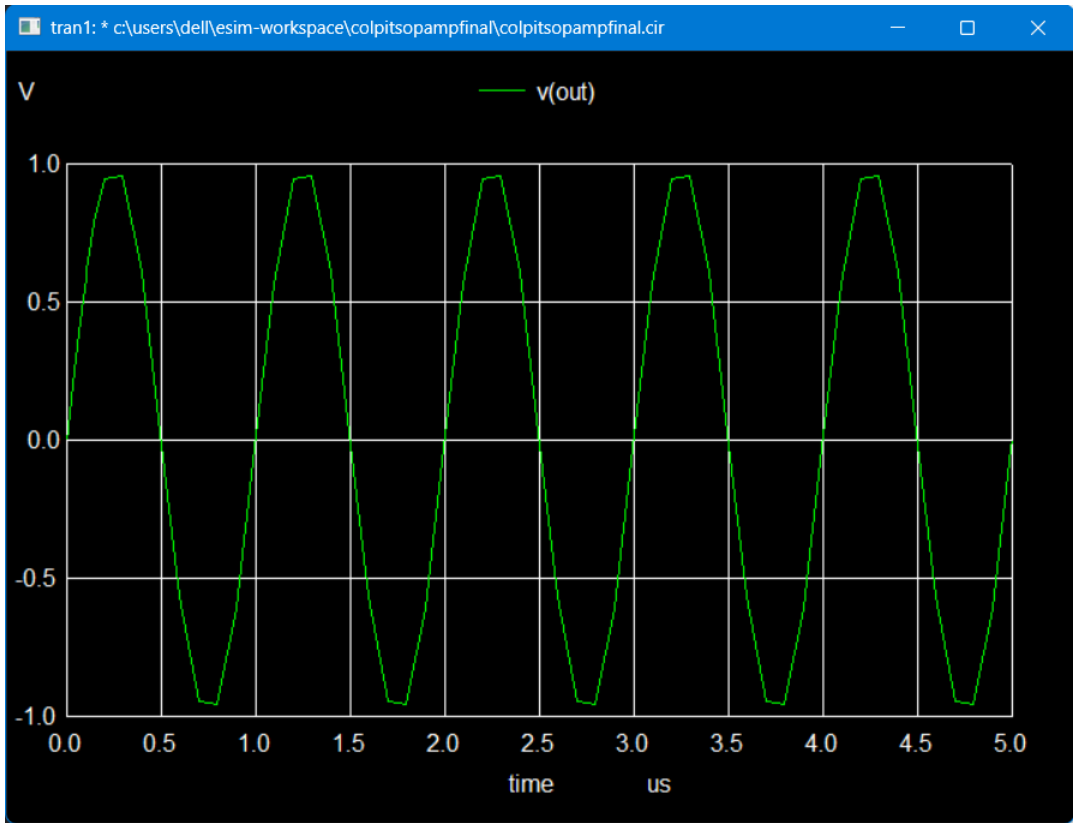


Fig 4: Output waveform in eSim Software

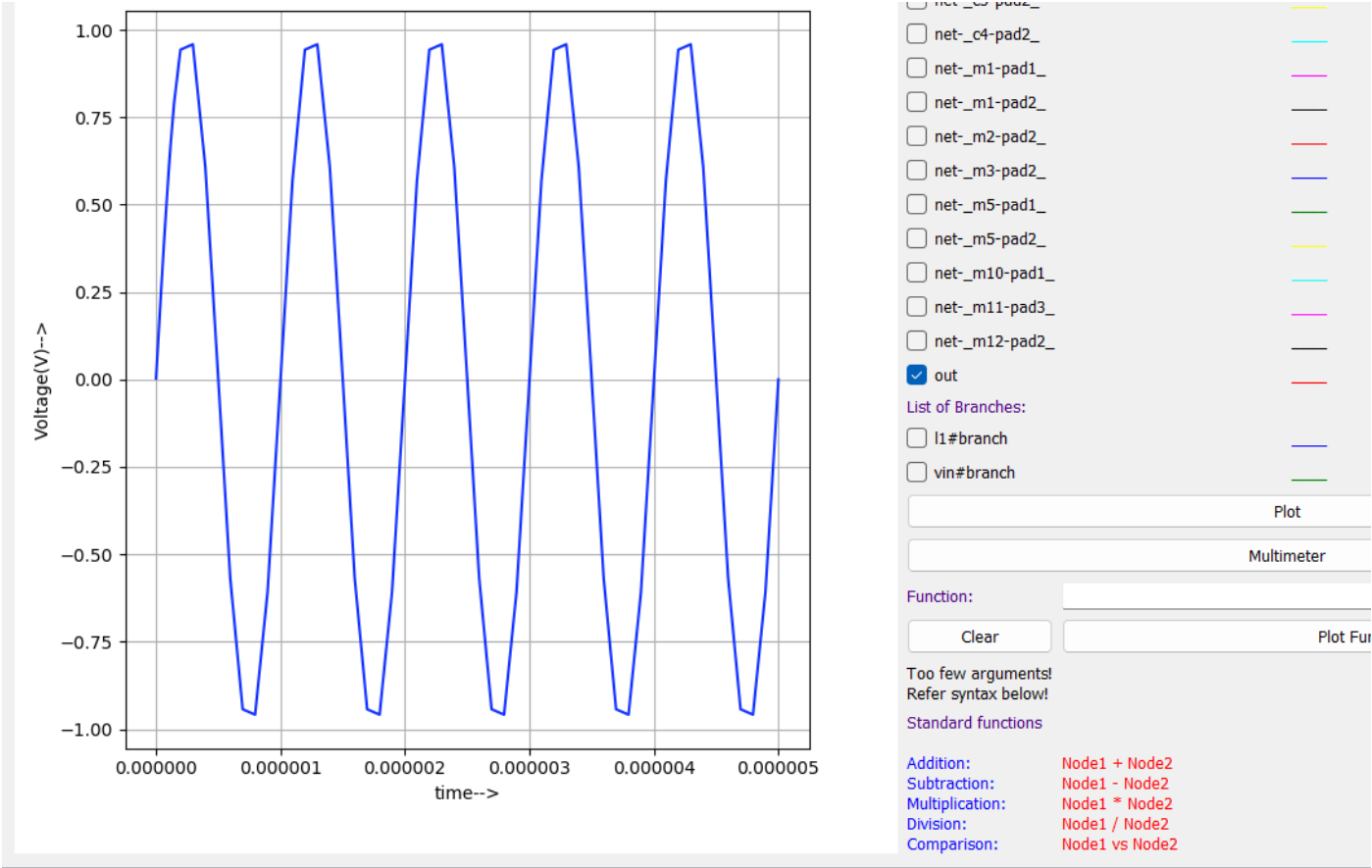


Fig 5: Output Waveform (Python Plot)

The output waveform of the Colpitts oscillator represents a sinusoidal signal generated by the LC tank circuit and CMOS op-amp configuration. The oscillations are sustained through the feedback provided by the capacitive divider, while the op-amp ensures the required gain. The waveform exhibits a nearly pure sinusoidal shape with stable amplitude and frequency, confirming the correct operation of the oscillator. The eSim simulation validates the circuit's ability to generate continuous oscillations, demonstrating its frequency stability, efficiency, and suitability for RF and communication applications.

### **Conclusion:**

Designing a Colpitts oscillator using CMOS technology has been successfully demonstrated in this study. The circuit utilizes an LC tank network and a CMOS op-amp to generate a stable sinusoidal output, with the capacitive divider providing the required feedback for sustained oscillations. The CMOS-based design ensures low power consumption, stability, and ease of integration, making the oscillator suitable for RF circuits, communication systems, and signal generation applications. Simulation results from eSim validate the frequency stability and efficiency of the design, confirming its effectiveness for practical implementation in modern electronic systems.

### **References:**

1. Tutorial: Colpitts Oscillator Using Op-Amp, Electronics-Tutorials, available at: <https://www.electronics-tutorials.ws/oscillator/colpitts.html>.
2. S. P. Rajagopalan, "Low-Frequency Colpitts Oscillator Using Operational Amplifiers," IEEE Transactions on Education, vol. E-23, no. 3, pp. 153–156, Aug. 1980
3. "Design of Analog CMOS Integrated Circuits" – *Behzad Razavi*