Design and Simulation of a Series Crystal Oscillator Using 2N2219 Bipolar Junction Transistors in eSim

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Abstract

This paper presents the design and simulation of a series crystal oscillator using the open-source eSim 2.3 platform. Crystal oscillators are essential in communication and embedded systems because of their excellent frequency stability and precision. The proposed design incorporates a quartz crystal operating in series resonance, ensuring reliable oscillation at a fixed frequency. An amplifier stage along with a feedback network is employed to provide the necessary gain and sustain continuous oscillations. At the point of series resonance, the crystal exhibits minimum impedance, which allows efficient frequency selection and stability. Simulation results confirm the oscillator's ability to generate a clean and stable sinusoidal output waveform. The frequency response demonstrates high accuracy and minimal drift compared to conventional oscillator circuits. The observed output validates the practical behavior of crystal resonance in maintaining precision. Overall, the study emphasizes the effectiveness of using eSim as a reliable platform for designing and analyzing oscillator circuits.

Keywords: Series Crystal Oscillator, Quartz Crystal Resonance, Frequency Stability, Sinusoidal Oscillations, Feedback Network, Amplifier Stage, Resonant Circuit, Oscillator Simulation, Precision Frequency Generation

I. INTRODUCTION

Crystal oscillators are fundamental components in modern electronic systems, widely used as stable clock sources for microcontrollers, communication modules, and precision measuring instruments. Their importance lies in providing highly accurate and reliable timing signals, which are critical for synchronization in both digital and analog circuits. Unlike RC or LC oscillators, crystal oscillators offer superior frequency stability and minimal drift, making them highly suitable for long-term and high-performance applications. The series crystal oscillator operates at the series resonant frequency of the quartz crystal, a point where the crystal exhibits minimum impedance. At this resonance, the oscillator achieves efficient energy transfer and produces a highly stable sinusoidal waveform. To maintain continuous oscillations, an amplifier stage and feedback network are incorporated into the circuit design. This combination ensures that the oscillation is self-sustaining and resistant to variations in external conditions. Simulation in eSim provides a practical platform to study the oscillator's transient and steady-state behavior. The analysis validates the performance and confirms the crystal's role in achieving precision frequency generation.

II. PURPOSE OF SERIES CRYSTAL OSCILLATOR

The primary purpose of the series crystal oscillator is to provide a stable and precise frequency reference for electronic systems requiring accurate timing. By exploiting the crystal's series resonance, the circuit operates at minimal impedance, allowing efficient energy transfer and reliable oscillation. An amplifier stage sustains the oscillations by compensating for energy losses, while the design ensures high frequency stability against load variations and parasitic capacitances. Its output is a clean and consistent sinusoidal signal, making it ideal as a clock source for microcontrollers, communication systems, and precision instruments. The oscillator's ability to maintain stability under varying conditions further enhances its reliability, serving as a robust solution for generating precise frequency signals in modern electronics.

III. WORKING PRINCIPLE

- Stage 1: Crystal Resonator – A quartz crystal connected in series provides resonance at its natural frequency, offering minimal impedance for stable oscillations.
- Stage 2: Amplifier Stage – An inverting amplifier using an op-amp or transistor sustains oscillations by compensating for energy losses.
- Stage 3: Feedback Network – A feedback path ensures the correct phase shift and gain conditions (Barkhausen criterion) required for continuous oscillation.
- Stage 4: Output Stage – Generates a stable sinusoidal signal with high precision, suitable for clock or reference use.
- Stage 5: Load and Buffer Stage – A buffer circuit isolates the oscillator from load variations, preventing frequency shifts and ensuring consistent output for connected systems.

IV.CIRCUIT DIAGRAM

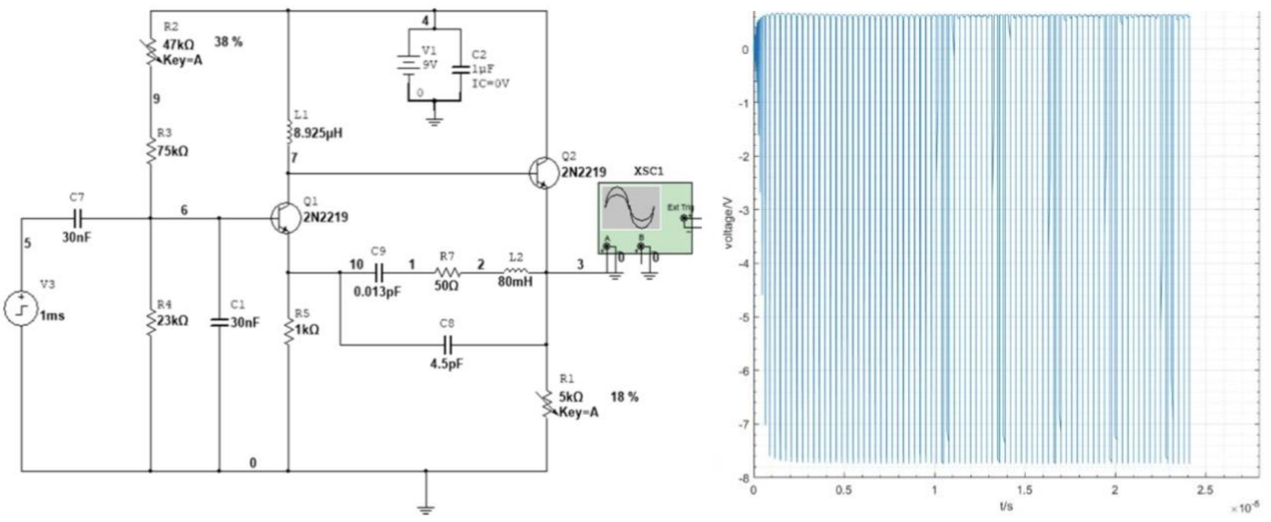

Fig. 1: Series Crystal Oscillator with sample output waveform

V. Proposed System

The system combines a quartz crystal in series resonance with an amplifier-based feedback network to sustain oscillations at the resonant frequency. The crystal ensures frequency selectivity and long-term stability, while the amplifier compensates for energy losses. The open-source eSim platform enables accurate modeling of the crystal's equivalent circuit. This allows precise simulation of the oscillator's frequency characteristics for reliable performance analysis.

eSIM CIRCUIT

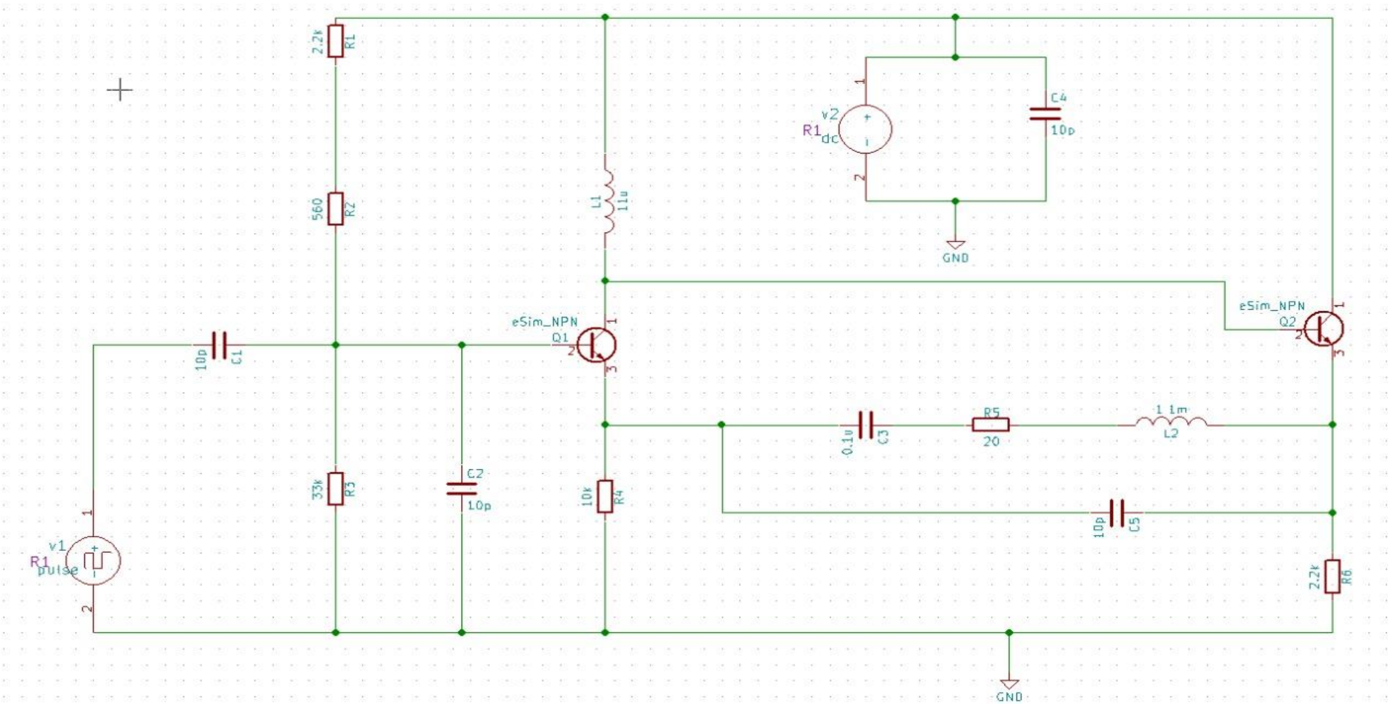

Fig. 2: Series Crystal Oscillator Circuit in eSim

The circuit consists of a quartz crystal in series resonance with an amplifier-based feedback network. Each stage sustains oscillations, stabilizes frequency, and ensures phase conditions for continuous operation. Intermediate nodes reflect the buildup of oscillations as energy is transferred through the resonant path. At the output, the oscillator delivers a stable sinusoidal waveform with high frequency accuracy, suitable for clock generation or reference applications.

OUTPUT WAVEFORM

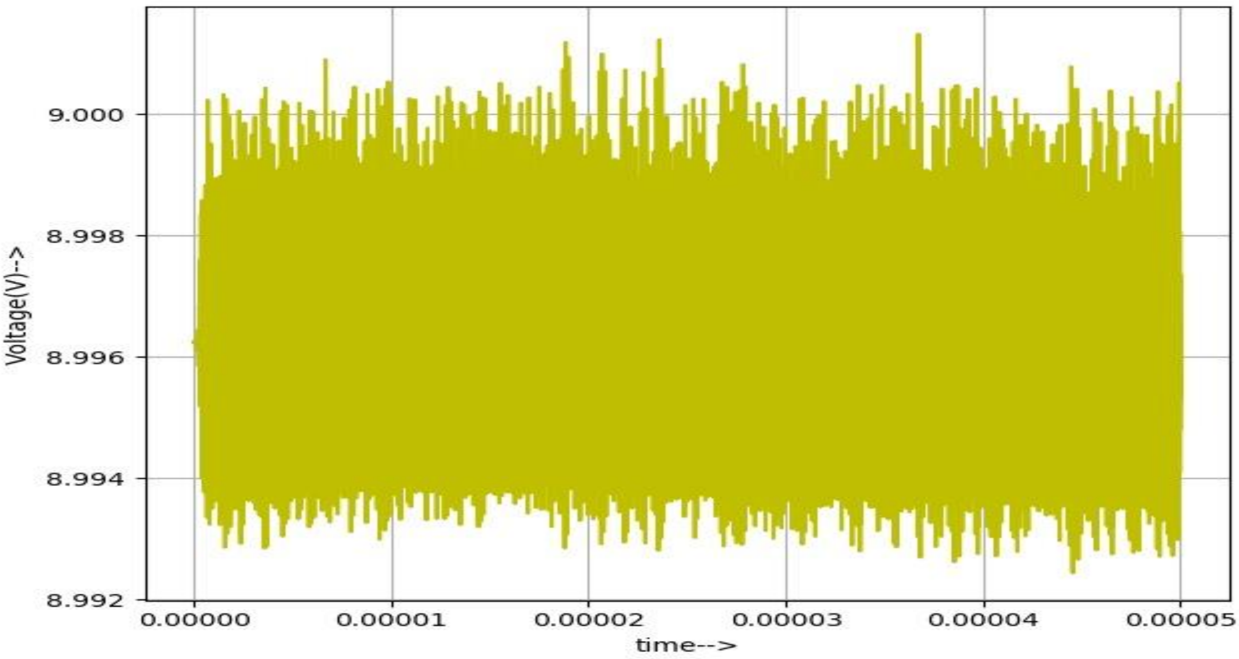

Fig. 3: Output Series Crystal Oscillator Circuit in eSim

Fig. 3 This graph shows the output waveform of the simulated series crystal oscillator over a short time interval. The waveform demonstrates a stable sinusoidal signal with consistent amplitude, indicating proper resonance and sustained oscillations after circuit stabilization. The graph highlights the effectiveness of the designed oscillator in maintaining frequency accuracy and waveform integrity. Such a result validates the reliable operation and stability of the oscillator circuit simulated in eSim without noticeable drift or distortion.

V. CONCLUSION

In this study, we presented the design and simulation of a series crystal oscillator using the open-source eSim platform. By integrating a quartz crystal in series resonance with an amplifier-based feedback network, the circuit successfully achieved sustained oscillations with excellent frequency stability. The crystal ensured high selectivity and accuracy, while the amplifier compensated for energy losses, maintaining continuous operation. The simulation results demonstrated the generation of a clean sinusoidal waveform with consistent amplitude and frequency, validating the effectiveness of the design. Beyond confirming theoretical principles, the study provided deeper insights into resonance behavior, phase conditions, and stability under varying load effects. The successful implementation highlights the reliability of crystal oscillators for use in communication systems, clock generation, and precision instruments, while also showcasing the capability of eSim to model and analyze high-performance oscillator circuits.

VI. REFERENCE

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