Design and Analysis of Crystall Oscillator using Operational Amplifer

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Abstract

A crystal oscillator is a key electronic component that can provide the most stable and accurate frequency reference to clocks, communication systems and digital application. Contrary to simple RC or LC oscillators, crystal oscillators use the mechanical resonance of vibrating piezoelectric material in order to create an electric signal with a very precise frequency. In this note we discuss design and operation of crystal oscillators with op-amps in an approach that is useful for constructing crystal oscillators in eSim. By exploiting the op-amp gain with crystal frequency selectivity, these oscillators provide an easy yet effective way of generating stable sinewave signals. The intent of this guide is to explain the theory, circuit design and practical aspects making the topic understandable for students and engineers.

Keywords : Crystall Oscillator, Operational Amplifier, eSim, Circuit Design.

I. Introduction :

Crystal oscillators produce highly stable and accurate signals, this is important for clocks, communications, computers. The Op-amps act as an active element which provides necessary gain while the crystal ensures the frequency. This paper presents the design and analysis of op-amp based crystal oscillators for high accuracy and reliable signal generation.

II. Purpose of Crystall Oscillator :

The main function of a Crystall Oscillator is to produce a stable and steady frequency signal with less deviation in temperature and time. The op amp provides the necessary gain required for oscillations while the crystal ensures frequency and accuracy. From this combination we can get a sine wave as an output. These are widely used in clocks, communication systems, microcontrollers and other components.

III. Working Principle :

A crystal oscillator works by exploiting the mechanical resonance of a quartz crystal to produce a steady frequency. The op-amp provides amplification to sustain oscillations, while the crystal determines the stable output frequency. Feedback through the crystal ensures that the oscillation condition is maintained continuously. This results in a stable sine wave output suitable for timing and signal generation applications.

IV. Circuit Diagram :

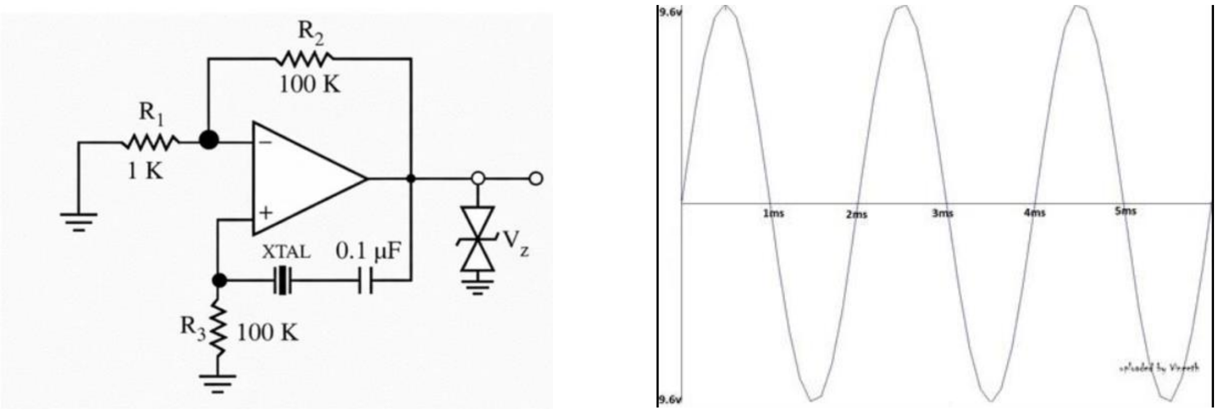

Fig 1 : Crystall Oscillator Using Operational Amplifier with sample output

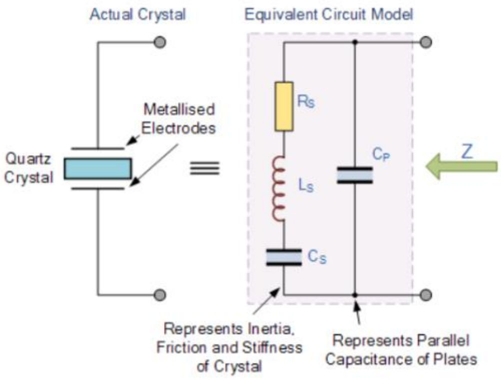

Fig 2 : Equivalent circuit for Quartz Crystall

The circuit diagram of a Crystall Oscillator consists of a quartz crystall, biasing resistors, load capacitors and an operational amplifier. The electrical equivalent circuit for quartz crystall can be represented by a series RLC network and a capacitor is connected parallelly to the RLC network. The operational amplifier is made by a combination of MOSFETS which act as the main active gain element. The crystall ensures the oscillators to generate consistent and accurate output with stable and steady frequency. the Load capacitors fine tune the output frequency and the biasing resistors ensures the MOSFETS operate in linear region.

V. Proposed system :

The proposed system includes Operational amplifier using MOSFETS, resistors, capacitors, quartz crystal. This system has been simulated in eSim software. The generated output has advantages of low power, reliability, and high accuracy.

Figure 3 represents the circuit diagram for Crystall Oscillator implemented using eSim software. The circuit include op-amp, biasing resistors, load capacitors and quartz crystal(in electrically equivalent circuit). The output of the system is a clean, stable sine wave, suitable for precision timing, clocks, and signal generation applications.

eSim Circuit :

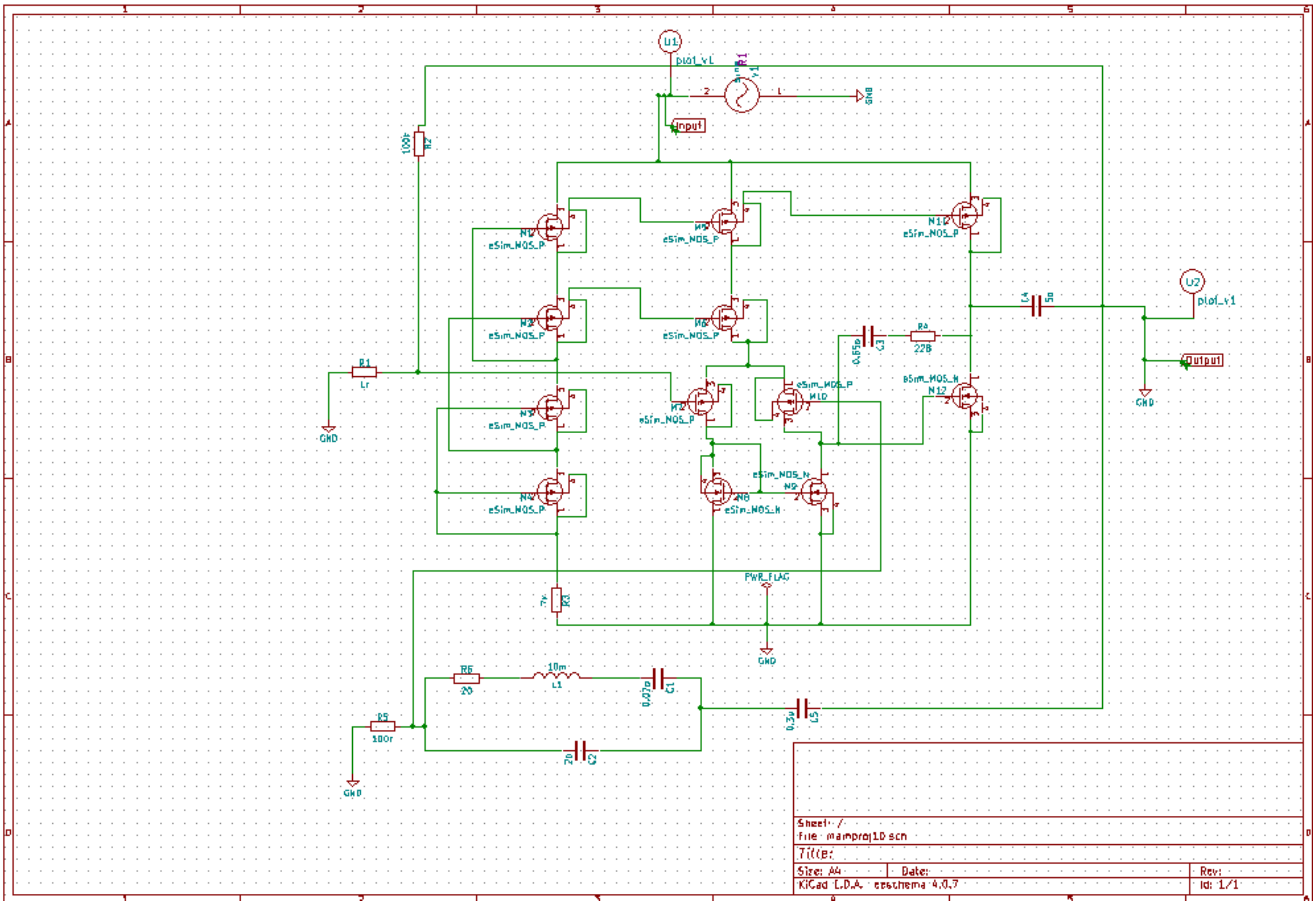

Fig 3 : Crystall Oscillator in eSim software

OUTPUT WAVEFORM :

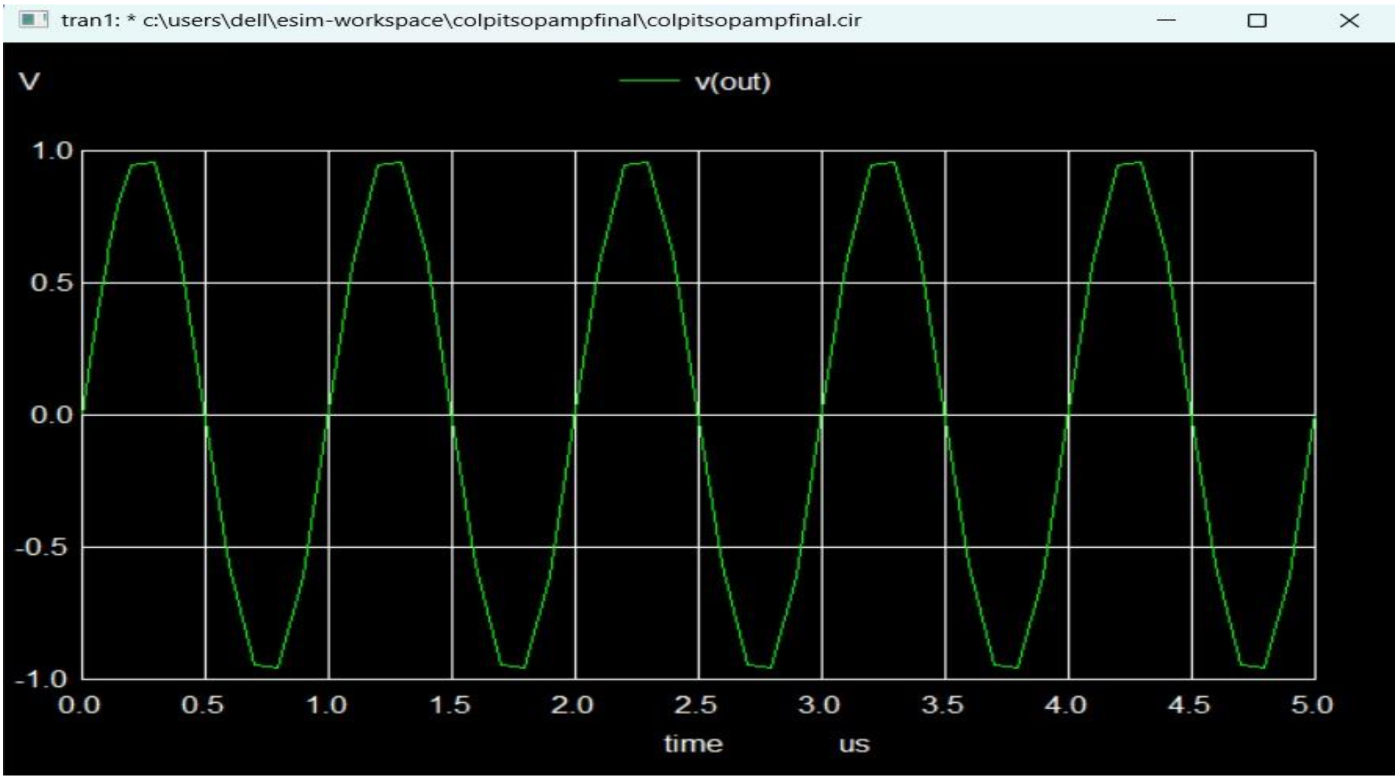

Fig 4 : Output waveform

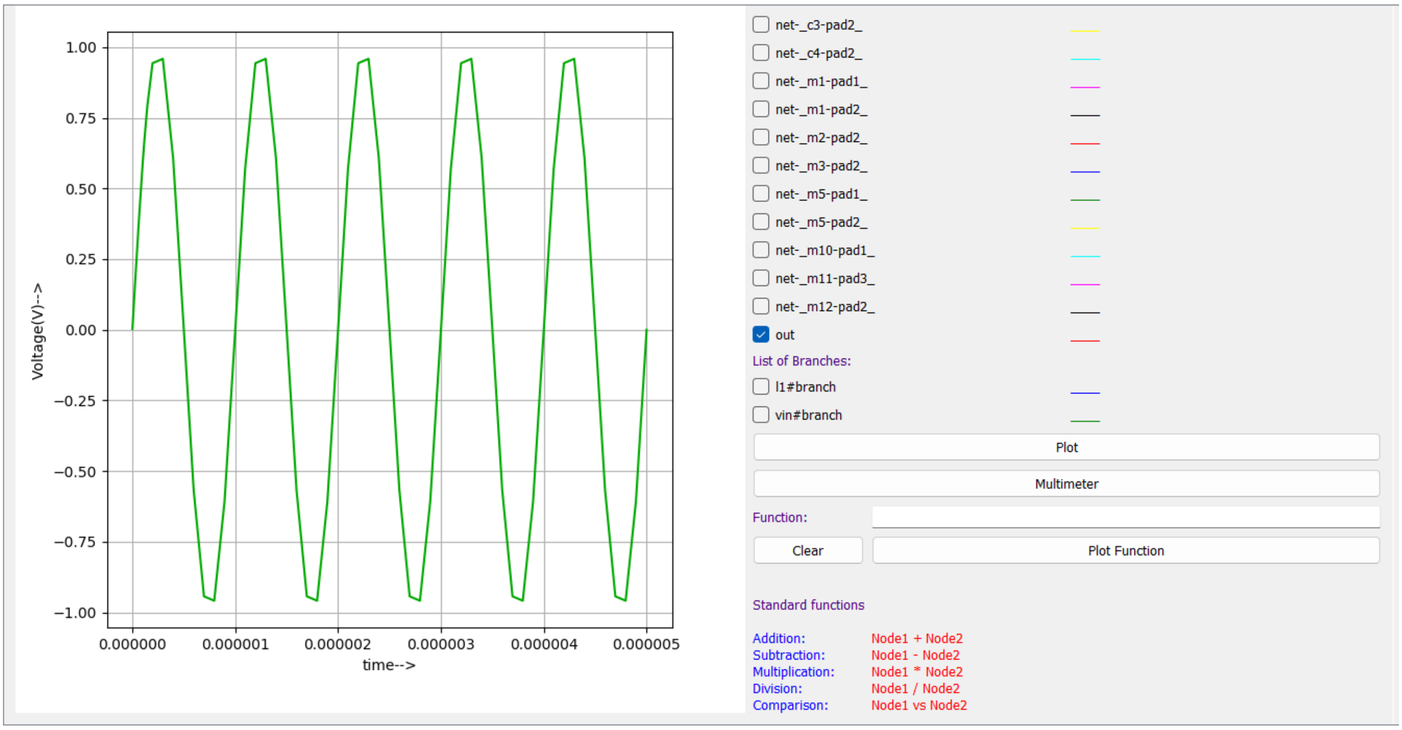

Fig 5 : Output waveform (Python plot)

From the figure 4 and 5 we can say that the output of the op-amp crystal oscillator is a stable sinusoidal (sine) wave. The quartz crystal ensures that the oscillation occurs at its resonant frequency, providing precise and consistent timing. The op-amp supplies the necessary gain to sustain continuous oscillations, resulting in a clean waveform with minimal distortion. This output is ideal for timing circuits, signal generation, and other precision electronic applications, and can be further converted to a square wave using a comparator or buffer if digital logic levels are needed.

Conclusion :

In this project, a crystal oscillator using a op-amp was designed and analyzed. The system demonstrates how a custom op-amp can provide the necessary gain while the quartz crystal ensures precise and stable frequency oscillations. The resulting sine wave output is clean, reliable, and suitable for timing, communication, and signal generation applications. This design highlights the effectiveness of combining MOSFETs with crystal frequency selectivity, offering a low-power, accurate, and practical solution for high-stability oscillator circuits.

References :

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