Resonant Frequency Analysis of Quartz Shear Oscillator

Dr. T. Satyanarayana[1], V. Sai Pavan Rajesh[2]

1. NPMASS Centre, Department of EIE, Lakireddy Bali Reddy Autonomous Engineering College, Mylavaram, AP.
2. Lakireddy Bali Reddy Autonomous Engineering College, Mylavaram, Andhra Pradesh, India.

Introduction: Quartz crystals are widely used in frequency control applications because of their high Q factor, stability, small size and low cost. Quartz crystal also exhibits strong mechanical properties and good stability with respect to temperature variation. Depending on the shape and orientation of the crystal blank, many different modes of vibration can be used and it is possible to control the frequency-temperature characteristics of the quartz crystal.

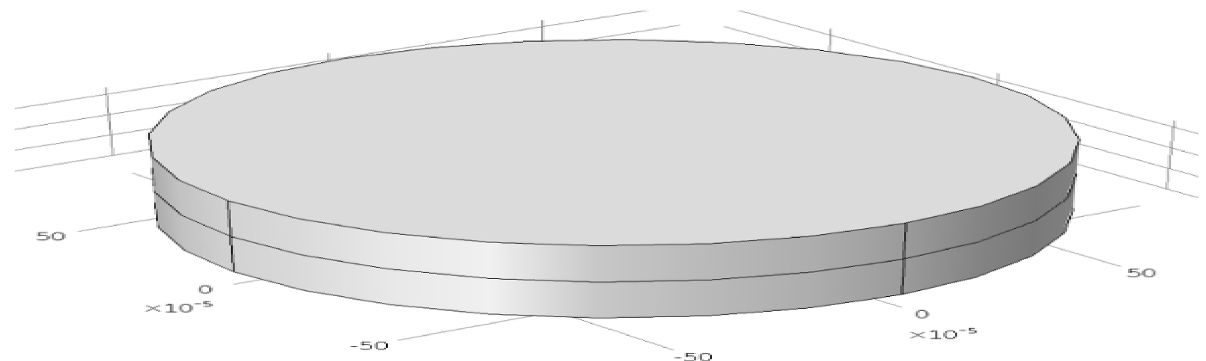

Figure 1. Piezoelectric quartz oscillator.

Computational Methods: The present paper reports the modelling of quartz oscillator for resonant frequency analysis based on piezoelectric effects. The proposed oscillator consists of a single quartz disc of radius 0.835 mm and thickness 334 um. There are two electrodes on the top and bottom surfaces of the geometry; one of them is grounded. Resonant frequency was determined in two different steps. In the first step, an AC voltage of 10v is applied to the top electrode. In the second step, the crystal is still driven by an AC voltage, but a capacitor of 1 pF is introduced between the voltage source and the top electrode of the crystal. Coupling between the strain and the electric field is given by relation,

$$\mathbf{T} = c_E \mathbf{S} - e^T \mathbf{E}$$

$$\mathbf{D} = e \mathbf{S} + \varepsilon_S \mathbf{E}$$

Domain level equations within piezoelectric device.

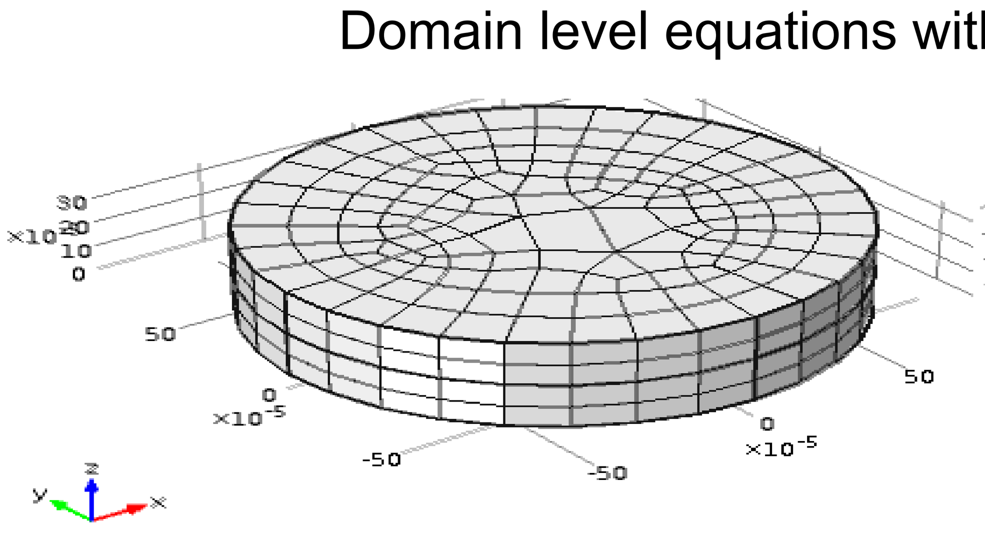

Figure 2. Meshing the geometry with an average element quality 0.7832.

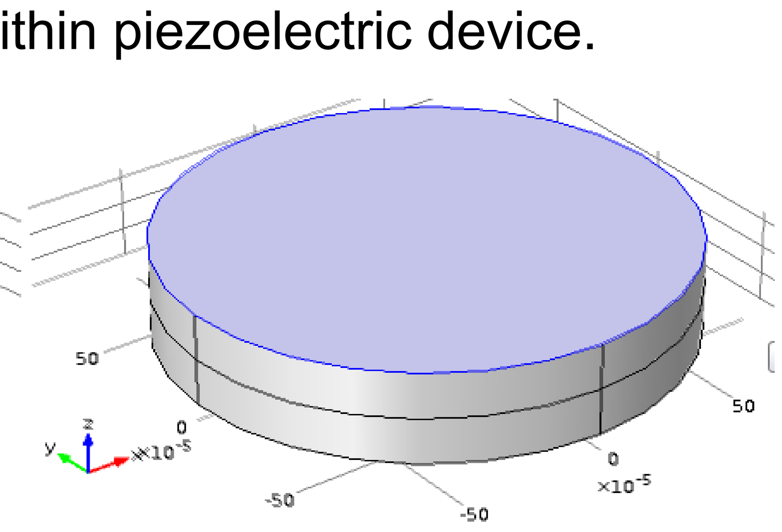

Figure 3. Selecting boundary 7 as terminal 1 for applying Vsrc.

Results: Frequency response versus displacement for applied voltage with various capacitance values suggest that capacitor with higher value will produce maximum displacement before adding series capacitances.

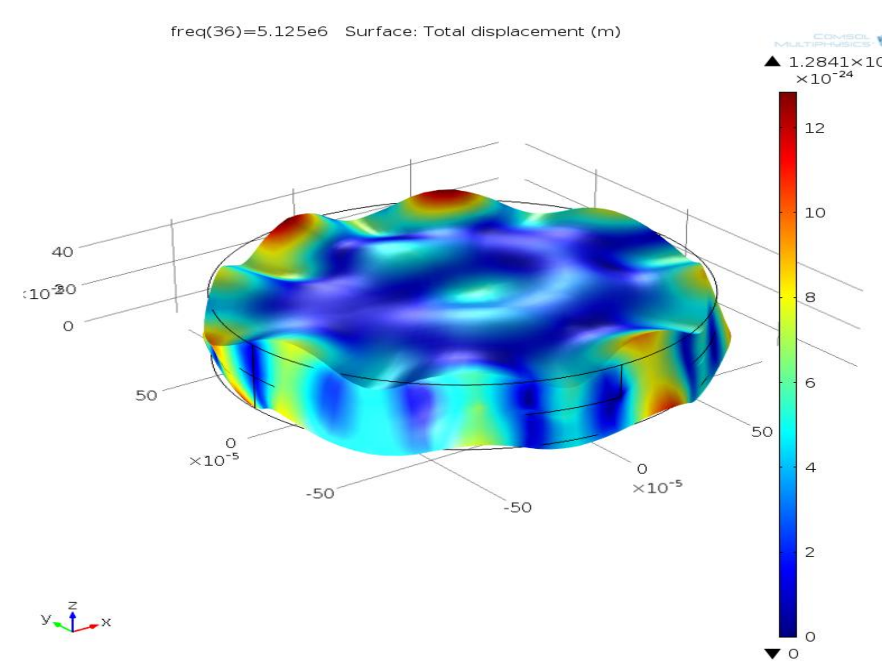

Figure 4. Displacement of the crystal at resonance for 1nF Cs.

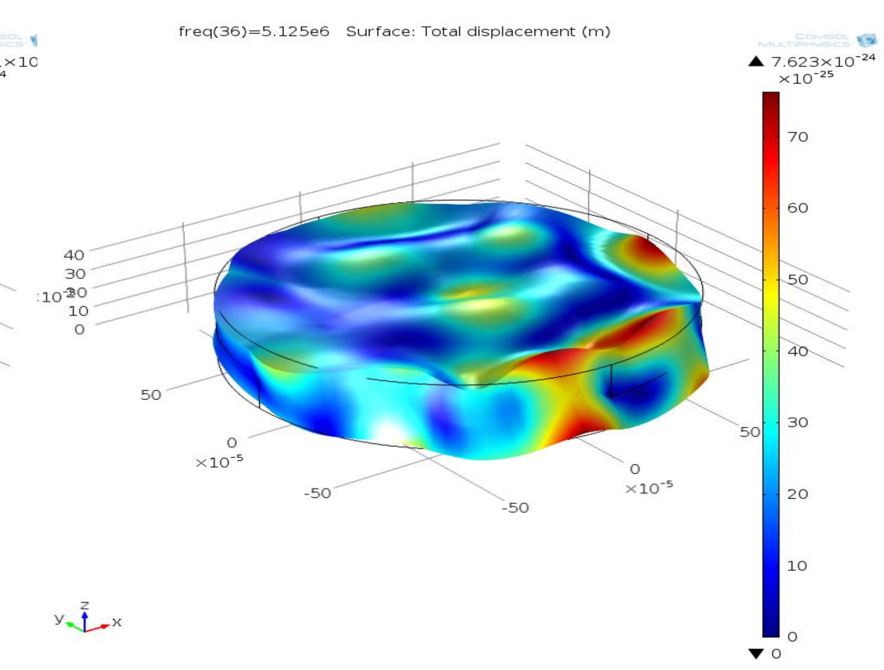

Figure 5. Displacement of the crystal at resonance for 1MF Cs.

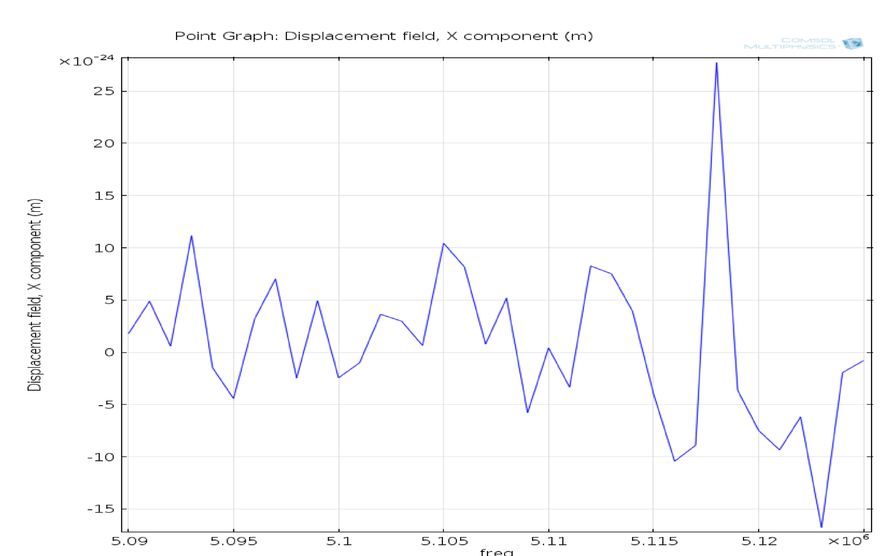

Figure 6. Mechanical response of the structure with no series capacitance(1nF).

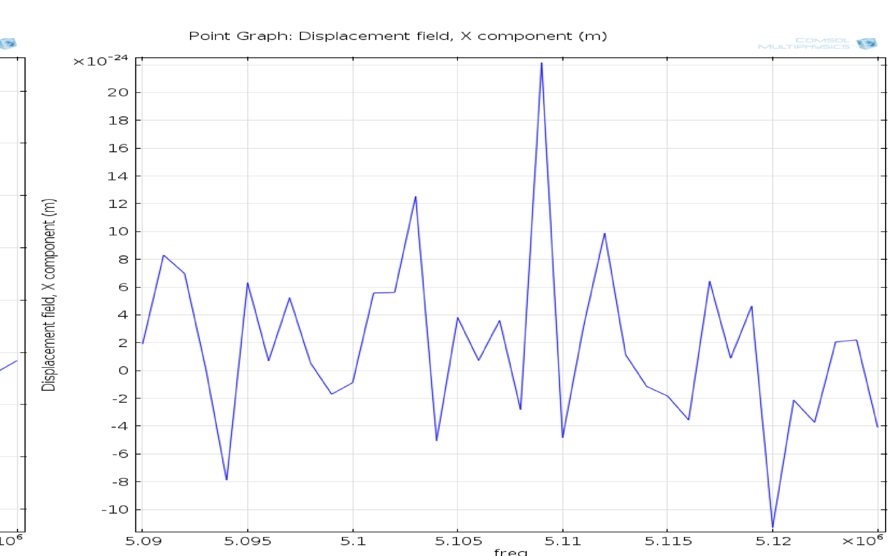

Figure 7. Mechanical response of the structure with no series capacitance(1MF).

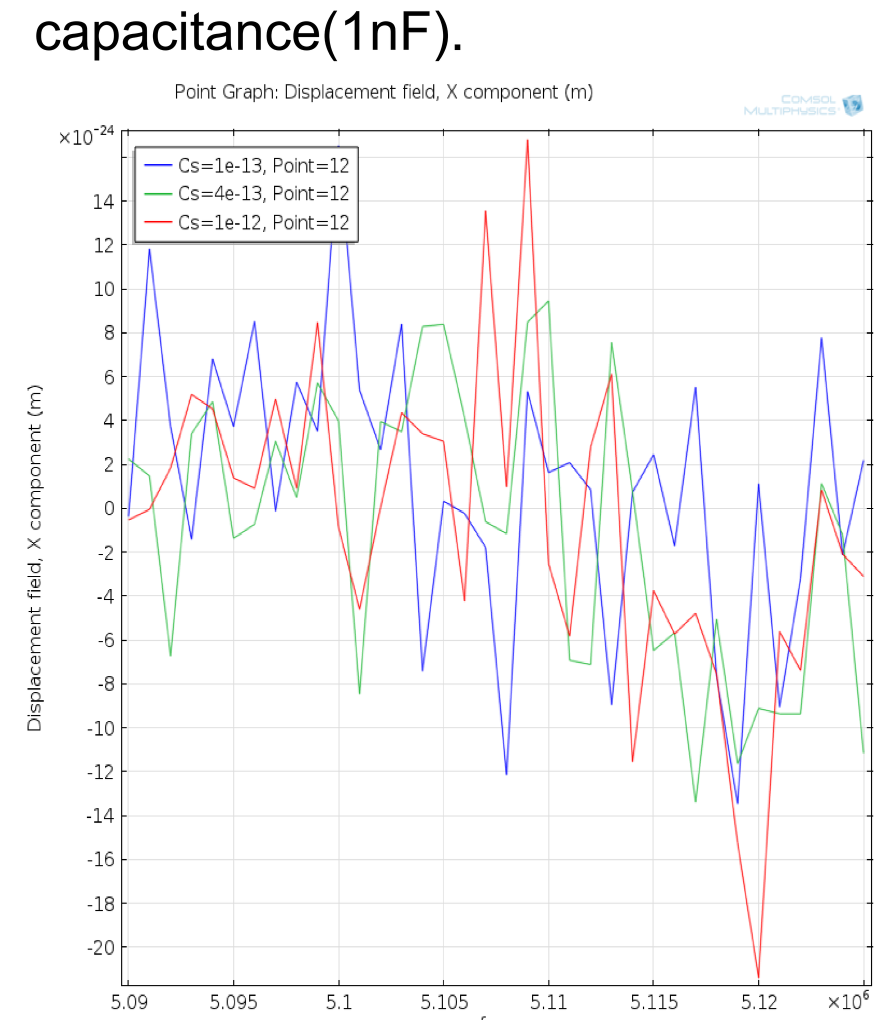

Figure 8. Mechanical response of the structure with different series Capacitances 1 nF.

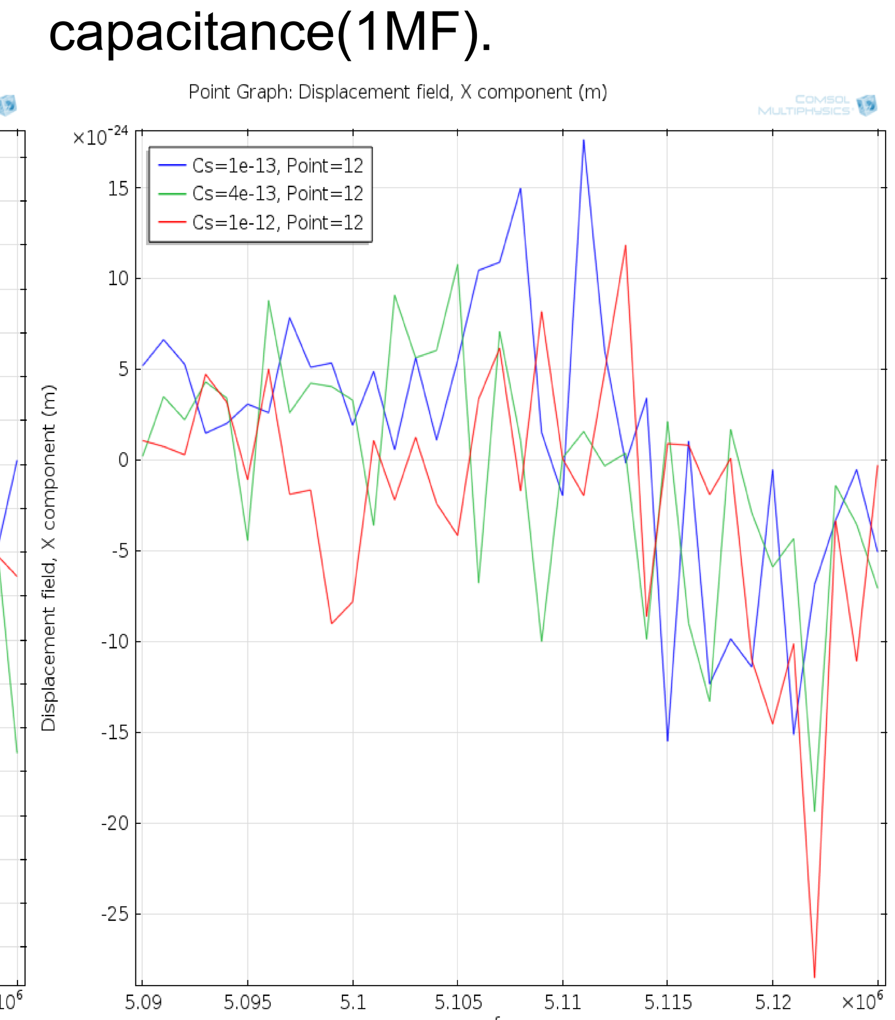

Figure 9. Mechanical response of the structure with different series Capacitances 1 MF.

Variable	Total Displacement (m)
Series Capacitance= 1nF	$1.2841*10^{-23}$
Series Capacitance=1MF	$7.623*10^{-24}$

Table 1. Displacement for various Series Capacitance.

Conclusions: Quartz crystal when driven by an AC voltage but with a low series capacitance value produces greater displacement when compared with high values. Resonance can tack place easily by adding a lower capacitance values.

References:

1. IEEE Standard on Piezoelectricity, ANSI/IEEE Standard 176-1987, 1987.
2. B. A. Auld, Acoustic Fields and Waves in Solids, Krieger Publishing Company, 1990.

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