Active Control of MEMS Resonator Parameters Via Electromechanical Feedback

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Abstract

MEMS resonators have been recently adopted in a wide variety of timing, sensing, and actuation applications. The ability to control the dynamics of resonance, namely the resonance frequency and quality factor of these resonators is crucial in achieving high precision performance within the desired response time. Active control of resonator parameters by applying an electromechanical feedback loop around the resonator is of particular interest because not only can it be applied to all types of resonators regardless of their transduction mechanism, but also it provides a means for real-time tuning of resonance parameters to compensate for possible variations during the operation of the MEMS device. To implement the control loop, the actuation signal is modified by adding a signal proportional to the displacement or the velocity of resonator. An actuation signal proportional to displacement in effect changes the resonance frequency while the actuation signal proportional to velocity has the effect of modifying the quality factor of the resonator.

In this paper we describe modeling and simulation of the electromechanical feedback loop in the COMSOL Multiphysics® software to implement parameter control of a piezoelectric MEMS resonator. The resonator consists of a thin film of aluminum nitride stacked on top of a silicon structural device layer. The Solid Mechanics and Electrostatics interfaces are used to solve the equations of motion for structural analysis of both the aluminum nitride and silicon domains and to solve for the Gauss's law in the aluminum nitride domain. These two physics interfaces are coupled in the AlN domain to model the piezoelectric behavior. To implement the unidirectional feedback path, ODE and DAE interfaces are also added to the model. These interfaces provide the ability to access the previously stored displacement solution which is then used to construct the appropriate actuation signal to the resonator. The resulting actuation signal is then applied to the piezoelectric layer similar to any other independent actuation signal but with the application of the nojac() operator. The nojac() operator is used to avoid the Jacobian evaluation so that there is no additional contribution to the system matrix. Simulation results show bidirectional control of the resonance frequency and quality factor for three different levels of displacement and velocity feedback.

Figures used in the abstract

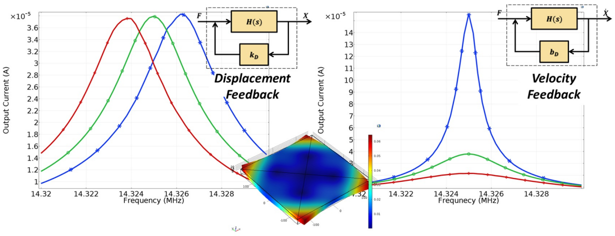

Figure 1: Tuning of the resonance frequency by applying a displacement feedback (left) and quality factor by applying a velocity feedback (right) to the AlN-on-Si MEMS resonator