Theory and Analysis of Quartz Crystal Resonators

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Abstract

Quartz crystal resonators as a key element for frequency control and detection have wide applications in modern electronics. The manufacturing technology of quartz crystal resonators have under gone tremendous changes in last few decades with focused efforts on accuracy, stability, miniaturization and novel applications. These changes required extensive investigations on improving the theory and analytical techniques as represented by improvements in the Mindlin plate equations and the development of finite element analysis aimed at the analysis and design of novel structures of resonators. The critical roles of traditional quartz crystal resonators have been targeted to be replaced by newer technologies such as the surface acoustic wave (SAW) resonators, acoustic wave MEMS, and lately the film bulk acoustic wave resonators (FBAR), but the sophistication of quartz crystal resonator technology itself has demonstrated the continuing and sustainable presence of the traditional quartz resonator with improved performance and refined structure for unique roles in many critical applications.

This tutorial will provide an overview of the needs of future development, design, and research of the quartz resonator technology through an introduction of the material, basic theory, approximate equations, practical methods, and design of the traditional resonator. The lecture will be presented to cover the following: 1) History and trends of quartz crystal resonator technology, 2) Basic theory of wave propagation, 3) Quartz crystal material, 4) Mindlin plate equations, 5) Analytical considerations, 6) Finite element methods.