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.

Yook-Kong Yong is a professor at the Dept. of Civil and Environmental Engineering, Rutgers, the State University of New Jersey, U.S.A. Dr. Yong is a registered Professional Engineer in New Jersey. He received his B.S. degree in civil engineering(1979) from Lafayette College, and his M.A.(1981) and Ph.D.(1984) degrees in structures/mechanics from Princeton University. He serves as an associate editor for the journal *IEEE Transactions on Ultrasonics, Ferroelectrics, and*

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Ji Wang received his B.S. in structural engineering in 1983 from Gansu University of Technology (currently Lanzhou University of Technology). From 1983 to 1988, he was a structural engineer at the 11th Institute of Project Planning and Research in Xi'an, Shaanxi, China. From 1988 to 1990, he was a visiting scientist at Argonne National Laboratory working on structural analysis. From 1990 to 1995, he was a graduate student at Princeton University studying high frequency vibrations of piezoelectric plates. He received his M.S. and PhD in civil engineering from Princeton in 1993 and 1996, respectively. He has been employed by Epson Palo Alto Laboratory from 1995 to 1999, NetFront Communications from 1999 to 2001, and SaRonix from 2001 to 2002. From 2002, he has been a Qian River Fellow Professor at Ningbo University, China and the founding director of the Piezoelectric Device Laboratory. He has been associated with the IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society through Symposium Technical Program Committees and is the funding Chair of the Committee on Electromagnetic Devices of the Chinese Society of Theoretical and Applied Mechanics. His research has been on physical acoustic waves in piezoelectric resonators and computational methods.