Comparison of the Mason and KLM Equivalent Circuits for Piezoelectric Resonators in the Thickness Mode

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Abstract – The parameters of the KLM and Mason's equivalent circuits in the thickness mode are derived to include dielectric, elastic and piezoelectric loss. The models are compared under various boundary conditions with and without acoustic layers to the analytical solutions of the wave equation. We show that in the case of a free resonator (short circuit on the acoustic ports) both Mason's circuit and the KLM model produce impedance data that is the exact equivalent of the data produced by the analytical solution. In the case where both piezoelectric surfaces are rigidly fixed, the analytical solution and Mason's circuit describes impedance data that is associated with the clamped capacitance C_O. The KLM circuit was shown to have infinite impedance at the electric port when the acoustics ports were open circuited. In the case where one of the piezoelectric surfaces is rigidly fixed the analytical solution and Mason's circuits describe an identical quarter wavelength resonator whereas the KLM circuit is shown to describe a half wave resonator under the same conditions. Similar discrepancies between the analytical solution and the KLM model are observed for acoustic elements with large acoustic impedance. It is interesting to note that in the case where acoustic layers had lower acoustic impedance than the piezoelectric material (low density/velocity or thin layers) the KLM model was found to approximate the analytical solution. These discrepancies between the KLM model and the analytical solutions are independent of loss and are also found in cases where loss-less resonators are modeled. The limitations discussed above are important to address due to the wide use of the KLM model. Therefore, we have determined an alternative equivalent circuit, which contains all the salient features of the KLM but is not limited to low acoustic impedance elements