



Electrical Modeling of Piezoelectric Ceramics for Analysis and Evaluation of Sensory Systems

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Overview

- **Introduction**
 - ◆ **Structural Health Monitoring System**
- **Existing Models for PZT**
- **Proposed Model and Its Performance**
- **Summary**



Demands for Structural Health Monitoring

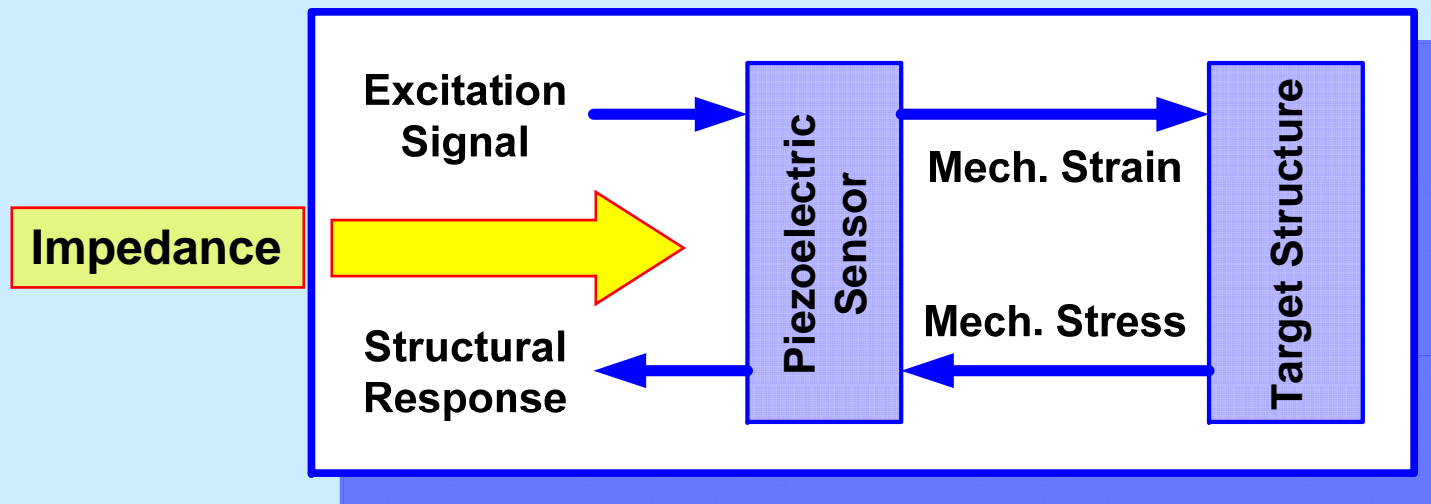
- **5% of the US Interstate bridges are structurally deficient (Siggerud 2002).**
- **I-35W Mississippi River bridge collapsed in Minnesota (2007).**
- **Space Shuttle Columbia disaster was caused by damage to the thermal protection system (2003).**





Impedance-Based SHM Operation Using PZT

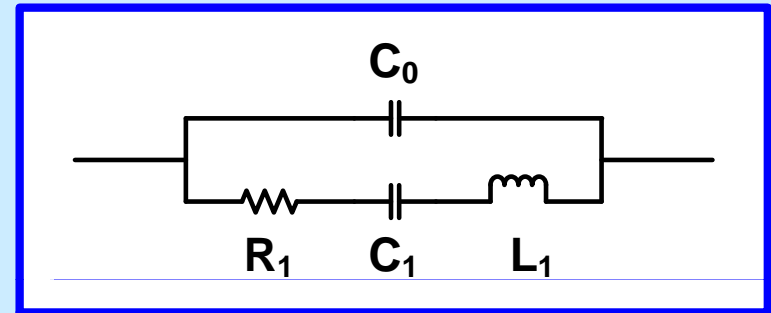
- **Generate excitation signals covering a target frequency range**
- **Excite a structure under test with PZT**
- **Measure structure responses**
- **Assess the damage of the structure**





Existing Models – Unloaded PZT

- **Van Dyke Model (1987)**
 - ◆ Near the resonant frequency
 - ◆ Series RLC: Mechanical behavior
 - ◆ Parallel C: Electrostatic capacitance
- **Sherrit Model (1997)**
 - ◆ Complex circuit components model piezoelectric losses
- **Guan Model (2004)**
 - ◆ R_s and R_p model energy dissipation.

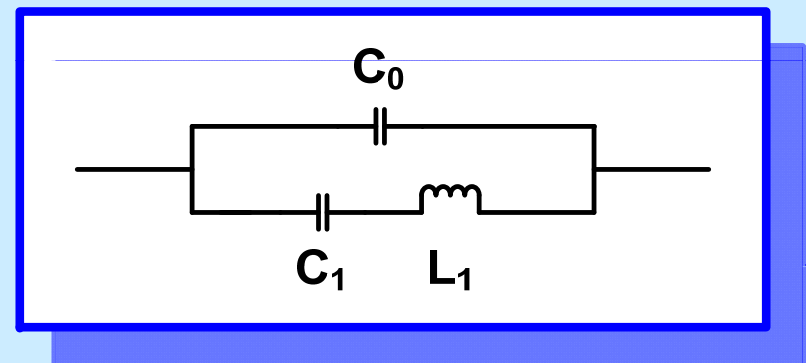


Van Dyke Model



Existing Models – Unloaded PZT

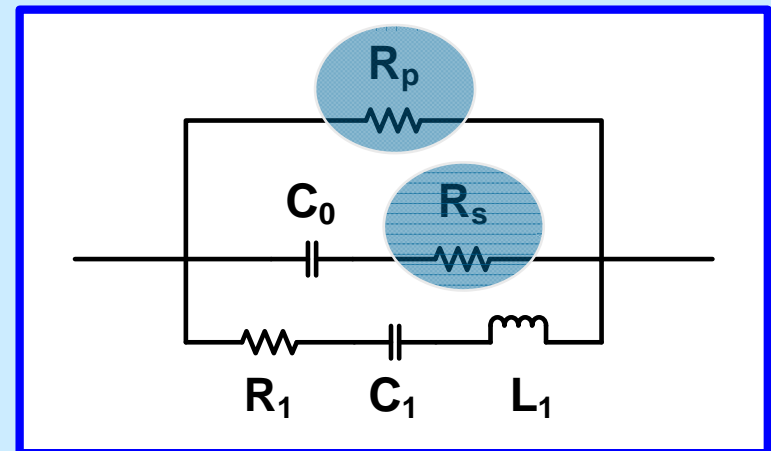
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Motivation

- **Previous models for PZT require complicated computations to determine electrical circuit component values.**

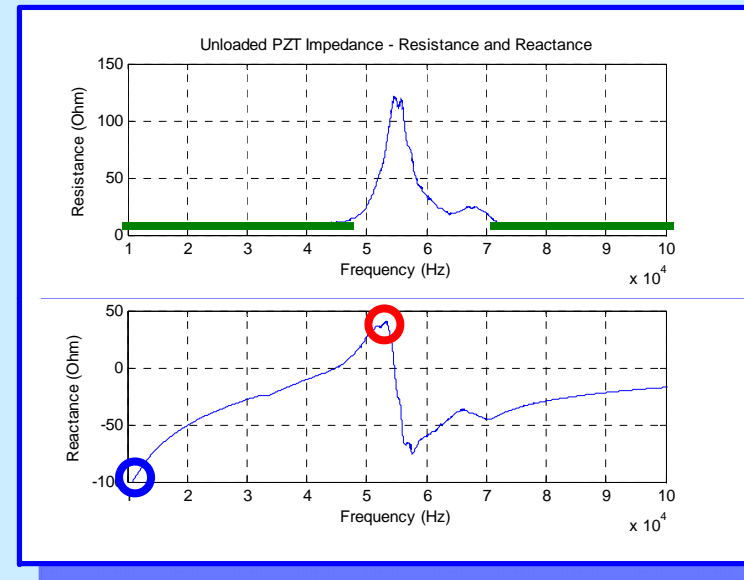


Automation of the modeling process is very difficult.

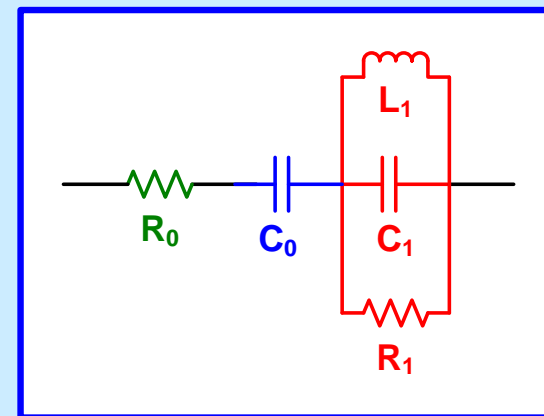


Proposed Model – Unloaded PZT

- **Observation of the impedance**
 - ◆ One parallel resonant frequency \Rightarrow **RLC tank**
 - ◆ Negative infinity reactance at DC \Rightarrow **Series C**
 - ◆ Constant resistance outside the resonant frequency \Rightarrow **Series R**



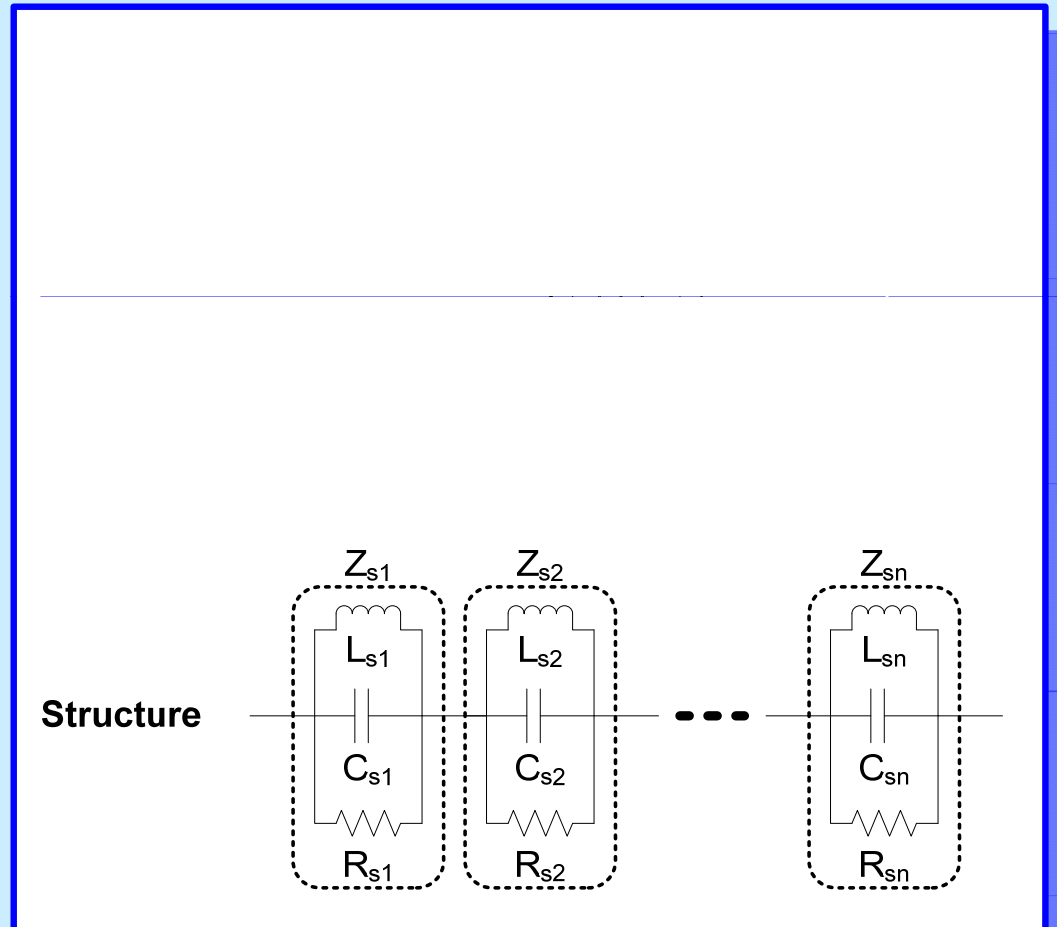
Proposed Model for Unloaded PZT





Interaction between Unloaded PZT and a Structure

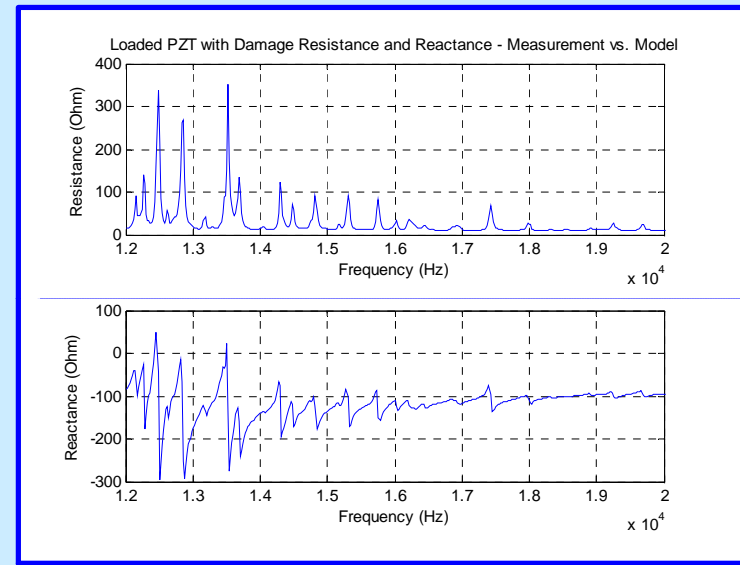
- **Mechanical structures have multiple resonant frequencies.**
- **The resonant mode of unloaded PZT has interaction with each resonant mode of the structure.**



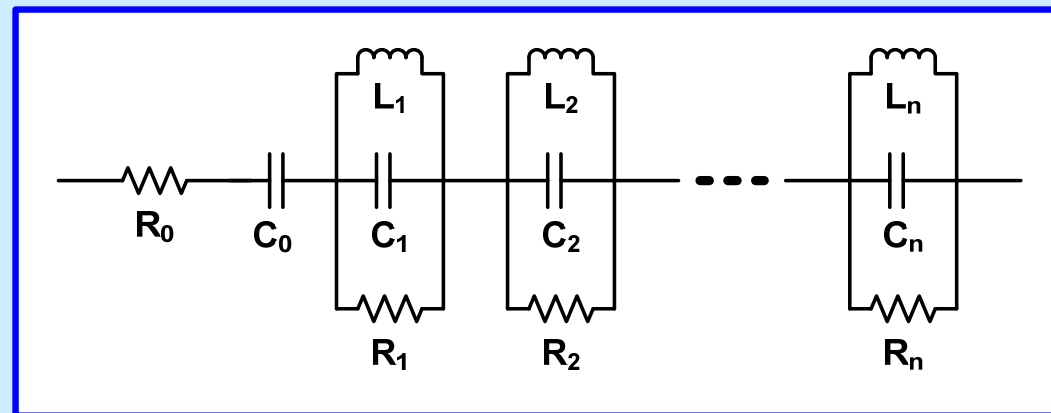


Proposed Model – Loaded PZT

- **Unloaded model is extended to accommodate multiple resonant frequencies**
 - ◆ **Multiple RLC tanks**



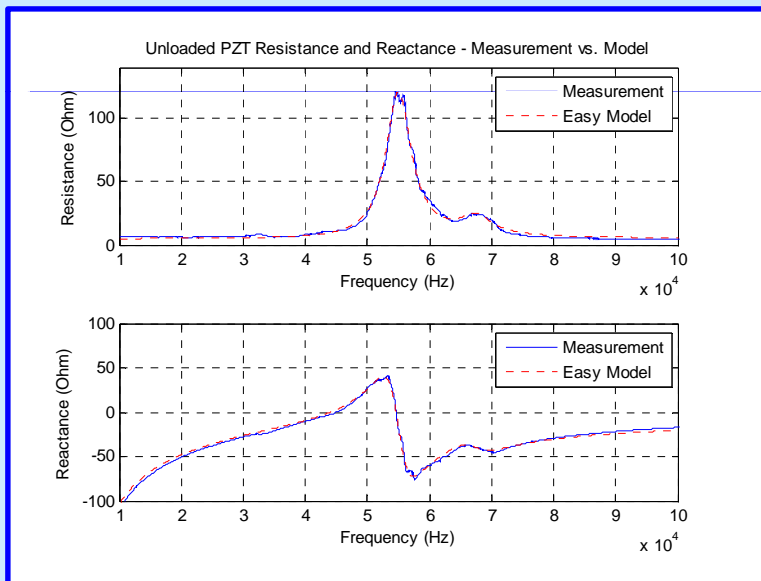
Proposed Model for Loaded PZT



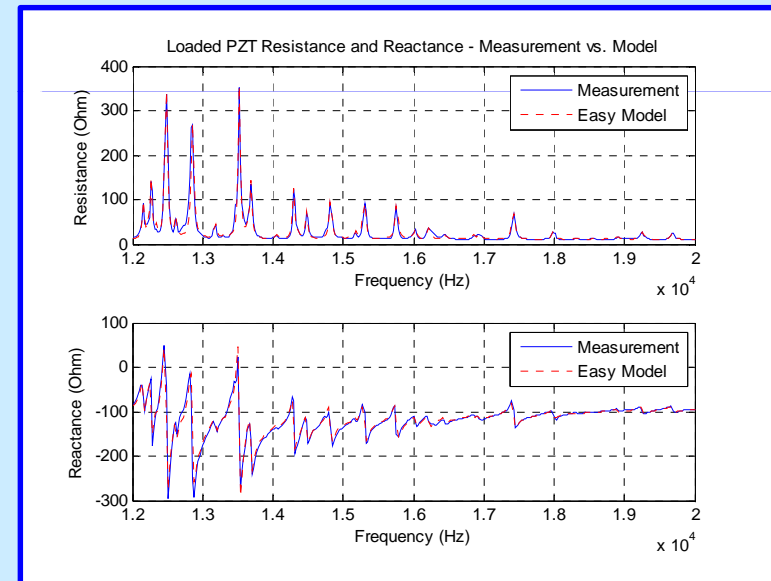


Performance Comparison

- **Measurement vs. Proposed Model**



Unloaded PZT
99.7% Match



Loaded PZT
96.8% Match



Summary of the Proposed Model

- **Equivalent circuit model based on PZT's impedance**
- **Advantages**
 - ◆ **Calculations for circuit component values are simple.**
 - ◆ **Offers an automation of the modeling procedure**
 - ◆ **Can be useful for system level simulation**