Simulation of Piezoelectric Transformers with COMSOL

T. Andersen, M. A. E. Andersen, O. C. Thomsen
Technical University of Denmark, DTU Elektro, Oersteds plads 349, DK-2800 Lyngby,

Introduction: Simulate the impedance plot of a piezoelectric transformer (PT) design and extract the values of the electric equivalent circuit with COMSOL.

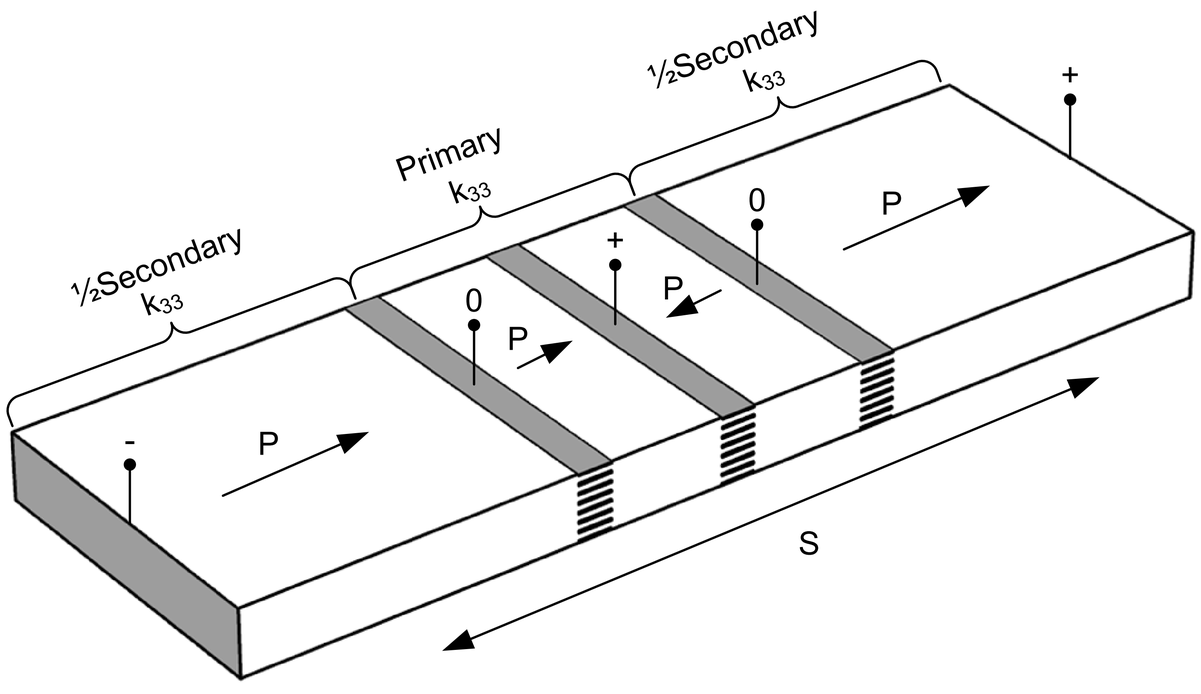

Figure 1. Piezoelectric transformer design: IDE Interleaved thickness mode.

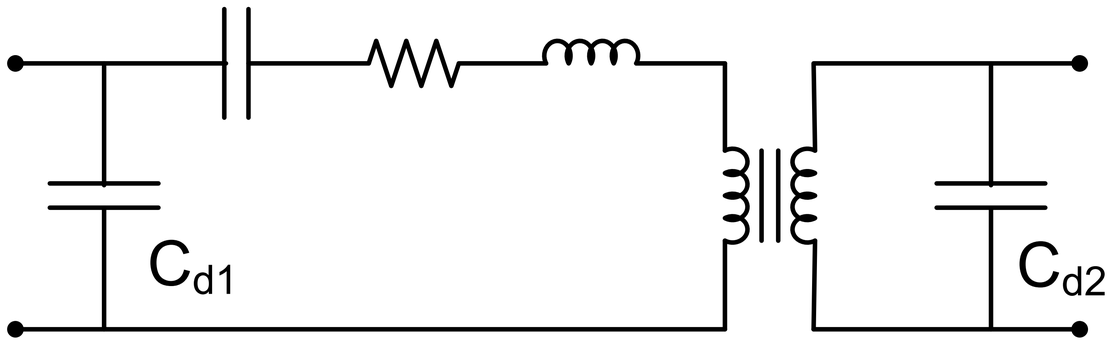

Figure 2. Electric equivalent circuit of a piezoelectric transformer. Only valid around a single resonance frequency.

Model simplification and transformation: Simplification of a model in COMSOL can reduce the simulation time by decades.

Dimension reduction:

$$Z(f) = \frac{Z_{2D}(f)}{d_z}$$

Layer reduction:

$$Z(f) = Z_{LR}(f) \cdot \left(\frac{L_{LR}}{L}\right)^2$$

Results:

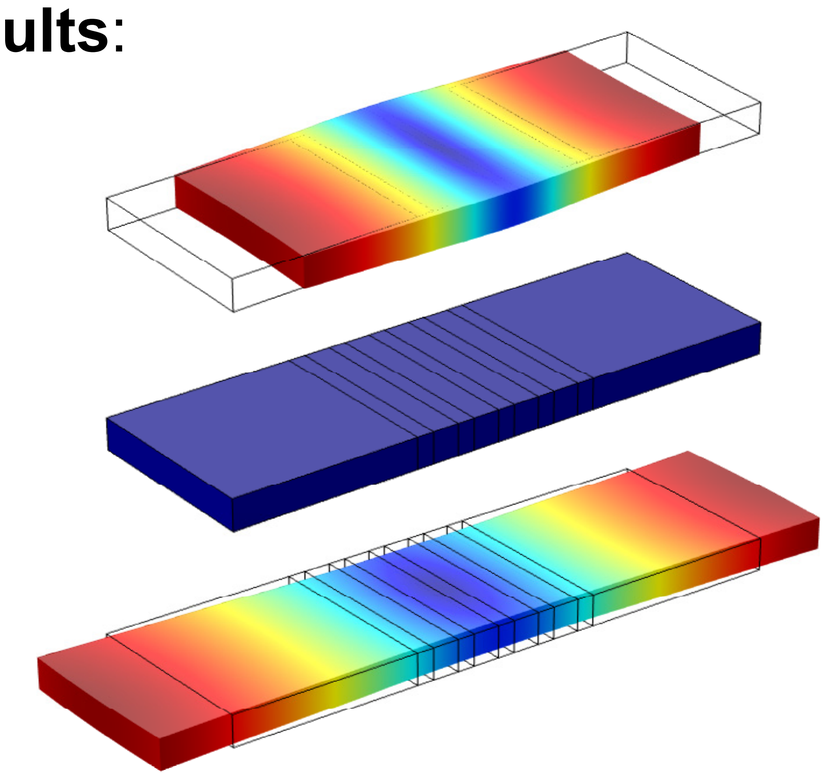

Figure 3. Displacement at first resonance mode.

1. PT measurement
2. 3D, 20 primary layers
3. 3D, 4 primary layers
4. 2D, 4 primary layers
5. Variations between simulations

	No. 1	No. 2	No. 3	No. 4	No. 5
R [Ω]	1.19	0.12	0.12	0.14	17 %
C [nF]	2.71	8.98	9.10	8.01	14 %
L [mH]	3.33	1.00	0.99	1.03	4 %
C_{d1} [nF]	23.8	53.2	57.0	55.4	7 %
C_{d2} [pF]	15.1	14.4	14.4	14.0	3 %
N	42.5	80.3	80.8	80.4	1 %
f_r [kHz]	54.3	54.3	54.3	56.7	4 %
R_m [kΩ]	195	203	203	200	1.5 %
η_m [%]	97.9	99.2	99.2	99.1	0.1%
V'_p [%]	99.0	153	145	143	7 %

Table 1. Resulting lumped parameters

Conclusions: Methods to simplify PT models in order to speed up simulation time is given. In this work the simplification errors is less than 17% in worse case. Experimental measurements indicate that care has to be taken about polarization and material parameters when simulating PTs with complex electrical field distributions.