Simple Disk Piezo Transformer Based Oscillator

J. P. Sandoz[1], J. M. Kissling[1]

[1]Institute of Applied Microtechnology, La Chaux-de-Fonds, HE-ARC, Switzerland

Abstract

In this contribution we present a COMSOL Multiphysics® example of a disk piezoelectric ceramic transformer (D-PT) coupled with a bipolar NPN transistor to form an auto-oscillator.

The comparison between the simulations and the measurements made on our prototype are found to be in good agreement. Having at our disposal a large number of homogenously poled disks, we decided to build and to investigate the performances of D-PT. From the many data found in the literature survey [1], the ring-dot type was selected.

The first simulation step consists in the modeling of the piezoelectric transformer without any clamping point. The two next physics interfaces are used for the frequency domain analysis: "Piezoelectric Devices" (pzd) and "Electrical Circuit" (cir). The geometry dimensions of the PZT-5H piezoelectric disk used in our work are the following: External diameter 8 mm; internal diameter 2mm and thickness 300µm. We also set the piezoelectric damping settings to "Rayleigh damping" with a starting value of $\alpha=0$, $\beta= 5 \cdot 10\text{-}9$, a value that would later be readjusted based on our measurements. It is worth mentioning that this type of damping is selected since it applies to both "Frequency domain" and "Time dependent" analysis.

In the second step of simulation, the D-PT clamping points positions are determined from the displacement plots. The following conditions must be simultaneously satisfied: (1) a voltage step-up ratio of at least 10 under a few k-ohms of load at the optimum frequency of operation, (2) A D-PT damping limited as much as possible so as to maintain the efficiency to an acceptable level, and (3) mechanical clamping points and electrical contacts practicable for an industrial product.

In Fig. 1 we can see the D-PT with its clamping pins and Fig. 2 displays a 3D plot of the displacement simulation. Then, from the measurements made on identical prototypes, the Rayleigh damping is readjusted to $\beta=10 \cdot 10\text{-}9$. Fig. 3 shows both the voltage step-up ratio and the efficiency versus frequency; the measurements match the COMSOL Multiphysics® simulation very well for all the resistive loads considered.
Finally, a third simulation step consisted in a "Time domain" analysis to confirm our laboratory measurements of our D-PT bipolar NPN transistor oscillator. Due to the low D-PT input impedance, we used a common collector configuration (Fig. 4). The results of the simulation validate the fact that with this simple schematic the running frequency is 20% higher than the optimal frequency of the D-PT running alone. A careful analysis of the D-PT input impedance as

well as its input-output phase as generated by the simulation gives the clue as to why there is such a frequency difference.

In conclusion, the use of COMSOL Multiphysics® turned out to be a very effective way to find good positions for the D-PT clamping points, a particular challenging problem with such a light weight device. Moreover, the coupling of "pzd" with "cir" gives the key electrical parameters (e.g. input impedance, efficiency....), the influence of the device geometry and of the clamping positions upon them.

Reference

[1] Disc piezoelectric ceramic transformers, IEEE Trans. on UFFC, VOL. 60, No. 8, August 2013

[2] Fabrication of High-Power Piezoelectric Transformers Using Lead-Free Ceramics for Application in Electronic Ballasts, IEEE Trans. on UFFC, VOL. 60, No. 2, February 2013

Figures used in the abstract

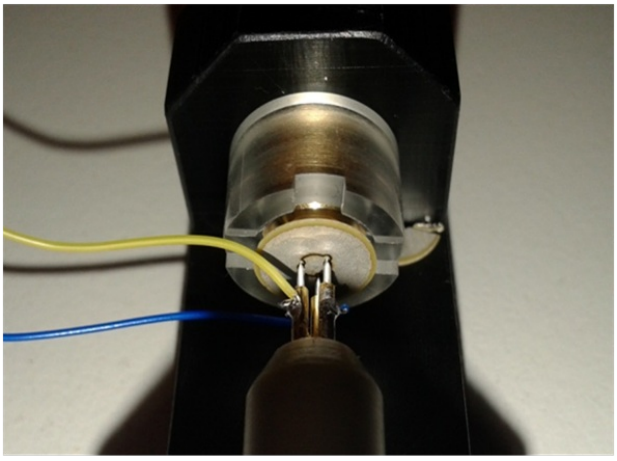

Figure 1: D-PT with its clamping pins.

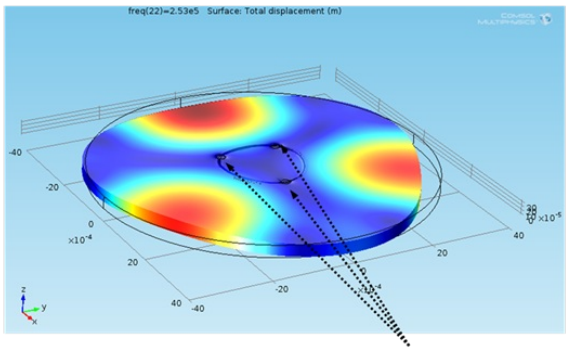

Figure 2: Displacement example with the 3 clamping points.

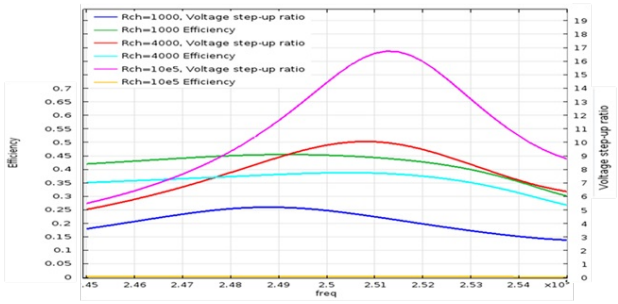

Figure 3: Voltage step-up ratio and efficiency versus frequency.

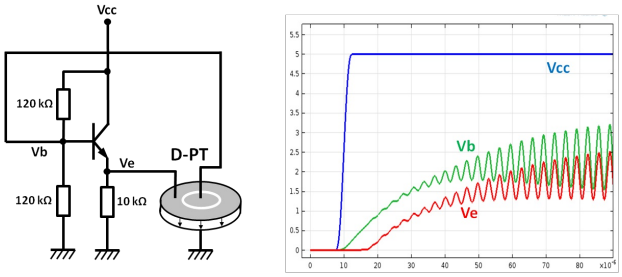

Figure 4: Electronics schematic with its start-up time response.