Novel Simulation of a Voltage-Driven Electro-Thermo-Mechanical MEMS Self-Oscillator

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ABSTRACT

This paper presents the modeling and simulation of electro-thermo-mechanical self-oscillators, an emerging type of MNEMS-enabled timing devices in which sustaining electronic amplifiers are not required for their operation. Indeed, they realize amplification in the mechanical domain and feedback by crossing three physical domains: electrical, thermal, and mechanical [1]. In a previous work [2], we proposed a new model to study such kind of MEMS oscillator. We demonstrated also the possible self-oscillation in case of the more attractive and practical direct voltage pumping for devices with a positive piezoresistive coefficient.

In this paper, we present a novel COMSOL Multiphysics® finite element model for an electro-thermo-mechanic self-oscillator and according simulations that support our theoretical developments.

ANALYTICAL MODEL

- **Methodology**: Direct application of Barkhausen criteria
- **Block model** of the voltage driven electro-thermo-mechanical oscillator representing the transfer function. The “loop gain” should be equal to one for satisfying the Barkhausen criterion [2].

Principle of Operation

- The current driven through the oscillator structure heats it up through Joule heating mainly concentrated in the thin and thick supporting beams.
- The resulting asymmetric temperature distribution generates thermal expansion forces that drive the mechanical structure mainly in bending.
- Given the piezoresistive character of silicon, the strain results in a change of electrical resistance, and thus of the Joule heating power, closing the loop.

Verification of Theoretical Conditions

- Novel study of the electro-thermo-mechanical self oscillator based on direct application of Barkhausen criteria was verified via COMSOL.
- New simulation of the complete behavior oscillation (voltage driven case).
- Nonlinearity option in COMSOL was identified to integrate the stability of oscillation.

Conclusions