Experimental Validation of an Electrical Equivalent Model for MEMS Coriolis Vibratory Gyroscopes

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In this paper, a new linear electrical equivalent model for a MEMS Coriolis Vibratory Gyroscopes (CVG) is presented. The MEMS CVG is represented as a 4-port (2-input ports and 2-output ports) system. This model includes the system dependence with respect to the tuning electrode voltages and applied rotational input. The model can be extended to reproduce the measured MEMS gyroscope response in operation while enabling co-design of the MEMS and surrounding electronics. The abstract reports on validation of the model through measurements of the response in open-loop at zero rate and during operation on a rotary table conducted on a fabricated MEMS gyroscope prototype. A good alignment between model and experimental results is seen.

MEMS Coriolis vibratory gyroscopes operate on the principle of coupling between two or more vibratory modes of a micromachined structure in the presence of an applied external rotation (Fig. 1). The MEMS element is closely integrated with front-end/signal conditioning electronics and design optimization relies on the development of accurate models of the integrated system. Traditional control loop models for MEMS gyroscopes are based on state-space representations. Although there are approaches to implement models for electromechanical systems in circuit simulators such as VerilogA, electrical equivalent models enable physical intuition in the design optimization process. In the case of the MEMS gyroscopes, as well as in coupled resonator systems, suitable approaches to implement the elastic, Coriolis and other coupling terms must be implemented. To our knowledge, this model is the first to propose an electrical equivalent model for MEMS CVGs that can also be extended for coupled resonator systems closely integrated with interface and control circuitry.

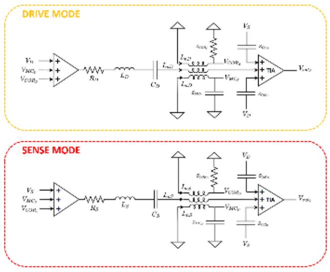

Fig. 1: Equivalent electrical circuit schematics for the MEMS Gyroscope.

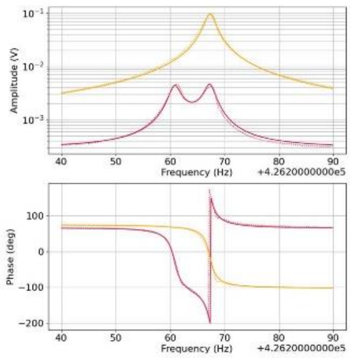

Fig. 2: Comparison of measured (dotted line) and simulated (continuous line) frequency sweep response of the drive (yellow line) and sense (red line) modes of the gyroscope when the input of the drive mode is actuated.

The model was experimentally validated through open-loop gyroscopic measurements conducted on microfabricated quatrefoil suspension gyroscope prototypes[1]. Good alignment is seen in the frequency response measurements measured experimentally and from the model as shown in Fig. 2. Rate table measurements of the gyroscope are also seen to align well with model predictions.

[1] M. Parajuli, G. Sobreviela and A. A. Seshia, "A Silicon MEMS Quatrefoil Suspension Gyroscope," JMEMS, vol. 32, no. 5, pp. 416-425, 2023