Experimental characterization of an electrostatically coupled oscillator MEM filter.

Rajashree Baskaran, Matthew Garten and Kimberly Turner
Department of Mechanical and Environmental Engineering
University of California, Santa Barbara CA 93106

Using MEMS based on-chip designs to substitute for off-chip or low Quality factor components of communication devices has been a driving force in MEMS research. The experimental characterization of an electrostatically coupled dual-oscillator MEMS filter design is presented. The basic design and fabrication of the coupled oscillators has been reported elsewhere[1]. The performance of the oscillator system as a MEM filter is reported here.

There have been many demonstrations of single oscillator filter designs and coupled MEMS oscillators filters[2,3]. The significant difference in the model presented here is that *the coupling between the two mechanically isolated oscillators is electrostatic* [Fig 1,2].

There are many advantages in implementing the MEMS based filter using this design. A linear system approach analysis shows that the coupling mechanism's compliance[strength] controls both the bandwidth and shape factor of the filter response[4]. Since the coupling strength is a function of the externally applied voltages, it a controllable parameter in this design. Additionally, by simultaneously implementing the frequency tuning concept[5], it allows for tunability of all the filter parameters through various input signals. Since any batch fabricated MEMS process involves some process specific variations from design values, the idea of total tunability eliminates the need for trimming using laser etching or deposition and hence can be performed after packaging as well.

The electrostatically coupled oscillators were made using the single mask bulk micromachining process, SCREAM[6]. The actuation is electrostatic and the motion is in the out-of plane direction due to fringing field effects. The design could be implemented on-chip with a comb finger based capacitive transduction from mechanical motion to electrical signal. To demonstrate the proof of concept, the characterization was done using a high accuracy (~4nm @ the filter frequency range) laser vibrometry measurement system[7] which measures displacement and velocity of the moving device. The MEMS device is mounted on a Joule Thomson refrigerator [MMR Technology] inside a vacuum chamber. The temperature was controlled using a controller interfaced with the refrigerator. It should be noted that since the transduction from mechanical motion to observed signal was not capacitive, the filter characteristics cannot be directly compared to that of a mechanical filter in a circuit.

The measured attenuation [defined here as 0dB at maximum amplitude of the oscillators and 20dB at half power points] as a function of frequency of the two-coupled oscillator system in shown in Fig 3. This data was taken at input voltage of 20Vpk-pk squarerooted sinusoidal signal, 10mTorr and 300K. A fractional bandwidth of 1.1% and shape factor of 3.13 was seen at the above mentioned experimental conditions. In addition, preliminary data for the effect of temperature on the frequency shift is presented in Fig 4. An increasing positive shift is expected due to the negative Young's modulus temperature co-efficient. The initial negative shift could be attributed to chamber pressure being influenced by the cooling initially. The decreasing chamber pressure would reduce the damping and increase the frequency.

We have presented the characterization of a novel design of coupled oscillator system for MEMS based filter applications. This design has many advantages over mechanically coupled filter designs. The filter characteristics have been obtained from motion amplitude data and temperature effects on frequency are under investigation. An in-plane motion and a multi-coupled oscillator design are under fabrication.

Word Count :542

References:

1.Baskaran, R and Turner,K,L ,2000, "Electrostatically coupled MEM Oscillators", Presented at 2000 IMECE, MEMS-Vol2, pg151-156 .

2.Nguyen, C.T.C., 1999, *Frequency-selective MEMS for miniaturized low-power communication devices.* IEEE Transactions on Microwave Theory and Techniques, . **47**(8): p. 1486-503.

3.Goldsmith, C.L., *et al.*, 1999, *RF MEMs variable capacitors for tunable filters.* International Journal of RF and Microwave Computer-Aided Engineering, . **9**(4): p. 362-74.

4.Johnson,Robert ,1983,"Mechanical Filters in Electronics", Wiley series in Filters.

5.Adams, S.G., *et al.*, 1998, *Independent tuning of linear and nonlinear stiffness coefficients [actuators].* Journal of Microelectromechanical Systems, . **7**(2): p. 172-80.

6. MacDonald, N.C., 1996, *SCREAM microelectromechanical systems.* Microelectronic Engineering, . **32**(1-4): p. 49-73.

7.Turner, K., L., P.G.Hartwell, R.Y.Webb, and N.C.MacDonald.1999. *Three dimenisonal motion characterisation using Laser Vibrometry*. in *Transducers '99- The 10th International conference on solid state sensors and Actuators, Japan, 7-10 June 1999.*

Submitting Author : Rajashree Baskaran , Department of Mechanical Engineering,
2355, ENGR II , University of California at SantaBarbara
CA 93106 Ph : 805 8937849 Fax : 805 893 8651
Email : raji@engineeirng.ucsb.edu

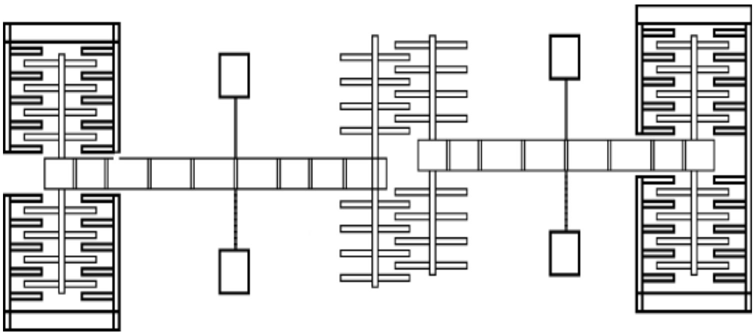


Fig 1: Schematic of the electrostatically coupled oscillator system. The features are 1micron wide and the overall area is of the order of 0.14 mm^2.

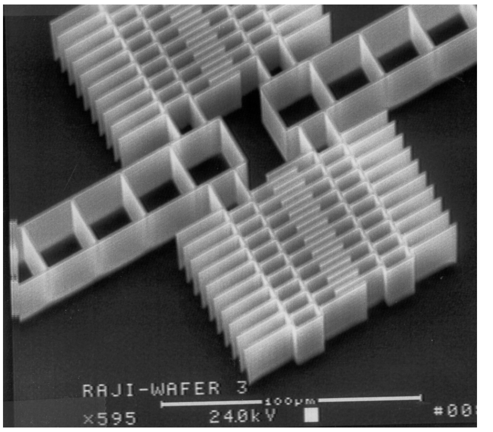
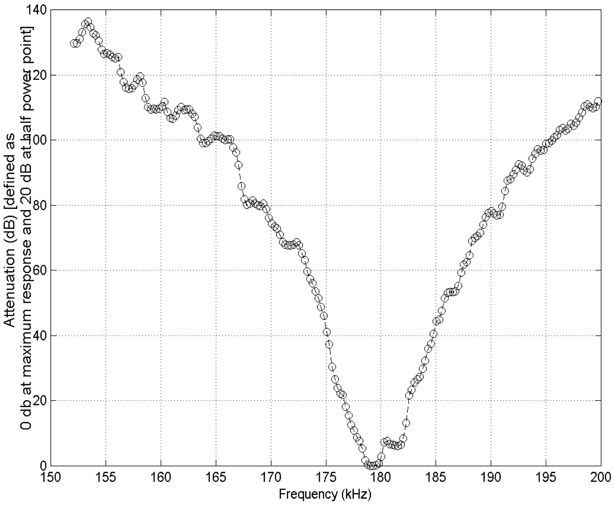


Fig 2: Scanning Electron micrograph of the detail of the coupling region.

Characteristics	**Experimental Value**
Central frequency (kHz) [f]	181.05
3dB Band width (kHz) [BW3]	1.99
20dB Band width (kHz) [Half power point] [BW20]	6.23
Fractional Band width [BW3/f]	1.1%
Shape factor [BW20/BW3]	3.13

Table 1 : Characteristics of the Filter tested [Fig3] .



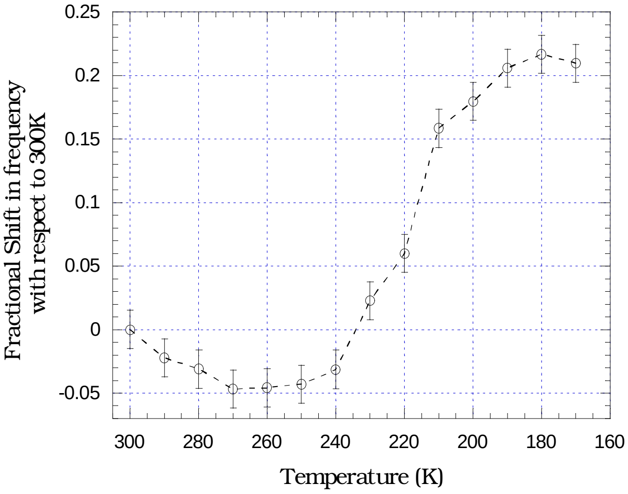


Fig 3: Experimental passband characteristics of the MEMS filter at 10mTorr, 300K, 20Vpk-pk input voltage.

Fig 4: Fractional frequency shift (Δf/f) as a function of temperature