FREQUENCY NOISE OPTIMIZATION IN MICROMACHINED RESONANT SENSORS

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Micromachined resonant sensors often operate on the principle of tracking shifts in resonant frequencies of one or more vibrating elements. The continuous tracking of resonant frequencies is aided by the implementation of a closed-loop oscillator front-end interface. In open-loop configurations, the phase noise is straightforwardly linked to additive noise[1]. Closed-loop operation introduces a corner frequency, connected to the resonant frequency and quality factor of the beam, influencing the integration of phase noise [2]. The resolution of the resonant sensor is directly connected to the noise integrated within the sensor bandwidth [3], highlighting the importance of considering this corner frequency. Our research addresses a domain where the limits are influenced by thermomechanical noise. Through achieving a relative reduction in electronic noise compared to thermomechanical noise according to the mathematical model [4]

Our system is predominantly influenced by thermomechanical noise, with vibrating beam resonator parameters ($f_0 \approx 100kHz$ / $Q = 100000$) leading to a 0.5 Hz corner frequency. The TIA feedback resistance Johnson noise dominates the output noise. To increase the relative difference between input and output noise, we employ three different feedback resistors, altering the transduction of the vibrating beam's motional current thus, affecting additive noise levels. The three defined domains persist, and the theory aligns as the SNR remains fixed. Figure 1 plots the measured frequency noise PSD. The noise floor remains consistent for different feedback resistances, while the corner frequency shifts from 1 to 5 Hz using optimal feedback resistance. This showcases our ability to push the corner frequency by a factor of 10 compared to the vibrating beam parameter (0.5 Hz), emphasizing the gains achieved through optimal feedback resistance usage. This reduces the integrated noise at 100 Hz by a factor of 2x from 37.8 mHz to 19.41 mHz.

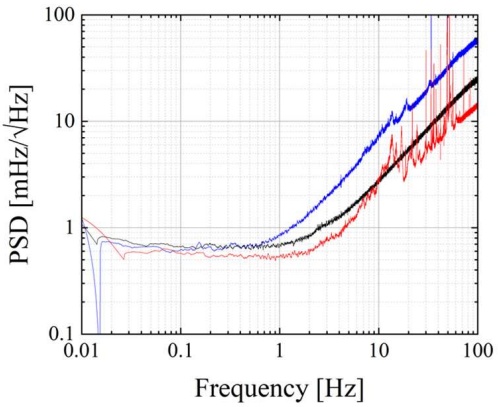

Fig. 1: Frequency noise PSD. In blue, black and red the acceleration noises for 500kΩ, 5MΩ and 50 MΩ feedback resistance respectively. After 5 Hz there are some spurious peaks relating to ambient vibrations.

[1]T. Miani *et al*., "Nanoresonator-based accelerometer with large bandwidth and improved bias stability," *2022 IEEE International Symposium on Inertial Sensors and Systems (INERTIAL)*, Avignon, France, 2022

[2] D. B. Leeson, "A simple model of feedback oscillator noise spectrum," in *Proceedings of the IEEE*, vol. 54, no. 2, pp. 329-330, Feb. 1966, doi: 10.1109/PROC.1966.4682.

[3] R. Levy and V. Gaudineau, "Phase noise analysis and performance of the Vibrating Beam Accelerometer," *2010 IEEE International Frequency Control Symposium*, Newport Beach, CA, USA, 2010

[4] G. Sauvage, "Phase Noise in Oscillators: A Mathematical Analysis of Leeson's Model," in *IEEE Transactions on Instrumentation and Measurement*, vol. 26, no. 4, pp. 408-410, Dec. 1977, doi: 10.1109/TIM.1977.4314586.