Tuning CMOS-MEMS Resonators with Embedded Heater

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MEMS resonators cover a wide range of applications, such as oscillators, gyroscopes, biosensors, and gas sensors. Frequency tuning capability is required to compensate for frequency changes due to fabrication tolerances, ambient temperature variations, or to cover broad range of frequencies for frequency hopping and signal tracking. Passive, as well as active techniques have been reported in the literature to address this requirement. Passive methods, with up to 4% frequency tuning, may only be used to address fabrication inconsistencies. On the other hand, active methods are repeatable and reversible. Such methods used for temperature compensation present a promising potential for use in frequency hopping, and signal tracking applications. Table-1 shows reported MEMs resonators of previous works having low resonance frequency and limited frequency tuning in comparison with the resonators designed in this work (Goktas and Zaghloul, *IEEE ED Letters, accepted)*.

In this work, wide range active frequency tuning (875 kHz) together with low power consumption are demonstrated through the use of simple electrostatically actuated fixed-beam type resonators with embedded heaters. Wide frequency tuning ranges are achieved by utilizing large axial loads on both fixed ends via the embedded heaters. Although a wider tuning range can cause the device to be more sensitive to physical changes such as temperature, this can be readily resolved by locating a second resonator with a feedback circuit next to the first one (Han Jianqiang, et al., *J. Micromech. Microeng.* Feb. 2005), (Salvia, et al., *J. Microelectromech. Syst*, Feb 2010).

The performances of the designs presented in this work compared to the results of recently published works are outlined in Table-1. The designs in this work need 14 times less voltage compared to Sviličić, et al. (*IEEE ED Letters,* Feb 2012), while consuming 14400 and 153 times less power compared to Zhang, et al. (*IEEE ED Letters,* July 2013) and Remtema, et al. (*Sens. Actuators A, Phys.*, 2001), respectively, to obtain the same frequency tuning ranges (ppm). In this paper, we present the theory and modeling of the device. Simulations and measurements results are also presented.

Table 1

Design	Freq. [kHz]	Tuning Range [kHz]	% Freq. Tuning	Freq. Tuning (ppm/V)	Freq. Tuning (ppm/mW)
This work (68 µm)	2053	875	42.6	-74800	<-24900
This work (152 µm)	303.4	108.4	35.7	-223000	-397000
Sviličić, et al., 2012	1766	171	9.7	-16100	NA
Manca, et al., 2013	81	33	40	NA	NA
Ru´a, et al, 2012	80	12.2	15	NA	NA
Zhang, et al., 2013	25.77	0.088	0.34	NA	-27.5
Remtema, et al., 2001	31	2	6.5	NA	-2600