Low power MEMS oscillators for sensor applications

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This abstract reports on the design of an oscillator circuit implemented in standard CMOS as a low power front-end circuit interface for micromachined resonant sensors. A Pierce oscillator topology is designed and fabricated in a 0.35 μm CMOS technology and integrated together with a 110 kHz electro-statically actuated micromachined single-crystal silicon double-ended tuning fork. Micromachined double-ended tuning fork resonators have been previously employed as transduction elements in accelerometers, gyroscopes, strain sensors and electrometers, and this low power front-end interface therefore has broad applicability to a variety of sensing contexts.

The CMOS oscillator is based on a Pierce topology[1] previously implemented for real-time clocks utilizing MEMS resonators[2]. The oscillator core is based on the single transistor Pierce configuration integrated with automatic amplitude level control. The automatic amplitude level control circuit is designed to keep the ac drive voltage below the bifurcation threshold associated with the onset of Duffing non-linearity in the resonator. The circuit is designed to operate over a range of supply voltages from 1.1 V – 3.3 V and to compensate for a relatively large motional resistance of upto 1.5 MΩ over frequencies from 30 kHz – 500 kHz.

Oscillator circuits were fabricated in the AMIS 0.35 μm technology (Fig. 1) and electrically packaged together with a microfabricated double-ended tuning fork resonator (Fig. 2) in a 44-pin LCC package. Open-loop measurements on the 110 KHz double-ended tuning fork resonator conducted prior to die assembly showed a resonator Quality factor of 32,000 at 30mTorr. Preliminary experiments (buffered output waveform shown in Fig. 3) have shown that the oscillator core draws less than 1 μA at 1.2 V supply for a resonator bias voltage of 10 V while demonstrating a short-term frequency stability of < 0.5 ppm.

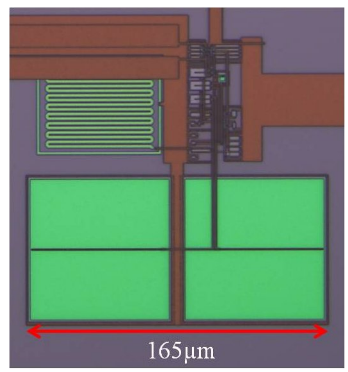

Fig. 1: Micrograph of the fabricated CMOS circuit.

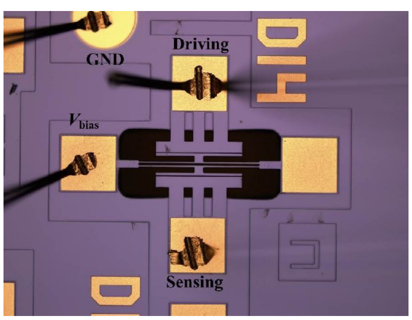

Fig. 2: Micrograph of the DETF resonator.

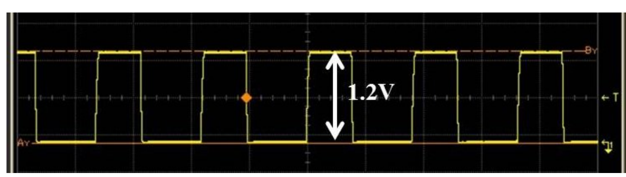

Fig. 3: Measured output waveform of 110KHz oscillator.

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[1] E. Vittoz, et. al., “High-performance crystal oscillator circuits: theory and application”, IEEE J. Solid-State Circuits, vol. 23, p. 774-783, 1988.

[2] K. R. Cioffi and W. T. Su, “32KHz MEMS-based oscillator for low power application”, Freq. Control Sym. And Exp., Proceedings of the 2005 IEEE International, p. 551-558, 2005