

# A 1.5GHz Temperature Stable CMOS/FBAR Frequency Reference

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This work presents a temperature compensated 1.5GHz Film Bulk Acoustic wave Resonator (FBAR) based frequency reference with better than  $\pm 5$ ppm frequency stability from 0-70°C. FBAR oscillators have been shown to demonstrate superior power/phase-noise performance compared to integrated LC oscillators<sup>1</sup>. The ultra small form factor and low power dissipation of a temperature compensated FBAR oscillator present a promising alternative for replacement of quartz crystal frequency references over silicon MEMS and on-chip compensated oscillators<sup>2</sup>. As shown in Fig.1 (a), this work uses a three step (sensing, digitizing & compensating) on-chip digital temperature calibration mechanism for temperature compensation of an FBAR-tuned oscillator. A 7-bit low power successive approximation register ADC digitizes the output of an on-chip switched-capacitor absolute temperature sensor. This digitized temperature reading addresses an integrated programmable 1024b look-up table (LUT). The contents of the LUT controls an 8-bit binary weighted capacitor array with an LSB step size of 0.7ppm (1kHz), allowing self-contained temperature compensation. Measured frequency drift pre- (>130ppm) and post-compensation (<10ppm) over a 0-70°C temperature range is shown in Fig.1 (c). The measured phase noise is -125dBc/Hz at 100kHz offset from the 1.5GHz carrier, with a total power consumption of 6.75mW. Dividing down to a low frequency reference would afford a proportional reduction in phase noise. The on-chip temperature calibration circuitry consumes 15% of the total power consumption. The system is implemented in 0.35 $\mu$ m CMOS process with die size of 0.79mm $\times$ 1.72mm (Fig.1 (b)).

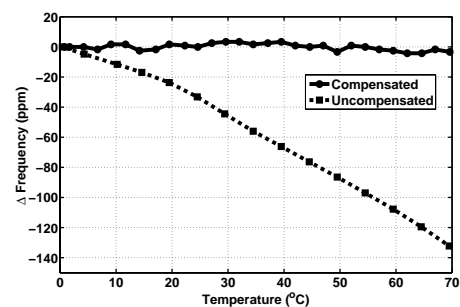
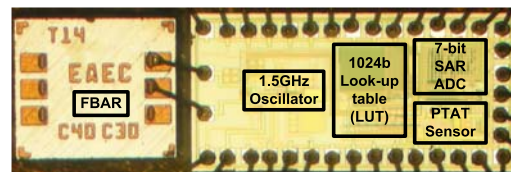
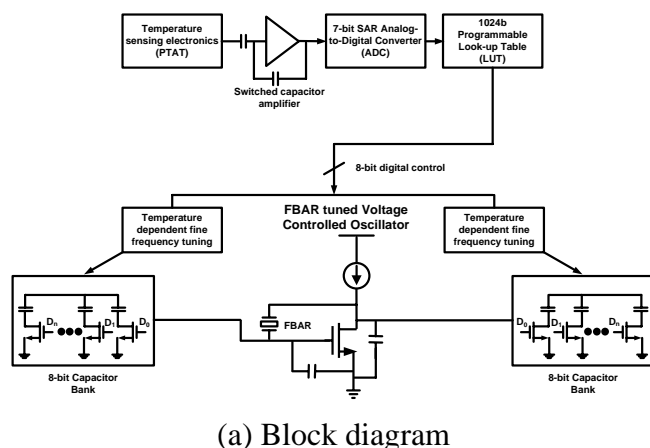


Figure 1: Temperature compensated FBAR frequency reference

<sup>1</sup> S. Rai, B. Otis, "A 1V 600 $\mu$ W 2.1GHz Quadrature VCO Using BAW Resonators," *IEEE International Solid-State Circuits Conference*, February 2007.

<sup>2</sup> M. S. McCorquodale, "Self-Referenced, Trimmed and Compensated RF CMOS Harmonic Oscillators as Monolithic Frequency Generators," *IEEE Frequency Control Symposium*, May 2008.