Noise-Driven Sensors

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Abstract:

Intrinsic noise processes impose fundamental limitations upon the signal-to-noise ratio (SNR) of MEMS & NEMS sensors. Typically, noise suppression measures or higher actuation levels have been deployed to increase the SNR. The former approach imposes stringent operating conditions, such as working in vacuum and at ultra-low temperatures. The latter is limited by the power handling capacity of the sensor.

We propose a paradigm shift that turns the intrinsic thermal noise from an impediment to a constituent of the sensor by adopting it as the driving force. A resonant sensor is deployed to `color' the white thermal bath energy, thereby creating features that can be used for sensing. The fundamental challenge to this approach is the fact that the driving force is phase incoherent which precludes the use of traditional phase-locked detection mechanisms.

As a proof-of-concept, we present noise-driven sensors that operate without external actuation and embody detection mechanisms immune to phase incoherence. The first measures the area under the power spectral density to estimate a stimulus that impactsthe level of excitation (thermal noise). The second observes quantitative changes in the magnitude of the resonant peak in response to a stimulus that affects the sensor damping or excitation levels, such as temperature or pressure. The third observes shifts in the resonant frequency in response to a stimulus that affects the structural stiffness or mass of the sensor.

We demonstrate noise-driven pressure and temperature sensors. Our design paradigm offers an opportunity to deliver practical NEMS sensors that function at room temperature and under ambient pressure.