**Docket #:** S21-457

# Negative Capacitance Tuning of Ultrasound Transducers

Stanford researchers developed a programmable tuning circuit for dynamic, all-electronic tuning of the resonance frequency, sensitivity, and bandwidth of ultrasound transducers.

Typically, ultrasonic sensing systems follow one of two design philosophies: using conventional transducers for general purpose use across broad application spaces, or fabricating custom transducers using novel materials, architectures, and transduction mechanisms that optimize for a specific application. The former approach suffers from sub-optimal performance, while the latter typically employs complex designs that require high fabrication time, effort, and cost. Moreover, with either of these approaches the operating frequency is fixed by geometric design decisions and scaling the system to incorporate large transducer arrays is particularly challenging due to inevitable process variations when using MEMS devices. Aside from the above challenges, all resonant transducers also have an inherent tradeoff between sensitivity and bandwidth, wherein one can either achieve high sensitivity or wide bandwidth but not both simultaneously.

To address these problems, Stanford researchers have developed a method that shifts complexity from custom transducer/MEMS fabrication to intelligent electronics instead, increasing system performance by overcoming the sensitivity-bandwidth limit and allowing for robust, reconfigurable, and cost-effective system scaling. This is accomplished through two all-electronic tuning circuits: 1) a tunable negative capacitance that can be utilized to shift the transducer to a desired resonance frequency while canceling any parasitic capacitance to maintain high sensitivity and combat process variations and 2) a tunable resistance that electronically dampens transducer resonance and increases bandwidth at the desired resonance frequency. Together, they provide an exclusively electronic means for tuning the transducer's resonance frequency, sensitivity, and bandwidth on the fly depending upon application requirements. Thus, with the proposed solution, one could use conventional, easy-to-fabricate transducers while employing the electronic tuning knobs to enable high-performance, yet highly reconfigurable ultrasonic sensing systems for a variety of applications ranging from medical ultrasound, non-destructive testing, and air-coupled sensing.

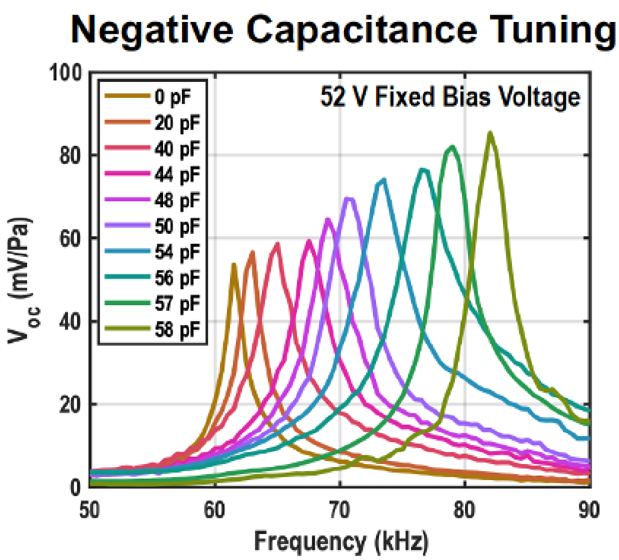


*Figure Description: Via the negative capacitance tuning technology described, the inventors are able to attain high sensitivity at all frequencies (source: inventors).*

**Stage of Development**

Proof of concept

# Applications

- Time-of-flight based applications like ultrasound localization, ranging, and distance estimation
- Medical ultrasound
- Non-destructive testing
- Non-contact 1D, 2D and 3D ultrasound sensing and imaging in air
- Cross-medium imaging
  - Airborne sonar imaging (water-to-air)
  - Underground mapping (soil-to-air)
  - Medical imaging (tissue-to-air)

## Advantages

- High sensitivity, wideband transducer response
- Single device for high performance across frequencies (versus needing multiple devices)
- Simple fabrication with electronic compensation of any process variations to enable robust, low-noise MEMS-electronics integration

## Publications

- Singhvi, A. Fitzpatrick, and A. Arbabian, "An Electronically Tunable Multi-Frequency Air-Coupled CMUT Receiver Array with sub-100μPa Minimum Detectable Pressure Achieving a 28kb/s Wireless Uplink Across a Water-Air Interface," *Proceedings of the 2022 IEEE International Solid-State Circuits Conference (ISSCC),* Feb 20-26, 2022.

## Innovators

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