**Goal:** Measure range and direction to targets in air using ultrasound, enabling low-power gesture recognition for mobile devices

**Motivation:** Optical 3D imagers for gesture recognition, such as Microsoft Kinect, suffer from large size and high power consumption. 3D range measurement using sound is an attractive alternative because of the potential for low power consumption and ambient light insensitivity. Aluminum nitride piezoelectric micromachined ultrasound transducers (pMUTs) offer high displacement and low voltage excitation, making them ideal for use in air.

**Prototype Depth Sensor:**
- a) Uses a single transmitter to send a pulse, and a linear array of seven transducers to receive the echo.
- b) Has a maximum range of 750mm and angular range of 70°
- c) Has random error of ~1° and <2.5mm over the entire range

**Localization Accuracy:**
The depth sensor was characterized on a radial path and on an arc with constant range. At left, a single point at each location is shown. The mean errors are between ±1.5mm and ±2° for the radial and ±3.5mm and ±3° for arc cases, respectively.

**CMOS electronics**
- Array size: 5mm x 5mm
- AIN piezoelectric transducer
- Range: up to 2m

**Ultrasonic Wave**
f = 200kHz

**Background**
Voltage applied between the electrodes causes the membrane to deflect out-of-plane, generating an ultrasound wave. Similarly, an ultrasound wave incident on the device generates a voltage between the electrodes.

**2D Depth Sensor**
We are designing a custom readout integrated circuit which will transmit and receive signals from a pMUT array. The readout circuit will consume approximately 150µW of power per channel while producing approximately 110 samples per second. The plot at right shows the energy consumption per measurement plotted vs. the maximum range of the system. At short ranges the energy consumption can be less than 10nJ/sample.

**Block Diagram**
Each channel will have a transmitter and a receiver that interfaces with a pMUT. The interface allows transmit beamforming and is optimized for low power operation.