SENTONS

A "ZERO DISPLACEMENT" ACTIVE ULTRASONIC FORCE SENSOR FOR MOBILE APPLICATIONS

HOTCHIPS 2016

23 AUGUST 2016

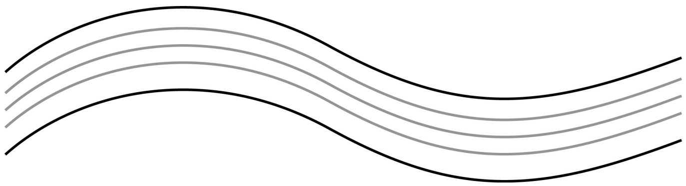
Ask an RF Engineer to Build a Touch Sensor….

- Use scattering/absorption of a propagating wave to detect position = radar/sonar
- Measure scattering/absorption of a propagating wave = channel equalization/training
- Need sub-mm accuracy = millimeter wave
- Millimeter wave = 60-100 GHz frequencies

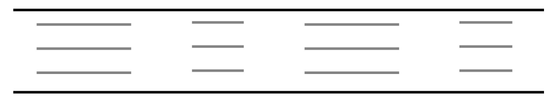
Eliminate the 100GHz requirement by eliminating the speed of light – can we use ultrasound*?*

Ultrasonic Propagation in Plate Solids

- A0 vs. S0 (lowest order propagation modes)



A0 – entire plate flexes compression/expansion



S0 – longitudinal

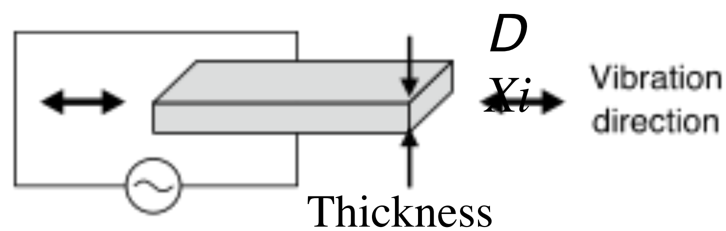
- Unlike radio waves, A0 and S0 propagate at very different group/phase velocities!
- Higher order modes exist and will propagate as well
- Modes can transition at boundaries/discontinuities
- Snell's law is *not* generally applicable!

Piezoelectric Ceramics

- Equivalent of an antenna for sound waves
  - Passive and reciprocal - converts electric field into mechanical excitation and vice-versa
  - Electrically like a parallel-plate capacitor
  - Exceedingly common/cheap
    - Quartz crystals/crystal oscillators
    - Hard drive precision head actuators
    - Fish finders/buzzer speakers/toothbrushes/etc.
- Strain/voltage relationship

  εi (strain in ith axis) = (DXi / Xi) = dij • (V/t),

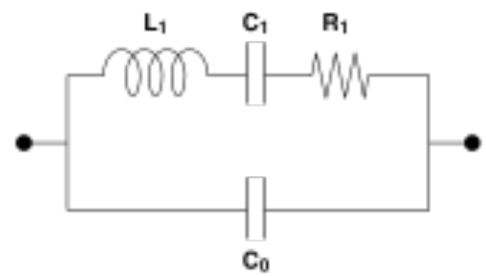
  where field is applied on j axis



Thickness t

Voltage V

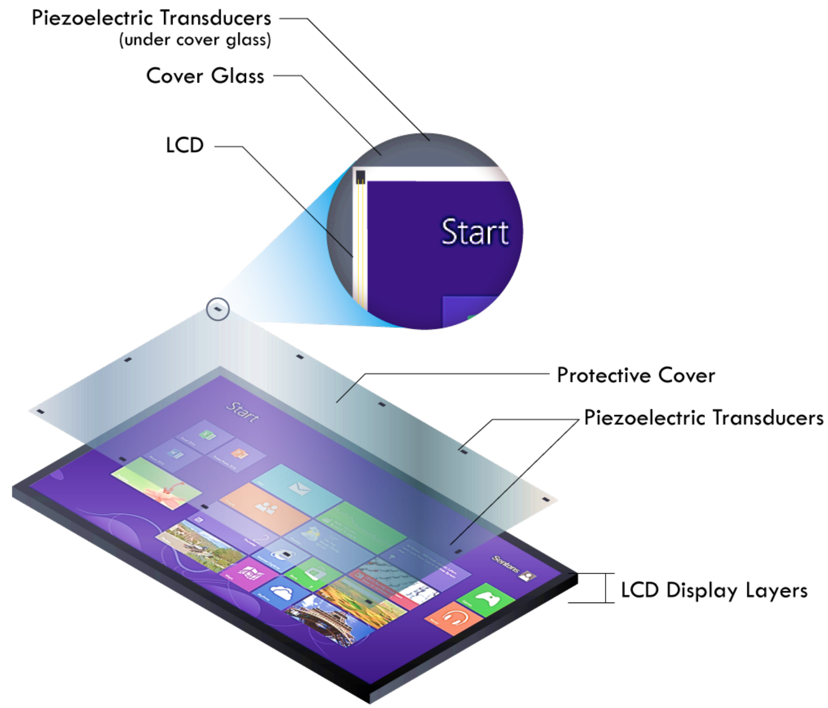
Electric Field = V/t



Electrical model

Sentons' Sensor Technology

- Uses inexpensive piezoelectrics as ultrasonic transmitters/receivers (acoustic antennas)
- All sensor components sealed behind glass, no lamination in visible area
- Ultrasound vibration field is continuously and uniformly propagated across the substrate (glass or metal)
- Carrier frequency ~ 500 kHz
- Can sense on metal, glass, and curved surfaces – any substrate that supports ultrasonic propagation



Industry's First New Sensor Technology…In A Very Long Time!

Visualized Response to Touch

- Actual measured glass response using laser vibrometer
- Amplitude of glass deformation ~ 20nm

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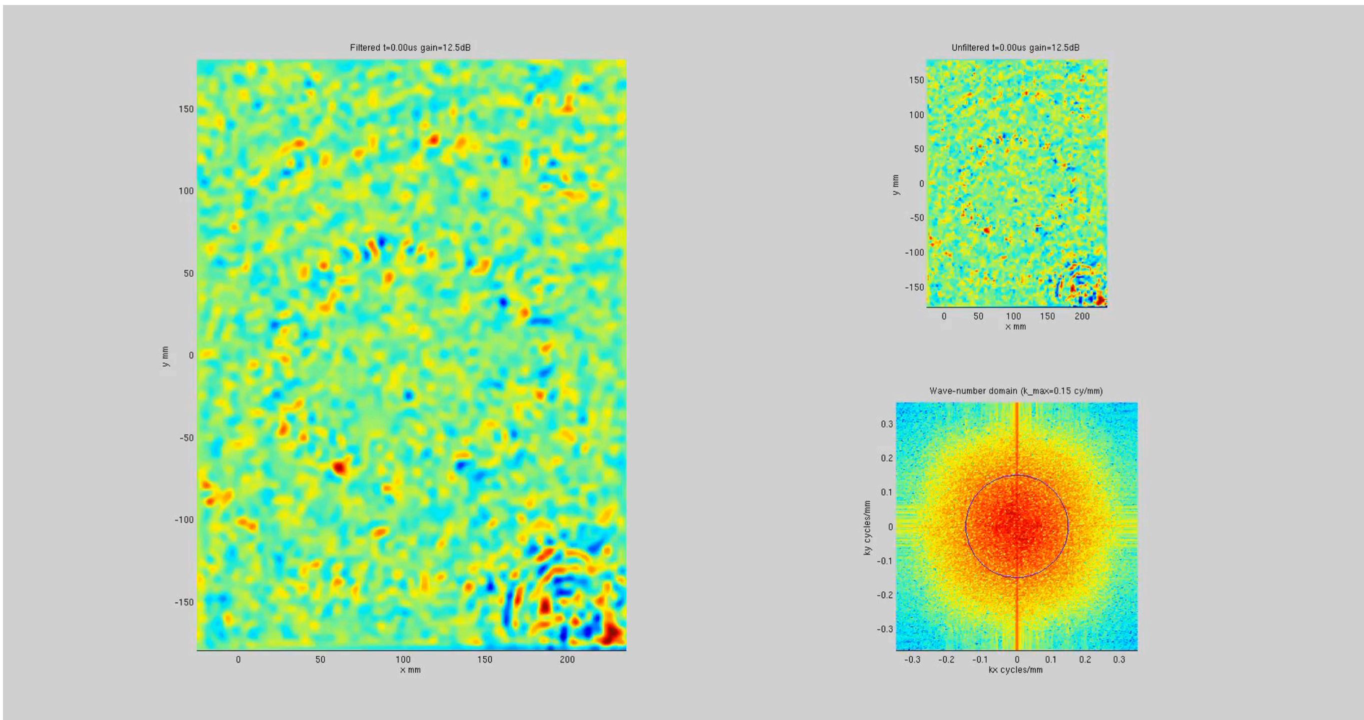
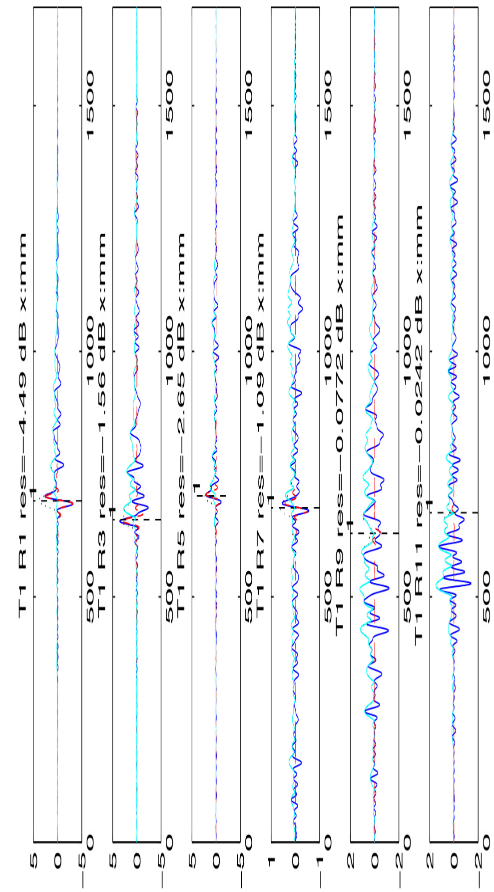


SENTONS

Touch and Force Detection

- Pulses in received waveforms correspond to touches
  - Which pulse goes with which finger?
  - Edge reflection can result in multiple pulses from a single finger
  - In general, *Time of flight* gives positional information
  - *Amplitude* of pulse response corresponds linearly to force – coupling between touch object and traveling wave
- Can *simultaneously* determine all 3 variables – X, Y, and force

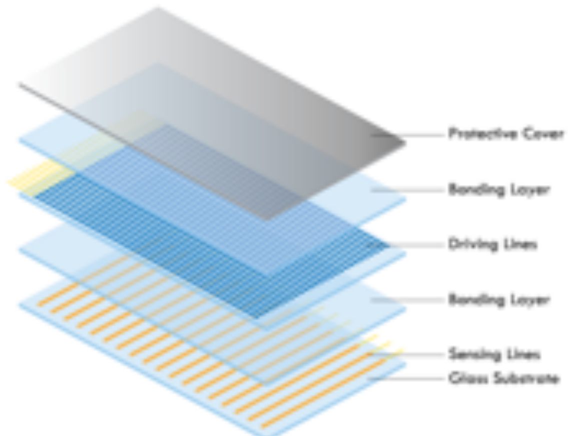


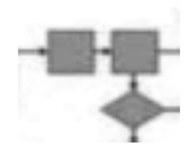
Compared to Existing Sensors?

Sensor Structure

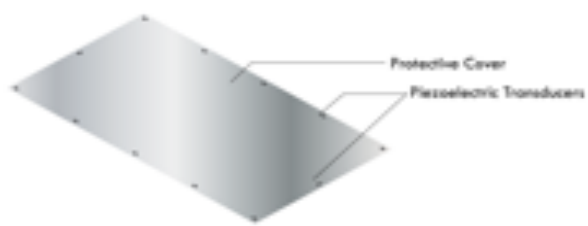
Algorithms

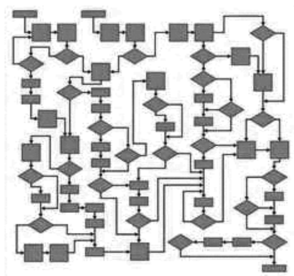
Projected
Capacitive
Touch Sensor
(no force)





Sentons
Ultrasound-Based
Touch Sensor
(includes force)



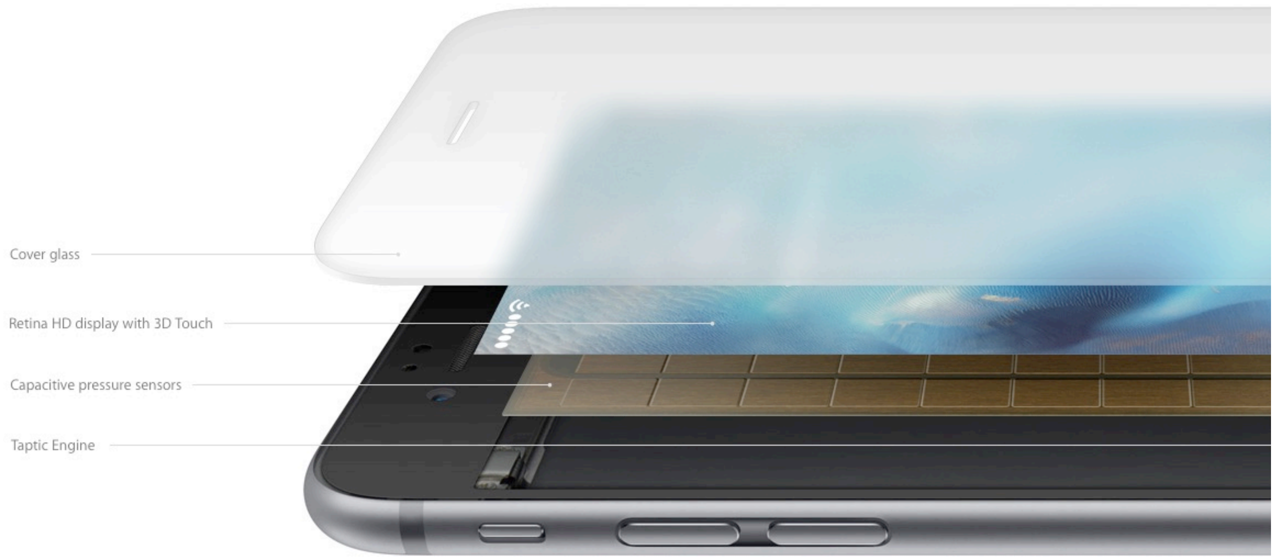


Two Specific Technology Use Cases

- **Cover Glass Force Sensing**
- Touch/Force Enabling the *Rest* of the Phone

Cover Glass Force Sensing (3D Touch)

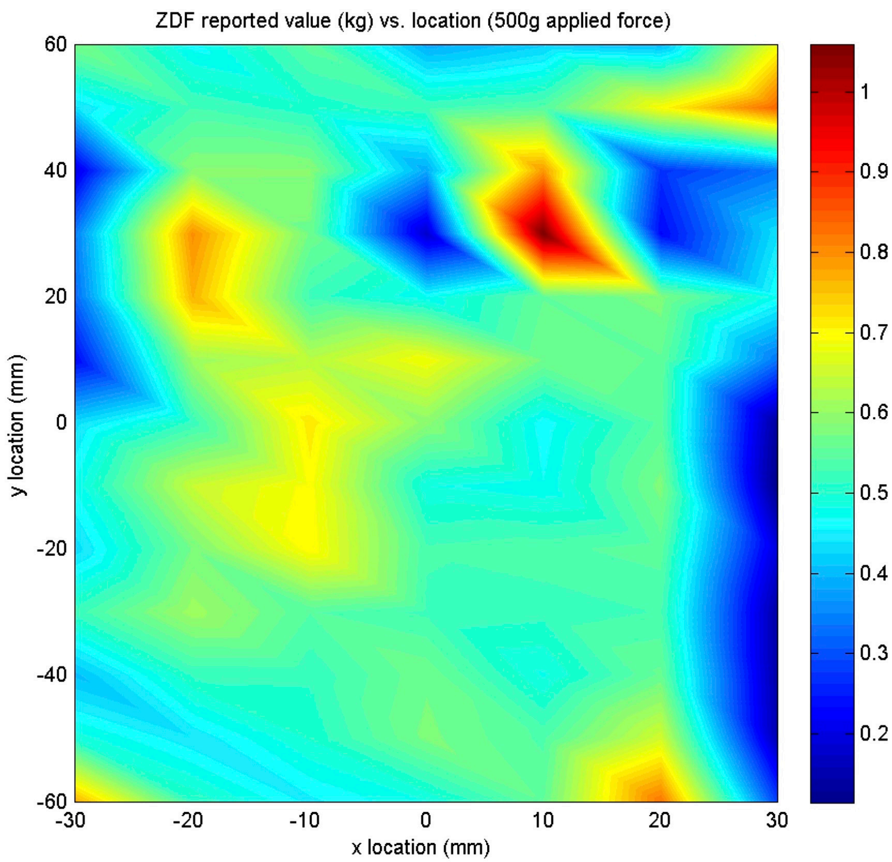
Iphone 6s – expensive cap sensor array (strain gauge) mounted behind LCD/backlight; measures deformation of glass/LCD due to pressure



Zero-Displacement Force Sensor

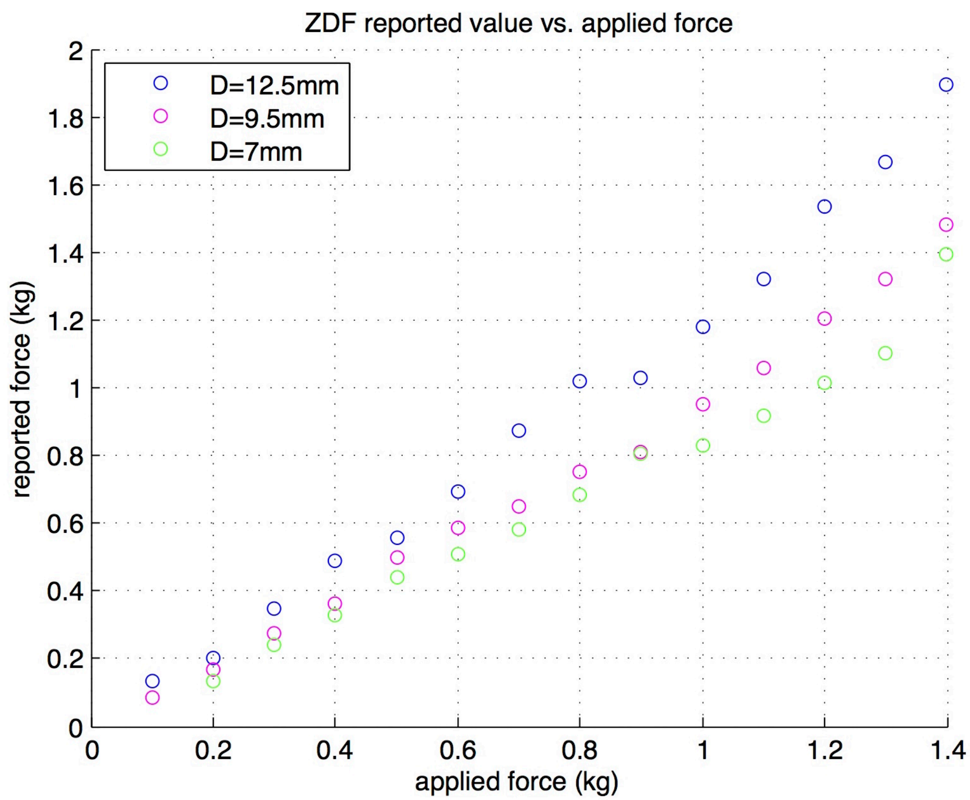
- Huge advantage over capacitive-based sensors – does not require *deflection* of glass/LCD to sense
  - Capacitive strain gauges are a major manufacturing headache due to tolerancing and calibration
  - Capacitive strain gauges require thicker glass and additional layer in vertical structure (Z-impact)
- Ultrasound wave "moves" the glass – force/pressure is measured by coupling between touch object and wave
- Can also detect force on highly rigid/curved glass surfaces, due to zero deflection requirement

Measured Force Heatmap



- Heat map of front force sensor on actual smartphone
- 0.5kg fixed load applied at points on face of phone
- Heat map is raw sensor report (in kg)
- Nonuniformity mostly due to structure of phone and is repeatable
- Can be calibrated/normalized out given touch location

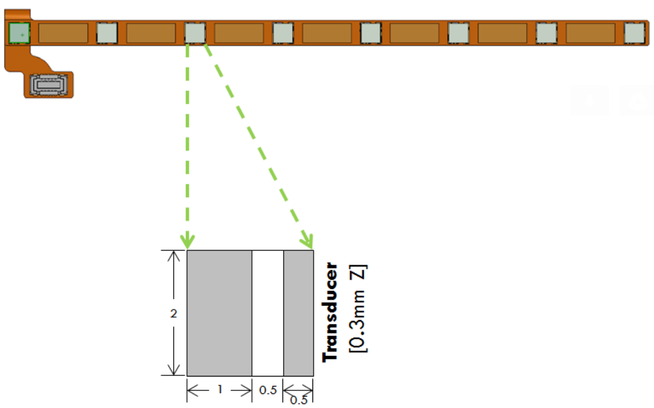
Linearity of Force Sensing

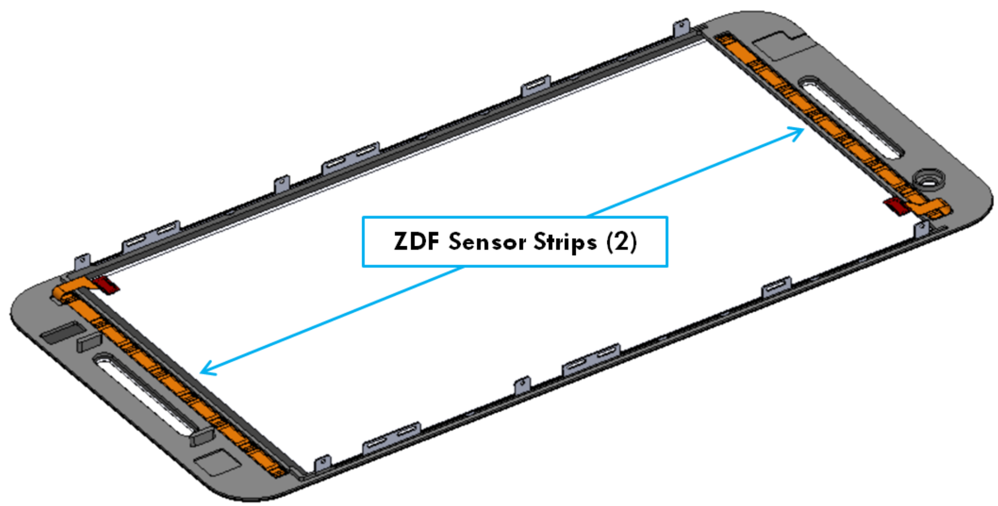


- Load cell applied at center of phone screen
- Each reported line is with a different size tip on load cell (D=diameter)
- 4X change in contact area – *not* pseudoforce!

Sensor Integration

- Sensor consists of two strips of piezoelectric transducers attached outside of the active LCD area to cover glass
- Piezoelectric arrays are preattached to FPC as a module
- Bar/array of piezos is needed for uniformity of pressure response across glass





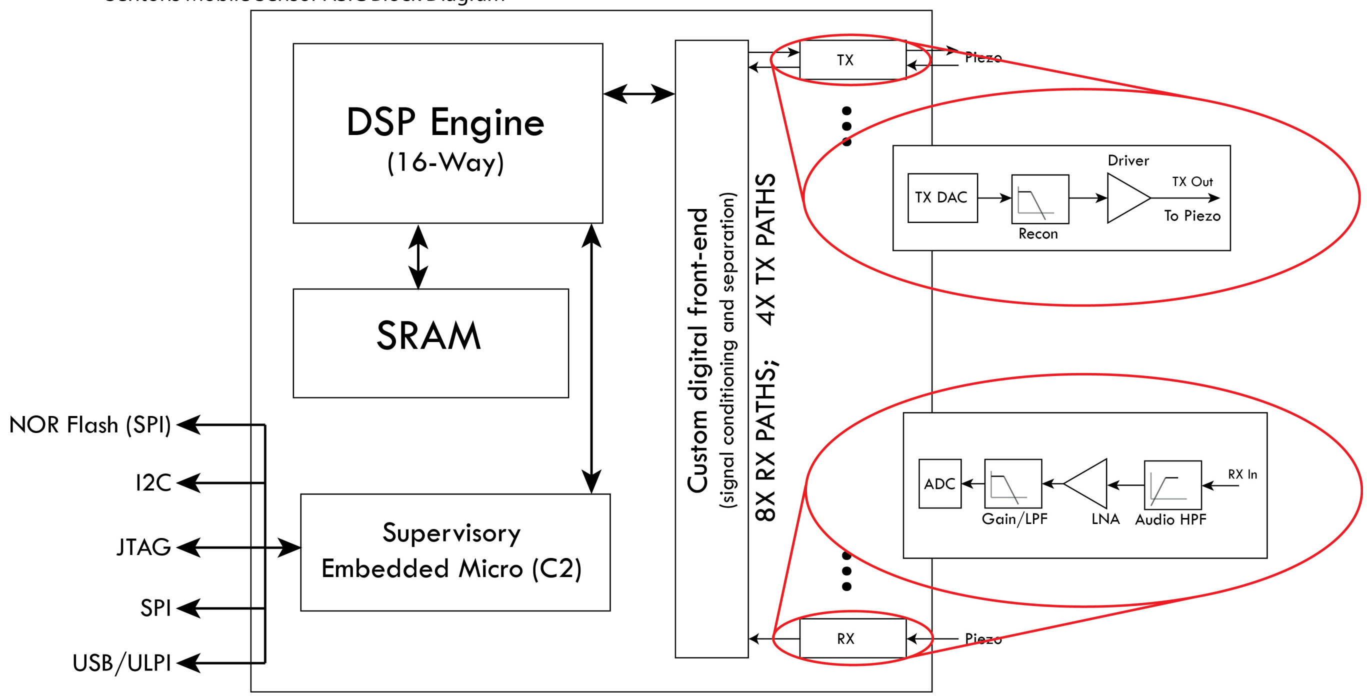
Two Specific ZDF Use Cases

- Cover Glass Force Sensing
- **Touch/Force Enabling the *Rest* of the Phone**

Touchbar (Sensing on Metal Case)

- Two sensor bars, one on each side of phone housing
  - Same FPC/piezo sensor array as for cover glass
  - Can sense up to 5+ fingers per bar, per-finger pressure
  - Replace buttons/switches on edge of phone
  - Can sense which hand is holding the phone

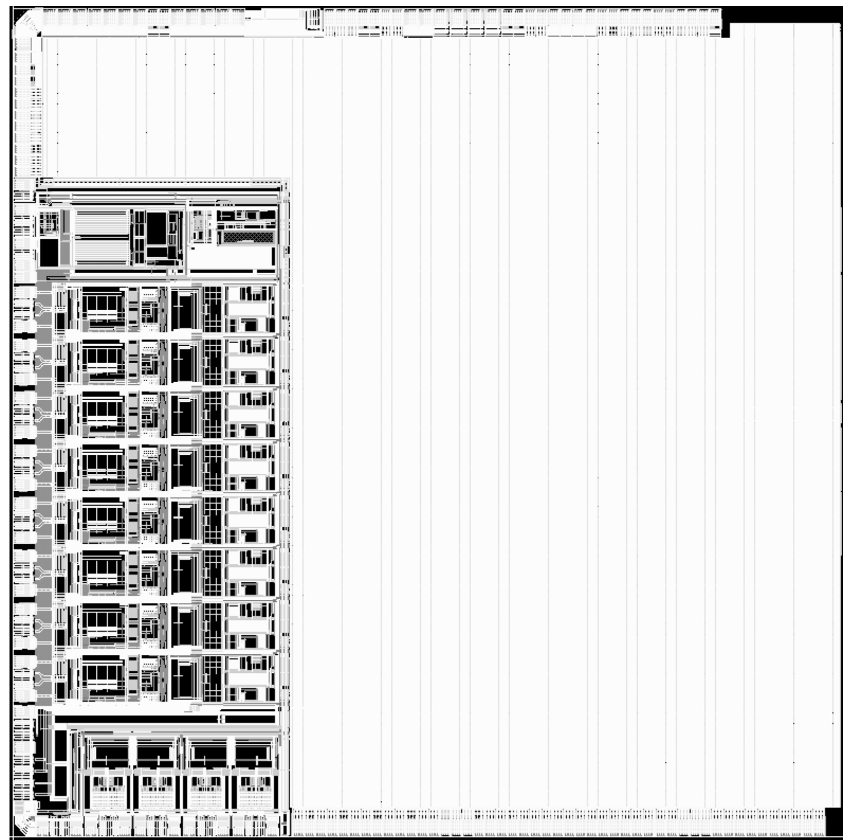
ASIC Architecture



- DSP/mProc licensed from third party
- Fixed-signal processing front-end in custom logic
  - Lower power/area
  - Relieves DSP MIPS reqt's
- All analog done in-house
  - Calibrated SAR ADC's
  - Overall RX dynamic range > 60 dB
  - TX *5V* capable in standard 65nm CMOS process

Parametrics and Die

ASIC Parameter	Value
Die size	19.4 mm2
Technology node	65nm
Package size	5mm x 5mm fcCSP
Max DSP clock	200 MHz
Supply Voltages	
Core	1.2V
I/O	1.8V
Piezo Driver	2.8V
Power Consumption	
Scan-to-wake	0.9 mW @ 5Hz report
Max scan rate	14 mW @ 100Hz report



Conclusion

SENTONS

Active ultrasonic sensing allows for simultaneous touch/force sensing on a wide variety of surfaces

- Can sense force *without* requiring surface deflection
- Allows for new device industrial design, as well as user interaction on traditionally inactive surfaces

Can Touch Enable Everything!