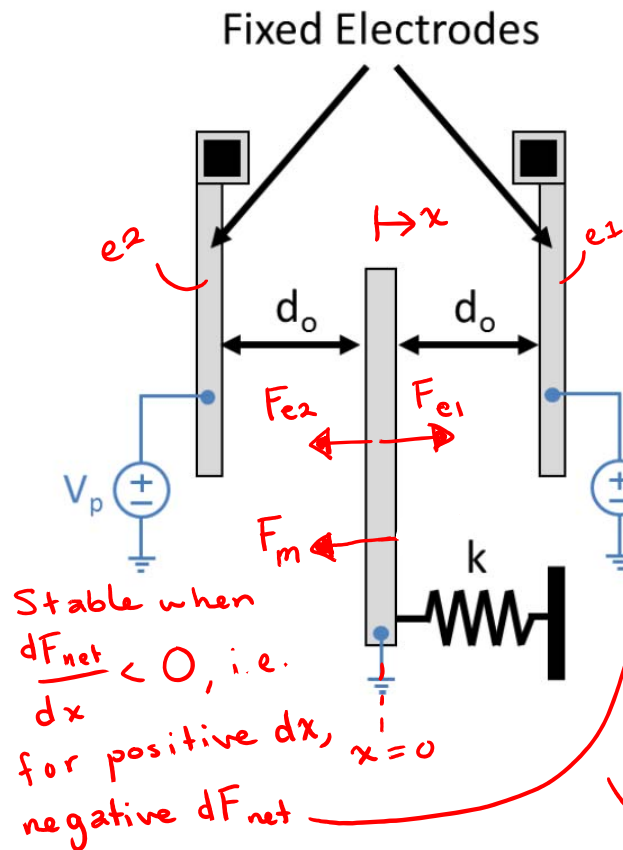# EE 247B / ME 218 Discussion 11

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Capacitive Transducers

Fixed Electrodes

Derive an expression for the DC voltage that will cause pull-in of the inner plate.

$$F_{e1} = \frac{1}{2} V_p^2 \frac{\partial}{\partial x} \left(\frac{\varepsilon A}{d_o - x} \right) \approx \frac{1}{2} V_p^2 \frac{\varepsilon A}{(d_o - x)^2}$$

$$x \uparrow \Rightarrow F_{e1} \uparrow \quad \left(\frac{\partial c_1}{\partial x} > 0 \right)$$

$$F_{e2} = \frac{1}{2} V_p^2 \frac{\partial}{\partial x} \left(\frac{\varepsilon A}{d_o + x} \right) \approx -\frac{1}{2} V_p^2 \frac{\varepsilon A}{(d_o + x)^2}$$

$$x \uparrow \Rightarrow |F_{e2}| \downarrow \quad \left(\frac{\partial c_2}{\partial x} < 0 \right)$$

from negative $\partial c / \partial x$

$$F_{net} = F_{e1} + F_{e2} + F_m = \frac{1}{2} V_p^2 \varepsilon A \left[\frac{1}{(d_o - x)^2} - \frac{1}{(d_o + x)^2} \right] - kx$$

$$\frac{dF_{net}}{dx} = \frac{1}{2} V_p^2 \varepsilon A \left[\frac{2}{(d_o - x)^3} + \frac{2}{(d_o + x)^3} \right] - k < 0$$

Stable when $\frac{dF_{net}}{dx} < 0$, i.e. for positive dx, $x = 0$ negative dF_{net}

$x = 0$ when pull-in occurs (w/ $V_p > V_{PI}$)

$$V_{PI}^2 \varepsilon A \cdot \frac{2}{d_o^3} < k \Rightarrow V_{PI} = \sqrt{\frac{k d_o^3}{2 \varepsilon A}}$$

Note that although the inner plate experiences equal forces on both sides, it would snap into one of the electrodes without a spring attachment since a tiny motion (e.g. due to thermal noise) would generate a force imbalance.

Cadence Setup

- Tutorial posted on course website, along with tech file and display.drf file
- Can connect to instructional machines
  - *hspe-9.eecs.berkeley.edu – hspe-15.eecs.berkeley.edu*
  - *c125m-6.eecs.berkeley.edu – c125m-24.eecs.berkeley.edu*
  - Use ssh client (PuTTY works for Windows) with X11 enabled & X windows server of your choice (Xming is free and easy to run)
    - For Macs, you can run the following command in Terminal, provided you have XQuartz installed (replace *x*'s with your username/machine number of choice)
      ssh -Y cs199-xxx@hspe-x.eecs.berkeley.edu
- After running cadence-setup.csh, use virtuoso6 to run Cadence (as opposed to icfb2)
- Use hotkeys! List of common layout shortcuts posted on course website

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