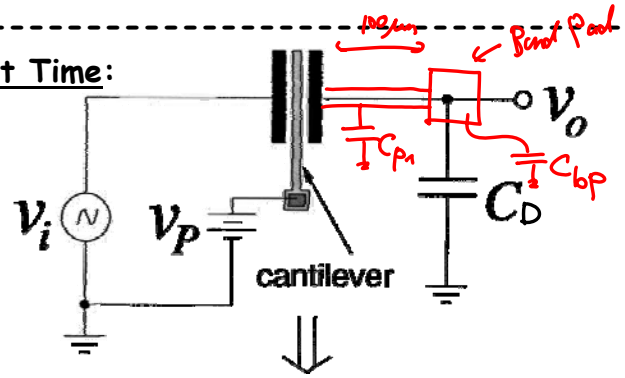
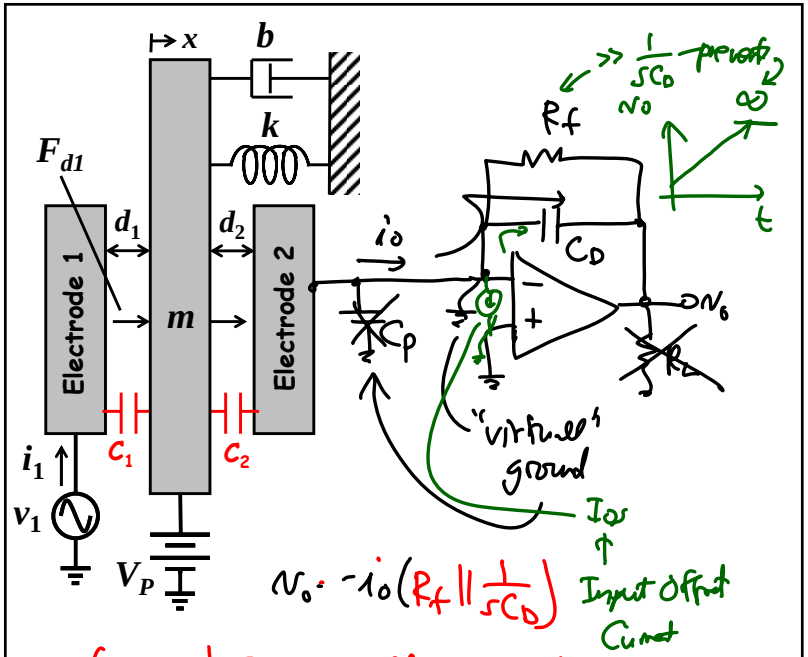
EE 245: Introduction to MEMS
Lecture 26: Gyroscopes

- Announcements:
- HW#7 emailed last week on Thursday AM; it's now online and due Thursday next week
- Reading: Senturia, Chpt. 14
- Lecture Topics:
  - Detection Circuits
    - Velocity Sensing
    - Position Sensing
- Reading: Senturia, Chpt. 16, Chpt. 21
- Lecture Topics:
  - Gyroscopes
  - Gyro Circuit Modeling
  - Minimum Detectable Signal (MDS)
    - Noise
    - Angle Random Walk (ARW)
- ----------
- Missing Info in HW#7:

$$\sqrt{\frac{\overline{v_{ia}^2}}{\Delta f}} = 12\ \mathrm{nV}/\sqrt{\mathrm{Hz}} \qquad \sqrt{\frac{\overline{i_{ia}^2}}{\Delta f}} = 0.01\ \mathrm{pA}/\sqrt{\mathrm{Hz}}$$

- ----------
- Last Time:





$$v_o = -i_o\left(R_f \| \frac{1}{sC_D}\right)$$

$$\left(R_f \gg \frac{1}{sC_D}\right) \Rightarrow = -\frac{v_i}{R_x}\Theta(s)\frac{1}{sC_D}$$

$$\boxed{\frac{v_o}{v_i}(s) = -\frac{1}{R_x C_D}\frac{\Theta(s)}{s}}$$

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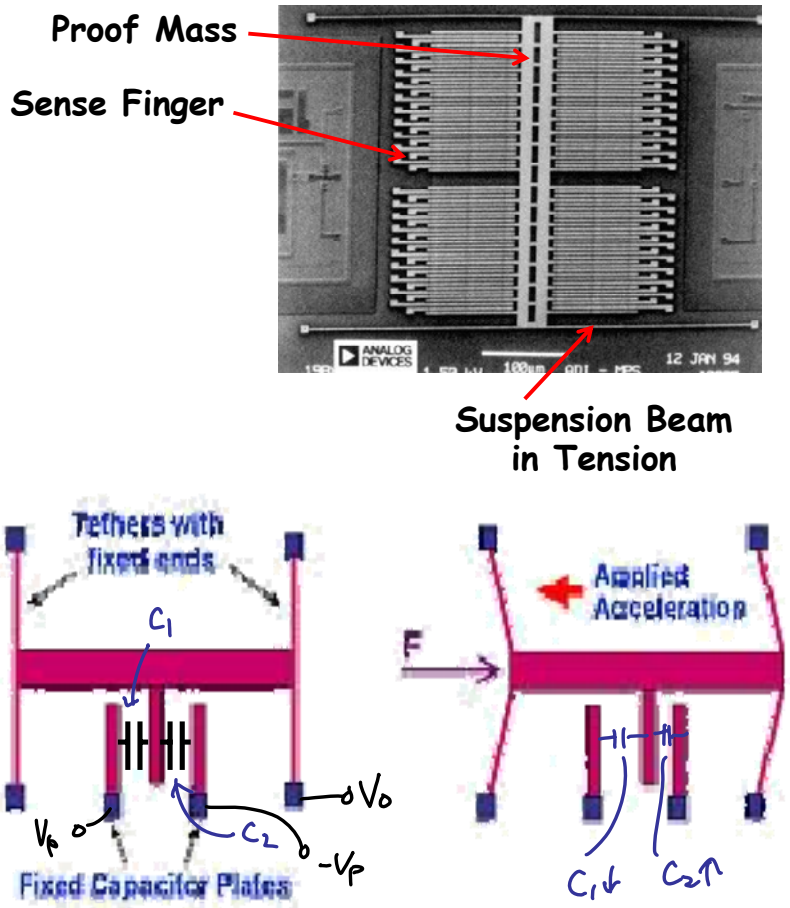
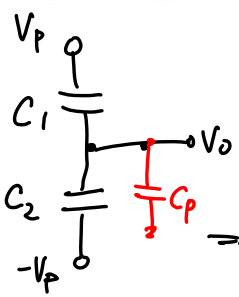
Differential Position Sensing





$$V_o = -V_P + (2V_P)\frac{C_1}{C_1+C_2}$$

$$= \frac{-V_P C_1 - V_P C_2 + 2V_P C_1}{C_1+C_2}$$

$$\Rightarrow \boxed{V_o = V_P\left(\frac{C_1-C_2}{C_1+C_2}\right)} \text{ (ideal)}$$

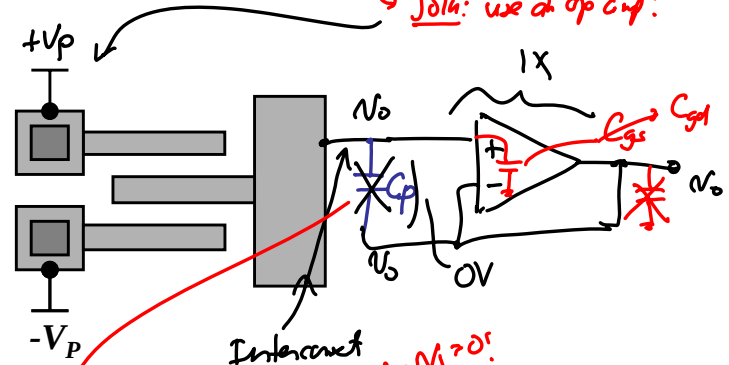
Issue: Parasitic C_p!

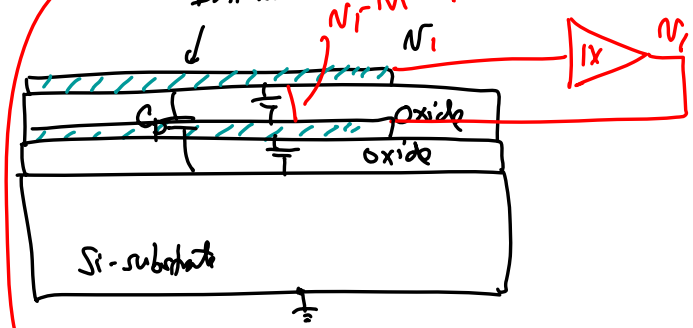
$$V_o = \left(\frac{C_1-C_2}{C_1+C_2+C_p}\right)V_P$$

This is lowering the sensitivity!

C_p still hurts us!

Soln: use an op amp!





This is nice ... but it's not perfect.

Why? → Op amps are not ideal!

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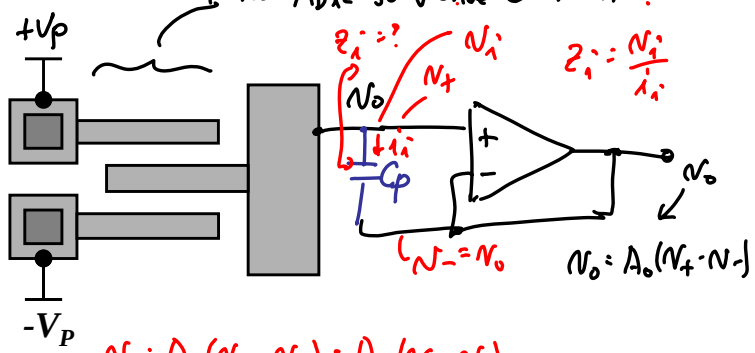
Case: Finite Op Amp Gain

Total ADXL-50 sense C ~ 100fF.



$$v_o = A_o(v_+ - v_-) = A_o(v_i - v_o)$$

$$v_o(1+A_o) = A_o v_i \rightarrow \boxed{\frac{v_o}{v_i} = \frac{A_o}{1+A_o}}$$

Get $Z_i = \frac{v_i}{i_i}$:

$$i_i = (v_i - v_o)sC_p = v_i\left(1 - \frac{A_o}{1+A_o}\right)sC_p$$

$$= v_i \frac{1}{1+A_o} sC_p$$

$$\therefore \frac{v_i}{i_i} = Z_i = \frac{1}{s\left[\frac{C_p}{1+A_o}\right]} \rightarrow \boxed{C_{eff} = \frac{C_p}{1+A_o}}$$

Ex: $A_o = 100$, $C_p = 2pF$

$$\rightarrow C_{eff} = \frac{2p}{101} = 20fF$$

Not negligible compared to the ADXL-50's 100fF → but it helps!

- Go through slide 20 in Module 14
- Go through Module 15, slides 3-12

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