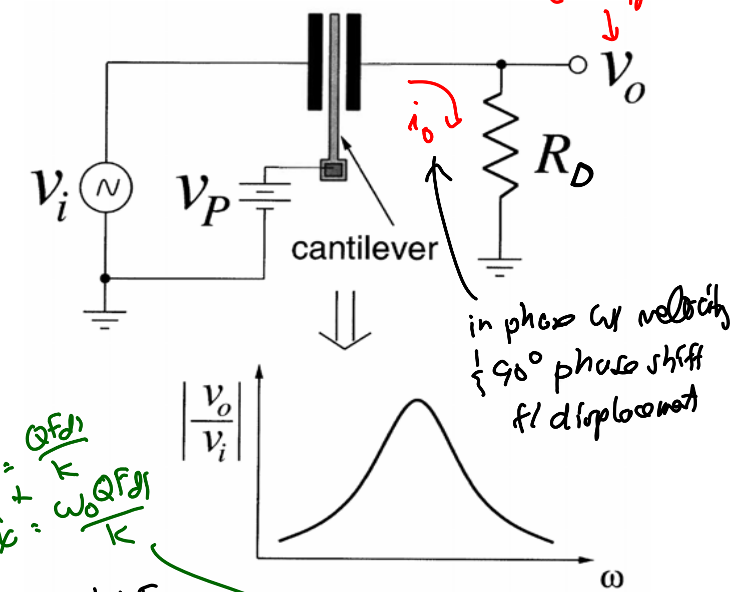
Lecture 27: Sensing Circuits II

- Announcements:
- HW#7 due Friday, May 9
- Project Slide 3 due this Friday (tomorrow)
- Project Outbrief Signup sheet has been on my door
  - If not already signed up, please do
- Handed out Final Exam Info
- -----------------------------------
- Reading: Senturia, Chpt. 14
- Lecture Topics:
  - Detection Circuits
    - Velocity Sensing
    - Position Sensing
- Reading: Senturia, Chpt. 14, Chpt. 16, Chpt. 21
- Lecture Topics:
  - Gyroscopes & MDS (brief skim)
  - Course Wrap Up
- -----------------------------------
- Last Time:
- Considering the benefits of op amp-based sensing circuits … continue with this

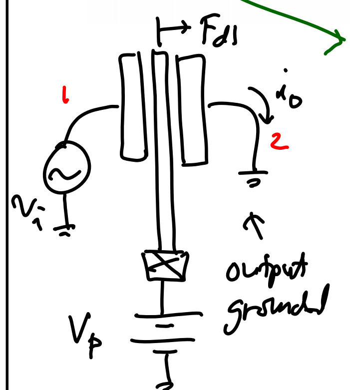
over

Velocity-to-Voltage Conversion



$x = \frac{QF_{d1}}{k}$

$\dot{x} = \frac{\omega_o Q F_{d1}}{k}$



$$\frac{\dot{x}}{F_{d1}}(s) = \frac{\omega_o Q}{k} H(s)$$

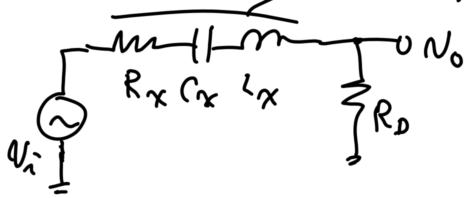
$$[F_{d1} = \eta_{e1} V_i]$$

$$\frac{\dot{x}}{v_i}(s) = \eta_{e1}\frac{\omega_o Q}{k} H(s)$$

$$[i_o = \eta_{e2}\dot{x}] \Rightarrow \frac{i_o}{v_i}(s) = \eta_{e1}\eta_{e2}\frac{\omega_o Q}{k} H(s) = \frac{\eta_{e1}\eta_{e2} Q}{m\omega_o} H(s)$$

$\frac{1}{R_{x12}}$

Now, include R_D: $Q = \frac{\omega_o L_x}{R_x}$



$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_D + R_x + \frac{1}{sC_x} + sL_x} = \ldots \text{math} \ldots$$

$$= \frac{R_D}{R_D + R_x} \cdot \frac{s\left(\frac{R_x + R_D}{L_x}\right)}{s^2 + s\left(\frac{R_x + R_D}{L_x}\right) + \frac{1}{L_x C_x}}$$

Gain Term — Freq. Shaping Term

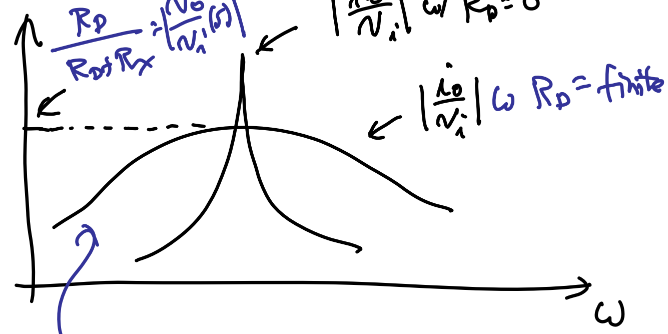
$$\left[Q = \frac{\omega_o L_x}{R_x} \rightarrow Q' = \frac{\omega_o L_x}{R_x + R_D} \rightarrow \frac{R_x + R_D}{L_x} = \frac{\omega_o}{Q'} \right]$$

$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_D + R_x} \cdot \frac{s(\omega_o/Q')}{s^2 + s(\omega_o/Q') + \omega_o^2}$$

$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_D + R_x} \cdot H(s, Q')$$

$$Q' = Q\left(\frac{R_x}{R_x + R_D}\right)$$

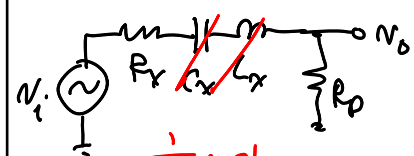
proportional to velocity



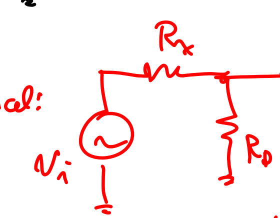
$\left|\frac{v_o}{v_i}(s)\right| \Rightarrow Q'$ = lower than Q $= Q\left(\frac{R_x}{R_x + R_D}\right)$ } Big Problem!

$\left(\frac{R_x}{R_x + R_D}\right) < 1$

Analysis @ Resonance:



$\frac{1}{sC_x} = sL_x$ → cancel!

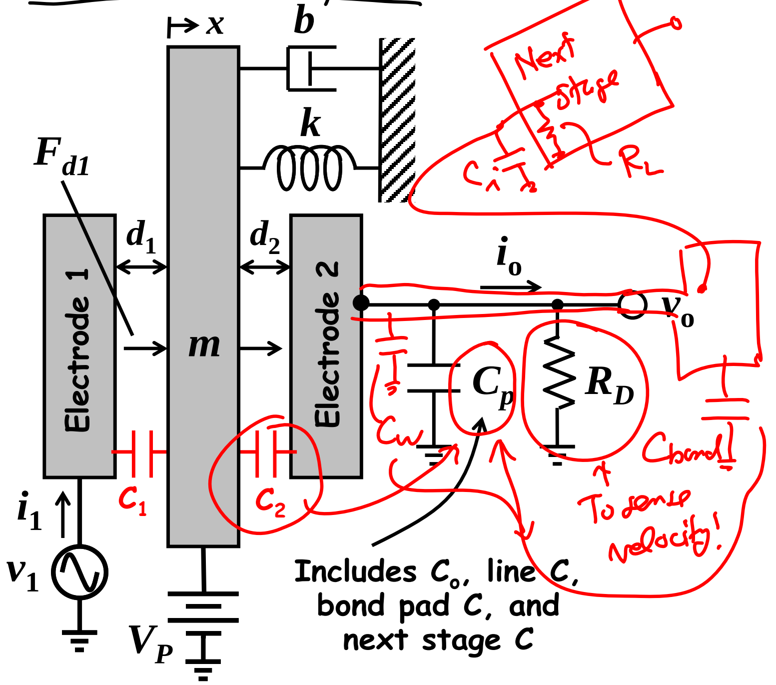


$v_o = \left(\frac{R_D}{R_D + R_x}\right) v_i$ ← @ resonance

Convert to general freqs: $\times H(s, Q')$

$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_D + R_x} H(s, Q'), \text{ where } Q' = Q\left(\frac{R_x}{R_x + R_D}\right)$$

The Problem is actually bigger:



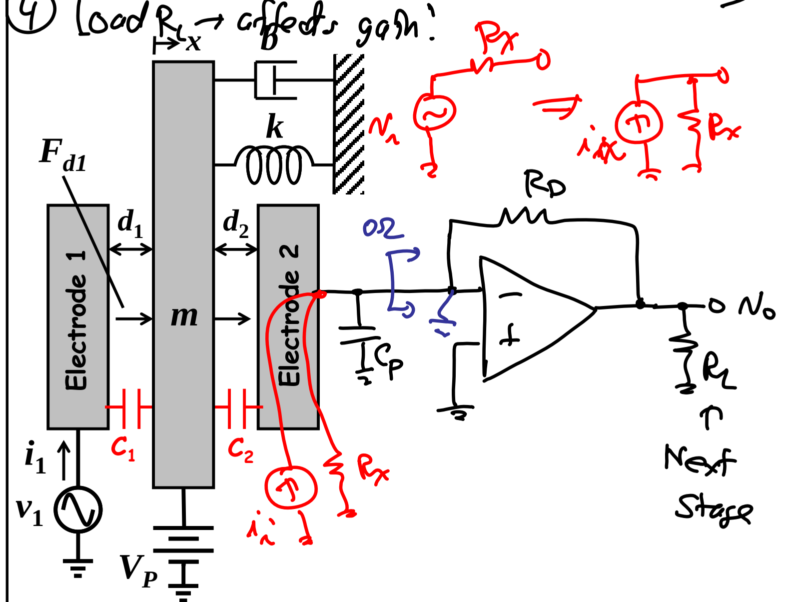
Now, we get:

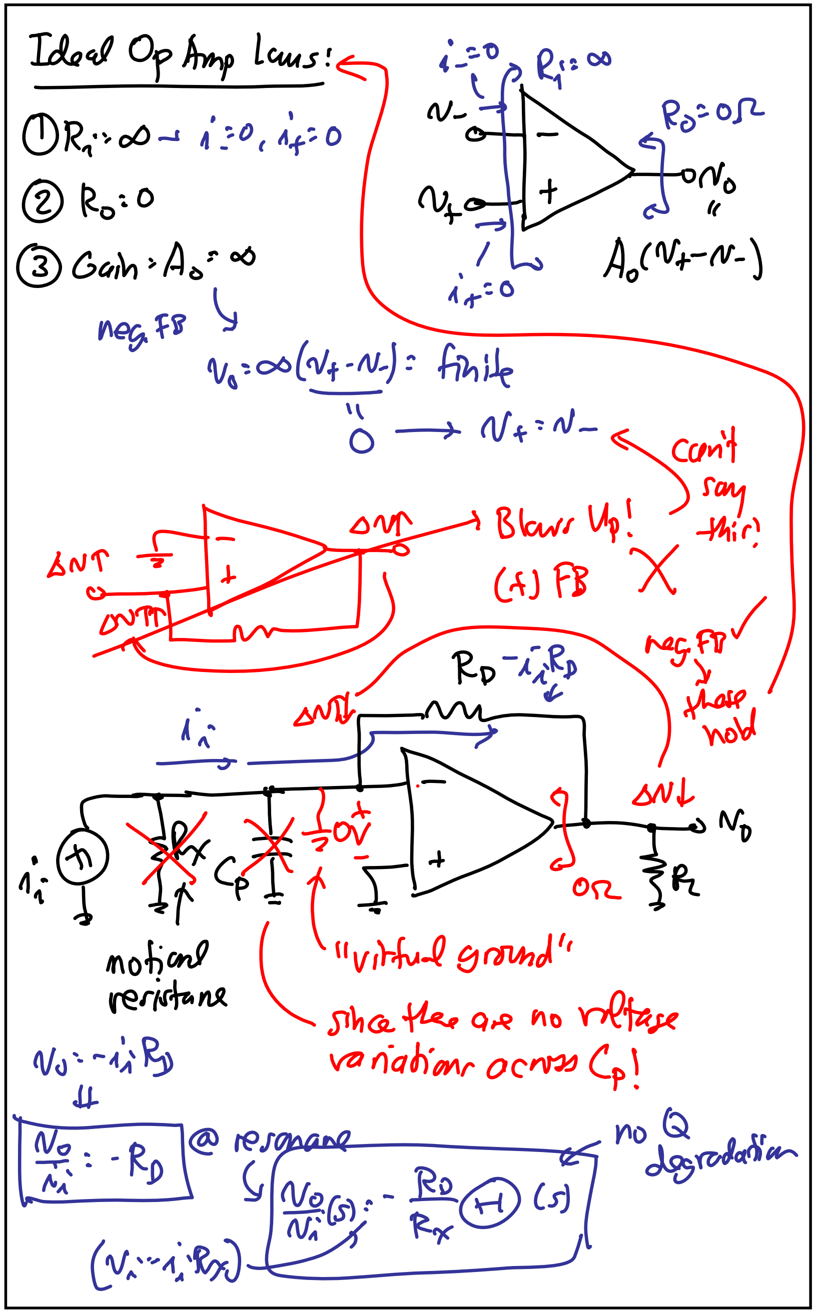
$$\frac{v_o}{v_1}(s) \sim \frac{R_D}{R_D + R_x} \cdot \frac{1}{1+\frac{s}{\omega_p}} \cdot H(s,\omega_o',Q')$$

$$\omega_p = \frac{1}{(R_x \| R_D)C_p}$$

Problems w/ Purely Resistive Detection

1. Need large R_D for large gain ... but...
2. $R_D\uparrow \rightarrow Q\downarrow$ ✗
3. $R_D\uparrow \rightarrow \omega_p \sim \frac{1}{R_D C_p}\downarrow \rightarrow$ get undesirable LPF cut-off ✗
4. Load $R_L \rightarrow$ affects gain!





- Note: Previous 7 pages are just review of last time
- This is where the new material of this lecture really starts
- Go through Module 14 on Sensing Circuits, slides 6-7 and 13-20
- Go through Final Exam Info Sheet
- Course Wrap up – next page …

- Related courses at UC Berkeley:
  - EE 143: Microfabrication Technology
  - EE 147/247A: Introduction to MEMS
  - ME 119: Introduction to MEMS (mainly fabrication)
  - BioEng 121: Introduction to Micro and Nano Biotechnology and BioMEMS
  - ME C219 – EE C246: MEMS Design
  - EE 290M?