Lecture 26: Sensing Circuits

- **Announcements:**
- HW#7 online last week & due Thursday, Dec. 8
- Reminder: 3rd project slide due Dec. 3
- Project Outbrief Signup Sheet is on my door
  - Some times on Tuesday, Dec. 13
  - Some times on Wednesday, Dec. 14
- Final Review Session:
  - Thursday, December 8, 5-7 pm?
  - Friday, December 9, 5-7 pm?
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- Reading: Senturia, Chpt. 14, Chpt. 16, Chpt. 21
- Lecture Topics:
  - Gyroscopes
- Reading: Senturia, Chpt. 14
- Lecture Topics:
  - Detection Circuits
    - Velocity Sensing
    - Position Sensing
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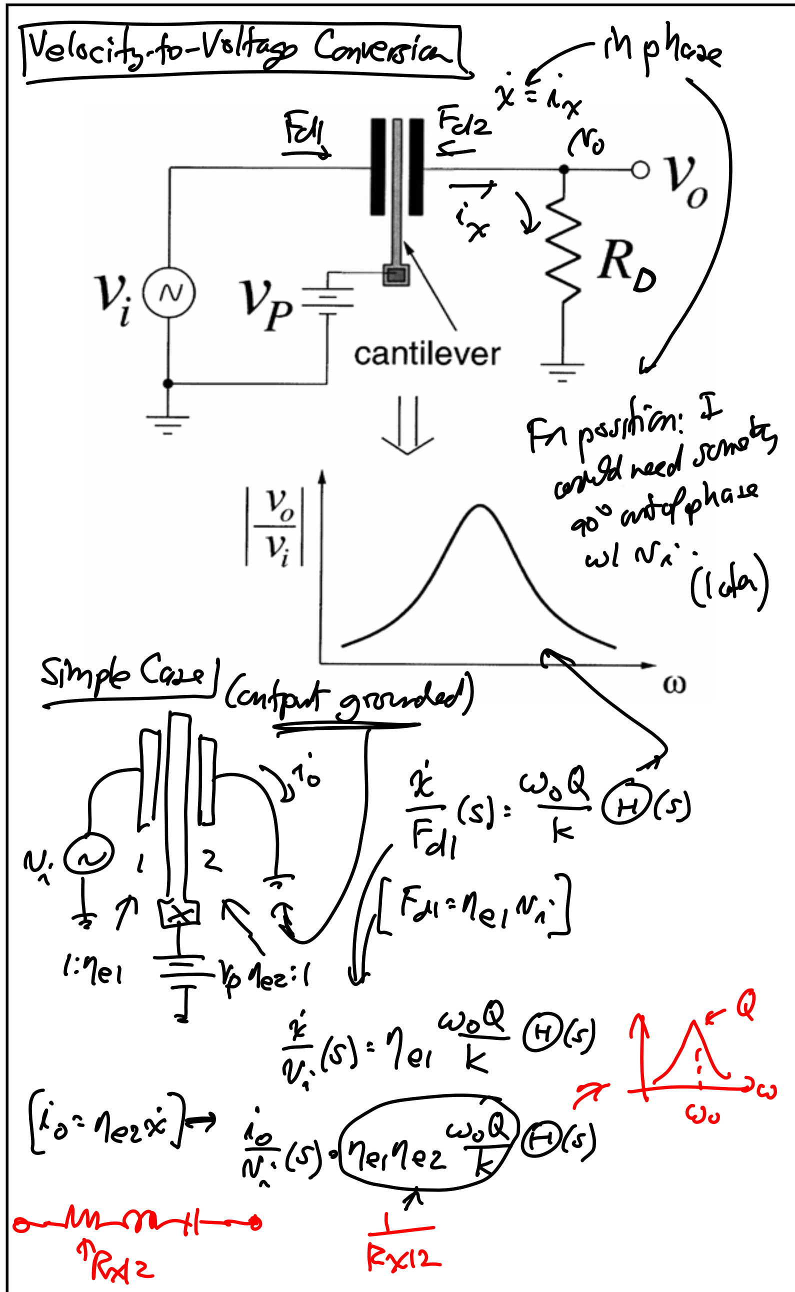
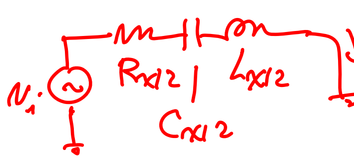
- Last Time:
- Going through Module 15 on gyroscopes

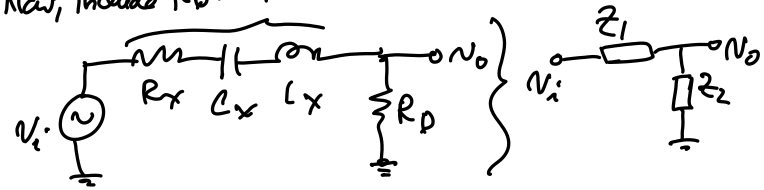
over





$i_o = \frac{v_i}{R_{x12}} \cdot \mathrm{H}(s)$

Now, include R_D: mechanical device



$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_x + \frac{1}{sC_x} + sL_x + R_D} \qquad \frac{v_o}{v_i} = \frac{Z_2}{Z_2 + Z_1}$$

⋮ math

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

Gain Term (of original device) — Freq. Shaping Term

$$Q = \frac{\omega_0 L_x}{R_x} \rightarrow Q' = \frac{\omega_0 L_x}{R_x + R_D} \rightarrow \frac{R_x + R_D}{L_x} = \frac{\omega_0}{Q'}$$

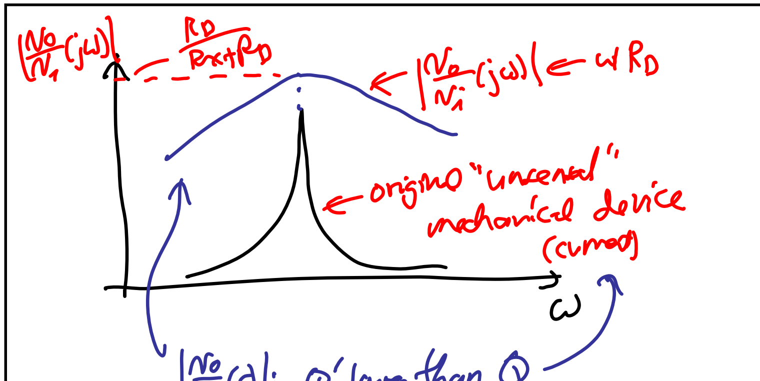
new Q of the R_D-loaded system

$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_x + R_D} \cdot \frac{s(\omega_0/Q')}{s^2 + s(\omega_0/Q') + \omega_0^2}$$

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

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

Q has been lowered by R_D!

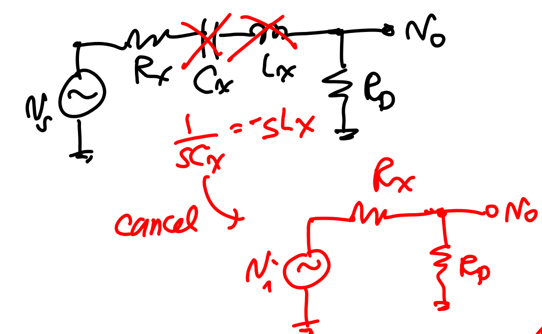


$\left|\frac{v_o}{v_i}(s)\right|$: Q' lower than Q

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

Big Problem!

Analysis @ Resonance



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

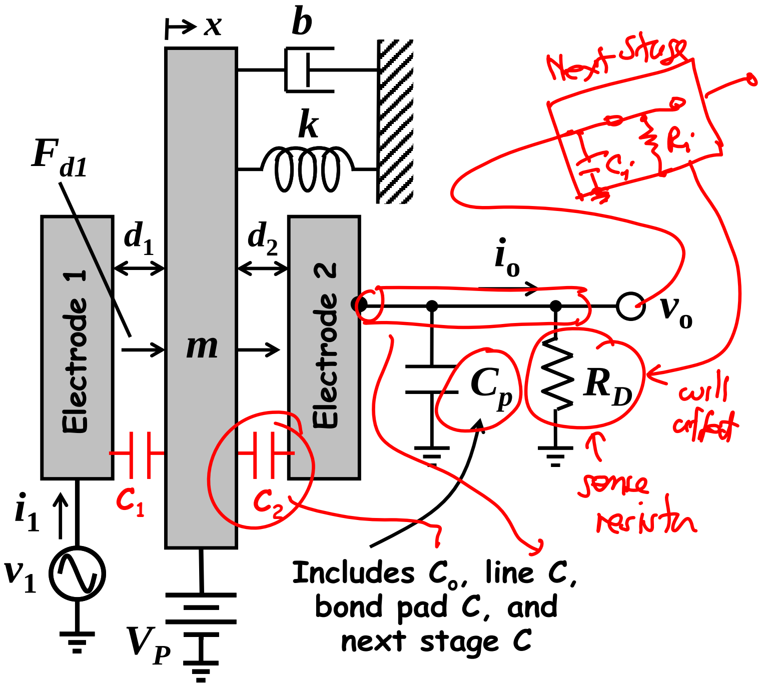
@ resonance

Convert to general freq.:

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

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

The Problem is actually much bigger!

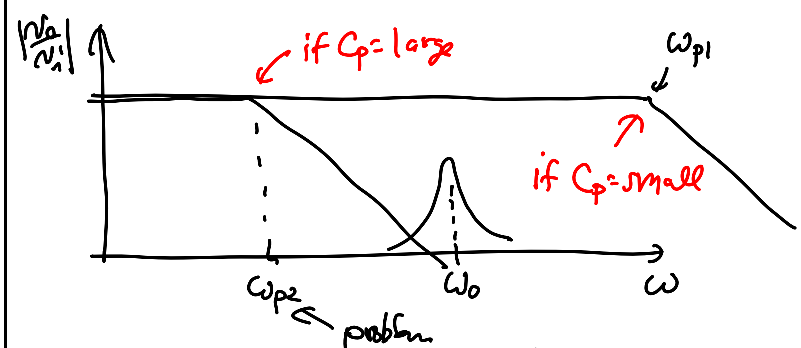


Now, we get:

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

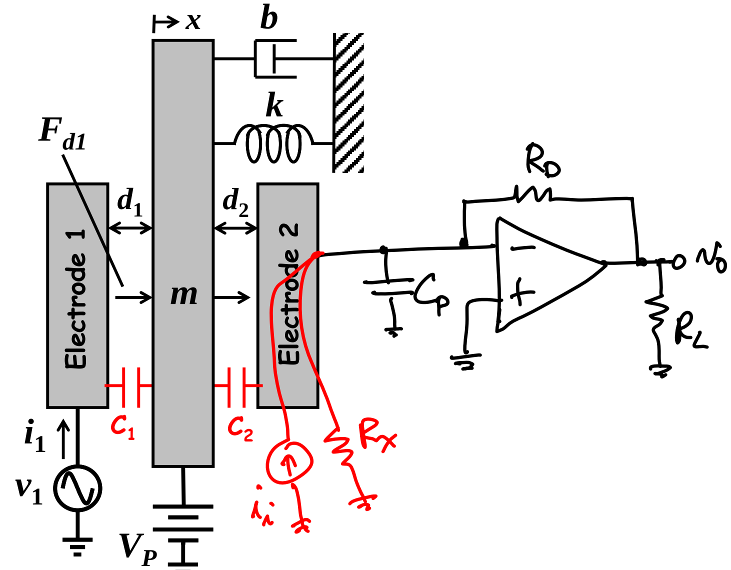
max. when $R_D \gg R_x$

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



Problems w/ Purely Resistive Detection

1. Need large R_D for high 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! $\rightarrow R_D \rightarrow R_D \| R_L$

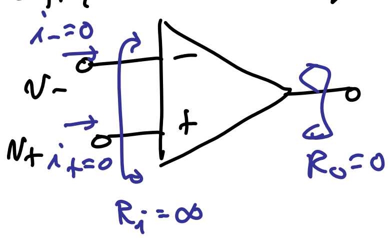


Ideal Op Amp Laws: (Apply when have (-) FB)

① $R_i = \infty$: $i_- = 0$, $i_+ = 0$

② $R_o = 0$

③ Gain $= A_o = \infty$



neg. FB → $v_+ = v_-$