Lecture 22: Gyroscopes & Sensing Circuits I

- Announcements:
- Project Slide Set #2 due Friday, April 17
- HW#6 online and due Friday, 5/1, at 8 a.m.
- Module 14 on "Sensing Circuits" online
- Module 15 on "Gyros, Noise, & MDS" online (actually with last lecture)
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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
- ----------------------------------
- Last Time:
- Finished equivalent circuits
- Now, move on to gyroscopes using Module 15

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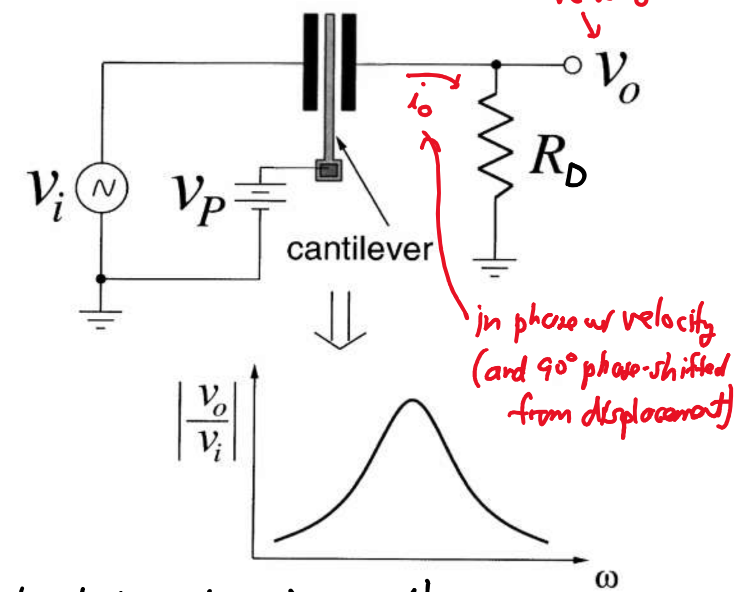
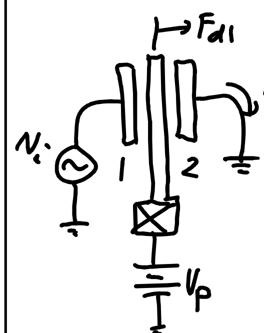
Velocity-to-Voltage Conversion



Get output current i_o into ground!



$\frac{x}{F_{d1}} = \frac{1}{k}$ @ DC

$\frac{x}{F_{d1}}\Big|_{\omega_o} = \frac{Q}{jk} = \frac{1}{k}\frac{Q}{j}$

$\frac{\dot{x}}{F_{d1}}(s) = \frac{\omega_o Q}{k}\Theta(s)$ ← f/ last time

$[F_{d1} = \eta_{e1} v_i]$ → $\frac{\dot{x}}{v_i}(s) = \eta_{e1}\frac{\omega_o Q}{k}\Theta(s)$

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

$\frac{1}{R_x/2}$

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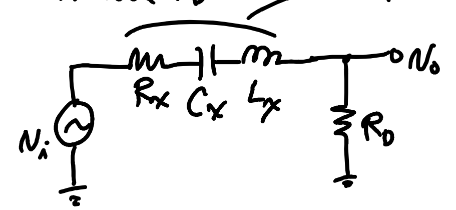
Now, include R_D: $Q = \frac{\omega_0 L_x}{R_x}$



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

$$= \underbrace{\frac{R_D}{R_x+R_D}}_{\text{Gain Term}} \underbrace{\frac{s\left(\frac{R_x+R_D}{L_x}\right)}{s^2 + s\left(\frac{R_x+R_D}{L_x}\right) + \frac{1}{L_x C_x}}}_{\text{Freq. Shaping Term}}$$

$$\left[Q = \frac{\omega_0 L_x}{R_x} \rightarrow Q' = \frac{\omega_0 L_x}{R_x+R_D} \rightarrow \frac{R_x+R_D}{L_x} = \frac{\omega_0}{Q'} \right]$$

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

$$\frac{v_o}{v_i}(s) = \frac{R_D}{R_x+R_D} \cdot \Theta(s, Q') \qquad Q' = Q\left(\frac{R_x}{R_x+R_D}\right)$$

$Q' < Q$ ✗ → not good

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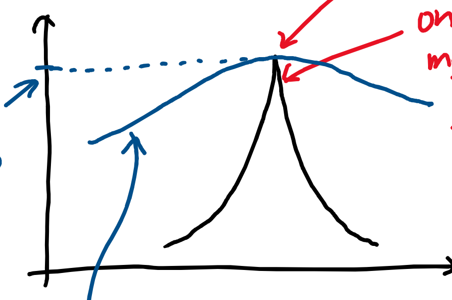
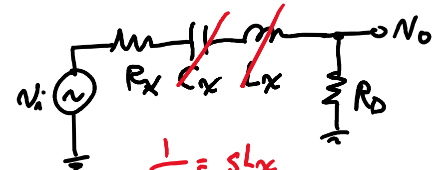
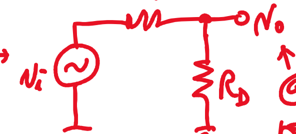


$\left|\frac{v_o}{v_i}(s)\right|$ sensed by R_D: $Q' < Q$ $= Q\left(\frac{R_x}{R_x+R_D}\right)$, $\frac{R_x}{R_x+R_D} < 1$ } Big Problem!

Analysis @ Resonance:



$\frac{1}{sC_x} = sL_x$ cancel! → @ resonance



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

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

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

✓ → *

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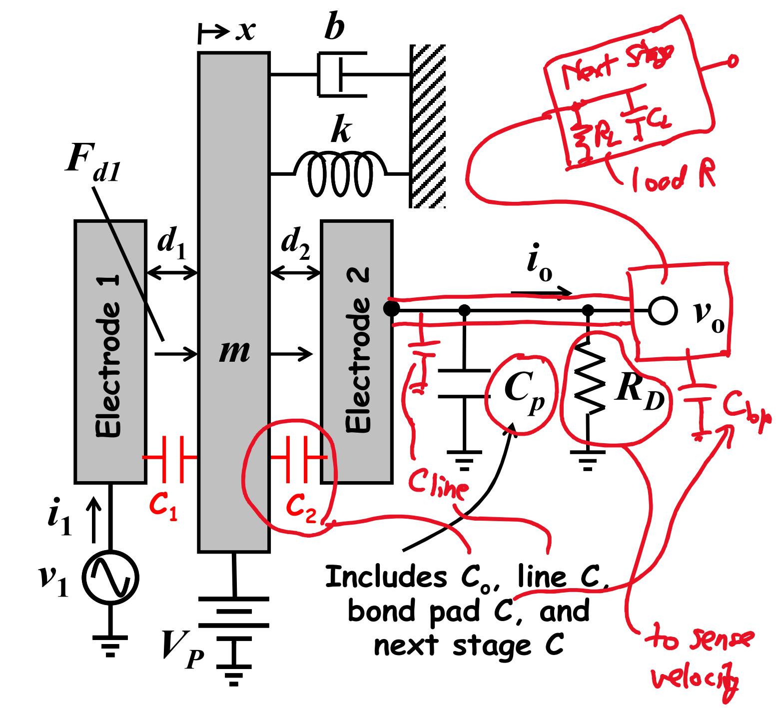
★ The Problem is actually much bigger!



Now, we get:

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

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

from mechanical device

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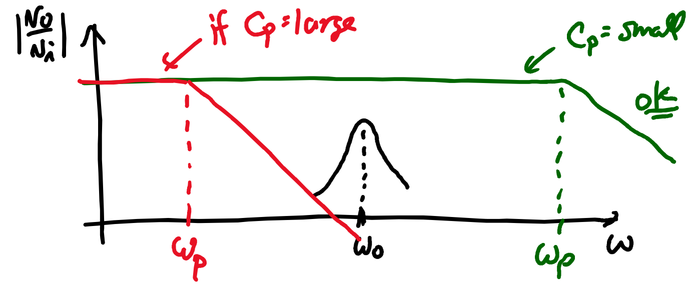
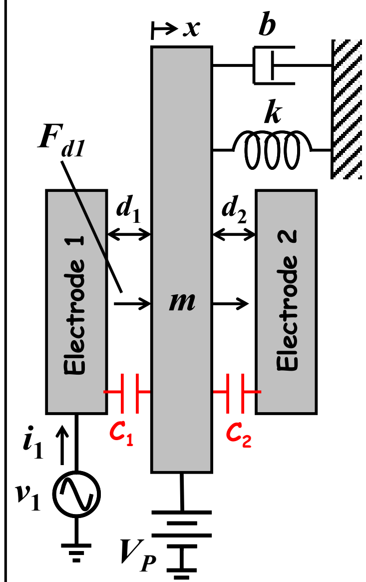


Problems w/ Purely Resistive Detection

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



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