Lecture 25: Gyroscopes & Sensing Circuits

- **Announcements:**
- Reminder: 3rd project slide due Dec. 3
- HW#7 has been online for a week & it's due on Thursday, Dec. 9
- Project Outbrief Signups
  - Monday, Dec. 13?
  - Friday, Dec. 10?
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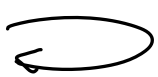
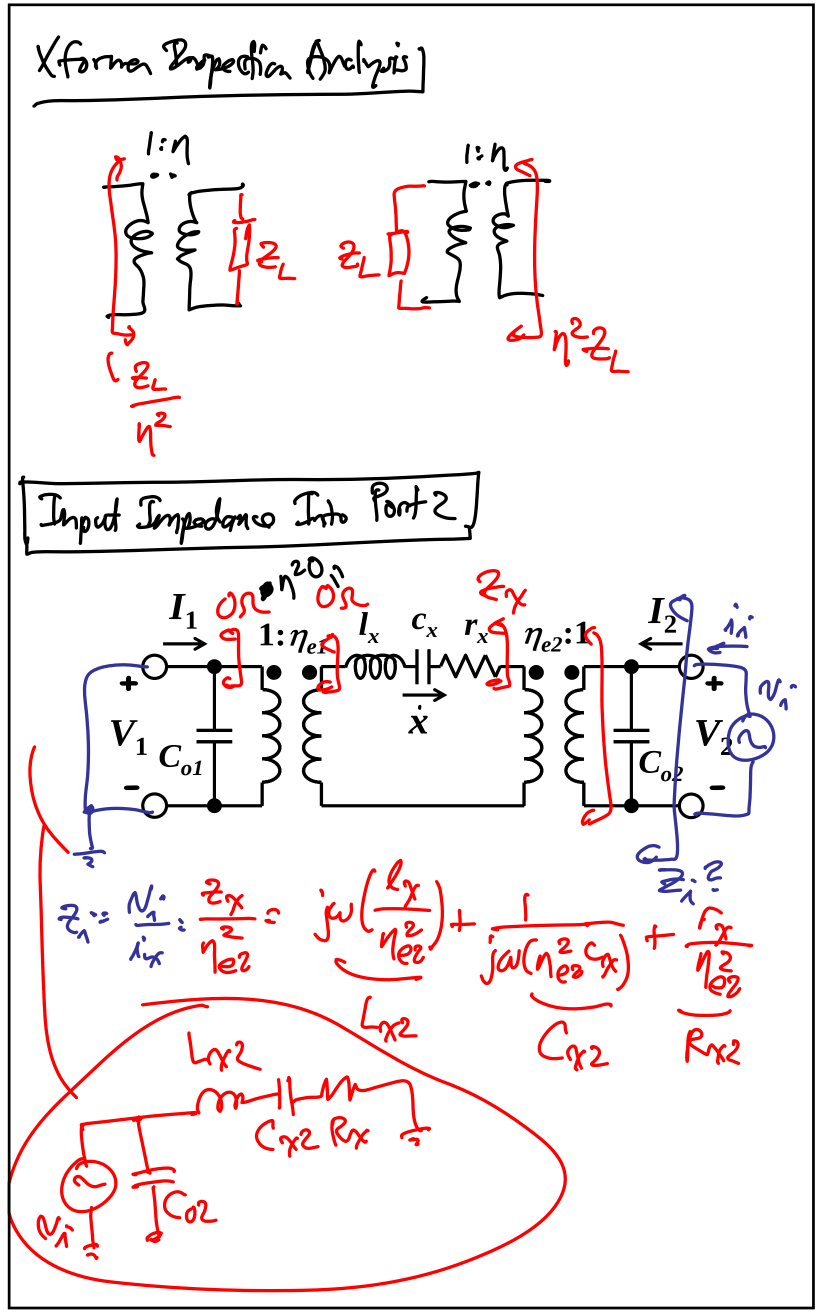
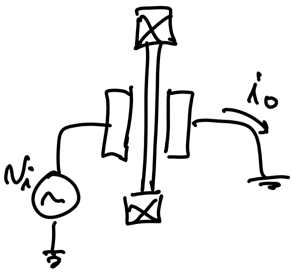
- Reading: Senturia, Chpt. 6, Chpt. 14
- Lecture Topics:
  - Input Modeling
    - Force-to-Velocity Equiv. Ckt.
    - Input Equivalent Ckt.
  - Current Modeling
    - Output Current Into Ground
    - Input Current
    - Complete Electrical-Port Equiv. Ckt.
  - Impedance & Transfer Functions
- Reading: Senturia, Chpt. 14, Chpt. 16, Chpt. 21
- Lecture Topics:
  - Gyroscopes
- Reading: Senturia, Chpt. 14
- Lecture Topics:
  - Detection Circuits
    - Velocity Sensing
    - Position Sensing
- -----------------------------------
- **Last Time:**

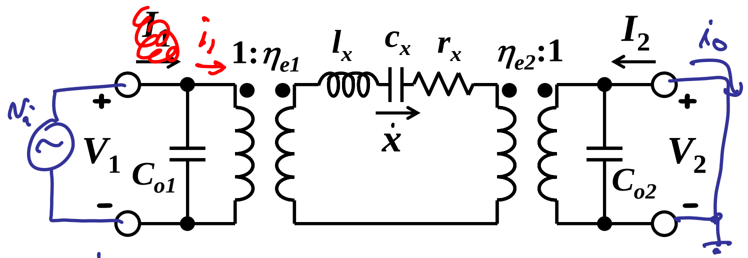




Port 1 to Port 2 Transconductance

$G = \frac{i_o}{v_i}$





$\dot{x} = \frac{1}{\eta_{e1}} i_1$

$i_o = \eta_{e2}\dot{x}$

$\rightarrow i_o = \frac{\eta_{e2}}{\eta_{e1}} i_1 = \frac{\eta_{e2}}{\eta_{e1}}\left(\frac{v_i}{z_i}\right)$

$= \frac{\eta_{e2}}{\eta_{e1}} v_i \left[\eta_{e1}^2 \frac{1}{j\omega l_x + \frac{1}{j\omega c_x} + r_x}\right]$

* $\therefore \frac{i_o}{v_i}(j\omega) = \frac{\eta_{e1}\eta_{e2}}{j\omega l_x + \frac{1}{j\omega c_x} + r_x}$

$= \left[j\omega L_{x12} + \frac{1}{j\omega C_{x12}} + R_{x12}\right]^{-1}$

$L_{x12} = \frac{l_x}{\eta_{e1}\eta_{e2}}, \quad C_{x12} = \eta_{e1}\eta_{e2} C_x, \quad R_{x12} = \frac{r_x}{\eta_{e1}\eta_{e2}}$

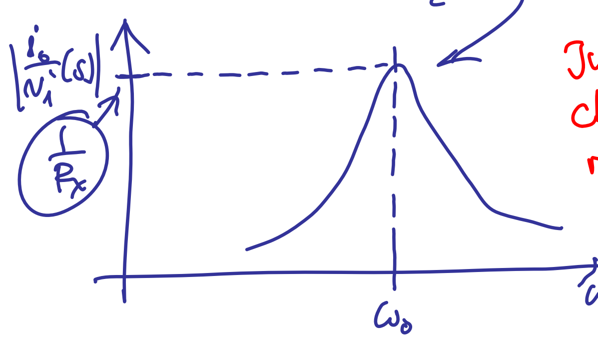
Separate freq. response & magnitude:

* — $\frac{i_o}{v_i}(s) = \frac{1}{sL_x + \frac{1}{sC_x} + R_x} = \frac{s\left(\frac{1}{L_x}\right)}{s^2 + \frac{1}{L_x C_x} + s\left(\frac{R_x}{L_x}\right)}$

$\left[\frac{1}{L_x C_x} = \omega_0^2, \quad Q = \frac{\omega_0 L_x}{R_x} \rightarrow \frac{R_x}{L_x} = \frac{\omega_0}{Q}\right]$

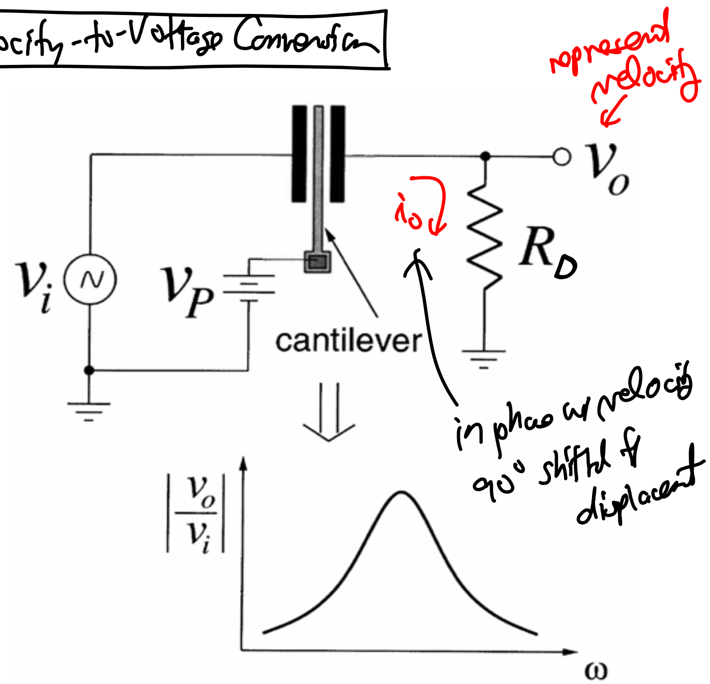
$\frac{i_o}{v_i}(s) = \frac{1}{R_x} \cdot \frac{s\left(\frac{\omega_0}{Q}\right)}{s^2 + s\left(\frac{\omega_0}{Q}\right) + \omega_0^2} = \frac{1}{R_x} H(s)$

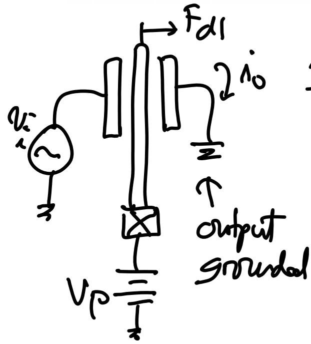
- $\frac{1}{R_x}$: Gain term
- Freq. shaping Term → Bandpass Biquad
- $\frac{1}{R_x}$ (before $H(s)$): resonance magnitude ↓ Just solve the ckt @ resonance ↓ then multiply the answer by $H(s)$!



- Go through Module 15 on Gyros, slides 1-16

Velocity-to-Voltage Conversion





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

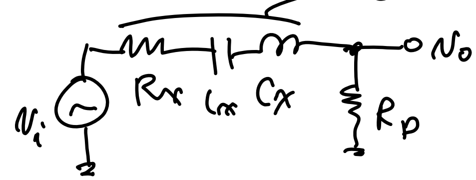
$[F_{d1} = \eta_{e1} v_i]$

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

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

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

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



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

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

↑ Gain Term ↑ Freq. Shaping Term

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

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

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

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