Lecture 23: Gyroscopes & Sensing Circuits I

- **Announcements:**
  - Project Slide Set #2 due Friday, April 19
  - HW#6 due Tuesday, 4/23, at 9 a.m.
  - Module 14 on Sensing Circuits online
  - Module 15 on Gyros, Noise, & MDS online (actually with last lecture)
- **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:**
  - Started gyroscopes by going through slides 1-6 in Module 15
  - Now, continue with this ...

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**Velocity-to-Voltage Conversion**

\[ \frac{V_o}{V_i} \]

\[ \frac{x}{x_i} (s) = \frac{\omega_0 Q}{s + \frac{\omega_0 Q}{k}} \]

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\[ \frac{V_o}{V_i} \]

\[ R_{in} \]

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\[ \frac{V_o}{V_i} \]
Now, include $R_0$ (damping resistor):

\[ N_0 = \frac{R_0}{R_x + R_0} \]

\[ N_0(s) = \frac{R_0}{R_x + R_0} \frac{s(\omega_0/Q')}{s^2 + s(\omega_0/Q') + \omega_0^2} \]

\[ N_0(s) = \frac{R_0}{R_x + R_0} \Theta(s, Q') \]

\[ \frac{N_0}{N_0} = \frac{R_0}{R_x + R_0} \Theta(s, Q') \]

\[ Q' = Q \left( \frac{R_x}{R_x + R_0} \right) \]

Analysis at resonance:

[Diagram of the circuit with annotations and equations related to resonance analysis.]
The Problem is Actually Bigger!

\[ F_{di} \]

\[ \begin{array}{c}
\text{Electrode 1} \\
\text{Electrode 2} \\
\end{array} \]

\[ \begin{array}{c}
\text{Includes } C_o, \text{ line } C, \\
\text{bond pad } C, \text{ and } \\
\text{next stage } C \\
\end{array} \]

Now, we get:

\[ \frac{V_o(s)}{V_i(s)} = \frac{R_o}{s^2 + \frac{1}{C_p R_p} s + \frac{1}{C_p R_p R_o}} \cdot \frac{1}{s^2 \omega_p^2 + \frac{1}{\omega_p^2}} \]

Problems with Purely Resistive Detection:

1. Need large \( R_o \) for large gain... but...
2. \( R_o \to \infty \) \( \times \)
3. \( R_p \to \omega_p \to \frac{1}{R_p} \) \( \to \) get undesirable LPF \( \times \) cut-off
4. Load \( R_L \) affects gain.