

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?

• 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:

• Going through Module 15 on gyroscopes

↩ over

Velocity-to-Voltage Conversion

For position: I could need something 90° out of phase w/ v_i (100%)

Simple Case (output grounded)

$\frac{x}{F_{d1}}(s) = \frac{\omega_0 Q}{k} \mathcal{H}(s)$

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

$\frac{x}{v_i}(s) = \eta_{e1} \frac{\omega_0 Q}{k} \mathcal{H}(s)$

$[i_o = \eta_{e2} x] \rightarrow \frac{i_o}{v_i}(s) = \eta_{e1} \eta_{e2} \frac{\omega_0 Q}{k} \mathcal{H}(s)$

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

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$$i_{i0} = \frac{V_i}{R_{x12}} \cdot \mathcal{H}(s)$$

Now, include R_D : mechanical device

$$\frac{V_o}{V_i}(s) = \frac{R_D}{R_x + \frac{1}{sC_x} + sL_x + R_D}$$

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

of original device Gain Term \uparrow $\frac{R_D}{R_x + R_D}$ Freq. Shaping Term $\frac{s \left(\frac{R_x + R_D}{L} \right)}{s^2 + s \left(\frac{R_x + R_D}{L} \right) + \frac{1}{L_x C_x}}$

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

new Q of the R_D -loaded system

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

$$\frac{V_o}{V_i}(s) = \frac{R_D}{R_x + R_D} \cdot \mathcal{H}(s, Q')$$

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

Q has been lowered by R_D !

$$\left| \frac{V_o}{V_i}(s) \right|: Q' \text{ lower than } Q$$

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

Big Problem!

Analysis @ Resonance

$$V_o = \left(\frac{R_D}{R_x + R_D} \right) V_i$$

@ resonance

Connect to general freq.:

$$\frac{V_o}{V_i}(s) = \frac{R_D}{R_x + R_D} \cdot \mathcal{H}(s, Q'), \text{ where } Q' = Q \left(\frac{R_x}{R_x + R_D} \right)$$

The Problem is actually much bigger!

Includes C_o , line C, bond pad C, and next stage C

Now, we get:

$$\frac{V_o}{V_s}(s) \sim \frac{R_D}{R_x + R_D} \cdot \frac{1}{1 + \frac{s}{\omega_p}} \cdot \mathcal{H}(s, \omega_0, Q)$$

max. when $R_D \gg R_x$

$$\omega_p = (R_x || R_D) C_p$$

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 $R_L \rightarrow$ affect 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 $\rightarrow V_+ = V_-$

(+) FB
blow up!

can apply ideal op amp laws
 - neg. FB laws

$N_+ = N_-$
 "virtual" ground