Position-to-Voltage Conversion

• To sense position (i.e., displacement), use a capacitive load

Velocity Sensing Circuits

Velocity-to-Voltage Conversion

• To convert velocity to a voltage, use a resistive load
Problems With Purely Resistive Sensing

Now, we get: (approximately)

\[
\frac{N_x}{N_y} = \frac{R_D}{R_x + R_i + \frac{1}{sC_p}}
\]

\[\text{Depends on both } R_D \text{ and } C_p.\]

Impact depends on where \( C_p \) is relative to \( \omega \).

The virtual ground provided by the ideal op amp eliminates the parasitic capacitance \( C_p \) and \( R_i \).

The zero output resistance of the (ideal) op amp can drive virtually anything \( \Omega = 0 \Omega \).

\[N_x = R_D \frac{1}{sC_p} \approx \frac{R_D}{R_i} \text{ or } C_p \text{ effectively isn't there!} \]

Problems With Purely Resistive Sensing

* In general, the sensor output must be connected to the inputs of further signal conditioning circuits → input \( R_i \) of these circuits can load \( R_D \)

These change w/ hook-up → not good.

Problem: need a sensing circuit that is immune to parasitics or loading.

Soln: use op amps.

Position Sensing Circuits
To sense position (i.e., displacement), use a capacitive load.

**Problems With Pure-C Position Sensing**

- To sense position (i.e., displacement), use a capacitive load.
- Integration yields displacement.
- To maximize gain, minimize $C_0$.
- $\frac{C_0}{C_0 + C_p}$ is problematic.
- $C_0 \rightarrow C_0 + C_p$
- DC Gain: $\frac{C_0(C_0 + C_p)}{1 + C_0(C_0 + C_p)}$
- Output will get smaller.
- **Remedy:** Suppress $C_0$ via use of op amps.

**The Op Amp Integrator Advantage**

- The virtual ground provided by the ideal op amp eliminates the parasitic capacitance $C_p$.
- $V_o = \frac{V_i}{sC_p}$

**Differential Position Sensing**

- Example: ADXL-50
- Proof Mass
- Sense Finger
- Tethers with fixed ends
- Fixed Electrodes
- Capacitive division
- Suspension Beam in Tension
- $V_o = \frac{V_p}{sC_p}$
- $V_0 = \frac{(V_p - V_0) + (2V_p)}{2sC_p}$
Buffer-Bootstrapped Position Sensing

Includes capacitance from interconnects, bond pads, and $C_p$ of the op amp

$C_{gd}$ = gate-to-drain capacitance of the input MOS transistor

* Bootstrap the ground lines around the interconnect and bond pads
  - No voltage across $C_p$
  - It's effectively not there!

Effect of Finite Op Amp Gain

Total ADXL-50 Sense C ~ 100fF

Unity Gain Buffer

Integrator-Based Diff. Position Sensing

$\frac{v_0}{C_F}$

Can drive next stage's $R_2$ into interference-free transfer function!