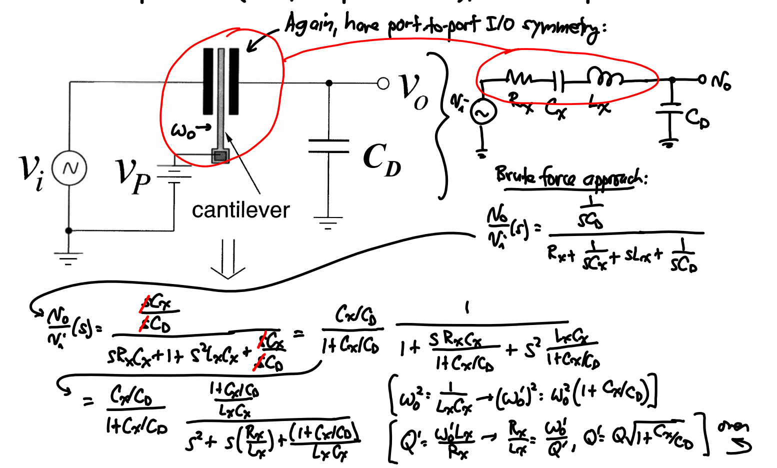
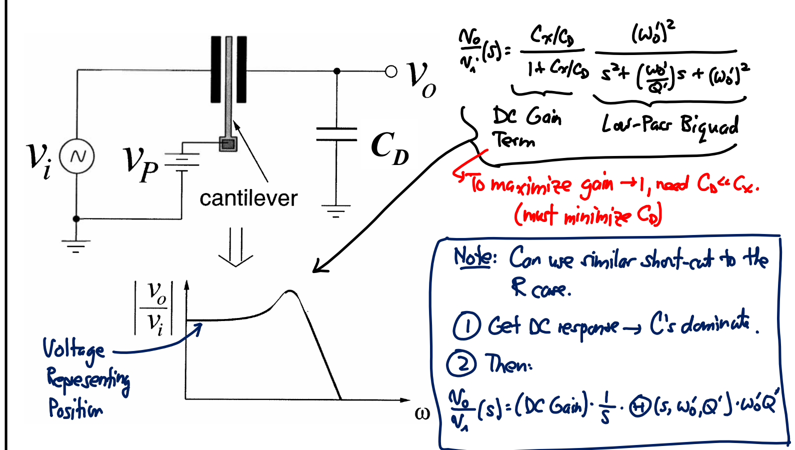
Position-to-Voltage Conversion

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



Position-to-Voltage Conversion

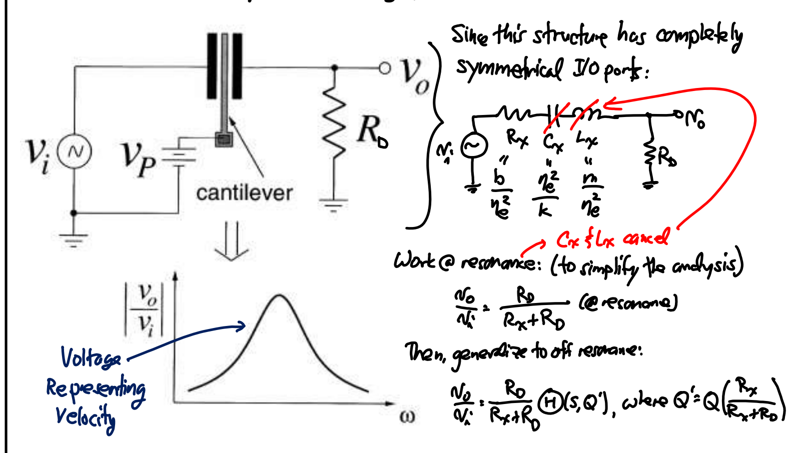
- To sense position (i.e., displacement), use a capacitive load



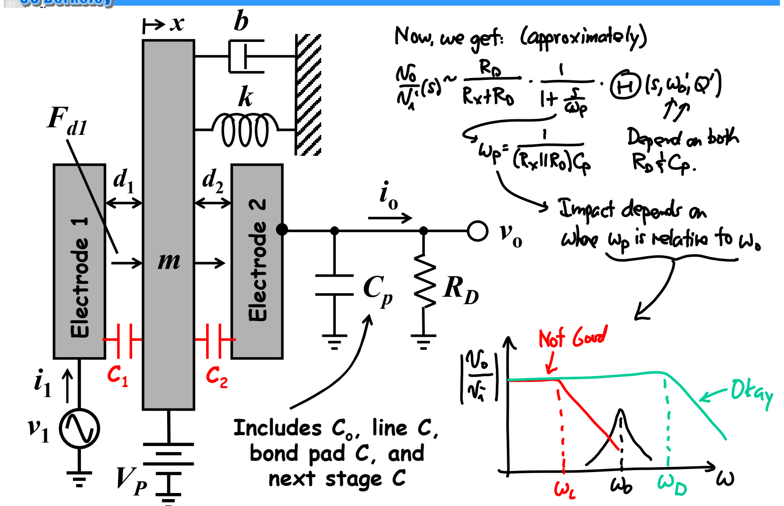
Velocity Sensing Circuits

Velocity-to-Voltage Conversion

- To convert velocity to a voltage, use a resistive load

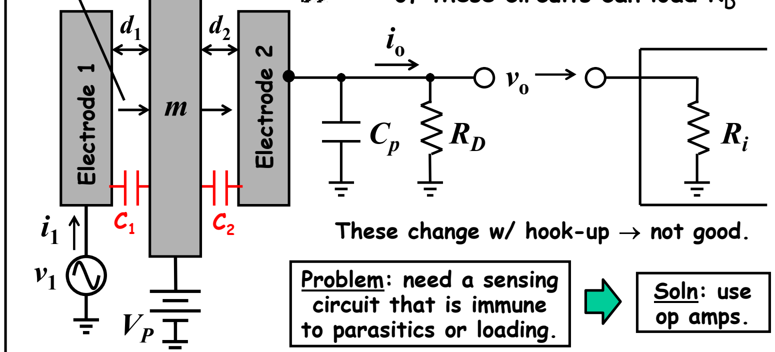


Problems With Purely Resistive Sensing



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

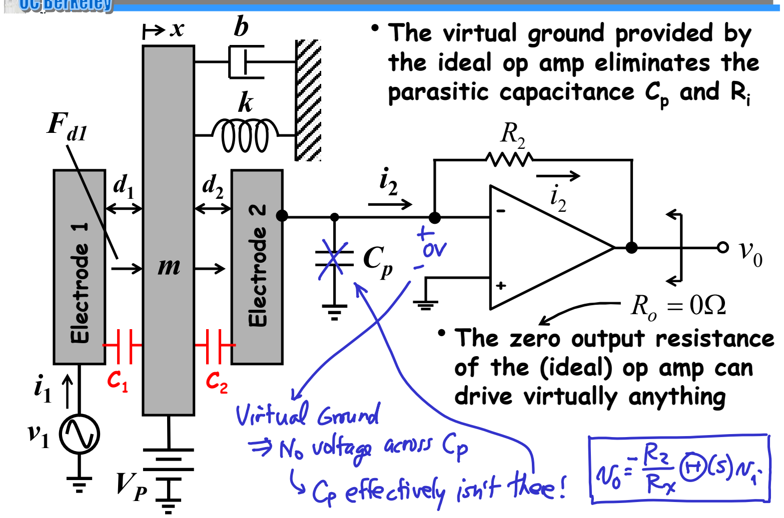


These change w/ hook-up → not good.

Problem: need a sensing circuit that is immune to parasitics or loading. → **Soln**: use op amps.

The TransR Amplifier Advantage

- The virtual ground provided by the ideal op amp eliminates the parasitic capacitance C_p and R_i

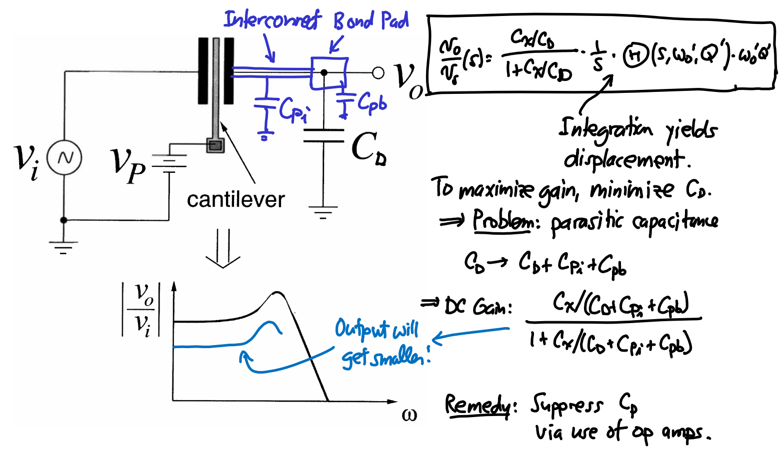


- The zero output resistance of the (ideal) op amp can drive virtually anything

Position Sensing Circuits

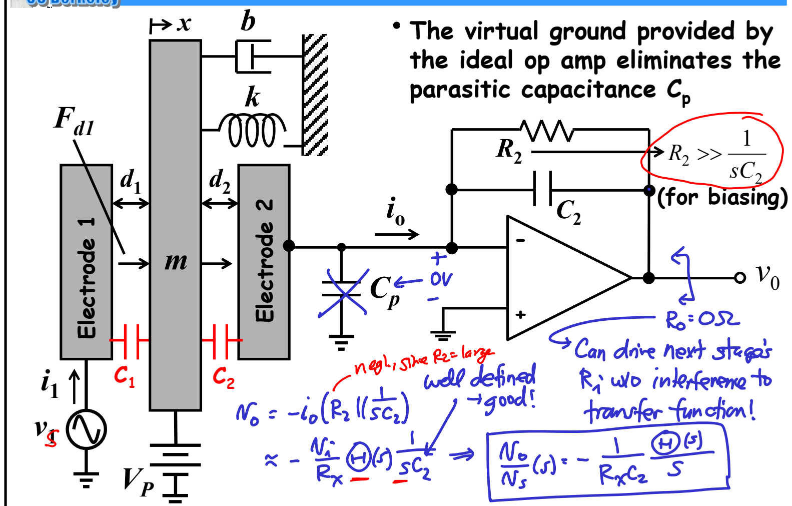
Problems With Pure-C Position Sensing

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



The Op Amp Integrator Advantage

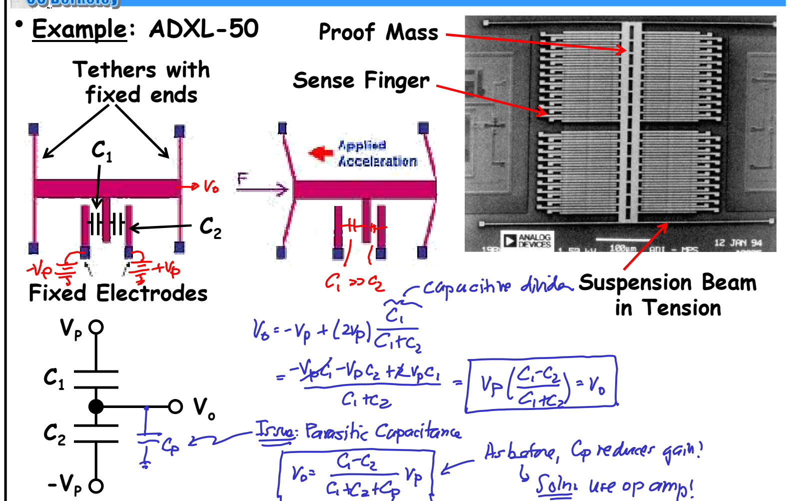
- The virtual ground provided by the ideal op amp eliminates the parasitic capacitance C_p



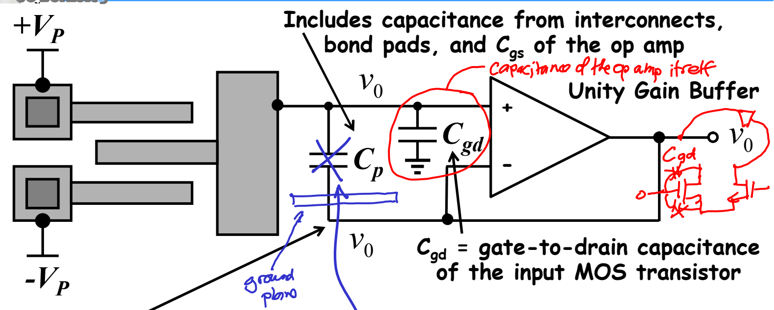
Differential Position Sensing

Differential Position Sensing

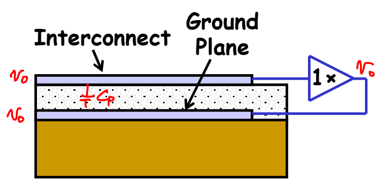
- **Example**: ADXL-50



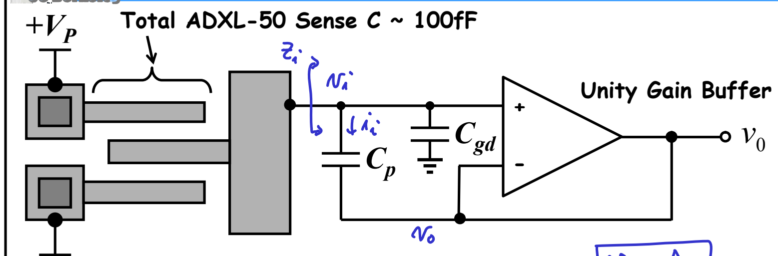
Buffer-Bootstrapped Position Sensing



- 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



$v_o = A_o(v_+ - v_-) = A_o(v_i - v_o) \rightarrow v_o(1+A_o) = A_o v_i \rightarrow \boxed{\frac{v_o}{v_i} = \frac{A_o}{1+A_o}}$

Get $z_i = \frac{v_i}{i_i}$: $i_i = (v_i - v_o)sC_p = v_i\left(1 - \frac{A_o}{1+A_o}\right)sC_p = v_i \frac{1}{1+A_o} sC_p$

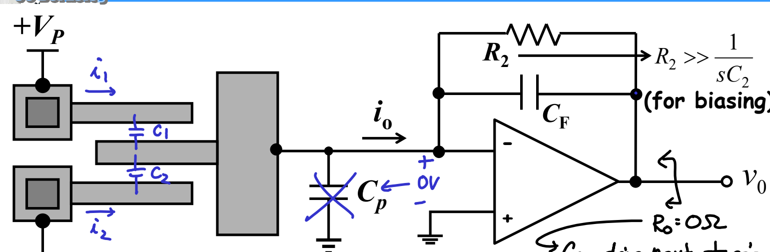
$\therefore \frac{v_i}{i_i} = z_i = \frac{1}{s\left[\frac{C_p}{1+A_o}\right]}$ → $\boxed{C_{eff} = \frac{C_p}{1+A_o}}$ No longer zero!

Ex: $A_o = 100$, $C_p = 2pF$

$\Rightarrow C_{eff} = \frac{2p}{101} = 20fF$

Not negligible compared w/ ADXL-50 $C_{tot} \sim 100fF$!

Integrator-Based Diff. Position Sensing



Can drive next stage's R_i w/o interference to transfer function!

$i_o = i_1 + i_2 = v_P(sC_1) - v_P(sC_2)$

$= v_P s(C_1 - C_2)$

$\therefore v_o = -i_o\left(\frac{1}{sC_F}\right) = -v_P\left(\frac{C_1 - C_2}{C_F}\right)$

$\boxed{\frac{v_o}{v_P} = -\frac{C_1 - C_2}{C_F}}$ ⇒ A seemingly perfect differential sensor/amplifier output! . . . but only when the op amp is ideal . . .