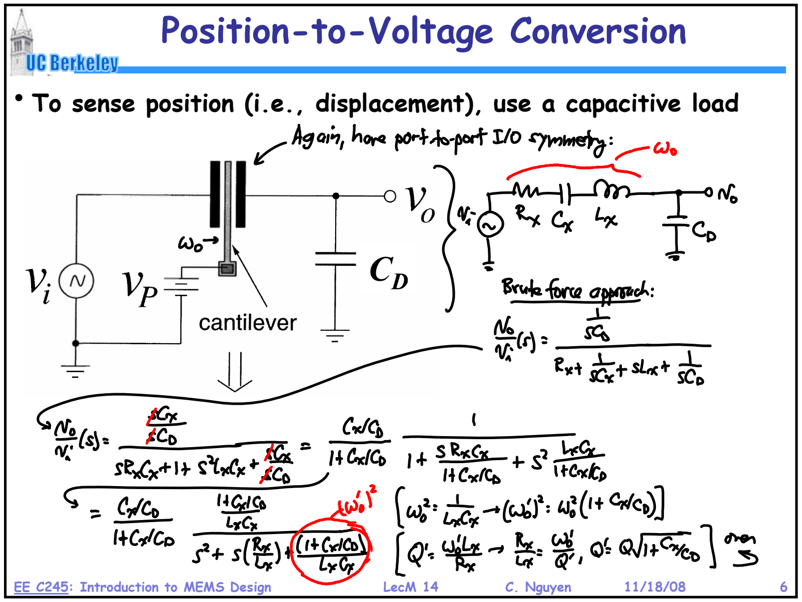
Position-to-Voltage Conversion
UC Berkeley
• To sense position (i.e., displacement), use a capacitive load
Again, have port-to-port I/O symmetry:
V_O
V_i
V_P
cantilever
C_D
Brute force approach:
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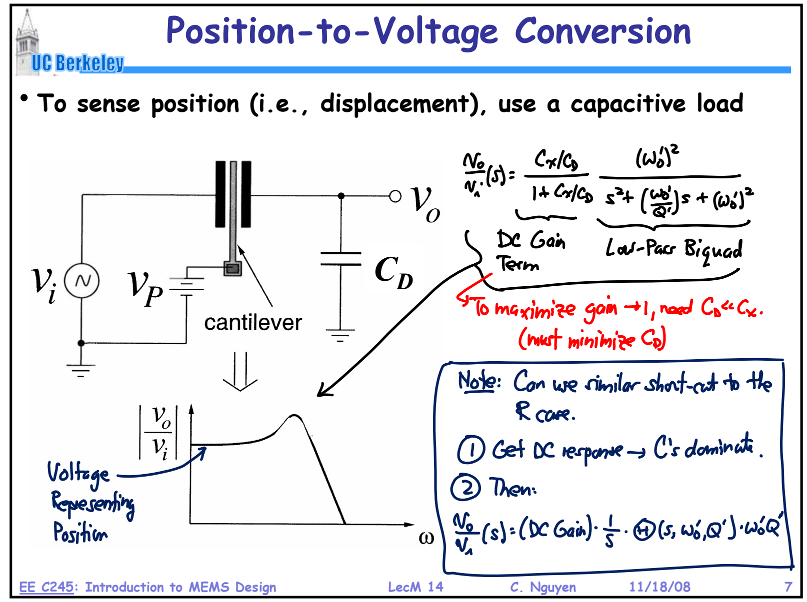
Position-to-Voltage Conversion
UC Berkeley
• To sense position (i.e., displacement), use a capacitive load
V_O
V_i
V_P
cantilever
C_D
DC Gain Term
Low-Pass Biquad
To maximize gain → 1, need C_D << C_x.
(must minimize C_D)
Note: Can use similar short-cut to the R case.
① Get DC response → C's dominate.
② Then:
Voltage Representing Position
ω
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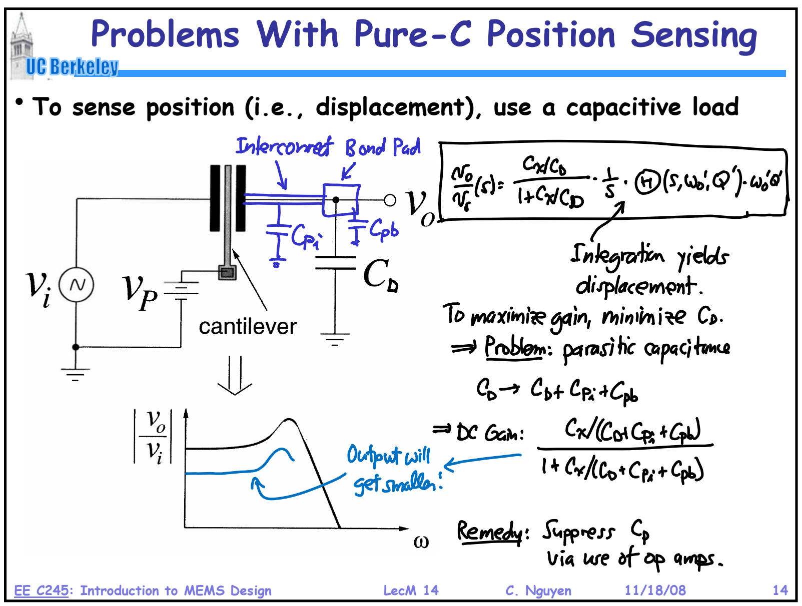
Problems With Pure-C Position Sensing
UC Berkeley
• To sense position (i.e., displacement), use a capacitive load
Interconnect
Bond Pad
V_O
V_i
V_P
cantilever
Integration yields displacement.
To maximize gain, minimize C_D.
⇒ Problem: parasitic capacitance
⇒ DC Gain:
Output will get smaller!
Remedy: Suppress C_p via use of op amps.
ω
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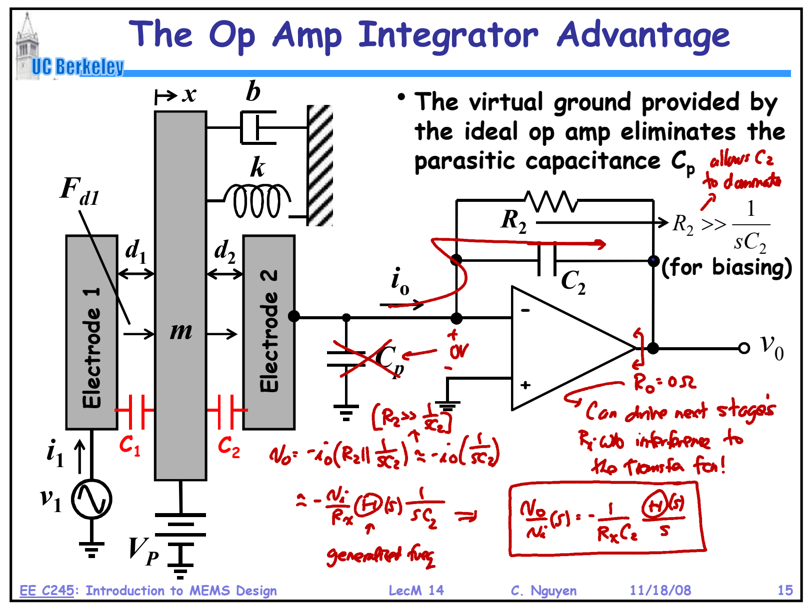
The Op Amp Integrator Advantage
UC Berkeley
• The virtual ground provided by the ideal op amp eliminates the parasitic capacitance C_p
allows C_2 to dominate
$R_2 >> \frac{1}{sC_2}$
(for biasing)
F_{d1}
d_1
d_2
b
k
m
Electrode 1
Electrode 2
C_1
C_2
i_1
v_1
V_P
R_2
C_2
i_o
C_p
v_0
Can drive next stages w/o interference to the transfer fcn!
generated fcn
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Differential Position Sensing

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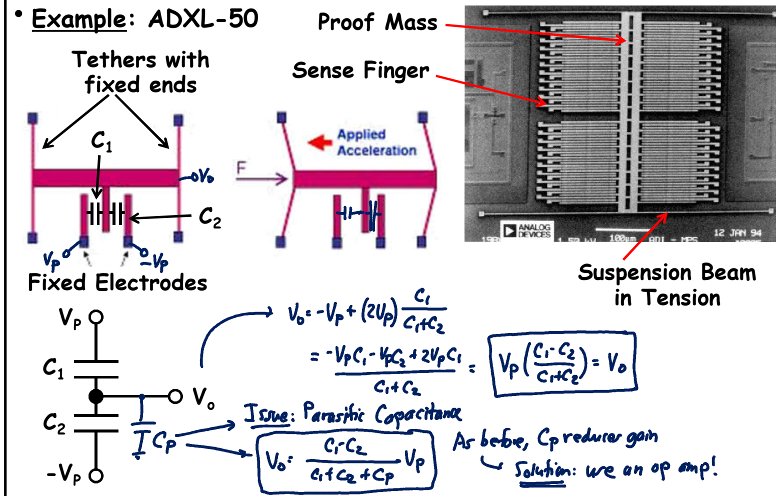
Differential Position Sensing

- Example: ADXL-50



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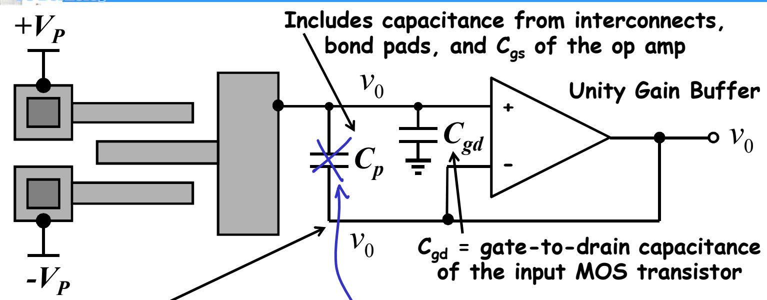
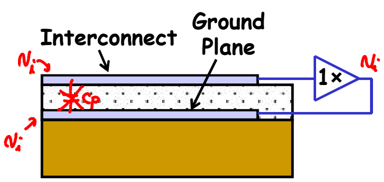
Buffer-Bootstrapped Position Sensing



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



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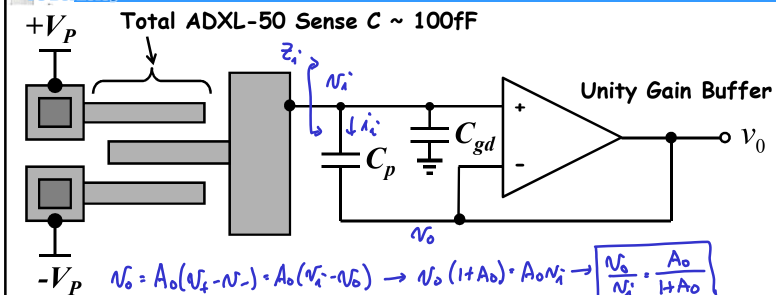
Effect of Finite Op Amp Gain



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

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

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

Ex: $A_o = 100$, $C_p = 2pF$ ⇒ $C_{eff} = \frac{2p}{101} = 20fF$

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

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Integrator-Based Diff. Position Sensing

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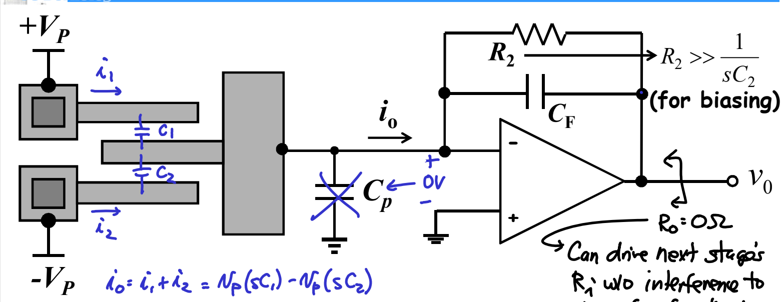

$i_o = i_1 + i_2 = v_P(sC_1) - v_P(sC_2)$

$= v_P s(C_1 - C_2)$

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

$$\boxed{\frac{v_o}{v_P} = -\frac{C_1 - C_2}{C_F}}$$

⇒ A seemingly perfect differential sensor/amplifier output! . . . but only when the op amp is ideal . . .

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