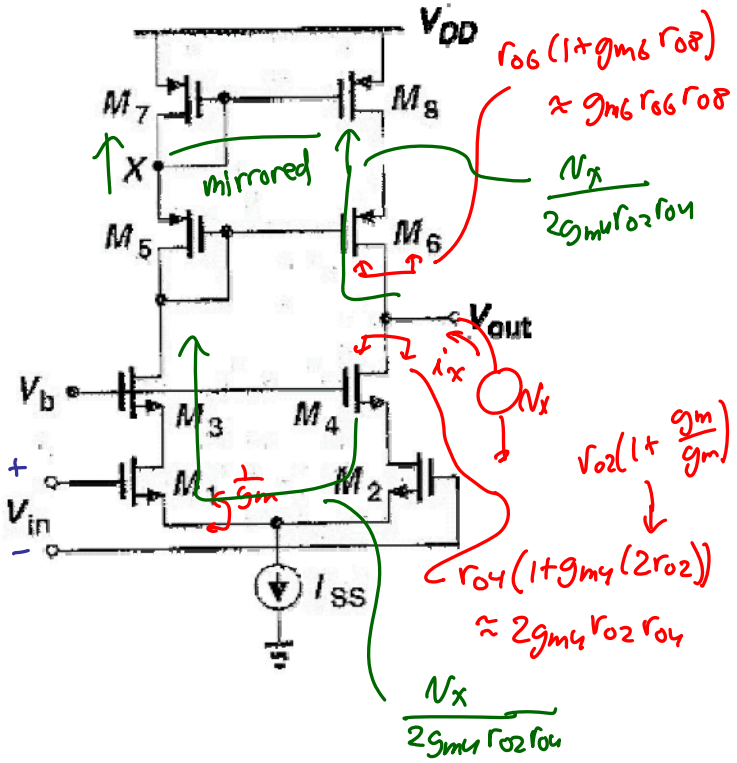
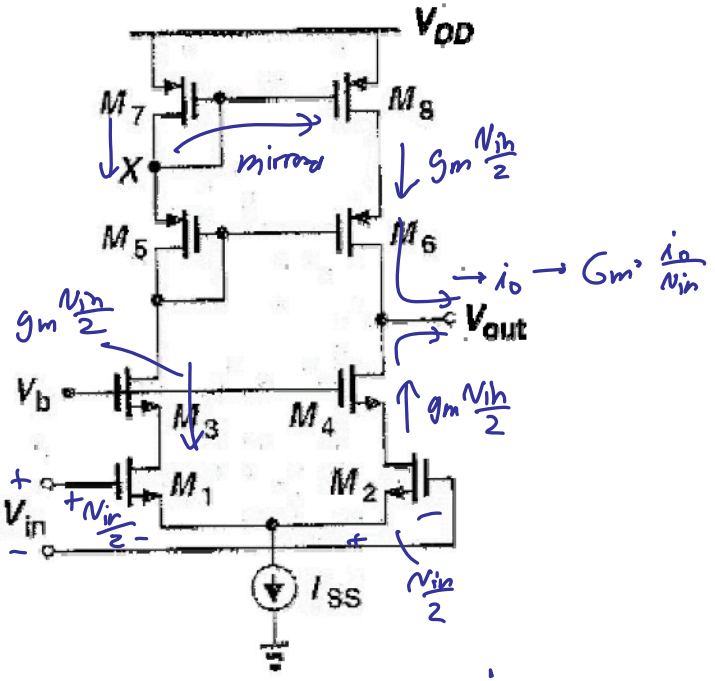
Lecture 16: High Gain Op Amps

- Announcements:
  - Lab#2 extended one week; due week of 3/19
  - This is our makeup lecture, occuring Friday, 3/9, 3-4:30 p.m., in 277 Cory
- Lecture Topics:
  - High Gain Op Amps
  - Slew Rate
- ----------
- Last Time: Telescopic Op Amp w/ Singe-Ended Output



$R_o = \frac{V_x}{I_x} = (g_{m6}r_{o6}r_{o8}) \| (g_{m4}r_{o2}r_{o4})$

$\simeq (g_{mp}r_{op}^2) \| (g_{mN}r_{oN}^2)$

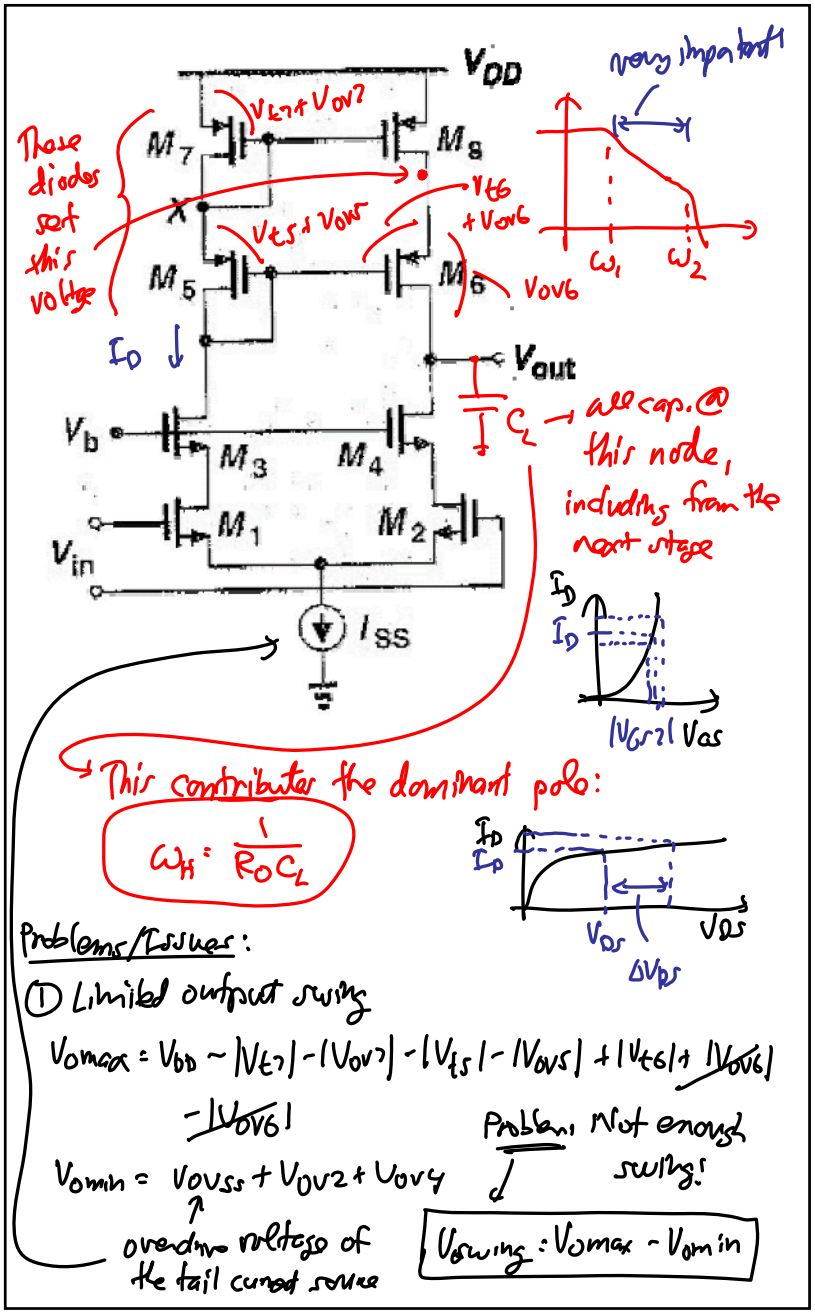


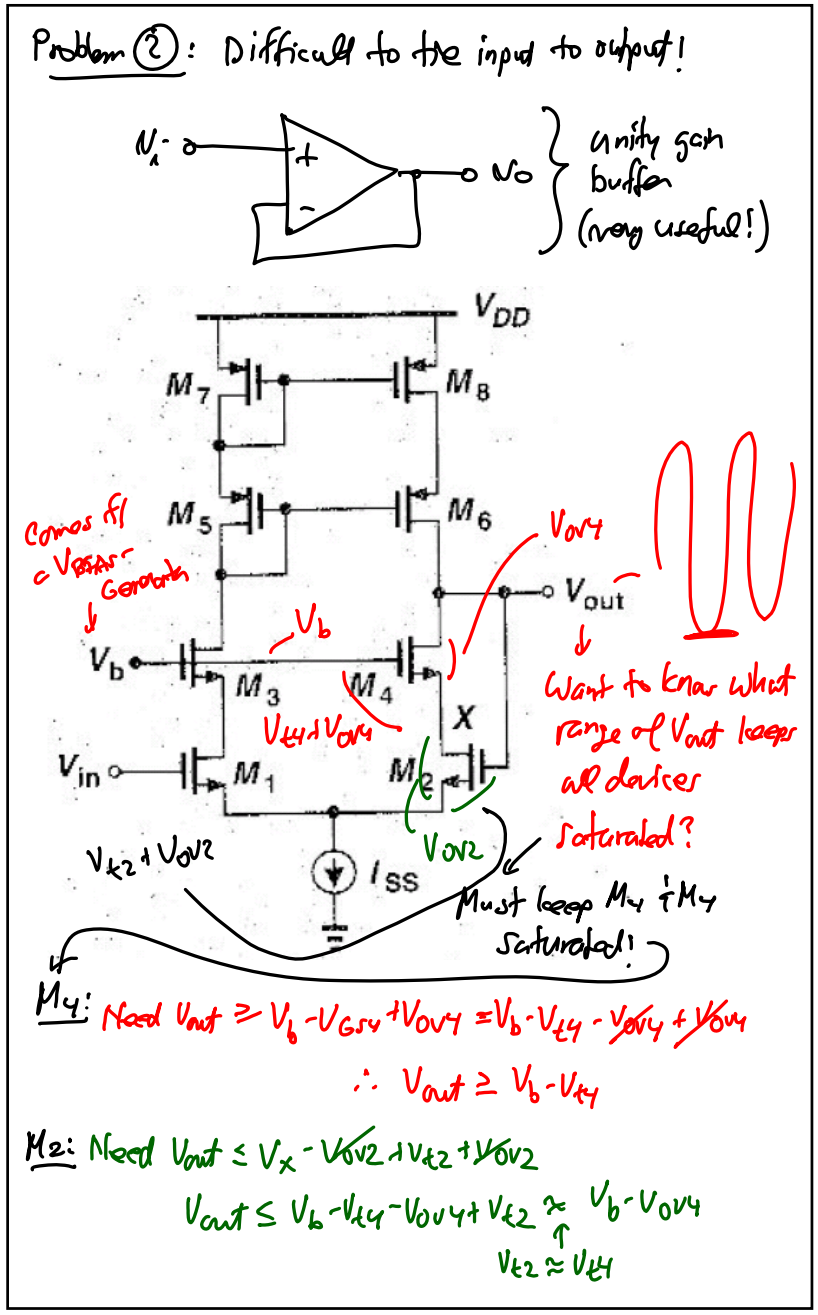
$i_o = g_m\frac{V_{in}}{2} + g_m\frac{V_{in}}{2} \rightarrow G_m = \frac{i_o}{V_{in}} = g_m$

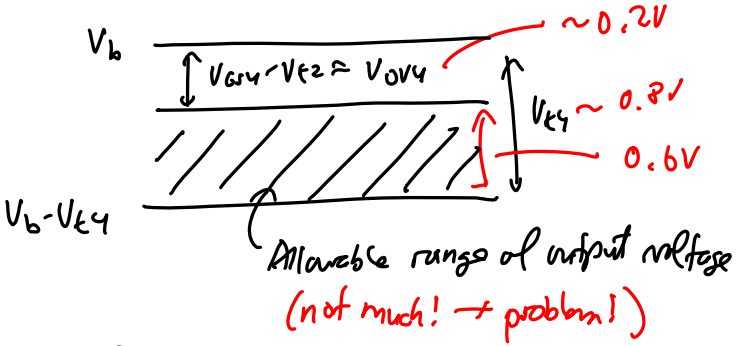
$\therefore$ Gain: $A_V = g_{mN}\left[(g_{mN}r_{oN}^2) \| (g_{mp}r_{op}^2)\right]$

huge R! huge R!

gain will be big!







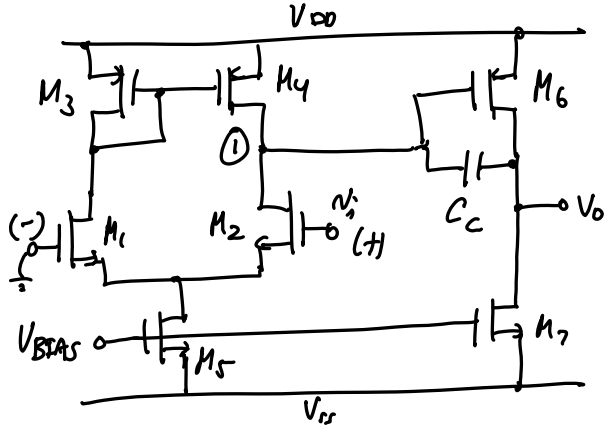
Problem ③:

Low freq. non-dominant pole associated w/ the "mirror" node → will hurt stability in feedback config.!
(we'll cover this later)

Soln: fully-differential, fully balanced op amp

Another solution: 2-stage op amp

Classic 2-Stage Op Amp



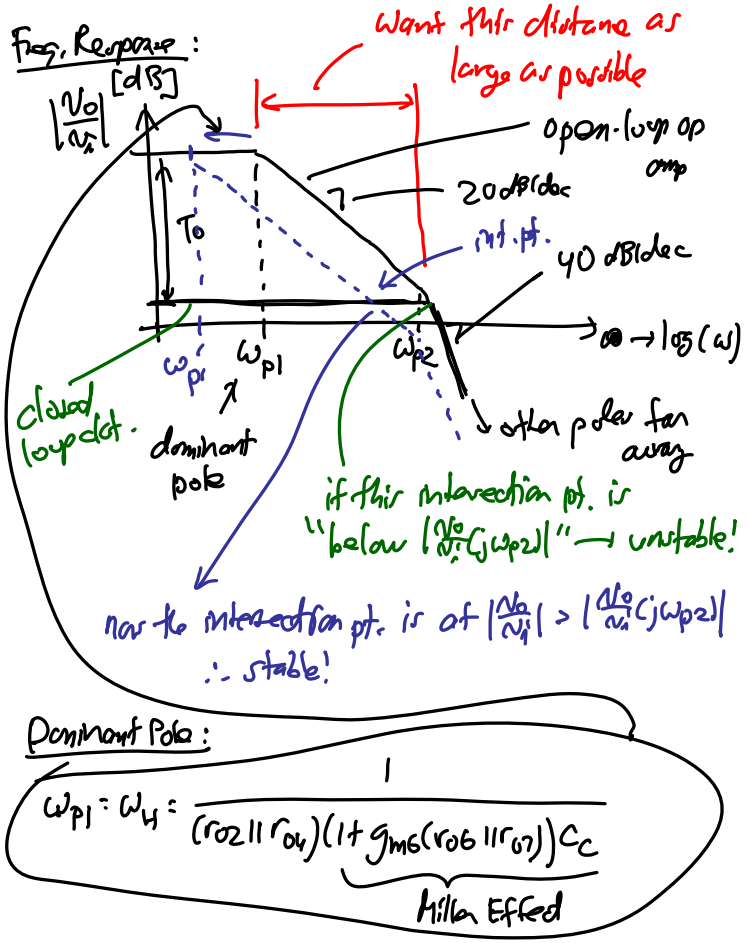
Gain:

1st Stage: $A_{V1} = \frac{V_{o1}}{V_i} = -g_{m2}(r_{o2} \| r_{o4})$

2nd stage: $A_{V2} = \frac{V_o}{V_{o1}} = -g_{m6}(r_{o6} \| r_{o7})$

$$A_V = A_{V1}A_{V2} = g_{m2}(r_{o2} \| r_{o4})\, g_{m6}(r_{o6} \| r_{o7})$$

Freq. Response:



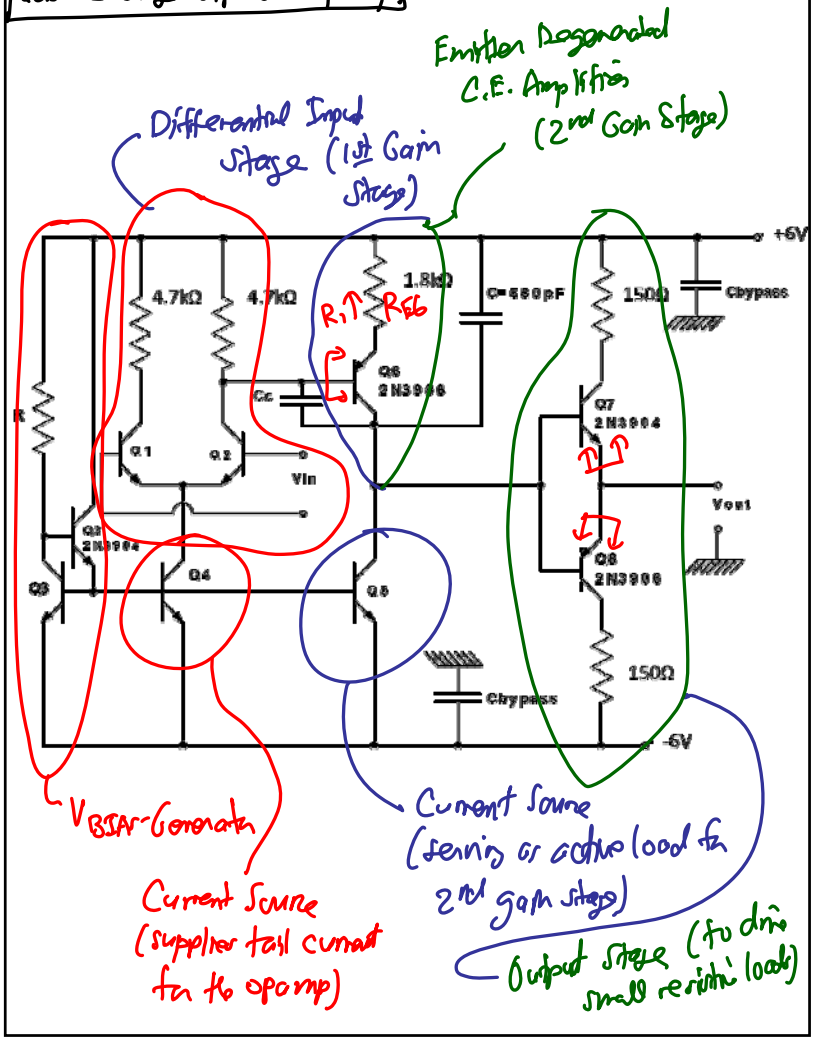
Dominant Pole:

$$\omega_{p1} = \omega_4 = \frac{1}{(r_{o2} \| r_{o4})\underbrace{(1+g_{m6}(r_{o6} \| r_{o7}))C_C}_{\text{Miller Effect}}}$$

Output Swing:

$V_{swing} = V_{DD} - V_{SS} - |V_{OV6}| - V_{OV7}$

Lab: 2-Stage Bipolar Op Amp



Remarks.

① You analyze this in Lab #2.

② Usually, the resistively-loaded diff. pair is replaced w/ an active current mirror load for more gain.

③ R_{E6} raises the input R of Q_6 (of the 2nd gain stage), plus helps w/ biasing.

④ Same comment as ③ for the output stage.

⑤ Output stage needed when driving a resistive load
↳ often the case for bipolar
↳ not often the case for MOS, where a capacitive load C_L is often more relevant → MOS op amps often don't need output stages!