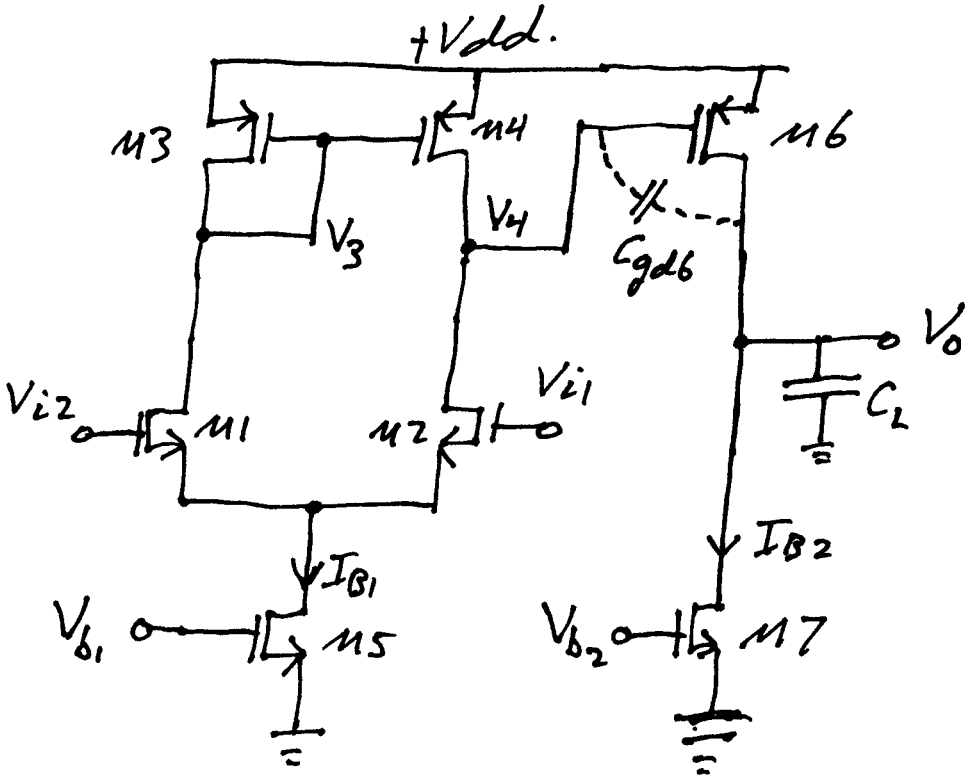
2-Stage Amps

- Achieve two gain stages by adding a CS-Amp to the basic differential input pair:



- Key equations are similar to before

- One key point for biasing is appropriate selection/design of $V_4 = V_{dd} - V_{SG6}$

- For low V_{OFFSET} $\Rightarrow$ need $V_3 = V_4$ due to I-mirror M_3/M_4 $\Rightarrow$ $\underline{V_{OV6} = V_{OV3} = V_{OV4}}$ } low offset.

- of course, also need $\underline{I_{B2} = I_{D6\_sat}}$

$\Rightarrow$ select I_{B2} & $(W/L)_6$ to meet above constraints.

Key Equations:

$$(V_{IC})_{max} = V_{dd} - V_{OV3} - V_{t3} + V_{t1}$$

$$(V_{IC})_{min} = V_{OV5} + V_{OV1} + V_{t1}$$

$$(V_O)_{max} = V_{dd} - V_{OV6} \quad ; (V_O)_{min} = V_{OV7}$$

$$V_{OV6} = V_{OV3} = V_{OV4}$$

$$SR_{C_{gd6}} = \frac{I_{B1}}{C_{gd6}} \quad ; \quad SR^-_{C_L} = \frac{I_{B2}}{C_L}$$

$$SR^+_{C_L} = \frac{I_{D6\_max} - I_{B2}}{C_L}$$

$$A_0 = G_{m1} R_1 G_{m2} R_2$$

$$f_{p1} = \frac{1}{2\pi \left(R_1 C_1 + R_2 C_2 + (R_1 + R_2 + G_{m2} R_1 R_2) C_{gd6} \right)}$$

where: $G_{m1} = g_{m1,2}$, $R_1 = r_{ds4} \| r_{ds2}$

$G_{m2} = g_{m6}$, $R_2 = R_{out} = r_{ds6} \| r_{ds7}$

C_1 = all caps @ V_4 to small-signal gnd

C_2 = all caps @ V_o to ss gnd (incl. C_L)

$$f_{p1} \approx \frac{1}{2\pi G_{m2} R_1 R_2 C_{gd6}}$$

- Unity-gain freq = $G \cdot BW = \dfrac{G_{m1}}{2\pi C_{gd6}}$

- Design Procedure:

  - Select bias currents I_{B1} & I_{B2}
    - Meet SR requirements, power limitations, size constraints.
  - $G \cdot BW \Rightarrow G_{m1} \Rightarrow (W/L)_{1,2}$
  - $ICMR \Rightarrow (W/L)_{3,4}$ & $(W/L)_5$
  - (V_O) Range $\Rightarrow (W/L)_6$ & $(W/L)_7$
  - $V_{OV3} = V_{OV6} \Rightarrow (W/L)_6$
  - $A_0 \Rightarrow G_{m2}$ & R_1 & $R_2 \Rightarrow (W/L)_6, L_7, L_6, L_4, L_2$

$\Rightarrow$ At this point, we have more degrees of freedom than constraints.

$\Rightarrow$ analyze feedback & stability

$\Rightarrow$ additional constraints.