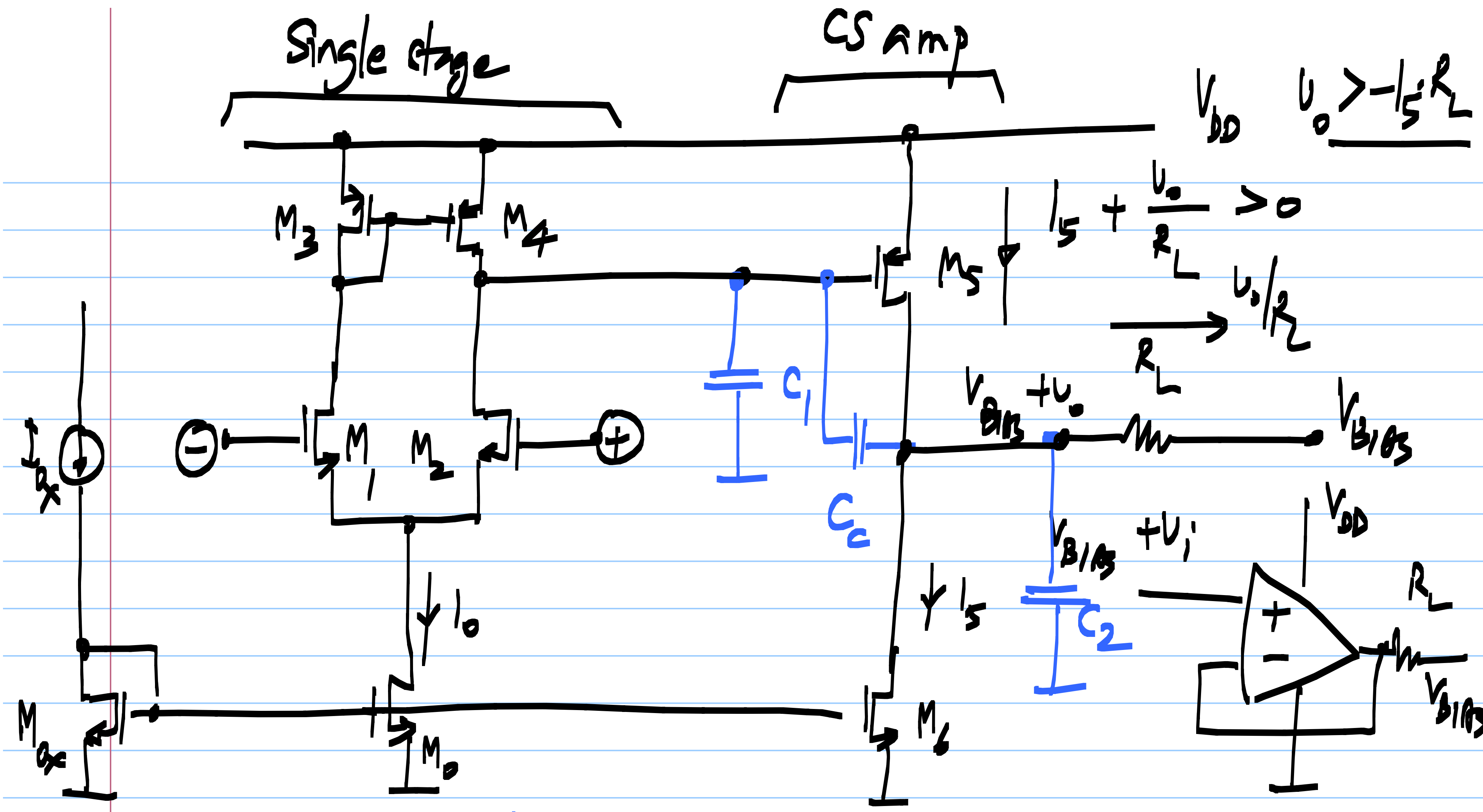
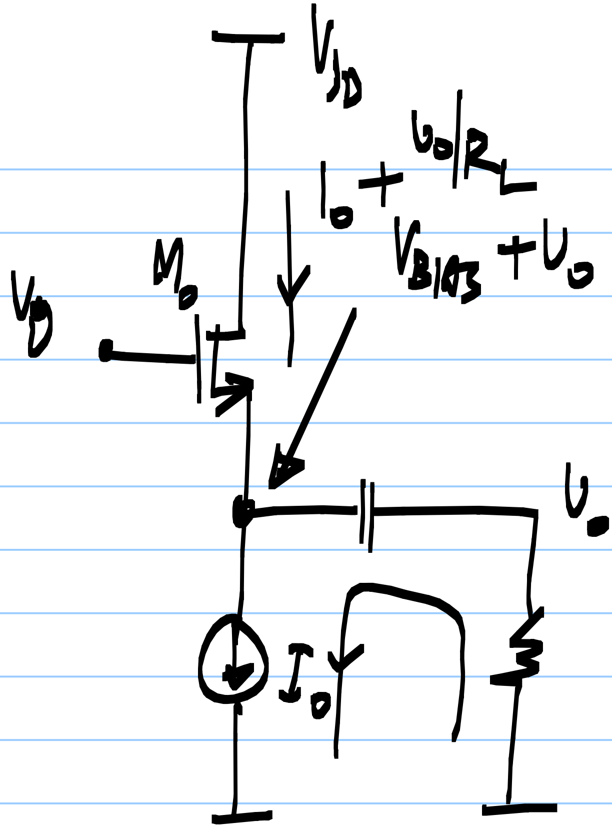
Two-stage opamp:

+ higher gain
+ Higher swing, o/p isolated from the input

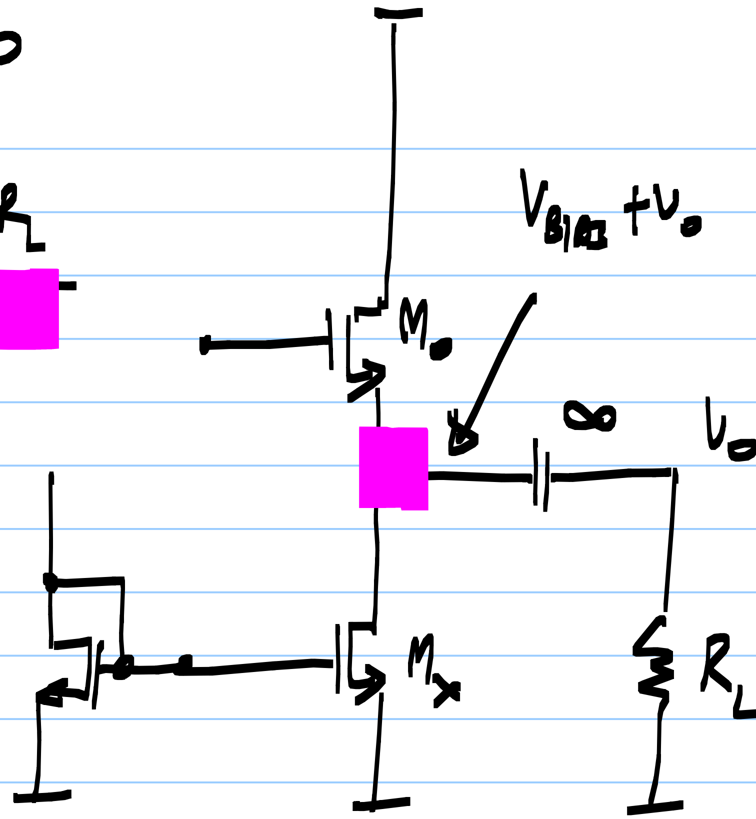


Miller compensated two-stage opamp

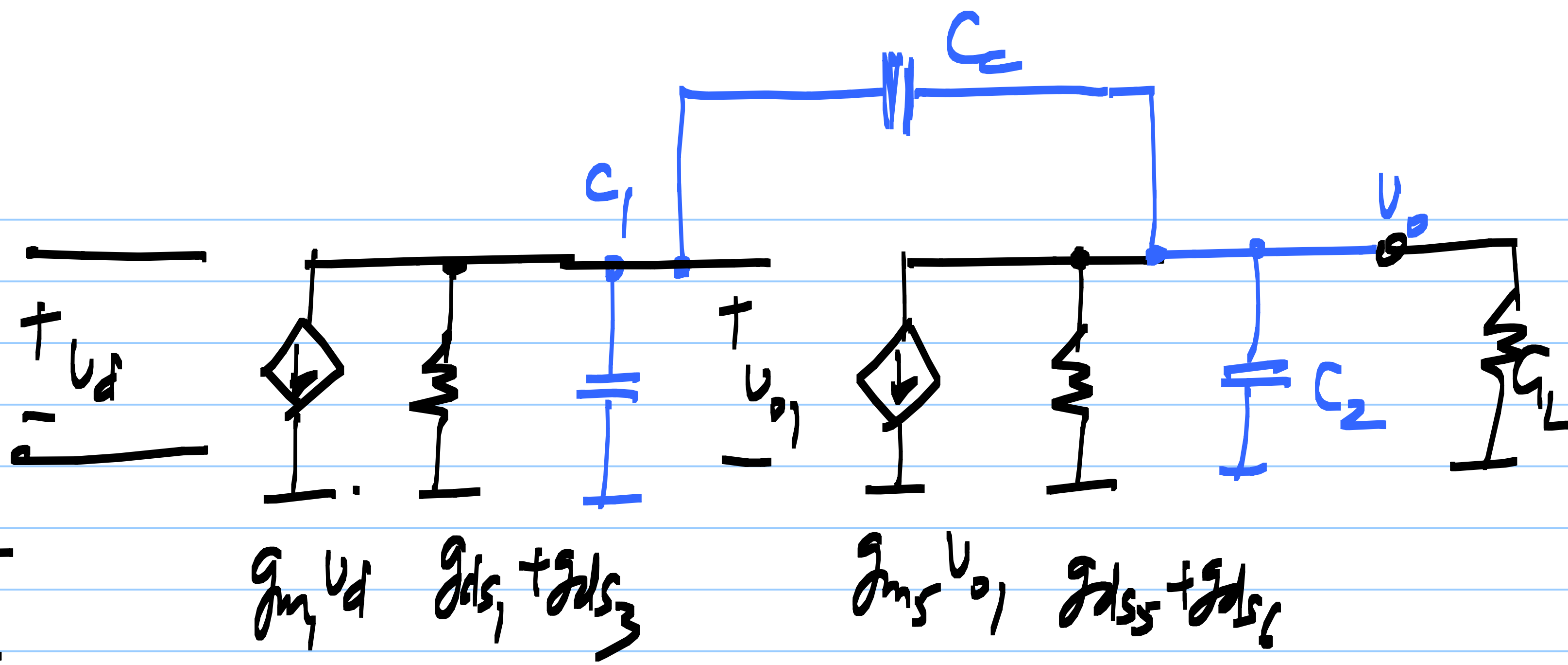


$$I_0 + \frac{v_0}{R_L} > 0$$

✓ $v_0 > -I_0 R_L$



✓ $V_{BIAS} + v_0 > V_{DSATx}\Big|_{I_0}$



$$\omega_u = \frac{g_{m1}}{C_c}$$

$$\frac{v_o}{v_d} = \frac{A_0 \cdot \left(1 - s \cdot \frac{C_c}{g_{m5}}\right)}{\left[\left(1 + \frac{s}{p_1}\right)\left(1 + \frac{s}{p_2}\right)\right]}$$

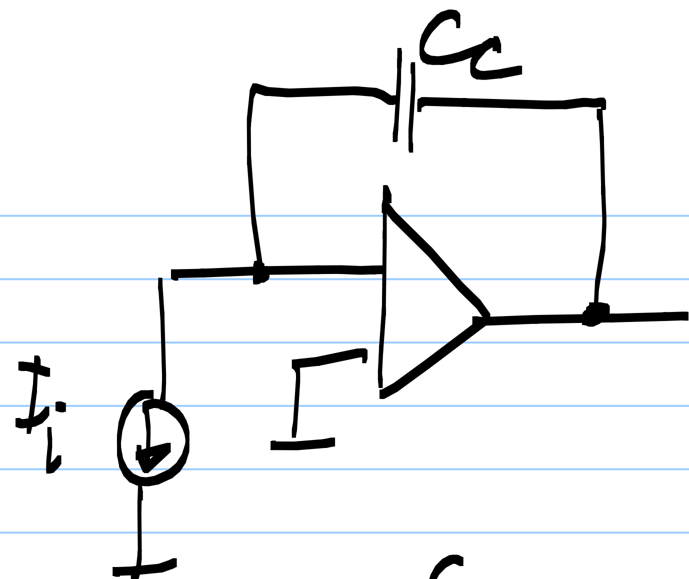
$$A_0 = \frac{g_{m_1}}{g_{ds_1} + g_{ds_3}} \cdot \frac{g_{m_5}}{g_{ds_5} + g_{ds_6}}$$

$$\omega_{u,opt} \approx \frac{g_{m_1}}{C_c}$$

$$p_1 \approx \frac{g_{ds_1} + g_{ds_3}}{C_1 + \left(1 + \frac{g_{m_5}}{g_{ds5} + g_{ds_6}} \cdot C_c\right)} + \dots$$

$$Z_1 = \frac{g_{m_5}}{C_c}$$

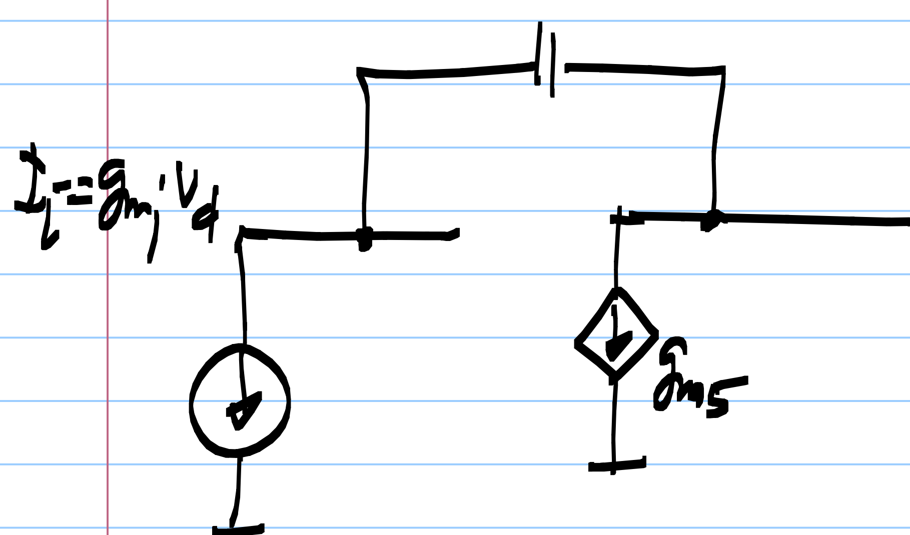
$$p_2 \approx \frac{g_{m_5} \cdot \frac{C_c}{C_c + C_1} + g_{ds_5} + g_{ds_6} + G_L}{C_2 + \frac{C_c \cdot C_1}{C_c + C_1}}$$



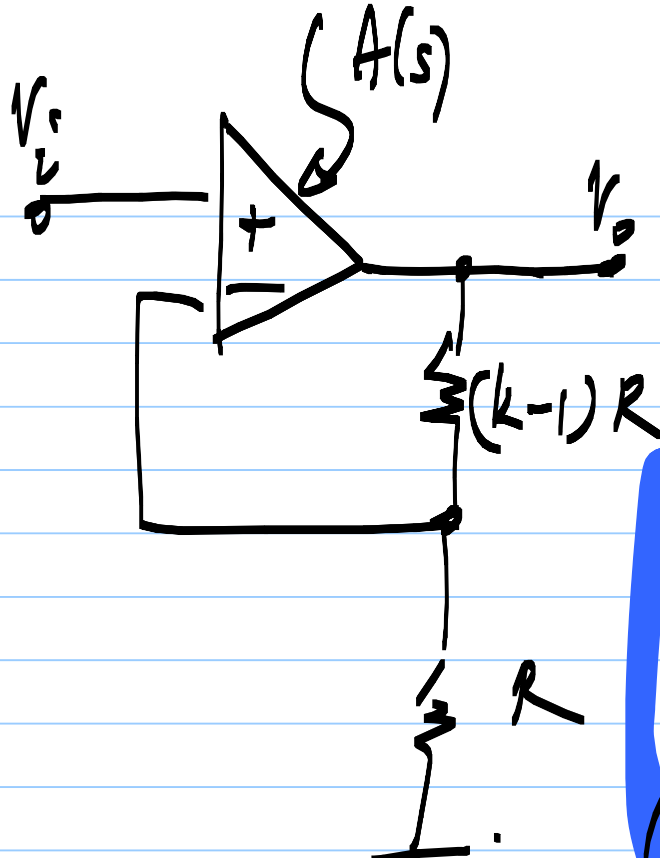
$$V_o = \frac{I_i(s)}{sC_c}$$

$$\left|\frac{g_{m1}}{sC_c}\right| = 1$$

$$|j\omega_u| = \frac{g_m}{C_c}$$



$$V_o(s) \approx \frac{g_{m1} \cdot V_d(s)}{sC_c} = V_d(s) \cdot \left[\frac{g_{m1}}{sC_c}\right]$$



$$A_{loop} = \frac{A(s)}{k}$$

$$-180^\circ + \phi_M > -120^\circ \qquad \phi_M > 60^\circ$$

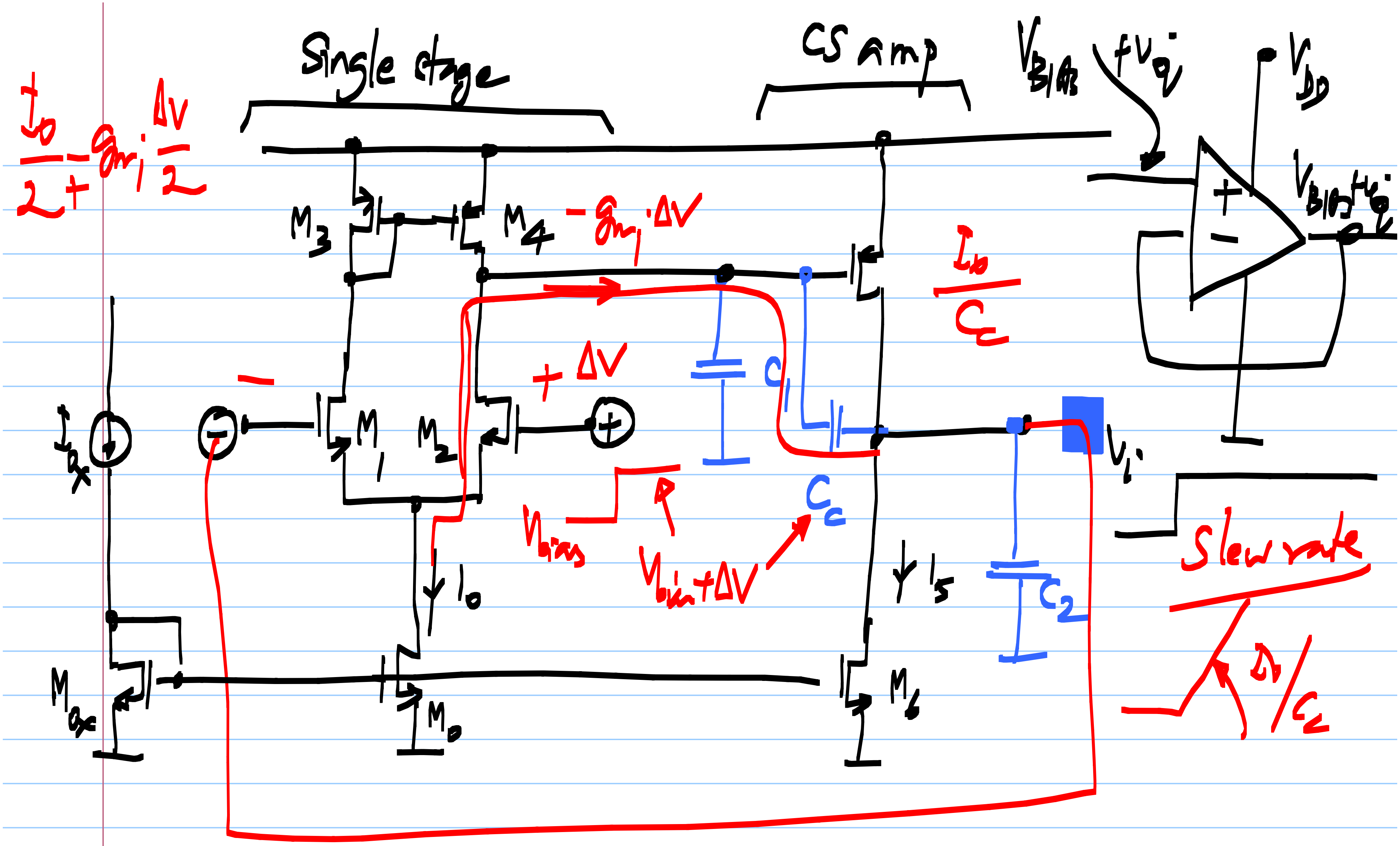
$$\omega_{u,loop} = \frac{\omega_{u,opA}}{k}$$

Total phase shift @ $\omega_{u,loop}$

$$\left[-\tan^{-1}\frac{\omega_{u,loop}}{p_1} - \tan^{-1}\frac{\omega_{u,loop}}{p_2} - \tan^{-1}\frac{\omega_{u,loop}}{z} \right] > -120^\circ$$

Adjust C_c so that (above) is satisfied

$$\tan^{-1} \frac{\omega_{n}/\omega_{p}}{z_1} = \underline{\tan^{-1}\left[\frac{g_{m_1}/k}{g_{m_5}}\right]}$$


Single stage
CS amp
$\frac{I_D}{2} + g_{m_1} \frac{\Delta V}{2}$
M_3
M_4
$-g_{m_1} \cdot \Delta V$
M_1
M_2
$+\Delta V$
C_1
C_c
$\frac{I_D}{C_c}$
I_{ax}
I_0
I_5
M_{ax}
M_0
M_6
C_2
V_{bias}
$V_{bias} + \Delta V$
V_{BIAS}
$+V_{Q}$
V_{DD}
$V_{BIAS} + V_Q$
V_i
Slew rate
I_D / C_c