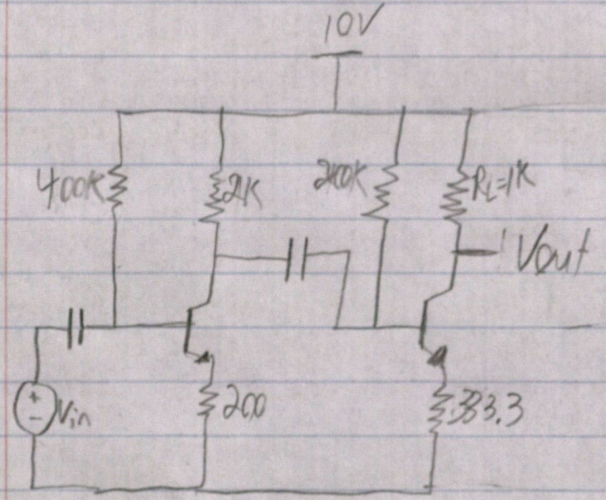
EE 330 F12
HW 12 - Solutions
Due 11/14/2012

10pts 1.

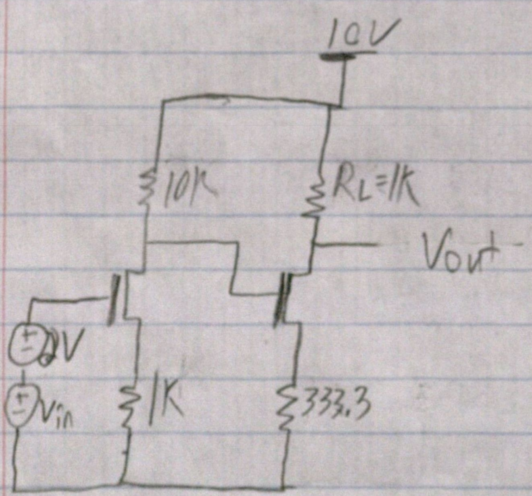


$$A_v = \left(\frac{-2K}{200}\right)\left(\frac{-1K}{333.3}\right) = \boxed{30\ V/V}$$

Three Common Emmitters w/ RE in series

$$R_{in} = \beta\left(\frac{V_t}{I_{cq}} + 2K\right) > 100K \quad \text{when } \beta = 100$$

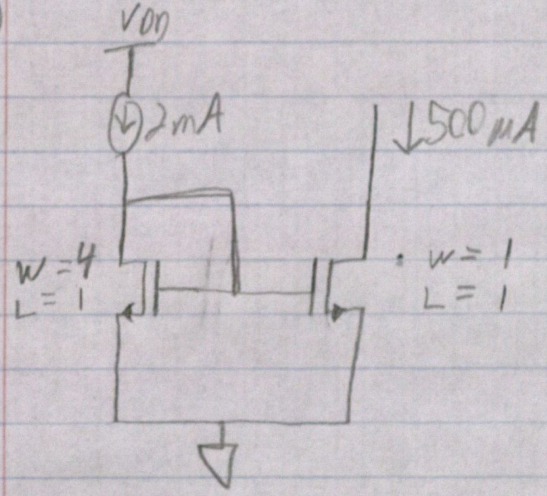
10pts 2.



$$A_v = \left(\frac{-10K}{1K}\right)\left(\frac{-1K}{333.3}\right) = 30$$

$$R_{in} = \infty$$

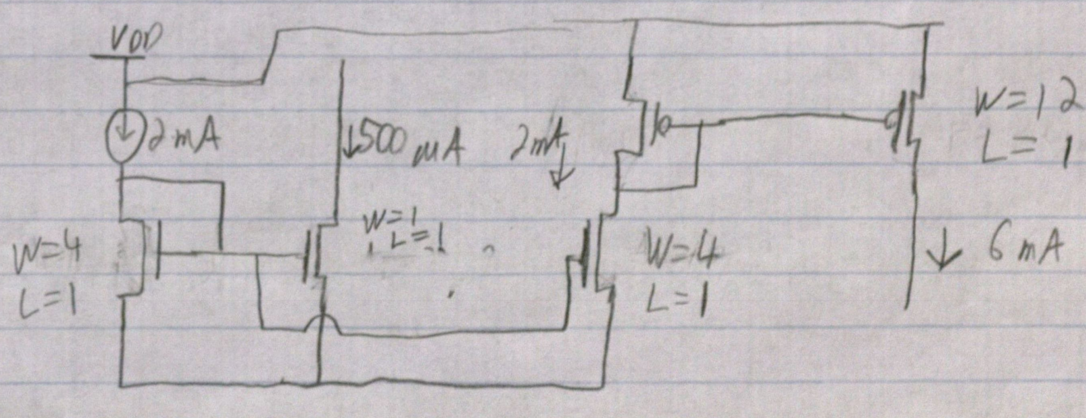
10pts

3a) 

b) $2mA = 100E-6 \; \frac{4}{2}(V_{GS} - .5)^2 \qquad V_{GS} = 3.66V$

$V_{DS} \geq V_{GS} - V_T \qquad V_{DS} \geq 3.66 - .5 \qquad \boxed{V_{DS} \geq 3.16V}$

10pts

4a) 

b) $V_{DS} \leq V_{GS} - V_T$

$V_S = V_{DD} \qquad 2mA = 33E-6 \cdot \frac{4}{2}(V_{GS} + .5)^2$

$V_{GS} = -6V$

$V_D - V_{DD} \leq V_G - V_{DD} + .5$

$\boxed{V_D \leq -5.5V + V_{DD}}$

10pts

5a) $I_{B_1} = \frac{10 - .6}{R_1}$ $I_{C_1} = \beta I_{B_1} = \beta \frac{9.4}{R_1}$

$I_{C_3} = I_{C_1} \cdot \frac{A_{E3}}{A_{E2}}$ $\boxed{V_{o1} = I_{C3} \cdot R_2 = \beta \cdot \frac{9.4}{R_1} \cdot \frac{A_{E3}}{A_{E2}} \cdot R_2}$

$I_{C4} = I_{C1} \cdot \frac{A_{E4}}{A_{E1}}$ $I_{D6} = I_{C4} \cdot (W_6/L_6) / (W_5/L_5)$

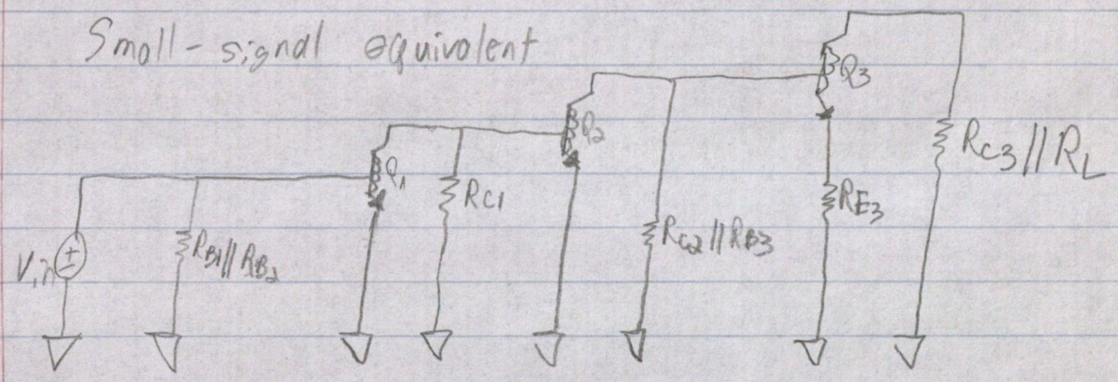
$$\boxed{V_{o2} = I_{D6} \cdot R_3 = \left(\beta \frac{9.4}{R_1}\right) \cdot \left(\frac{A_{E4}}{A_{E1}}\right) \cdot \left(\frac{\left(\frac{W_6}{L_6}\right)}{\left(\frac{W_5}{L_5}\right)}\right) \cdot R_3}$$

b)

$V_{o1} = 3 = 100 \cdot \frac{9.4}{20K} \cdot \frac{50}{100} \cdot R_2$ $\boxed{R_2 = 127.66\Omega}$

$V_{o2} = 6 = 100 \cdot \frac{9.4}{20K} \cdot \frac{200}{100} \cdot \frac{4}{10} \cdot R_3$ $\boxed{R_3 = 159.57\Omega}$

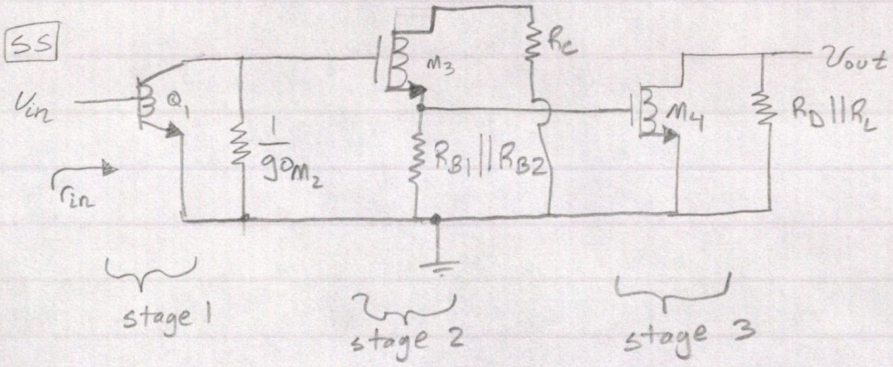
10pts 6. Small-signal equivalent



$$\boxed{A_V = \left(-g_{m1} R_{C1}\right)\left(-g_{m2}\left(R_{C2} \| R_{B3}\right)\right)\left(-\frac{\left(R_{C3} \| R_L\right)}{R_{E3}}\right)}$$

7 SS

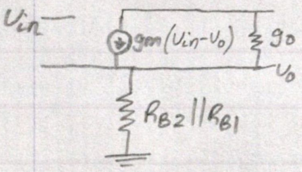
10 points



$$A_V = A_{V_1} \cdot A_{V_2} \cdot A_{V_3}$$

$$A_{V_1} = -\frac{g_{m_1}}{g_{m_2}}$$

stage 2



$$V_o = g_m(V_{in}-V_o)(R_{B2}||R_{B1}) \qquad A_{V_2} = \frac{-g_{m_3}(R_{B2}||R_{B_1})}{1+g_{m_3}(R_{B_2}||R_{B_1})} \approx 1$$

stage 2 = buffer

$$A_{V_3} = -g_{m_4} \cdot (R_D||R_L)$$

$$\boxed{\begin{aligned} R_{in} &= r_{\pi_1} \\ A_V &= \frac{g_{m_1}}{g_{m_2}} \cdot g_{m_4}(R_D||R_L) \end{aligned}}$$

8 Problem 7 in terms of DC operating parameters

+10 EC

$$g_{m_1} = \frac{I_{C_1}}{V_t} \qquad g_{m_2} = \mu C_{ox}\frac{W}{L}(V_{GSQ}-V_T) \qquad g_{m_4} = \mu C_{ox}\frac{W}{L}(V_{GSQ}-V_T)$$

$$I_{C_1} = I_{D_2} = \mu C_{ox}\frac{W}{2L}(V_{GS}-V_T)^2$$

$$= \mu C_{ox_p}\frac{W_2}{2L_2}(V_{CE}-V_{DD}-V_T)^2 = J_S A_E e^{\frac{V_{BE}}{V_t}}\left(1+\frac{V_{CE}}{V_{AF}}\right)$$

← with more information (sizing) solve for V_{CE} & then I_{C_1}

$$g_{m_4} \Rightarrow V_{GSQ} = V_{DD} \cdot \frac{R_{B2}}{R_{B1}+R_{B2}}$$

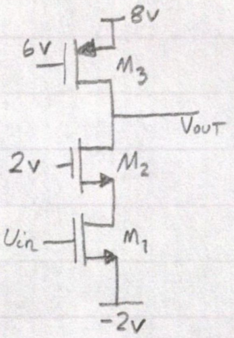
substitute

$$\boxed{A_V = \frac{I_{C_1}/V_t}{\mu C_{ox_p}\left(\frac{W}{L}\right)_2(V_{CE}-V_{DD}-V_{T_p})} \cdot \mu C_{ox_n}\left(\frac{W}{L}\right)_4\left(V_{DD}\cdot\frac{R_{B2}}{R_{B1}+R_{B2}} - V_{T_n}\right)(R_D||R_L)}$$

9

10 points

circuit 1

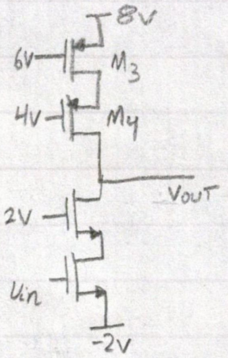


from lecture

L35 P3

$$\boxed{Av_1 = -\frac{g_{m_1}}{g_{o_1}}}$$

circuit 2

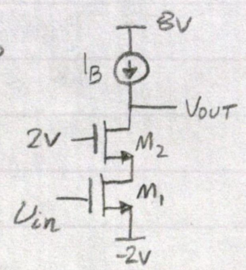


from lecture

L35 P3

$$\boxed{Av_2 = -\frac{1}{2}\,\frac{g_{m_1} \cdot g_{m_2}}{g_{o_1} \cdot g_{o_2}}}$$

circuit 3



from lecture

L35 P3

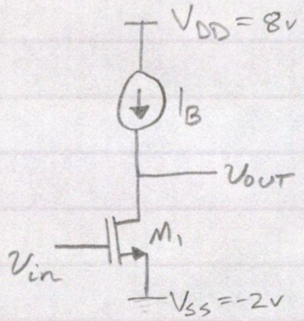
$$\boxed{Av_3 = -\frac{g_{m_1} \cdot g_{m_2}}{g_{o_1} \cdot g_{o_2}}}$$

Conclusion:

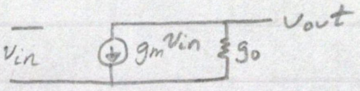
$$\boxed{|Av_3| > |Av_2| > |Av_1|}$$

$\boxed{10}$

10 points



$$I_B = I_D = \mu C_{ox} \frac{W}{2L} (V_{GS} - 0.5)^2$$



$$\frac{v_{out}}{v_{in}} = -\frac{g_{m_1}}{g_{o_1}}$$

$$g_m = \mu C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

$$g_m = \sqrt{2\mu C_{ox} \frac{W}{L}} \cdot \sqrt{I_{DQ}}$$

$$g_o = \lambda I_{DQ}$$

$$-100 = -\frac{\sqrt{2\mu C_{ox} \frac{W}{L}} \cdot \sqrt{I_{DQ}}}{\lambda I_{DQ}}$$

$$I_{DQ} = \left(\frac{100 \cdot \lambda}{\sqrt{2\mu C_{ox} \frac{W}{L}}} \right)^{-2}$$

$\lambda = 0.01$

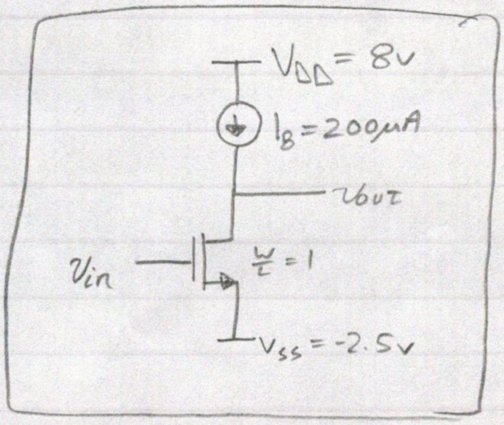
$\mu C_{ox} = 100\mu$

$\frac{W}{L} = 1$

$I_{DQ} = 200\mu A$

$$I_{DQ} = \mu C_{ox} \frac{W}{2L} \left((0 - V_{SS}) - 0.5 \right)^2 = 200\mu A$$

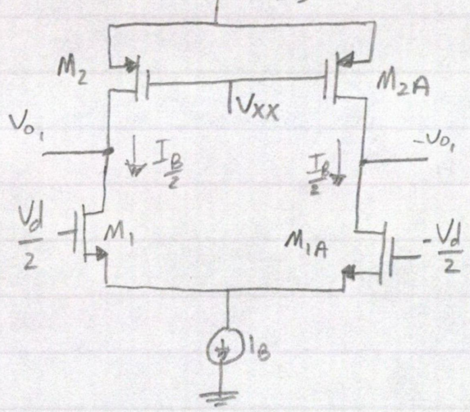
$$V_{SS} = -2.5$$



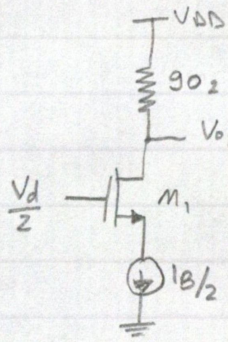
11

10 points

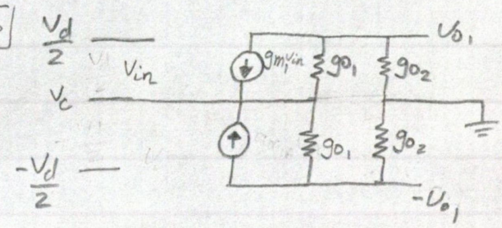
All in saturation



half circuit for differential
⇒ Amplifier



SS



V_c = common voltage for differential input

$$g_{m_1} v_{in} = (v_{o_1} - v_c) g_{o_1} + (v_{o_1}) g_{o_2}$$

$$v_{in} = \frac{v_d}{2} - v_c$$

$$v_c = 0$$

$$g_{m_1} v_{in} = v_{o_1}(g_{o_1} + g_{o_2})$$

$$\frac{v_{o_1}}{v_{in}} = \frac{g_{m_1}}{g_{o_1} + g_{o_2}}$$

$$\boxed{A_v = \frac{v_{o_1}}{v_d} = \frac{g_{m_1}}{(g_{o_1} + g_{o_2})} \cdot \left(\frac{1}{2}\right)}$$