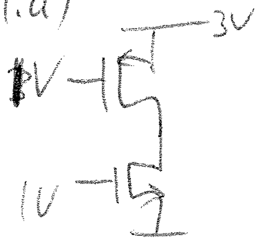
3.1.a)



assume both devices are saturated

$I_{DP} = \frac{K_p'}{2}\left(\frac{W}{L}\right)_p (2V-0.8V) = 200 \cdot 1.44\mu A = 288\mu A$

$I_{DN} = \frac{K_n'}{2}\left(\frac{W}{L}\right)_n (1V-0.7V) = 600 \cdot 0.09\mu A = 54\mu A$

$300 \cdot 0.09 = 27\mu A$

$I_{DN} < I_{DP} \Rightarrow$ p device is ohmic

$I_{DP} = I_{DN} = K_p' \frac{W}{L}\left((V_{GS}-V_T)V_{DS} - V_{DS}^2/2\right)$

$V_{DS}^2 - 2(V_{GS}-V_T)V_{DS} + \frac{2I_{DN}}{K_p'\frac{W}{L}} = 0$

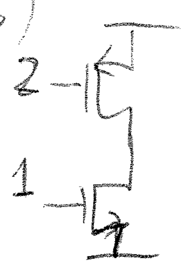
$V_{DS} = (V_{GS}-V_T) \pm \sqrt{(V_{GS}-V_T)^2 - \frac{2I_{DN}}{K'\frac{W}{L}}} = 251mV \Rightarrow V_{out} = 2.749V$

$1.2V + \sqrt{0.9}$ would get us into saturation $V_{out} = 2.882V$

linear ohmic equation only

$V_{DS} = \frac{I_{DN}}{K_p'\frac{W}{L}(V_{GSp}-V_{Tp})} = 225mV$

3.1.b)



assume both in saturation

$I_{DN} = 54\mu A$

$I_{DP} = \overset{100 \cdot (0.2)^2}{200 \cdot (0.2)^2} = 8\mu A = 4\mu A$

therefore N device is ohmic

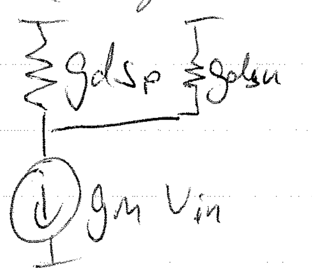
$I_{DN} = I_{DP} = K_N' \frac{W}{L}\left((V_{GS}-V_T)V_{DS} - V_{DS}^2/2\right)$

$V_{DS} = (V_{GS}-V_T) \pm \sqrt{(V_{GS}-V_T)^2 - \frac{2I_{DP}}{K'\frac{W}{L}}} = 48.3mV$

if I used linear only

$V_{DS} = V_{out} = 44.4mV = 23mV$

3.1 a small signal model



gain $A = \frac{V_{out}}{V_{in}} = -g_m/(g_{dsp}+g_{dsn})$

N-device saturation $g_m = \sqrt{2K_n' \frac{W}{L} I_D}$ ohmic $g_m = K' \frac{W}{L} V_{DS}$

P-device ohmic $g_{ds} = K_p' \left(\frac{W}{L}\right)_p (V_{GS}-V_T)$ sat. $g_{ds} = \lambda_p \cdot I_D$

a) $$\frac{V_{out}}{V_{in}} = -\frac{\sqrt{2K_n'\left(\frac{W}{L}\right)_n I_D}}{K_p'\left(\frac{W}{L}\right)_p (V_{GS}-V_T)} = -\frac{\sqrt{1200 \cdot 54} \to 27}{200 \cdot 1.2 + g_{dsn}} = -1.06 =$$

$=.106$

b) $$\frac{V_{out}}{V_{in}} = \frac{-K_n' \frac{W}{L} V_{DS}}{\lambda_p I_D + K_n'\left(\frac{W}{L}\right)_n (V_{GS_n}-V_T)} = \frac{-600 \cdot 48.3 \cdot 10^{-3}}{0.03 \cdot 8 + 600 \cdot 0.3} = -1.58$$

3.2

output impedance requires cascoding

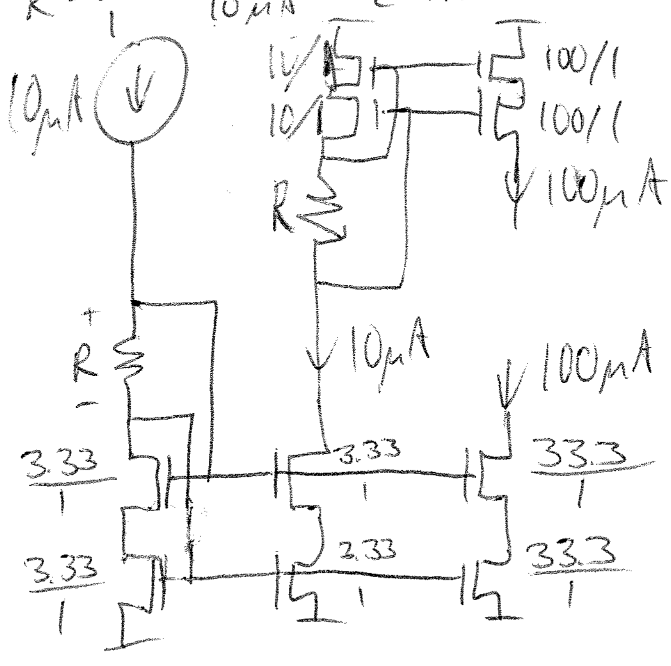
assume $V_{out\,min} = 2\,V_{DS\,min} = 2\,V_{on}$

N device: $V_{on} = \sqrt{\dfrac{I_D}{\frac{K'}{2}\frac{W}{L}}} = \sqrt{\dfrac{10\mu A}{75\mu A/V^2\,\frac{W}{L}}} = 0.2V$

$\Rightarrow \dfrac{W}{L} = \dfrac{10\mu A}{75\mu A/V^2\,(0.2V)^2} = 3.33$

P device W must be 3x larger $\Rightarrow \frac{W}{L} = 10$

$R = \dfrac{V}{I} = \dfrac{200mV}{10\mu A} = 20k\Omega$



3.3

from lecture $G = \sqrt{k' \frac{W}{L} I_D} = 1mS$

make $I_D = 100\mu A \Rightarrow \frac{W}{L} = \frac{(1mS)^2}{k' I_D} = 66.66$

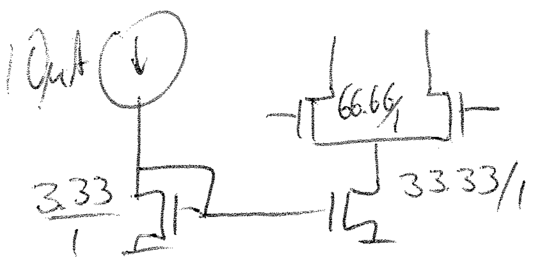
look at $V_{Cmin} = 1V$

$V_{Cmin} = V_T + V_{on\,tail} + V_{on\,diffpair}$

$V_{on\,diff} = \sqrt{\frac{I_D}{\frac{k'}{2}\frac{W}{L}}} = \sqrt{\frac{50\mu A}{75\mu A/V^2 \cdot 66.66}} = 100mV$

$V_{on\,tail} = \sqrt{\frac{I_D}{\frac{k'}{2}\frac{W}{L}}} = 200mV \Rightarrow \frac{W}{L} = \frac{100\mu A}{75\mu A/V^2 \cdot (0.2)^2} = 33.33$

$V_{out\,min} = V_{Cmin\,max} \cancel{+} V_T = 0.8V$



3.4

N current mirror takes in $10\mu A$, produces $I1 = 20\mu A$, $30\mu A$, $40\mu A$

balanced diffpair splits current evenly $I_2 = I_3 = 10\mu A$

P current mirror takes in $10\mu A$, produces $50\mu A$

$I_5 = 50\mu A - 40\mu A = 10\mu A$

unbalanced diffpair: all current goes through M2

$I_4 = \emptyset$ if $\sqrt{\frac{30\mu A}{\frac{k'}{2}\frac{W}{L}}} < 2V$