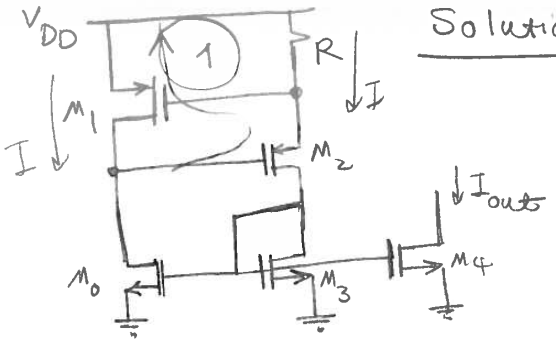
Solutions to Assignment 4

1)



Assuming all Trans. are in sat. & $\lambda = \gamma = 0$, $V_{DD} = 3^{V}$

$V_{tn} = .5^{V}$, $V_{tp} = -.5^{V}$ $K_n' = \mu_n C_{ox} = .2 \frac{mA}{V^2}$, $K_p' = \mu_p C_{ox} = .1 \frac{mA}{V^2}$

$\left(\frac{W}{L}\right)_{0,3,4} = \frac{W}{L}$, $\left(\frac{W}{L}\right)_1 = 16$, $I_{out} = 50\ \mu A \Rightarrow$ find R:

② Since $\lambda = \gamma = 0 \Rightarrow V_{gs_0} = V_{gs_3} = V_{gs_4} \Rightarrow I = I_0 = I_3 = I_4 = I_{out} = 50^{\mu A}$

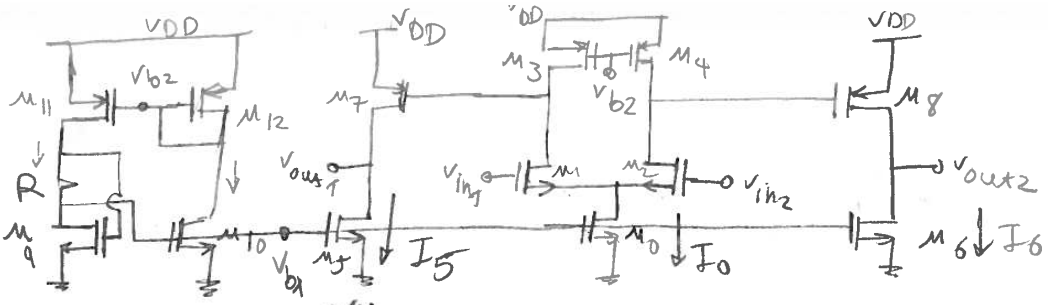
Having a KVL around loop 1: $V_{sg_1} = RI = RI_{out}$

Moreover: $I = \frac{1}{2} K_p' \left(\frac{W}{L}\right)_1 (V_{sg_1} - |V_{tp}|)^2 \Rightarrow 50^{\mu} = \frac{1}{2} \times 100 \times 16 \times (V_{sg_1} - |V_{tp}|)^2$

$\Rightarrow V_{sg1} - |V_{tp}| = \sqrt{\frac{2 \times 50}{100 \times 16}} = .25^{V} \Rightarrow V_{sg1} = .5 + .25 = .75^{V}$

$\Rightarrow V_{sg1} = .75 = R \times 50^{\mu A} \Rightarrow R = \frac{.75}{50} \times 1000 = 15^{K\Omega}$

2)



$V_{DD}=1.8^V$ $P_{de_{total}}=1.98^{mW}$ $A_{v_{total}}=4000$, $L=.4^{um}$, $W_{11}=W_{12}$

$W_{10}=4W_9$, $R=1^{k\Omega}$, $I_0=I_5+I_6$, $V_{ov_4}=V_{ov_6}=V_{ov_8}$, $I_{11}=.1I_0$

$\lambda_n=\lambda_p=.1\ V^{-1}$, $\gamma=0$, $V_{tn}=-V_{tp}=.4V$, $k_n'=1\ mA/V^2$, $k_p'=.5\ mA/V^2$

Find $W_0, W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8, W_9, W_{10}, W_{11}, W_{12}$

Since $(\frac{W}{L})_{11}=(\frac{W}{L})_{12} \Rightarrow I_9=I_{10}$, $P_{dc}=1.98=V_{DD}\{2\times I_{10}+2I_9+I_0\}$

$\Rightarrow \frac{1.98}{1.8}=2I_{10}+2I_5+I_0 \Rightarrow \frac{1.98}{1.8}=2\times.1I_0+I_0+I_0 \Rightarrow 2.2I_0=\frac{1.98}{1.8}$

$\Rightarrow I_0=.5^{mA} \Rightarrow I_{10}=.1\times.5=.05^{mA}$

Back to the last question: $.05=\left\{\sqrt{\frac{2}{1\times(\frac{W}{L})_9}}-\sqrt{\frac{2}{1\times4(\frac{W}{L})_9}}\right\}^2$

$\Rightarrow (\frac{W}{L})_9=\frac{1}{.05}\times\left\{\sqrt{2}-\sqrt{\frac{2}{4}}\right\}^2=\frac{1}{.05}\times\left\{2+\frac{1}{2}-2\right\} \Rightarrow \boxed{(\frac{W}{L})_9=10}$

$\Rightarrow \boxed{(\frac{W}{L})_{10}=10\times4=40}$

$A_{v_{total}}=+g_{m_1}(r_{o_3}\|r_{o_1})\times g_{m_7}\times(r_{o_7}\|r_{o_5})$

$r_{o_1}=r_{o_3}=\frac{1}{\lambda I_{\frac{0}{2}}}=\frac{1}{.1\times\frac{.5}{2}}=40^{k\Omega}$, $r_{o_7}=r_{o_5}=\frac{1}{\lambda I_5}=\frac{1}{\lambda I_{\frac{0}{2}}}=r_{o_1}=r_{o_3}$

$A_{v_{total}}=4000 \Rightarrow \boxed{g_{m_1}\times g_{m_7}=10}$

$V_{b_1}=V_{tn}+\sqrt{\frac{2I_{10}}{k_n'(\frac{W}{L})_{10}}} \Rightarrow V_{b_1}=.45^V \Rightarrow I_5=\frac{1}{2}k_n'(\frac{W}{L})_5(V_{b_1}-V_{tn})^2$

$\Rightarrow \boxed{(\frac{W}{L})_5=\frac{2\times.05}{.05^2}=40=(\frac{W}{L})_6}$, $\boxed{(\frac{W}{L})_0=2(\frac{W}{L})_5=80}$

Since $V_{ov_4} = V_{ov_6} = V_{ov_8} = .05^{V}$, $I_8 = I_6 = \frac{I_o}{2} = .025^{mA}$

$\Rightarrow .15 = \frac{1}{2} k'_p \left(\frac{W}{L}\right)_8 (.05)^2 \Rightarrow .25 = \frac{1}{2} \times .5 \times \left(\frac{W}{L}\right)_8 \times .0025 \Rightarrow \left(\frac{W}{L}\right)_8 = 400$

$\Rightarrow \boxed{\left(\frac{W}{L}\right)_8 = \left(\frac{W}{L}\right)_7 = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = 400}$

$\Rightarrow g_{m_7} = \sqrt{2 \times k'_p \times \left(\frac{W}{L}\right)_7 \times I_7} = \sqrt{2 \times .5 \times 400 \times .025} = 10^{mV}$

$g_{m_1} \times g_{m_7} = 10 \Rightarrow g_{m_1} = \frac{10}{10} = 1^{mV}$

$\Rightarrow 1 = \sqrt{2 k'_n \times \left(\frac{W}{L}\right)_1 \times \frac{I_o}{2}} \Rightarrow \boxed{\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = 2}$

$V_{ov_4} = .05 \Rightarrow V_{sg_4} = .4 + .05^{V} = .45^{V} \Rightarrow V_{b_2} = V_{DD} - V_{sg_4} = 1.8 - .45 = 1.35^{V}$

$\Rightarrow V_{sg_{11,12}} = 1.8 - 1.35 = .45^{V} \Rightarrow I_{D_{11,12}} = \frac{1}{2} k'_p \left(\frac{W}{L}\right)_{11,12} (.05)^2$

$\Rightarrow \boxed{\left(\frac{W}{L}\right)_{11} = \left(\frac{W}{L}\right)_{12} = 80}$