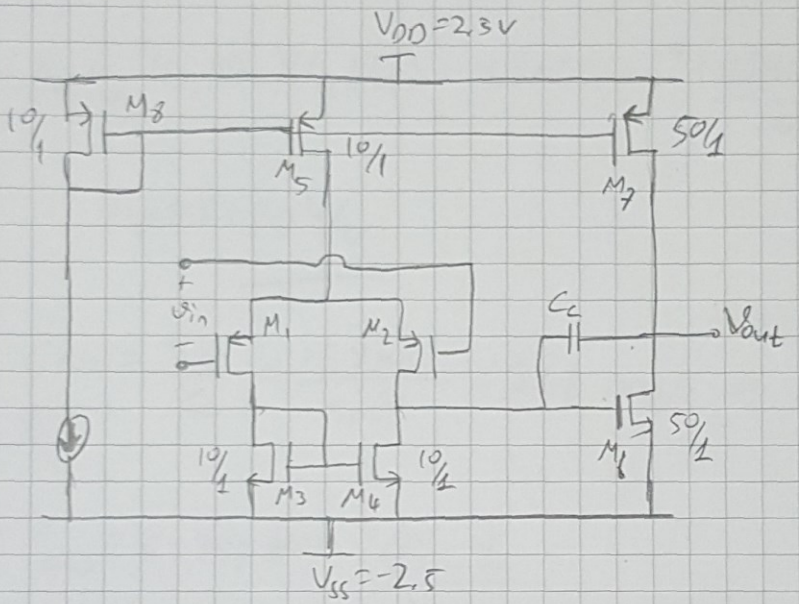
EE 414 - Introduction to Analog Integrated Circuits

Take Home Exam - 3

Problem 1:



M_N: $\lambda = 0.04 V^{-1}$, $V_{TN} = 0.7V$, $K_N' = 110 \mu A/V^2$

M_P: $\lambda = 0.05 V^{-1}$, $V_{TP} = 0.7V$, $K_P' = 50 \mu A/V^2$

a) Slew Rate $= I_5/C_C = \frac{50\mu A}{5pF} = \underline{\underline{10^7 V/sec}}$

b) $V_{SD_7} = \sqrt{\frac{2I_7}{K_P(W/L)_7}} = \sqrt{\frac{500}{50 \times 50}} = 0.447V$ similarly $V_{DS_6} = \sqrt{\frac{500}{110 \times 50}}$

$V_{DS_6} = 0.302V$

$V_{OUT_{max}} = V_{DD} - V_{DS_7} = \underline{\underline{2.053V}}$

$V_{OUT_{min}} = V_{SS} + V_{DS_6} = \underline{\underline{-2.198V}}$

c) $ICM_{min} = V_{SS} + V_{GS_3} - |V_{TP}| = -2.5 + \sqrt{\frac{2 \times 25}{110 \times 10}} + 0.7 - 0.7 = \underline{\underline{-2.287V}}$

$ICM_{max} = V_{DD} - V_{SD_5(SAT)} - V_{SG_1} = 2.5 - 0.447 - 1.016 = \underline{\underline{1.0366V}}$

d) $A_V = g_{m_1} g_{m_6} (r_{O2} \| r_{O4})(r_{O6} \| r_{O7})$

$g_{m_1} = \sqrt{2K_P'(W/L)_1 I_1} = \sqrt{2 \times 50 \times 10 \times 25} = 158 \mu S$

$g_{m_6} = \sqrt{2K_N'(W/L)_6 I_6} = \sqrt{2 \times 110 \times 50 \times 250} = 1.66 mS$

$r_{o2} = 1/\lambda_p I_2 = \frac{1}{0{,}05 \times 25 \times 10^{-6}} = 0{,}8\,M\Omega$ $\quad r_{o4} = \frac{1}{\lambda_n I_4} = \frac{1}{0{,}04 \times 25 \times 10^{-6}} = 1\,M\Omega$

$r_{o7} = \frac{1}{\lambda_p I_2} = \frac{1}{0{,}05 \times 250 \times 10^{-6}} = 80\,k\Omega$ $\quad r_{o6} = \frac{1}{\lambda_n I_6} = \frac{1}{0{,}04 \times 250 \times 10^{-6}} = 100\,k\Omega$

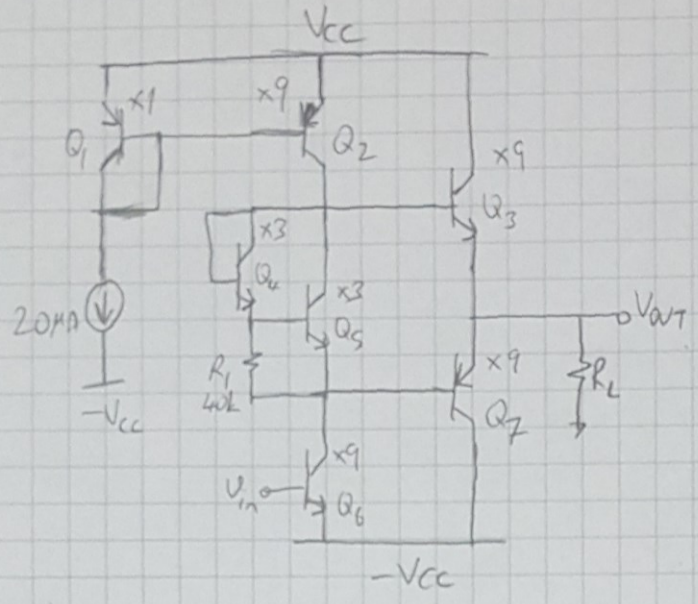
$A_v = g_{m1}\, g_{m6} (r_{o2} \| r_{o4})(r_{o6} \| r_{o7}) = 158 \times 1{,}66 \times 10^{-9} \underbrace{(0{,}8M \| 1M)}_{444k} \underbrace{(80k \| 100k)}_{44{,}4k}$

$A_v \simeq 5170\ V/V$

e) $GBW = \frac{g_{m1}}{C_c} = \frac{158\,\mu S}{5pF} = 31{,}6\ Mrad/s \Rightarrow GBW = 5{,}03\,MHz$

f) $P_{diss} = 5 \times 350\,\mu A = 1{,}75\,mW$

Problem 2:



$I_{S_1} = 1,11\,fA \quad \beta_{npn} = \beta_{pnp} = 100$

$V_{BE(ON)} = 0,6V \quad V_{CE(SAT)} = 0,2V$

$V_{CC} = 10V \;,\; V_T = 26mV$

$I_{C_2} = 9 I_{C_1} = \underline{\underline{180MA}} \Rightarrow I_{C_6} = \underline{\underline{180MA}}$

$I_{C_4} = \frac{0,6}{40k} = \underline{\underline{15MA}} \qquad I_{C_5} = 180 - 15 = \underline{\underline{165MA}}$

$V_{BE_3} + V_{EB_7} = V_{BE_4} + V_{BE_5}$

$V_T \ln \frac{I_{C_3}}{I_{S_3}} + V_T \ln \frac{I_{C_7}}{I_{S_7}} = V_T \ln \frac{I_{C_4}}{I_{S_4}} + V_T \ln \frac{I_{C_5}}{I_{S_5}}$

$\frac{I_{C_3} \cdot I_{C_7}}{I_{S_3} I_{S_7}} = \frac{I_{C_4}}{I_{S_4}} \cdot \frac{I_{C_5}}{I_{S_5}} \Rightarrow I_{C_3} = I_{C_7} = \sqrt{I_{C_4} I_{C_5}}$

$= \underline{\underline{149,2MA}}$

b) $V_{OUT_{max}} = 10 - V_{BE_3} - V_{EB_2} = 10 - 0,6 - 0,2 = \underline{\underline{9,2V}}$

$V_{OUT_{min}} = -10 + 0,2 + 0,6 = \underline{\underline{-9,2V}}$

$R_L = 1k\Omega \quad I_{OUT_{max}} = \frac{15 - 0,2 - V_T \ln \frac{I_{OUT_{max}}}{R_L}}{R_L} \Rightarrow I_{OUT_{max}} = \underline{\underline{14,07A}}$

c) $P_L = \frac{1}{2} I_o^2 R_L = 99\,mW$

$P_{supply} = \frac{1}{\pi} \times (2V_{CC} \times \hat{I}_o) = 134mW$

$\eta = \frac{P_L}{P_{supply}} \times 100 = \underline{\underline{73,68\%}}$