03/25-04/04/10
K.

Solutions 303 Midterm

#1. $I_C = \beta I_B$ & $V_{CE} = V_{CC} - (R_L + \frac{R_E}{\alpha}) I_C = V_{CC} - (R_L + [\frac{1+\beta}{\beta}] R_E)\beta I_B$ so find I_B

$I_{R_a} = I_B + I_{R_b}$

$V_{R_b} = V_{BE} + R_E \cdot \frac{I_C}{\alpha} = V_{BE} + R_E \frac{\beta}{\alpha} I_B = V_{BE} + R_E(1+\beta) I_B$

$\Rightarrow I_{R_b} = \frac{1}{R_b}\{V_{BE} + R_E(1+\beta)I_B\} \Rightarrow I_{R_a} = \{1 + \frac{R_E}{R_b}(1+\beta)\} I_B + \frac{V_{BE}}{R_b}$

$V_{CC} = R_a I_{R_a} + R_b I_{R_b} = R_a\{1 + \frac{R_E}{R_b}(1+\beta)\} I_B + \frac{R_a}{R_b} V_{BE} + \{V_{BE} + R_E(1+\beta) I_B\}$
$= [R_a\{1 + \frac{R_E}{R_b}(1+\beta)\} + R_E(1+\beta)] I_B + (1 + R_a/R_b) V_{BE} = [R_a + \{1 + \frac{R_a}{R_b}\} R_E(1+\beta)] I_B + \{1 + \frac{R_a}{R_b}\} V_B$

$\Rightarrow I_B = \frac{V_{CC} - \{1 + \frac{R_a}{R_b}\} V_{BE}}{R_a + \{1 + \frac{R_a}{R_b}\} R_E (1+\beta)} = \frac{9 - 2 \times 0.7}{10^6 + 2\times 10^3 (1+\beta)} = \frac{7.6}{10^6 + 2\times 10^3(\beta+1)}$

$I_B \Big|_{\beta=200} = 5.42 \times 10^{-6} A = 5.42\ \mu A$

$\Rightarrow I_C \Big|_{\beta=200} = 1.084 \times 10^{-3} A = 1.08\ mA$

a) $V_{CE} = 9 - 10^3(1 + \frac{201}{200}) \times 1.084 \times 10^{-3} = 9 - 2.17 = 6.83\ V$

b) $I_B = \frac{7.6}{10^6 + 10^3 \times 22} = \frac{7.6 \times 10^{-6}}{1.022} = 7.44\ \mu A$

$I_C = 10 \times 7.44 \times 10^{-6} = 0.0744\ mA$

$V_{CE} = 9 - 10^3(1 + \underbrace{\frac{11}{10}}_{21}) \times 10 \times 7.44 \times 10^{-6} = 9 - 156 \times 10^{-3} = 9 - 0.156 = 8.844\ V$

c) $g_m = \frac{I_C}{V_T}$, $V_T = 0.026 \Rightarrow g_{m_s} = \frac{1.09 \times 10^{-3}}{26 \times 10^{-3}} = 0.0419$

$g_{m_r} = \frac{74.4 \times 10^{-6}}{26 \times 10^{-3}} = 2.863 \times 10^{-3} = 0.00286$

as $A_v = -g_m R_L \Rightarrow A_{v_s} = -41.9$

$\Rightarrow A_{v_r} = -2.86$

#2. a) By symmetry the drains sit at ground potential when no external signals are applied. Then all NMOS currents are equal & PMOS their negatives as all transistors are in saturation (#'s 1 are by connection & #'s 2 by having all voltages of #1's).
Thus

$$I_{D_{n_1}} = I_{D_{n_2}} = -I_{D_{p_1}} = -I_{D_{p_2}} = I_D$$

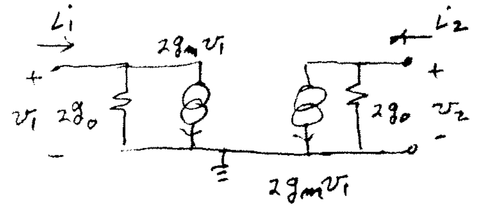
$$= \frac{KP}{2}\frac{W}{L}(V_{dd}-V_{TO})^2(1+\lambda V_{dd})$$

$$= \frac{20.54\times10^{-6}}{2}\cdot\frac{144\mu}{8\mu}(5-1.3)^2(1+15\times10^{-3}\times5)$$

a) $$= 184.86\times10^{-6}(13.69)(1.075) = 2,721\times10^{-6} = 2.72\ mA$$

b) The bias power is that supplied by the batteries for the currents of part a). Thus

$$Power_{bias} = 4\times I_D\times V_{dd} = 54.4\times10^{-3}\ Watts = 54.4\ mW$$

c) 

$$\Rightarrow Y = \begin{bmatrix} 2(g_0+g_m) & 0 \\ 2g_m & 2g_0 \end{bmatrix}$$

$$g_m = \frac{2I_D}{(V_{GS}-V_{TO})} = 2\frac{2.72\times10^{-3}}{(5-1.3)} = \frac{5.44}{3.7}m\mho = 1.47\ m\mho$$

$$g_0 = \frac{\lambda I_D}{1+\lambda V_{DS}} = \frac{15\times10^{-3}\times2.72\times10^{-3}}{1.075} = 37.95\times10^{-6}\ \mho$$

d) $$A_v(s) = \frac{-y_{21}}{y_{22}+y_L} = \frac{-2g_m}{2g_0+sC_L} = \frac{-2.94\times10^{-3}}{75.9\times10^{-6}+20\times10^{-9}s} = -\frac{2.94\times10^{-3}}{20\times10^{-9}}\times\frac{1}{s+\frac{75.9\times10^{-6}}{20\times10^{-9}}}$$

$$= -147\times10^{3}\times\frac{1}{s+3.80\times10^{3}}$$

pole @ $s_p = -3.80\times10^{-3}$
zero @ s_z = infinity