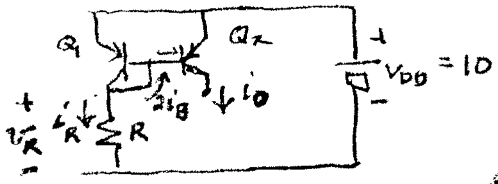
EE303H F2013 Midterm Solutions

#1.



$i_{E_1} = i_{E_2} = -\frac{1}{\alpha} i_{C_1} = -\frac{1}{\alpha} i_{C_2}$; $i_o = -i_{C_2} = 3\times10^{-3}A$

$i_R = -i_{C_1} - 2i_B = -\beta i_B - 2i_B = -(2+\beta) i_B$

$\beta i_B = i_{C_2} = -i_o \Rightarrow i_B = -\frac{i_o}{\beta} \Rightarrow i_R = \frac{2+\beta}{\beta} \cdot i_o$

$\Rightarrow i_R = \left(\frac{102}{100}\right) \cdot 3\times10^{-3} = 3.06\,mA$

$v_R = V_{DD} - V_{BE} = 9.3 = R\, i_R = R\times3.06\times10^{-3} \Rightarrow R = \frac{9.3}{3.06}\times10^{3} = 3.04K\Omega$

since $i_C(v_{EC}) = i_{C_0}\left(1+\frac{v_{EC}}{V_A}\right) \Rightarrow i_{C_0} = \frac{3\times10^{-3}}{1+2/100} = i_C(8)$

$\Rightarrow i_C(9) = \frac{3\times10^{-3}}{1+2/100}\left(1+\frac{1}{100}\right) = \frac{101}{102}\times3\times10^{-3} = 2.971\times10^{-3} = 2.97mA$

(vs. 3.0 designed)

#2. For complementary M_p & M_n, $v_O = V_{DD}/2$ when $v_I = V_{DD}/2$
so both transistors are in saturation as

$|v_{GS}| - |V_{TO}| = 5-1=4 < 5 = |v_{DS}|$

$i_S = \frac{KP}{2}\cdot\frac{W}{L}\cdot(|v_{GS}|-|V_{TO}|)^2(1+\lambda|v_{DS}|) = \frac{5}{2}\times10^{-4}(5-1)^2(1+0.01\times5)$

a) $= \frac{5\times16}{2}\times(1.05)\times10^{-4} = 4.20\times10^{-3}A$

b) as no current flows in V_i its power delivered is 0.
The power out of V_{DD} is $i_S\times V_{DD} = 42\times10^{-3}$ Watts

#3.

a) $I_S = V_o/R_L = 3V/2k\Omega = \frac{3}{2}\times 10^{-3} A$

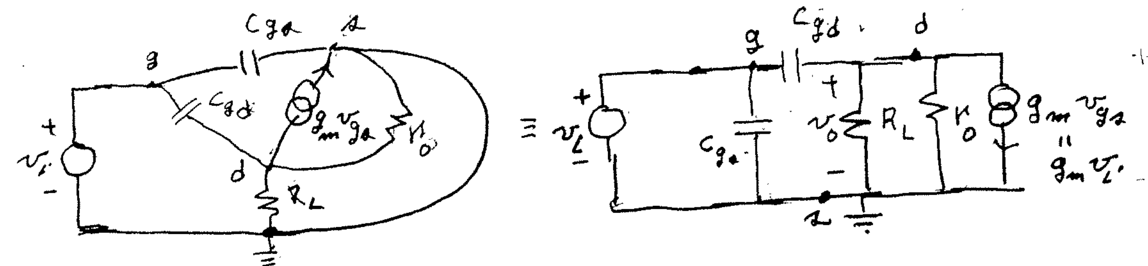
$g_m = \frac{\partial i_S}{\partial v_{GS}}\Big|_{I_S = 1.5mA}$; M_p is in saturation as $|V_{GS}| = 10-8 = 2$

so $|V_{GS}| - |V_{TO}| = 2-1 = 1 < 10-3 = 7 = |V_{DS}|$

$= 2\frac{I_S}{(|V_{GS}| - |V_{TO}|)} = \frac{3\times10^{-3}}{1} = 3\, m\mho$

$g_o = \frac{\partial i_S}{\partial v_{DS}}\Big|_{I_S = 1.5mA} = \frac{\lambda I_S}{(1+\lambda|V_{DS}|)} = \frac{0.01\times 3/2\times10^{-3}}{1+0.01\times 7} = \frac{1.5\times10^{-5}}{1.07} \approx 1.40\times10^{-5}\,\mho$

b)



c) Use KCL @ d-s;

$i_{C_{gd}} = sC_{gd}(v_i - v_o) = i_{R_L} + i_{r_o} + g_m v_{gs} = (G_L + g_o)v_o + g_m v_i$

$\equiv \quad (sC_{gd} - g_m)v_i = (sC_{gd} + [G_L + g_o])v_o$

$\Rightarrow \quad \frac{v_o}{v_i}(s) = \frac{C_{gd}(s - g_m/C_{gd})}{C_{gd}\left(s + \frac{[G_L+g_o]}{C_{gd}}\right)} = \frac{s - \left(\frac{g_m}{C_{gd}}\right)}{s + \left(\frac{G_L+g_o}{C_{gd}}\right)}$

zero: $s = g_m/C_{gd}$, pole: $s = -\left(\frac{G_L+g_o}{C_{gd}}\right)$

d) zero: $s = \frac{3\times10^{-3}}{5\times10^{-12}} = \frac{3}{5}\times10^{9} = 0.6\times10^{9}$ (radian Hertz)

pole: $s = -\left(\frac{\frac{10^{-3}}{2} + 1.4\times10^{-5}}{5\times10^{-12}}\right) = -\frac{(50+1.4)\times10^{-5}}{5\times10^{-12}} = -10.28\times10^{+7}$ (radian Hertz)