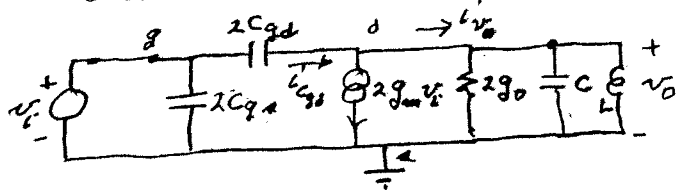
11/05-09/12
V.1

EE 303 Midterm Continuation F2012

#1. a) as $V_G = V_D = V_{DD}/2 = 5 = |V_{DS}|_{n or p} = |V_{GS}|_{n or p} \Rightarrow |V_{DS}| > |V_{GS}| - |V_{TO}| \Rightarrow$ saturation of M_p & M_n

$$\Rightarrow I_{D_n} = -I_{D_p} = \frac{KP}{2}\cdot\frac{W}{L}(V_{GS_n} - VTO_n)^2(1+\lambda_n V_{DS_n})$$
$$= \frac{4\times10^{-4}}{2}\times1\times(5-1)^2(1+0.01\times5) = 2\times10^{-4}\times16\times1.05 = 33.6\times10^{-4}$$
$$= 3.36\ mA$$

b) M_n & M_p become in parallel and have equal g_m, g_o and C's these become double



c) $i_{C_{gd}} = 2C_{gd}s(v_i - v_o)$; $i_{v_o} = i_{C_{gd}} - 2g_m v_i = (2g_o + sC + \frac{1}{sL})v_o$

$\therefore (2g_o + sC + \frac{1}{sL})v_o = 2C_{gd}sv_i - 2C_{gd}sv_o - 2g_m v_i$

$\Rightarrow (2g_o + sC + \frac{1}{sL} + 2C_{gd}s)v_o = (2C_{gd}s - 2g_m)v_i$

$$\Rightarrow \frac{v_o}{v_i}(s) = \frac{2sL(C_{gd}s - g_m)}{(C+2C_{gd})Ls^2 + 2g_oLs + 1}$$

d) for $C = C_{gd}$, $\frac{v_o}{v_i} = \frac{2sLC(s + g_m/C)}{3CLs^2 + 2g_oLs + 1} = \frac{2sLC(s - g_m/C)}{3LC(s^2 + \frac{2g_o}{3C}s + \frac{1}{3CL})}$

$= \frac{2}{3}\cdot\frac{s(s - g_m/C)}{s^2 + \frac{2g_o}{C}s + \frac{1}{3LC}}$; denominator factors $s_{1,2} = -\frac{g_o}{C} \pm \frac{1}{2}\sqrt{4(\frac{g_o}{C})^2 - 4\frac{1}{3LC}}$

$= -\frac{g_o}{C}\left[1 \pm \sqrt{1 - \frac{C}{3Lg_o^2}}\right]$

zeros: $s = 0,\ g_m/C$

poles: $s = -\frac{g_o}{C}\left[1+\sqrt{1-\frac{C}{3Lg_o^2}}\right], -\frac{g_o}{C}\left[1-\sqrt{1-\frac{C}{3Lg_o^2}}\right]$

Numerically need $g_m = \frac{I_{D_n}}{2(V_{GS_n} - VTO_n)} = \frac{2\times16\times1.05\times10^{-4}}{2\times4} = 4.2\times10^{-4}$; $g_o = \frac{\lambda I_{D_n}}{(1+\lambda V_{DS_n})} = \frac{10^{-2}\times2\times16\times1.05\times10^{-4}}{1.05} = 32\times10^{-6}$

$\therefore g_m/C = \frac{4.2\times10^{-4}}{10\times10^{-12}} = 4.2\times10^{+7}$

$g_o/C = \frac{32\times10^{-6}}{10\times10^{-12}} = 32\times10^{+5}$; $\frac{C}{3Lg_o^2} = \frac{1}{3\cdot10\times10^{-9}\times g_o\times g_o/C} = \frac{1}{3\times10^{-8}\times32\times10^{-6}\times32\times10^{5}} = \frac{10^9}{3\times32^2}$

$1 - \frac{C}{3Lg_o^2} = \frac{3\times32^2 - 10^9}{3\times32^2} = \frac{0.3074\times10^4 - 10^9}{3\times32^2} \approx -\frac{10}{3}\times\frac{10^8}{32^2}$

$\Rightarrow -(g_o/C)\left[1 \pm \sqrt{1 - \frac{C}{3Lg_o^2}}\right] \approx -32\times10^5\left[1 \pm j\sqrt{\frac{10}{3}}\cdot\frac{10^4}{32}\right]$

$\therefore$ zero @ $s = 0, +4.2\times10^7$

poles @ $s \approx -32\times10^5\left[1 + j\frac{3.15}{32}\times10^4\right], -32\times10^5\left[1 - j\frac{3.15}{32}\times10^4\right]$

$= -32\times10^5 \pm j\,3.15\times10^9$

#2. If in saturation

a) $I_S = \frac{KP}{2}\frac{W}{L}(|V_{GS_p}| - |VTO_p|)^2(1+\lambda|V_{DS_p}|) = \frac{4}{2}\times10^{-4}\cdot 1\cdot(V_{DD}-V_G-1)^2(1+\lambda[V_{DD}-V_O])$

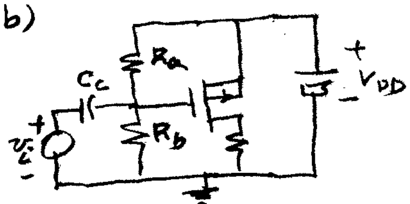
But $I_S = 2\times10^{-3} \Rightarrow V_O = I_S \cdot R_L = 2\times10^{-3}\times1\times10^3 = 2V$

$\Rightarrow I_S = 2\times10^{-3} = 2\times10^{-4}(10-V_G-1)^2(1+0.01[10-2]) = 2\times10^{-4}\times(9-V_G)^2(1+0.08)$

$\Rightarrow (9-V_G)^2 = \frac{10}{1.08} \Rightarrow 9-V_G = \pm\sqrt{\frac{10}{1.08}}$ $\Rightarrow$ need + as $V_{SG} = 9-V_G > 0$

$\Rightarrow V_G = 9-\sqrt{\frac{10}{1.08}}$; check for saturation $V_{SG}-1 = \sqrt{\frac{10}{1.08}}-1 = \; < V_{SD} = 8$

$\approx 9-3.043 = 5.957$

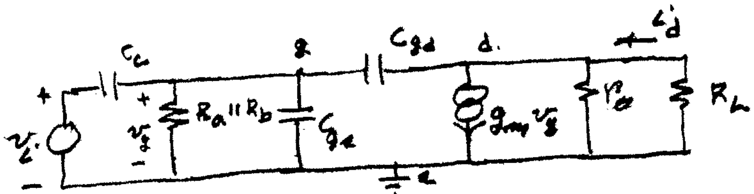
b) 

Need C_c large $\to\infty$

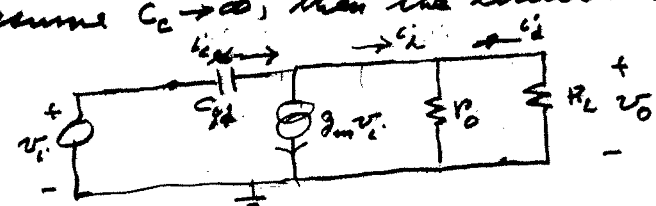
Need $\frac{R_b}{R_a+R_b}\cdot V_{DD} = V_G = \frac{1}{1+R_a/R_b}\cdot V_{DD}$

$\Rightarrow 1+\frac{R_a}{R_b} = \frac{V_{DD}}{V_G} \Rightarrow \frac{R_a}{R_b} = \frac{V_{DD}}{V_G} - 1 = \frac{10}{5.96} - 1 \approx 0.68$

Choose R_b large, say 10 Meg Ω $\Rightarrow R_a = 6.8$ Meg Ω if $R_b = 10$ Meg Ω

c) 

d) assume $C_c \to \infty$, then the circuit is



Here $i_d = -v_o/R_L$; $= -G_L v_o$

$i_{C_{gd}} = sC_{gd}(v_i - v_o)$; $i_L = (g_o+G_L)v_o = i_{C_{gd}} - g_m v_i$

$\Rightarrow (g_o+G_L)v_o = (sC_{gd}-g_m)v_i - sC_{gd}v_o$

$\Rightarrow v_o = \frac{(sC_{gd}-g_m)}{sC_{gd}+g_o+G_L}\cdot v_i$

$\Rightarrow \frac{i_d}{v_i} = -G_L\cdot\frac{s - g_m/C_{gd}}{s+(g_o+G_L)/C_{gd}}$

zeros: @ $s = g_m/C_{gd}$
poles: @ $s = -(g_o+G_L)/C_{gd}$