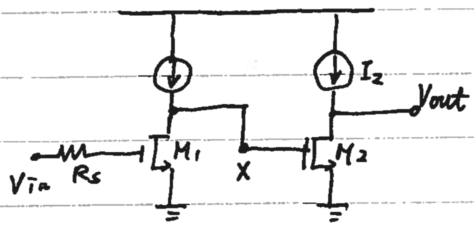
6.7

(a)



There are three poles associated with this circuit.

The first pole @ Vout

$$\omega_{p,out} = \frac{1}{r_{o2} \cdot (C_{gd2} + C_{DB2})}$$

Note that Cgd2 shoudld technically be multiplied by (1 + A) / A (Miller cap approximation), where A is the gain, 1 + gm*ro. However, in this case, (1 + A) / A is approximately 1

The pole @ the input

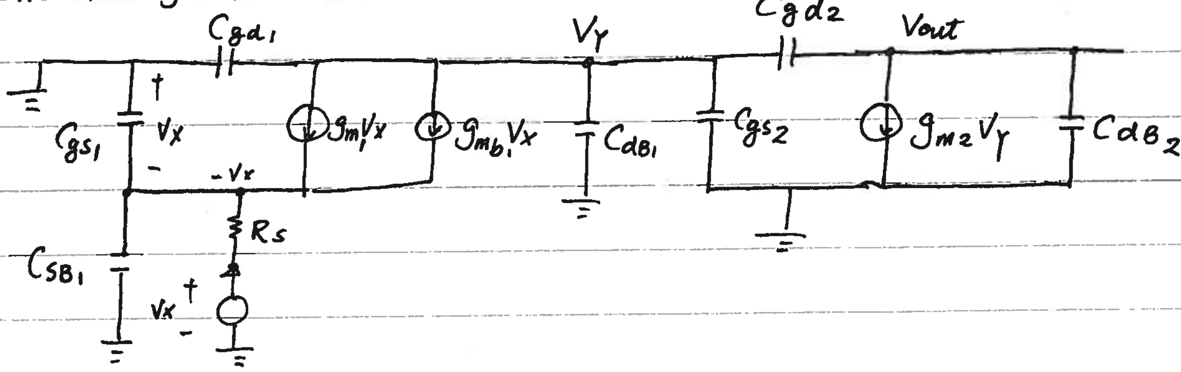
$$\omega_{p,in} = \frac{1}{R_S \cdot [(1 + g_{m1} r_{o1}) C_{gd1} + C_{gs1}]}$$

The pole @ node X

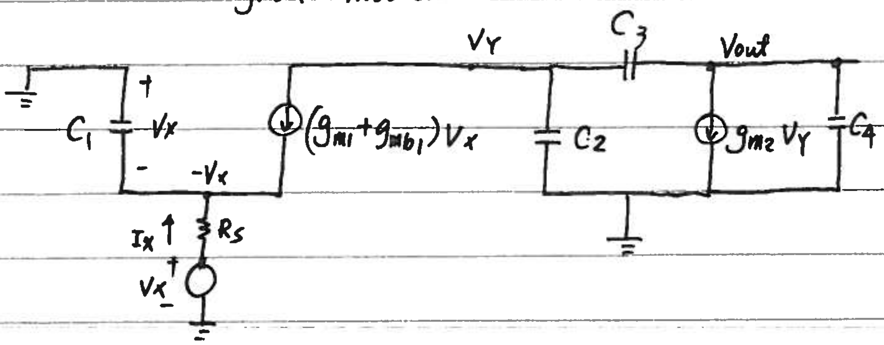
$$\omega_{p,X} = \frac{1}{r_{o1} \cdot [(C_{gd1} + C_{DB1} + C_{gs2}) + (1 + g_{m2} r_{o2}) \cdot C_{gd2}]}$$

Please note that the above approximation is based on Miller effect. In order to get more accuracy approximation, transfer function has to be derived.

(b) Small signal model



Redraw small signal model



where,

$C_1 = C_{gs1} + C_{SB1}$

$C_2 = C_{gs2} + C_{dB1} + C_{gd1}$

$C_3 = C_{gd2}$

$C_4 = C_{dB2}$

KCL @ V_{out} : $sC_3(V_Y - V_{out}) = g_{m2}V_Y + sC_4V_{out}$

$$\Rightarrow \frac{V_{out}}{V_Y} = \frac{-g_{m2} + sC_3}{s(C_3+C_4)}$$

KCL @ V_Y : $(g_{m1}+g_{mb1})V_X + sC_2V_Y + sC_3(V_Y - V_{out}) = 0$

$$\cancel{(g_{m1}+g_{mb1})V_X = -V_Y\left(sC_2 + \frac{s^2C_3C_4 + sC_3\cdot g_{m2}}{s(C_3+C_4)}\right)}$$

$$\frac{V_Y}{V_X} = -\frac{g_{m1}+g_{mb1}}{\left[s(C_2C_3+C_2C_4+C_3C_4) + C_3g_{m2}\right]/(C_3+C_4)}$$

KCL @ V_X : $\frac{V_{in}+V_X}{R_S} + sC_1V_X + (g_{m1}+g_{mb1})V_X = 0$

$$\frac{V_X}{V_{in}} = -\frac{1}{sC_1R_S + (1+(g_{m1}+g_{mb1})\cdot R_S)}$$

Thus there are three poles

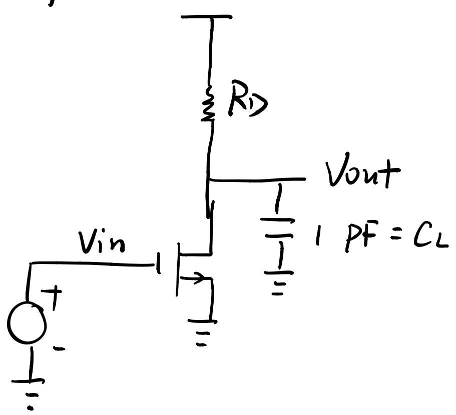
$\omega_{p0} = 0$

$$\omega_{p1} = \frac{-C_3g_{m2}}{C_2C_3+C_2C_4+C_3C_4} \quad ☆$$

$$\omega_{p2} = \frac{-(1+(g_{m1}+g_{mb1})\cdot R_s)}{C_1R_s} \quad ☆$$

Problem 2

(a) Half circuit:



According to Eq 6.30

$$\frac{V_{out}}{V_{in}} = \frac{-g_m R_D}{R_D C_L s + 1} \quad \text{- single pole circuit.}$$

The 3-dB bandwidth is the pole frequency:

$$f_{3\text{-dB}} = \frac{1}{2\pi R_D C_L} = 100\,\text{MHz}$$

$$R_D = \frac{\quad}{2\pi C_L f_{3\text{-dB}}} = \frac{1}{2\pi \times 1 \times 10^{-12} \times 100 \times 10^{6}} = 1.6\,k\Omega$$

(b) $A_v = -R_D g_m = -20$

$$g_m = \frac{20}{1.6 \times 10^3} = \frac{2}{160} = 0.013\ S$$

(c) $g_m = \mu_n C_{ox} \left(\frac{W}{L}\right) V_{od}$

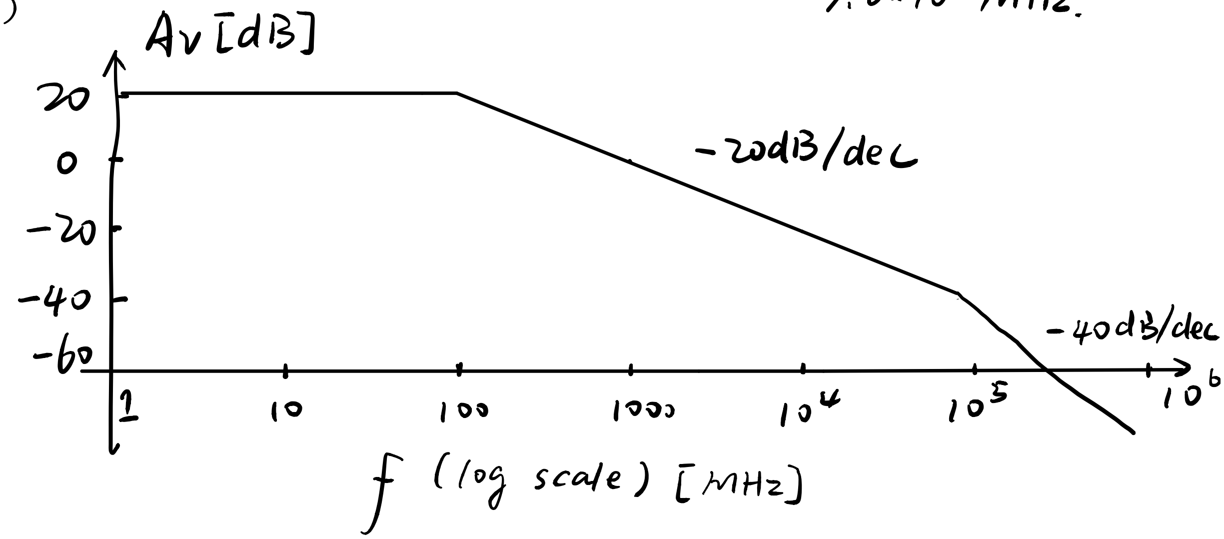
$$\Rightarrow \quad W = \frac{g_m L}{\mu_n C_{ox} V_{od}} = \frac{0.013 \times 65 \times 10^{-9}}{2 \times 10^{-4} \times 0.2} = 21\,\mu m.$$

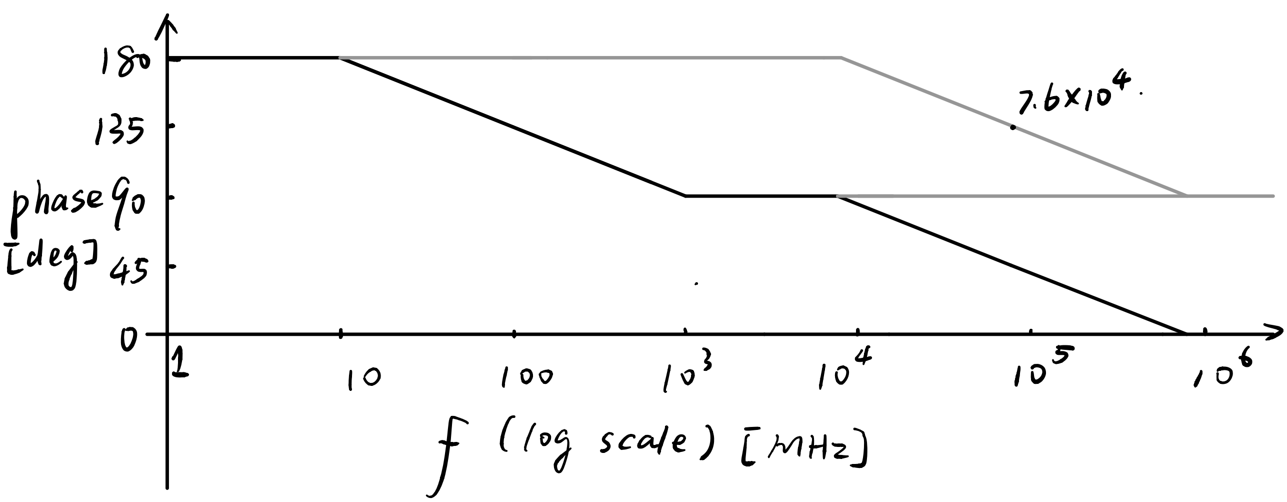
(d) $$\omega_{in} = \frac{1}{R_S \cdot C_{GS}}$$

$$= \frac{1}{100 \times 1 \times 10^{-15} \times 21} = 4.8 \times 10^{11}\ Hz$$

$$\Rightarrow f_{in} = 7.6 \times 10^{10}\ Hz$$
$$= 7.6 \times 10^{4}\ MHz.$$

(e)





line in black is final result, gray lines are Bode plots of each pole