EE 105 Midterm-2 Solution

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$q := 1.6 \cdot 10^{-19} C$ $ni := 10^{10} cm^{-3}$ $Vth := 0.026V$

$\varepsilon0 := 8.854 \cdot 10^{-14} \frac{F}{cm}$ $\varepsilon s := 11.7 \cdot \varepsilon0$ $\varepsilon ox := 3.9 \cdot \varepsilon0$

$mS := 0.001S$ $fF := 10^{-15} \cdot F$

(1) $g\_m := 0.1mS$ $ro := 100k\Omega$ $Cgd := 10fF$ $Cgs := 100fF$ $Cdb := 10fF$

$Rs := 1k\Omega$ $R\_L := 100k\Omega$

(a) $Rout := \frac{ro \cdot R\_L}{ro + R\_L}$ $Rout = 5 \times 10^{4} \Omega$

$Av := -g\_m \cdot Rout$ $Av = -5$

(c) There are 2 poles, one at input and another at output

$Cin := Cgs + Cgd \cdot (1 - Av)$ $Cin = 1.6 \times 10^{-13} F$

$Cout := Cdb + Cgd \cdot \left(1 - \frac{1}{Av}\right)$ $Cout = 2.2 \times 10^{-14} F$

$\omega p\_in := \frac{1}{Rs \cdot Cin}$ $\omega p\_in = 6.25 \times 10^{9} \frac{1}{s}$

$\omega p\_out := \frac{1}{Rout \cdot Cout}$ $\omega p\_out = 9.091 \times 10^{8} \frac{1}{s}$

(d) Output pole is the dominant pole. The 3-dB frequency is

$f\_3dB := \frac{1}{2 \cdot \pi} \cdot \omega p\_out$ $f\_3dB = 144.686 MHz$

(2) $\mu nCox := 100 \frac{\mu A}{V^2}$ $\mu pCox := 50 \frac{\mu A}{V^2}$ $V\_TH := 0.4V$ $Vdd := 2V$

$W\_L1 := 10$ $W\_L2 := 20$ $W\_L3 := 40$ $W\_L4 := 20$ $V\_GS1 := 1V$

(a) Id1 = Id2 (magnitude)

$V\_overdrive1 := V\_GS1 - V\_TH$ $V\_overdrive1 = 0.6V$

$V\_overdrive2 := V\_overdrive1 \cdot \sqrt{\frac{\mu nCox \cdot W\_L1}{\mu pCox \cdot W\_L2}}$ $V\_overdrive2 = 0.6V$

$Vx := Vdd - V\_TH - V\_overdrive2$ $Vx = 1V$

$V\_overdrive3 := Vdd - Vx - V\_TH$ $V\_overdrive3 = 0.6V$

$V\_overdrive4 := V\_overdrive3 \cdot \sqrt{\frac{\mu pCox \cdot W\_L3}{\mu nCox \cdot W\_L4}}$ $V\_overdrive4 = 0.6V$

$Vout := V\_overdrive4 + V\_TH$ $Vout = 1V$

(b)

$$A_V = \left(-\frac{g_{m1}}{g_{m2}}\right)\left(-\frac{g_{m3}}{g_{m4}}\right) = \frac{g_{m1}g_{m3}}{g_{m2}g_{m4}}$$

$$= \frac{\sqrt{2\mu_n C_{ox}(W/L)_1}\sqrt{2\mu_p C_{ox}(W/L)_3}}{\sqrt{2\mu_p C_{ox}(W/L)_2}\sqrt{2\mu_n C_{ox}(W/L)_4}}$$

$$= \sqrt{\frac{(W/L)_1 (W/L)_3}{(W/L)_2 (W/L)_4}}$$

$$Av := \sqrt{\frac{W\_L1 \cdot W\_L3}{W\_L2 \cdot W\_L4}} \qquad Av = 1$$

(3) $\mu nCox := 100 \frac{\mu A}{V^2}$ $\quad \mu pCox := 50 \frac{\mu A}{V^2}$ $\quad \lambda n := 0.1 \cdot \frac{1}{V}$ $\quad \lambda p := 0.1 \cdot \frac{1}{V}$ $\quad Rs := 100\Omega$

(a) This is a common gate amplifier. M1 is the main amplifying transitor

(b) The current going through M4-M5 can be found from the current mirror

$W\_L6 := 10 \qquad W\_L5 := 10 \qquad W\_L2 := 10 \qquad Iref := 100\mu A$

$$Id5 := Iref \cdot \frac{W\_L5}{W\_L6} \qquad Id5 = 100\,\mu A$$

$$Id2 := Iref \cdot \frac{W\_L2}{W\_L6} \qquad Id2 = 100\,\mu A$$

(c) The output current is equal to the input current, with opposite sign. So Ai = -1

(d)

$W\_L1 := 10$

$Id1 := Id2 \qquad gm1 := \sqrt{2 \cdot \mu nCox \cdot W\_L1 \cdot Id1}$

$gm1 = 4.472 \times 10^{-4} S$

(e)

$$v_s = v_{in} \frac{\frac{1}{g_{m1}} \| r_{o2}}{R_S + \frac{1}{g_{m1}} \| r_{o2}} \approx v_{in} \frac{\frac{1}{g_{m1}}}{R_S + \frac{1}{g_{m1}}}$$

$$vs\_vin\_ratio := \frac{\frac{1}{gm1}}{Rs + \frac{1}{gm1}} \qquad vs\_vin\_ratio = 0.957$$

(f)

$$A_V = g_{m1}\left(r_{03} \,||\, r_{o1}\right)\frac{v_s}{v_{in}} = g_{m1}\left(r_{03} \,||\, r_{o1}\right)\frac{\frac{1}{g_{m1}}}{R_S + \frac{1}{g_{m1}}} = \frac{r_{03} \,||\, r_{o1}}{R_S + \frac{1}{g_{m1}}}$$

$Id3 := Id1$

$ro1 := \frac{1}{\lambda n \cdot Id1}$ $\quad ro1 = 1 \times 10^5 \, \Omega$

$ro3 := \frac{1}{\lambda p \cdot Id3}$ $\quad ro3 = 1 \times 10^5 \, \Omega$

$Av := \frac{\frac{ro1 \cdot ro3}{ro1 + ro3}}{Rs + \frac{1}{gm1}}$ $\quad Av = 21.403$