

## Homework Assignment #7

ECE 0257 – Spring 2019

### Name

Avery Peiffer

### Collaborators

Daniel Stumpp

### Book Problems

Sedra & Smith 7.118 [Parts (a) and (b) only]

Sedra & Smith 7.121

Sedra & Smith 8.1 (Only answer the first part posted below)

Sedra & Smith 8.36

### Check-list Before Submission

- ☐ Write within boxes, no boxes are moved
- ☐ Write your full names in designated area
- ☐ Save this file as a PDF before uploading, keep the number of pages (8) unchanged
- ☐ Notify “TO BE CONTINUED” accordingly if you used the extra pages (page 6-8)

# Sedra & Smith 7.118 [Parts (a) and (b) only]

7.118

At DC:  $V_{GS} = 0.7 \text{ V}$   
 $V_{DS} = 50 \text{ V}$

(a) at DC:

$V_G = 5 \text{ V} \left( \frac{200}{500} \right) = 2 \text{ V}$   
 $I_D = 0.5 \text{ mA}$   
 $V_{GS} = 0.3 \text{ V}$   
 $0.3 \text{ V} = V_{GS} - V_T$   
 $0.3 \text{ V} + 0.7 \text{ V} = V_{GS} = 1.0 \text{ V}$   
 $1.0 \text{ V} = V_G - V_S = 2 \text{ V} - V_S \Rightarrow V_S = 1 \text{ V}$   
 $\frac{5 \text{ V} - V_D}{5 \text{ k}\Omega} = 0.5 \text{ mA} \Rightarrow V_D = 2.5 \text{ V}$

Saturation Condition:  $V_{DS} \geq V_{GS} - V_T$   
 $V_G - V_S \geq V_{GS}$   
 $2.5 \text{ V} - 1 \text{ V} \geq 0.3 \text{ V}$   
 $1.5 \text{ V} \geq 0.3 \text{ V} \Rightarrow$  The MOSFET is operating in the saturation region

(b) For CS amplifier,

$R_{in} = R_{G1} \parallel R_{G2} = \frac{(300)(200)}{300+200} = 120 \text{ k}\Omega$   
 $G_v = \frac{120}{240} \text{ A/V} \Rightarrow A_v = -8.33 \text{ V/V}$   
 $G_v = -\frac{(R_{G1} \parallel R_{G2})}{(R_{G1} \parallel R_{G2}) + R_{S13}} \cdot g_m (r_o \parallel R_D \parallel R_L)$   
 $g_m = \frac{2I_D}{V_{GS}} = \frac{2(0.5 \text{ mA})}{0.3 \text{ V}} = 0.333 \text{ mA/V}$   
 $r_o = \frac{V_A}{I_D} = \frac{50 \text{ V}}{0.5 \text{ mA}} = 100 \text{ k}\Omega$   
 $r_o \parallel R_D = \frac{(100 \text{ k}\Omega)(5 \text{ k}\Omega)}{105 \text{ k}\Omega} = 4.76 \text{ k}\Omega$   
 $(r_o \parallel R_D) \parallel R_L = \frac{(4.76)(5)}{9.76} = 2.44 \text{ k}\Omega$   
 $G_v = \left( \frac{-120 \text{ k}\Omega}{(120 \text{ k}\Omega + 120 \text{ k}\Omega)} \right) \left( 0.333 \frac{\text{mA}}{\text{V}} \right) (2.44 \text{ k}\Omega)$   
 $G_v = -48.75 \frac{\text{V}}{\text{V}}$

# Sedra & Smith 7.121

7.121

$V_t = 0.8 \text{ V}$   
 $k_n = 5 \frac{\text{mA}}{\text{V}^2}$   
 $V_A = 40 \text{ V}$

(a) All capacitors eliminated at DC:

$R_{in} = R_G = 10 \text{ M}\Omega$   
 $V_G = 0$   
 $0.4 \text{ mA} = \frac{1}{2} k_n V_{ov}^2 = \frac{1}{2} (5 \frac{\text{mA}}{\text{V}^2}) V_{ov}^2$   
 $V_{ov} = 0.4 \text{ V}$   
 $V_{DS} = V_G + 0.4 = 1.2 \text{ V}$   
 $V_S = -1.2 \text{ V}$   
 $R_S = \frac{-1.2 - (-5)}{0.4 \text{ mA}} = 9.5 \text{ k}\Omega$   
 $R_D = \frac{5 - 0}{0.4} = 12.5 \text{ k}\Omega$

Minimum drain voltage must be limited to  $-0.8 \text{ V}$  to remain in saturation.  
 Signal swing  $\rightarrow V_D = 0 \text{ V}$

(b) At the bias point:

$g_m = \frac{2I_D}{V_{ov}} = \frac{2(0.4 \text{ mA})}{0.4 \text{ V}} = 2 \frac{\text{mA}}{\text{V}}$   
 $V_o = \frac{V_A}{I_D} = \frac{40 \text{ V}}{0.4 \text{ mA}} = 100 \text{ k}\Omega$

(c)

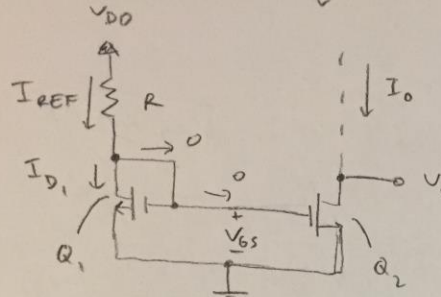
$V_L = 5$   
 $V_G = -5.556 \text{ V}$   
 $\frac{V_o}{V_i} = -11.1 \frac{\text{V}}{\text{V}}$   
 $G_v = \frac{10}{11} (-11.1)$   
 $= -10.10 \frac{\text{V}}{\text{V}}$

(d)  $R_o = 5 \text{ M}\Omega$

$A_v = \frac{9.5 \text{ k}}{9.5 \text{ k} + 5}$   
 $A_v = 99.995$

**Sedra & Smith 8.1 (Only answer the first part posted below)**

8.1



$V_{DD} = 1.3 \text{ V}$   
 $I_{REF} = 100 \mu\text{A}$   
 Output current =  $100 \mu\text{A}$   
 $L_{Q1} = L_{Q2} = 0.5 \mu\text{m}$   
 $W_{Q1} = W_{Q2} = 5 \mu\text{m}$   
 $V_t = 0.4 \text{ V}$   
 $k'_n = 500 \frac{\mu\text{A}}{\text{V}^2}$

$Q_1$  is in saturation

$$I_{D1} = \frac{1}{2} k'_n \left( \frac{W}{L} \right) (V_{GS} - V_t)^2 \quad 100 \mu\text{A} = \frac{1}{2} \left( 500 \frac{\mu\text{A}}{\text{V}^2} \right) \left( \frac{5}{0.5} \right) (V_{GS} - 0.4)^2$$

$$I_{D1} = I_{REF} = \frac{V_{DD} - V_{GS}}{R} \quad V_{GS} = 0.6 \text{ V}$$

$$100 \mu\text{A} = \frac{1.3 \text{ V} - 0.6 \text{ V}}{R} \Rightarrow \boxed{R = 7 \text{ k}\Omega}$$

8.36 CS amplifier

$L = 0.36 \mu\text{m}$

$\frac{W}{L} = 8$

# Sedra & Smith 8.36

8.36

$I_D = 25 \mu A$

$$A_0 = \frac{5 \sqrt{2(400)(1.04 \times 10^{-12})}}{\sqrt{25}}$$

$$= \boxed{28.8 \frac{V}{V}}$$

$$g_m = \frac{2(25 \mu A)}{0.125 V} = \boxed{0.4 \frac{mA}{V}}$$

$V_{ov}$  from saturation equation

$I_D = 2500 \mu A$

$$A_0 = \frac{5 \sqrt{2(400)(1.0 A)}}{\sqrt{2500}}$$

$$= \boxed{2.88 \frac{V}{V}}$$

$$g_m = \frac{2(2500 \mu A)}{1.25 V} = \boxed{4 \frac{mA}{V}}$$

$I_D = 250 \mu A$

$$A_0 = \frac{5 \sqrt{2(400)(1.0 A)}}{\sqrt{250}}$$

$$= \boxed{9.12 \frac{V}{V}}$$

$$g_m = \frac{2(250 \mu A)}{0.395 V} = \boxed{1.27 \frac{mA}{V}}$$

EXTRA PAGES

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