TOTAL: ____/20

ECE 548: Electronic Design I

Homework #4

Due: Friday, April 19th, 2019 (6 P.M.)

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Note:
- **Please use this sheet as a cover page.**
- **Your work must be hand-written (no typing please).**
- **Homework must be submitted electronically through Canvas in a PDF format.**

Do the following problems from Microelectronic Circuit Design by Jaeger & Blalock (5th Edition)

Solve the following problems (from pages 204 – 207):
- Choose at least 3 from: 4.21, 4.24, 4.38, and 4.43
- Choose at least 1 from: 4.33 and 4.34
- Choose at least 2 from: 4.48, 4.50, 4.57

Note: Use the parameters in Table 4.6 (page 203) as needed for the problems assigned.

Thomas Collins
ECE 548
Due 4/19

Homework #4

Chapter #4 Problem # 21

What is the value of K_n

V_{DS} $V_{GS} - V_{TN}$

$4v > 3v - 1.5v$ Saturation region

$i_D = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{TN})^2$

$i_D = \frac{200\mu A/V^2}{2}\left(\frac{10\mu m}{1\mu m}\right)(3V - 1.5V)^2$ $i_D = 2250\,\mu A$

$K_N = k_n'\left(\frac{W}{L}\right)$ $\boxed{K_N = (200\mu A)\left(\frac{10\mu m}{1\mu m}\right)}$ $\boxed{K_N = 2000\,\mu A/V^2}$

Chapter #4 Problem # 38

Calculate the drain current for an N Mos transistor

(a) $\lambda = 0\,V^{-1}$

V_{DS} $V_{GS} - V_{TN}$

$6v < 5v - (-2v)$ triode region

$i_D = K_N\left[(V_{GS} - V_{TN})V_{DS} - \frac{V_{DS}^2}{2}\right]$

$i_D = (250\mu A/V^2)\left[(5v - (-2v))6v - \frac{(6V)^2}{2}\right]$ $i_D = 6000\,\mu A$

$\boxed{i_D = 6mA}$

(b) $\lambda = 0.03\,V^{-1}$

Triode region → λ has no effect

$\boxed{i_D = 6mA}$

Chapter #4 Problem #43

(a) What is the drain current in the transistor

$V_{TN} = V_{TO} + \gamma\left(\sqrt{V_{SB} + 2\phi_F} - \sqrt{2\phi_F}\right)$

$V_{TN} = 1v + (0.7\sqrt{v})\left(\sqrt{3v + 0.6v} - \sqrt{0.6v}\right)$ $V_{TN} = 1.78V$

V_{DS} $V_{GS} - V_{TN}$

$5v > 2.5v - 1.78v$ Saturation region

$i_D = \frac{K_N'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{TN})^2$ $i_D = \left(\frac{100\mu A/V^2}{2}\right)\left(\frac{8}{1}\right)(2.5v - 1.78v)^2$

$\boxed{i_D = 207.403\,\mu A}$

Chapter # 4. Prob # 43 (cont.)

(b) Repeat for $V_{DS} = 0.5 v$

$V_{DS} < V_{GS} - V_{TN}$

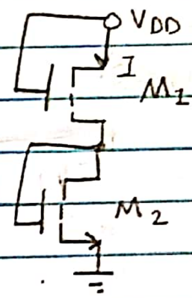
$0.5v < 2.5v - 1.78v$ Triode Region

$i_D = k_N' \left(\frac{W}{L}\right)\left[(V_{GS} - V_{TN})V_{DS} - \frac{V_{DS}^2}{2}\right]$

$i_D = (100 \mu A/V^2)\left(\frac{8}{1}\right)\left[(2.5v - 1.78v)(0.5v) - \frac{(0.5v)^2}{2}\right]$

$\boxed{i_D = 188.03 \mu A}$

Chapter # 4 Problem # 34



(a) Find the current I

#1 $i_D = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{TN})^2(1 + \lambda V_{GS})$

$i_D = \frac{(100 \mu A/V^2)}{2}\left(\frac{10}{1}\right)(V_{GS} - 0.75)^2$

#2

$i_D = \frac{(100 \mu A/V^2)}{2}\left(\frac{10}{1}\right)(V_{GS} - 0.75)^2$

$i_{D\#1} = i_{D\#2} \Rightarrow V_{GS\#1} = V_{GS\#2}$

$V_{DD} = V_{GS\#1} + V_{GS\#2}$ $V_{DD} = 2V_{GS\#1}$ $10 = 2V_{GS\#1}$ $V_{GS\#1} = 5v$

$i_D = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{TN})^2(1 + \lambda V_{GS})$

$i_D = \frac{(100 \mu A/V^2)}{2}\left(\frac{10}{1}\right)(5v - 0.75v)^2$ $\boxed{i_D = 9.030 \; mA}$

Chapter # 4 Problem # 34 (cont.)

(b) What is the current if both transistors have $W/L = 20/1$

$$i_D = \frac{K_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{TN})^2(1 + \lambda V_{GS})$$

$$i_D = \frac{(100\mu A/V^2)}{2}\left(\frac{20}{1}\right)(5V - 0.75V)^2$$

$$\boxed{i_D = 18.10\,mA}$$

(c) Repeat part (a) for $\lambda = 0.05\,V^{-1}$

$$i_D = \frac{K_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{TN})^2(1 + \lambda V_{GS})$$

$$i_D = \frac{(100\mu A/V^2)}{2}\left(\frac{10}{1}\right)(5V - 0.75V)^2(1 + (0.05V^{-1})(5V))$$

$$\boxed{i_D = 11.30\,mA}$$

Chapter # 4 Problem # 48

What are the values of K_p and V_{TP} for this transistor?

$$i_D = \frac{K_P}{2}(V_{GS} - V_{TP})^2$$

$$1250\mu A = \frac{K_P}{2}(-3V - V_{TP})^2 \qquad 4050\mu A = \frac{K_P}{2}(-5V - V_{TP})^2$$

$$\frac{1250\mu A}{4050\mu A} = \frac{K_P/2\,(-3V - V_{TP})^2}{K_P/2\,(-5V - V_{TP})^2}$$

$$0.56 = \frac{(-3V - V_{TP})}{(-5V - V_{TP})} \qquad 0.56(-5V - V_{TP}) = (-3V - V_{TP})$$

$$-2.8V - 0.56V_{TP} = -3V - V_{TP}$$

$$0.44\,V_{TP} = 0.2 \qquad \boxed{V_{TP} = -0.45V \approx -0.5V}$$

$$K_P = \frac{2 i_D}{(V_{GS} - V_{TP})^2} \qquad K_P = \frac{(2)(1250\mu A)}{(-3V - (-0.5))^2} \qquad \boxed{K_P = 400\mu A/V^2}$$

Chapter # 4 Problem # 4.48 (Cont)

Is this an enhancement mode or depletion mode Transistor? What is the W/L value?

$K_P = K_P'\left(\frac{W}{L}\right)$ $\quad \frac{K_P}{K_P'} = \left(\frac{W}{L}\right)$ $\quad \frac{W}{L} = \frac{(1400 mA/v^2)}{(20 mA/v^2)}$

$\frac{W}{L} = \frac{20}{1}$ ⟹ Table #4.1

$\boxed{\text{Enhancement mode}}$

Chapter # 4 Problem # 57

What are the region of operation of the drain current in this device for W/L = 40/2

$V_{TP} = V_{TO} + \gamma\left(\sqrt{V_{SB} - 2\phi_F} - \sqrt{2\phi_F}\right)$

$V_{TP} = (-0.75v) + (0.5\sqrt{v})\left[\left(\sqrt{0v - 0.6v} - \sqrt{0.6v}\right)\right]$

$V_{TP} = -0.75V$

$V_{DS} \quad V_{GS} - V_{TP}$

$-0.5V \leq -1.5V - (-0.75V)$ Triode Region

$i_D = K_P'\left(\frac{W}{L}\right)\left[(V_{GS} - V_{TP})V_{DS} - \frac{V_{DS}^2}{2}\right]$

$i_D = (40 mA/v^2)\left(\frac{40}{1}\right)\left[(-1.5v + 0.75v)(-0.5v) - \frac{(-0.5v)^2}{2}\right]$

$\boxed{i_D = 400 mA}$