EE4C10 Analog Circuit Design Fundamentals

Homework Assignment I

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August 31, 2021

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Problem 1

For $I_D = 40\mu A$:

$$I_D = \frac{1.8V - V_D}{R}$$
$$V_D = 1.8V - I_D R$$
$$\underline{V_D} = 1.0V$$

Saturation region:

$$V_{GS} = 1.0V > V_{TH}$$
$$V_{GS} - V_{TH} = 0.4V < V_{DS}$$

1. $\lambda = 0V^{-1}$

$$I_D = \frac{\mu_n C_{OX}}{2}\frac{W}{L}(V_{GS} - V_{TH})^2$$
$$L = \frac{\mu_n C_{OX}}{2}\frac{W}{I_D}(V_{GS} - V_{TH})^2$$
$$\underline{L} = 0.39\mu m$$

2. $\lambda = 0.06V^{-1}$

$$I_D = \frac{\mu_n C_{OX}}{2}\frac{W}{L}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$$
$$L = \frac{\mu_n C_{OX}}{2}\frac{W}{I_D}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$$
$$\underline{L} = 0.41\mu m$$

Problem 2

$W = \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2}$

1. Bulk of the transistors are connected to the source, $V_B = V_S$

$$V_{TH} = V_{TH0} + \gamma(\sqrt{2\varphi_F + V_{BS}} - \sqrt{|2\varphi_F|})$$
$$V_{TH} = V_{TH0} = 0.33V$$

(a) Transistor M_1

$$V_{SG} = 2.5V - 1.7V = 0.8V$$

$$\begin{aligned} I_D &= \frac{\mu_p C_{OX}}{2}\frac{W}{L}(V_{SG} - V_{TH})^2 \\ W &= \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2} \\ W_1 &= 2.72\mu m \end{aligned}$$

(b) Transistor M_2

$$V_{SG} = 1.7V - 1V = 0.7V$$

$$\begin{aligned} W &= \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2} \\ W_2 &= 4.38\mu m \end{aligned}$$

(c) Transistor M_3

$$V_{SG} = 1V$$

$$\begin{aligned} W &= \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2} \\ W_3 &= 1.37\mu m \end{aligned}$$

2. Bulk terminals are attached to the V_{DD}, $V_B = V_{DD}$.

(a) Transistor M_1

$$V_{BS} = 2.5V - 2.5V = 0V$$

$$\begin{aligned} V_{TH} &= V_{TH0} + \gamma(\sqrt{2\varphi_F + V_{BS}} - \sqrt{|2\varphi_F|}) \\ V_{TH} &= V_{TH0} = 0.33V \end{aligned}$$

$$\begin{aligned} W &= \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2} \\ W_1 &= 2.72\mu m \end{aligned}$$

(b) Transistor M_2

$$V_{BS} = 2.5V - 1.7V = 0.8V$$

$$\begin{aligned} V_{TH} &= V_{TH0} + \gamma(\sqrt{2\varphi_F + V_{BS}} - \sqrt{|2\varphi_F|}) \\ V_{TH} &= V_{TH0} = 0.43V \end{aligned}$$

$$\begin{aligned} W &= \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2} \\ W_2 &= 8.23\mu m \end{aligned}$$

(c) Transistor M_3

$$V_{BS} = 2.5V - 1.0V = 1.5V$$

$$\begin{aligned} V_{TH} &= V_{TH0} + \gamma(\sqrt{2\varphi_F + V_{BS}} - \sqrt{|2\varphi_F|}) \\ V_{TH} &= V_{TH0} = 0.49V \end{aligned}$$

$$\begin{aligned} W &= \frac{2LI_D}{\mu_p C_{OX}}\frac{1}{(V_{SG} - V_{TH})^2} \\ W_3 &= 2.31\mu m \end{aligned}$$

Problem 3

Problem 4

Problem 5

Problem 6

Problem 7