EE 334 - Homework 2 Report

Aras Güngöre - 2018401117
Ertuğrul Tatlı - 2018401081

1)

$$V_{OV} = 0.2\ V\ , \qquad V_{DD} = 1\ V\ , \qquad V_{SS} = -1\ V$$

$$A_d = g_m R_D = \frac{2I_D}{V_{OV}} R_D = 7.5 \Longrightarrow I_D R_D = \frac{A_d V_{OV}}{2} = 7.5 \cdot \frac{0.2}{2} = 0.75\ V$$

$$V_{D_1} = V_{D_2} = V_D = V_{DD} - I_D R_D = 1 - 0.75 = \boxed{0.25\ V = V_D}$$

2)

$$For\ NMOS:$$

$$t_{OX} = 4.1 \cdot 10^{-9}\ m\ , \qquad \mu_n = 327.3736992\ \frac{cm^2}{V \cdot s}\ , \qquad L = 0.18\ \mu m = 180\ nm$$

$$I_{tail} = 120\ \mu A\ , \qquad R_{tail} = 1\ M\Omega$$

$$C_{OX} = \frac{\varepsilon_{OX}}{t_{OX}} = \frac{3.9 \cdot (8.85418782 \cdot 10^{-12})}{4.1 \cdot 10^{-9}} = \boxed{8.4223 \cdot 10^{-3}\ \frac{F}{m^2} = C_{OX}}$$

$$k_n' = \mu_n C_{OX} = (327.3736992 \cdot 10^{-4}) \cdot (8.4223 \cdot 10^{-3}) = \boxed{2.7572 \cdot 10^{-4}\ \frac{F}{V \cdot s} = k_n'}$$

$$I_D = \frac{1}{2} k_n' \frac{W}{L}\ V_{OV}^2 = \frac{I_{tail}}{2} = \frac{120 \cdot 10^{-6}}{2} = 60\mu A$$

$$\Longrightarrow \frac{W}{L} = \frac{2I_D}{k_n' V_{OV}^2} = \frac{2 \cdot (60 \cdot 10^{-6})}{(2.7572 \cdot 10^{-4}) \cdot (0.2)^2} = \boxed{10.8806 = \frac{W}{L}}$$

$$W = \frac{W}{L} \cdot L = 10.8806 \cdot (180 \cdot 10^{-9}) = \boxed{1.958508\ \mu m = W}$$

$$R_D = \frac{A_D}{g_m} = \frac{A_D}{\frac{2I_D}{V_{OV}}} = \frac{7.5}{\frac{2 \cdot (60 \cdot 10^{-6})}{0.2}} = \boxed{12.5\ k\Omega = R_D}$$

3)

$$For\ NMOS:$$

$$t_{OX} = 4.1 \cdot 10^{-9}\ m\,, \qquad \mu_n = 327.3736992\ \frac{cm^2}{V \cdot s}\,, \qquad L = 0.18\ \mu m = 180\ nm\,,$$

$$W = 1.958508\ \mu m\,,$$

$$V_{bias} = V_{OV} + V_{th} = 0.2 + 0.354505 = \boxed{0.554505\ V = V_{bias}}$$

$$For\ PMOS:$$

$$t_{OX} = 4.1 \cdot 10^{-9}\ m\,, \qquad \mu_p = 128.7704538\ \frac{cm^2}{V \cdot s}\,, \qquad L = 0.18\ \mu m = 180\ nm,$$

$$W = 1.958508 \cdot 3.27 = 6.40432116\ \mu m,$$

$$V_{bias} = V_{OV} + V_{th} = -0.2 - 0.4120614 = \boxed{-0.6120614\ V = V_{bias}}$$

$$A_d = g_m \cdot (r_{o_2} || r_{o_4}) = \frac{2I_D}{V_{OV}} \cdot \frac{r_o}{2} = \frac{2I_D}{V_{OV}} \cdot \frac{V_A}{2I_D} = \frac{V_A}{V_{OV}} = 21.977425$$

$$\Longrightarrow V_A = A_d \cdot V_{OV} = 21.977425 \cdot 0.2 = \boxed{4.395485\ V = V_A}$$

4)

$$For\ NMOS:$$

$$t_{OX} = 4.1 \cdot 10^{-9}\ m\,, \qquad \mu_n = 327.3736992\ \frac{cm^2}{V \cdot s}\,,$$

$$L = L_{old} \cdot 3 = (18 \cdot 10^{-6}) \cdot 3 = 0.54\ \mu m = \boxed{540\ nm = L}\,,$$

$$W = W_{old} \cdot 4.5 = (1.958508 \cdot 10^{-6}) \cdot 4.5 = \boxed{8.813286\ \mu m = W}\,,$$

$$V_{bias} = V_{OV} + V_{th} = 0.2 + 0.354505 = \boxed{0.554505\ V = V_{bias}}$$

$$For\ PMOS:$$

$$t_{OX} = 4.1 \cdot 10^{-9}\ m\,, \qquad \mu_p = 128.7704538\ \frac{cm^2}{V \cdot s}\,,$$

$$L = L_{old} \cdot 3 = (18 \cdot 10^{-6}) \cdot 3 = 0.54\ \mu m = \boxed{540\ nm = L}\,,$$

$$W = W_{old} \cdot 3.727 = (6.40432116 \cdot 10^{-6}) \cdot 3.727 = \boxed{23.868905\ \mu m = W}\,,$$

$$V_{bias} = V_{OV} + V_{th} = -0.2 - 0.4120614 = \boxed{-0.6120614\ V = V_{bias}}$$

$$A_d = 14.361143$$

5)

$$I_D = \frac{\mu_n C_{OX}}{2} \cdot \frac{W}{L} \cdot V_{OV}^2 \cdot \left(1 + \frac{V_{DS}}{V_A}\right)$$

$$\Longrightarrow \frac{W}{L} = \frac{2I_D}{\mu_n C_{OX} \cdot V_{OV}^2 \cdot \left(1 + \frac{V_{DS}}{V_A}\right)} =$$

$$\frac{2 \cdot 120 \cdot 10^{-6}}{(327.3736992 \cdot 10^{-4}) \cdot (8.4223 \cdot 10^{-3}) \cdot (0.2)^2 \cdot \left(1 + \frac{(-1 - (0.0665635))}{4.395485}\right)}$$

$$= \boxed{28.732936 = \frac{W}{L}}$$

$$For\ NMOS:$$

$$t_{OX} = 4.1 \cdot 10^{-9}\ m\,, \qquad \mu_n = 327.3736992\ \frac{cm^2}{V \cdot s}\,, \qquad L = 0.54\ \mu m = 540\ nm\,,$$

$$W = \frac{W}{L} \cdot L = 28.732936 \cdot (540 \cdot 10^{-9}) = \boxed{15.51578\ \mu m = W}\,,$$

$$V_{bias} = V_{OV} + V_{th} = 0.2 + 0.354505 = \boxed{0.554505\ V = V_{bias}}$$

$$A_d = 84.500313$$