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3.1

$V_{DD} = 3V$

$C_{ox} = 3.9 \frac{\epsilon_0}{t_{ox}} = 3.83693 \times 10^{-7}\ F/cm^2$

$\mu_n = 350\ cm^2/V/s$ $\quad V_{t_n} = 0.7$

$\mu_p = 100\ cm^2/V/s$ $\quad V_{t_p} = -0.8$

$k'_n = 0.13428\ mA/V^2$ $\quad k'_p = 0.03837\ mA/V^2$

$\lambda_n = 0.1$

$\lambda_p = 0.2$

(a) $k_{1,2,3} = 26.856\ mA/V^2$

$I_1 = I_{ref} = 0.4\ mA = \frac{1}{2} \cdot 26.856\ m\ (V_x - 0.7)^2 (1 + 0.1 X)$

$V_x = V_{gs_1} = 0.86558$

$V_b = 2 V_x = 1.73116\ V$ #

(b) $V_{ds1} = V_{gs1}$

$I_{out} = I_{ref} \frac{1 + \lambda (V_{ds1} + \Delta V_b)}{1 + \lambda V_{ds1}}$

$\Delta I_{out} = I_{ref} \times \frac{\lambda \Delta V_b}{1 + \lambda V_{ds1}}$

$= 0.4m \times \frac{0.1 \cdot 0.1}{1 + 0.1 \cdot 0.86558}$

$= 3.681\ mA$ #

(c) Let V_Y increase by Δx

$V_Y = V_{ds1} = V_{gs1}$

$V_{gs3} = V_{gs1}$

$I_{out} = I_{ref} \times \frac{(\frac{W}{L})_2}{(\frac{W}{L})_1} \frac{1 + \lambda (V_{ds1} - \Delta x)}{1 + \lambda V_{ds1}}$ (given by M2)

$I_{out} = \frac{1}{2} \cdot 26.856\ m\ (V_{gs1} - \Delta x - 0.7)^2 \left(\frac{1 + \lambda (V_{gs1} + 1 - \Delta x)}{1 + \lambda V_{gs1}} \right)$ (given by M3)

$0.4\ m \times \frac{1 + 0.1\ (0.86558 - \Delta x)}{1 + 0.1 \cdot 0.86558} = \frac{1}{2} \cdot 26.856\ m (0.16558 - \Delta x)^2 \left(\frac{1 + 0.1 (0.86558 + 1 - \Delta x)}{1 + 0.1 \cdot 0.86558} \right)$

$\Delta x = 0.331\ V$ #

3.2

$V_{DD} = 3V$

$C_{ox} = 3.9 \frac{\epsilon_0}{t_{ox}} = 3.83693 \times 10^{-7}\ F/cm^2$

$\mu_n = 350\ cm^2/V/s$ $\quad V_{t_n} = 0.7$

$\mu_p = 100\ cm^2/V/s$ $\quad V_{t_p} = -0.8$

$k'_n = 0.13428\ mA/V^2$ $\quad k'_p = 0.03837\ mA/V^2$

$\lambda_n = 0.1$

$\lambda_p = 0.2$

(a) $k_{0,1} = 10.7424\ mA$

$k_{2,3} = 16.1136\ mA$

$I_{ref} = I_1 = 0.12\ m = \frac{1}{2} 10.7424m (V_{gs_1} - 0.7)^2 (1 + 0.1 V_{gs_1})$

$V_x = V_{gs_1} = 0.89354 = 0.894\ V$ #

$V_{b\,max} = V_x + 0.7 = 1.59354\ V$

$V_{d_1\,min} = 0.19354$

$V_{b\,min} - V_{d,min} = 0.7$

$V_{b\,min} = 0.89354\,V$

$0.894\,V \le V_b \le 1.594\,V$ #

(b) Let V_B increase by Δx

$$\begin{cases} I_{out} = I_{ref} \cdot \frac{3}{2} \cdot \left(\frac{1+0.1(V_{gs1}-\Delta x)}{1+0.1V_{gs1}} \right) \\ I_{out} = \frac{1}{2} \cdot 16.1136m\,(V_{gs1}-\Delta x-0.7)^2 \left(\frac{1+0.1V_{gs1}+1-\Delta x}{1+0.1V_{gs1}} \right) \end{cases}$$

$$0.12m \cdot \frac{3}{2} \cdot \frac{1+0.1(0.89354-\Delta x)}{1+0.1\cdot 0.89354} = \frac{1}{2} \cdot 16.1136m\,(0.19354-\Delta x)^2 \left(\frac{2+0.1\cdot 0.89354-\Delta x}{1+0.1\cdot 0.89354} \right)$$

$\Delta x = 0.03499$

$= 0.035\,V$ $\qquad I_{ref} \cdot \frac{3}{2} \cdot \left(\frac{-0.1\Delta x}{1+0.1V_{gs1}} \right) = -580.825\,\mu A$ #

3.3

$k_n = 10.7424\,mA/V^2 \qquad k_p = 3.0696\,mA/V^2$

$0.25mA = \frac{1}{2} k (V_{sg3}-0.799)^2 (1+0.2V_{sd3})$

$V_{sd3} = V_{sg3} = 3 - V_F$

$0.25mA = \frac{1}{2} \cdot 3.0696m\,(3-V_F-0.799)^2\,[1+0.2(3-V_F)]$

$V_F = 1.83746$

$0.25mA = \frac{1}{2} k (V_{sg4}-0.8)^2 (1+0.2V_{sd4})$

$V_{sg4} = 3 - 1.83746 \qquad V_{sd4} = 3 - V_{out}$

$0.25mA = \frac{1}{2} \cdot 3.0696m\,(1.16254-0.8)^2\,[1+0.2(3-V_{out})]$

$V_{out} = 1.80350$

$V_{out} - V_F = -33.960\,mV$ #

(b)

$A_{dm} = g_{m1}(r_{o3} \parallel r_{o1})$

$= g_{m1} \cdot 13.333k$

$= \sqrt{2kI_1} \cdot 13.333k$

$= 2.31758m \cdot 13.333k$

$= 30.90098\ V/V$

$g_{m1} = 2.31758m$

$g_{m3} = 1.23887m$

$g_{m5} = 3.27756m$

$r_{o1} = 40k$

$r_{o3} = 20k$

$r_{o5} = 20k$

$$A_{cm} = \frac{-\frac{1}{2g_{m3}} \parallel \frac{r_{o3}}{2}}{\frac{1}{2g_{m1}} + r_{os}}$$

$$= \frac{-397.93672}{215.9423 + 20k}$$

$$= -19.6845 \text{ mV/V}$$

$$CMRR = \left| \frac{A_{dm}}{A_{cm}} \right| = \frac{30.90098}{19.6845 \text{ m}}$$

$$= 1569.813 \ \#$$