Exercises for Tutorial 2: Differential Amplifiers

1. Problem 4.18 in the course book (Only for Fig. 4.38. Assume $\gamma = 0$. For Fig. 4.38(a) assume $r_o \gg R_1$ and $r_o \gg 1/g_m$. Also in Fig. 4.38(e), assume $\lambda = 0$).

a) $A_V = \frac{g_{m1}R_1}{2+g_{m3}R_1}$

b) $A_V = -g_{m1}(r_{o1} \parallel (r_{o3} + R_1 + R_1 g_{m3} r_{o3}))$

c) $A_V = -g_{m1}(r_{o1} \parallel r_{o3} \parallel R_1/2)$

d) $A_V = -g_{m1}(r_{o1} \parallel r_{o3} \parallel R_1)$

e) $A_V = -\frac{g_{m1}}{g_{m3}}(1 - g_{m3}R_1)$

2. Problem 4.22 in the course book.

$$A_{DM-DM} = -\left(g_m + \frac{1}{2R_P}\right)(R_D \parallel 2R_P \parallel 2g_m R_D R_P)$$

$$A_{CM-DM} = \frac{R_D \parallel 2R_P \parallel 2g_m R_D R_P}{R_P}$$

$$CMRR = g_m R_P + 0.5$$

3. Problem 5.3(a) in the course book for $\gamma = 0$. Assume all the transistors in the saturation region and $\mu_n C_{ox} = 4\mu_p C_{ox} = 200\,\mu A/V^2$, $V_{tn} = |V_{tp}| = 0.5\,V$ and $V_{DD} = 2.5\,V$.

$V_P = 0.45$ V, the drain voltage of the PMOS diode-connected transistors are 1.37 V and 1.68 V (from left to right respectively).

4. Calculate the small-signal voltage gain of the cascade differential pair shown in Figure 3.Assume $\gamma = 0$.

$$|A_V| \approx g_{m1} \frac{(g_{m3} g_{m5} r_{o1} r_{o3} r_{o5} r_{o7})}{g_{m3} r_{o3} r_{o1} + g_{m5} r_{o5} r_{o7}}$$

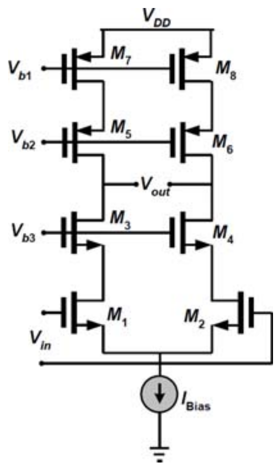

Figure 3 A differential amplifier.

5. Consider the differential amplifier shown in Figure 4. Due to a manufacturing defect, a large parasitic resistance has appeared between the drains of M_1 and M_4. Assume $\lambda = \gamma = 0$. Calculate the small-signal gain, common-mode gain, and CMRR. Assume that $\left(W/_L\right)_1 = \left(W/_L\right)_2$ and $\left(W/_L\right)_3 = \left(W/_L\right)_4$.

$$A_0 = \frac{V_{out1} - V_{out2}}{V_{ind}} = \frac{-g_{m1}R_P}{1 + \frac{R_P}{R_D} + \frac{1}{g_{m3}R_D}}$$

$$A_{CM} = 0 \qquad \{\lambda = 0, g_{m1} = g_{m2}\}$$

$$CMRR = \infty$$

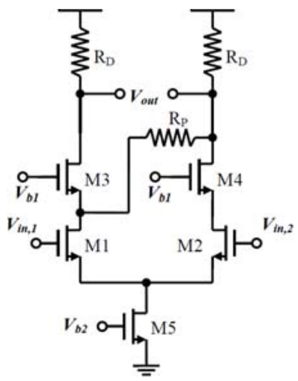

Figure 4 A differential amplifier.

6. A simple current mirror is shown in Figure 5. Calculate the value of V_{bias} in order to have $V_N = {}^{V_{DD}}/_{2}$. Using this value calculate the error percentage of mirroring. Error percentage can be defined as $E(\%) = \frac{|I_{ref} - I_{out}|}{I_{ref}} \times 100$.

$$\mu_n C_{ox} = 200 \frac{\mu A}{V^2}$$

$$\mu_p C_{ox} = 50 \frac{\mu A}{V^2}$$

$$V_{DD} = 3\ V$$

$$\left(\frac{W}{L}\right)_3 = 4\left(\frac{W}{L}\right)_1 = 4\left(\frac{W}{L}\right)_2 = 20$$

$$R = 1\ k\Omega$$

$$V_{tn} = |V_{tp}| = 0.5\ V$$

$$\lambda_n = |\lambda_p| = 0.1\ V^{-1}$$

$\mathrm{V_{Bias}} = 1.5\ \mathrm{V}, \qquad \mathrm{E}(\%) = 7.65\ \%$

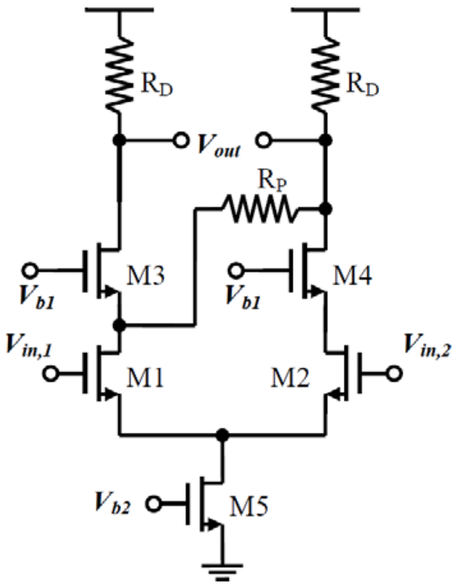

Figure 5 Simple current mirror.