PROBLEM SET #5

Issued: Thursday, Sep. 30, 2015

Due (at 8 a.m.): Wednesday, Oct. 7, 2015, in the EE 140/240A HW box near 125 Cory.

1. This problem considers a Wildlar current source design. In Fig. PS5-1(a), assume all BJTs have $V_{BE\{on)}$ = 0.7V when I_C = 1mA. I_{ref} = 100μA.

(a) Assuming $\beta = \infty$, design the circuit to have I_o = 10μA.

(b) Assuming β = 200 and V_A = 100V, find the value of the output resistance R_O and the change in output current corresponding to a 5-V change in output voltage.

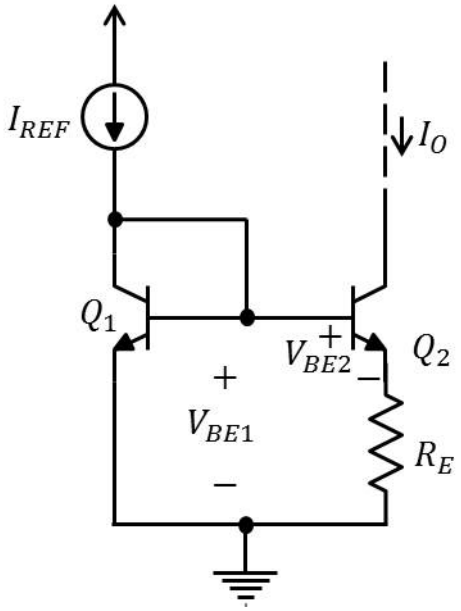

Fig. PS5-1

2. In the circuit shown in Fig. PS5.2, a source follower using a wide transistor M_4 and a small bias current is inserted in series with the gate of M_3 so as to bias M_2 at the edge of saturation. Assuming M_0 - M_3 are identical with non-zero channel length modulation parameter, i.e. $\lambda \neq 0$, estimate the mismatch between I_{out} and I_{ref} if:

(a) $\gamma = 0$.

(b) $\gamma \neq 0$.

Express your final answers in terms of λ, zero-bias threshold voltage V_{t0}, threshold voltage parameter γ, Fermi level ϕ_f, transconductance parameter k_n', transistor W/L ratios, and I_1.

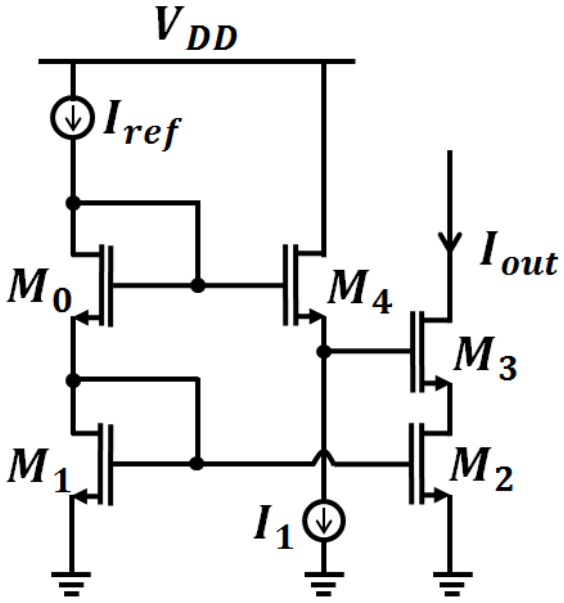

Fig. PS5.2

3. Fig. PS5-3 shows a cascode current mirror modified for high-swing operation.

(a) Find V_X and determine the minimum value of V_b.

(b) Estimate the deviation of I_{out} from 300μA if the drain voltage of M_4 is higher than V_X by 1 V.

MOS Parameters:

$$\mu_n C_{ox} = \frac{130\mu A}{V^2}, L_{ovn} = 0.08\mu m, V_{Tn} = 0.7, V_{Tp} = -0.8, \lambda_n = 0.1, I_{REF} = 100\mu A.$$

$$\left(\frac{W}{L}\right)_{1,2} = \frac{20\mu m}{0.5\mu m}, \left(\frac{W}{L}\right)_{3,4} = \frac{60\mu m}{0.5\mu m}$$

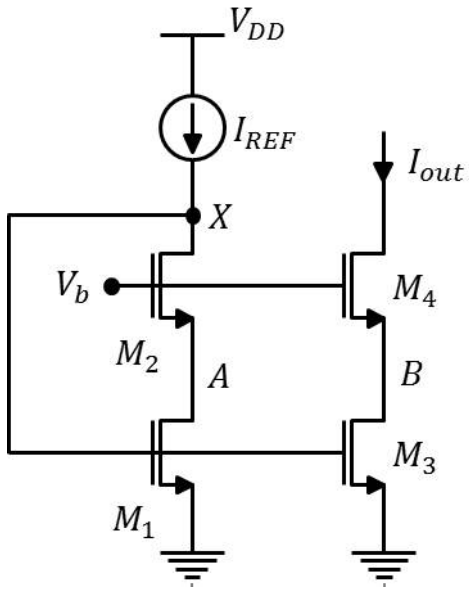

Fig. PS5-3

4. Fig. PS5.4 depicts a self-biasing V_t reference circuit capable of providing a current reference independent of supply voltage.

(a) Provide expressions for I_{out}, I_{bias1}, and I_{bias2} in terms of circuit elements and transistor parameters. Ignore the body effect and channel length modulation.

(b) Calculate the numerical values for the expressions in the previous part.

(c) Calculate the ratio of small-signal variations in I_{out} to small-signal variations in V_{DD} at low frequencies. Ignore the body effect but include finite transistor r_o in this calculation.

MOS Parameters:

$$V_{th} = 0.5\text{V}, k_n{}' = \frac{200\mu\text{A}}{\text{V}^2}, k_p{}' = \frac{100\mu\text{A}}{\text{V}^2}, \lambda = 0.05\text{V}^{-1}, V_{DD} = 3\text{V}, R = 1.75\text{k}\Omega$$

$$\left(\frac{W}{L}\right)_1 = \frac{12.5\mu\text{m}}{0.25\mu\text{m}}, \left(\frac{W}{L}\right)_2 = \frac{6.25\mu\text{m}}{0.25\mu\text{m}}, \left(\frac{W}{L}\right)_3 = \frac{31.25\mu\text{m}}{0.25\mu\text{m}}$$

$$\left(\frac{W}{L}\right)_4 = \frac{6.25\mu\text{m}}{0.25\mu\text{m}}, \left(\frac{W}{L}\right)_5 = \frac{12.5\mu\text{m}}{0.25\mu\text{m}}, \left(\frac{W}{L}\right)_6 = \frac{15.5\mu\text{m}}{0.25\mu\text{m}}$$

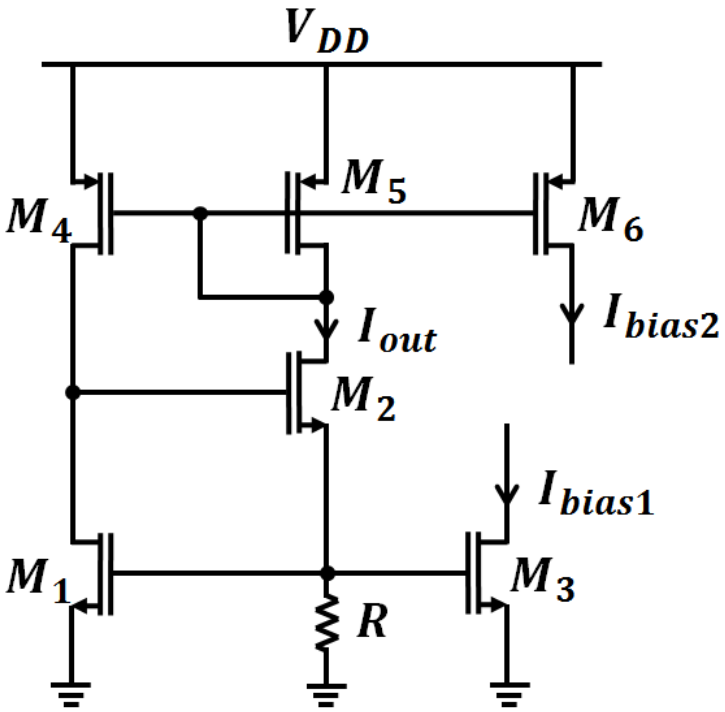

Fig. PS5-4