EEE 51 Assignment 4

2nd Semester SY 2018-2019
Due: 5pm Tuesday, February 26, 2019 (Rm. 220)

Instructions: Write legibly. Show all solutions and state all assumptions. Write your full name, student number, and section at the upper-right corner of each page. Start each problem on a new sheet of paper. Box or encircle your final answer.

Answer sheets should be color coded according to your lecture section. The color scheme is as follows:

THQ – yellow
THU – white
WFX – pink

1. **Current Mirrors**

   For Figure 1, assume that the BJT's are matched and ($V_A \longrightarrow \infty$) for all transistors and operate @$T = 300K$.

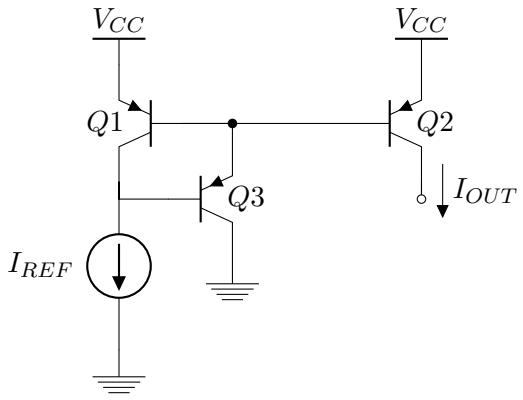

Figure 1: PNP BJT Current Mirror Circuit

   (a) Derive I_{OUT} in terms of I_{REF} and β. (Show complete derivation). *(3 pts.)*

   (b) Compare the derived expression for I_{OUT} to the simple current mirror configuration. *(1 pt.)*

   (c) What is the purpose of $Q3$ in the current mirror circuit? *(Bonus: 1 pt.)*

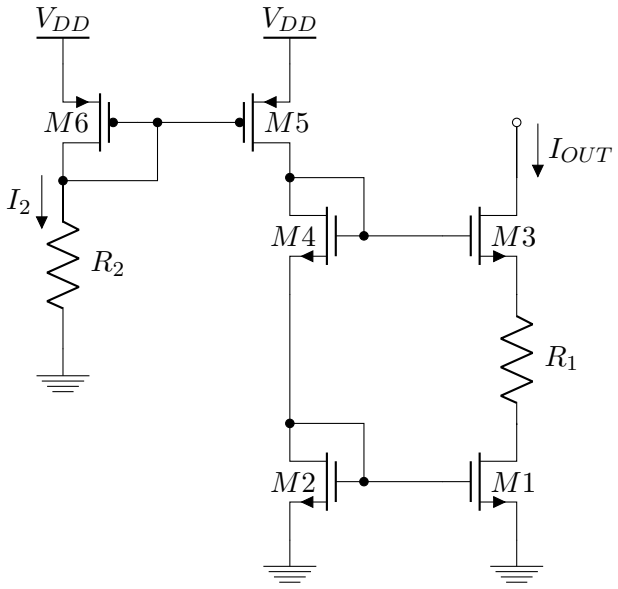

Figure 2: MOS Current Mirror Circuit

For Figure 2, use $V_{DD} = 2.5V$, for all NMOS parameters: $k_n = 312.5\mu A/V^2$, $V_{THn} = 0.4V$, $\lambda_n = 0$, and for all PMOS parameters: $k_p = 200\mu A/V^2$, $V_{THp} = -0.45V$, $\lambda_p = 0$. Assume that all transistors operate in saturation but $M1$ operates in minimum V_{DS} that would remain in saturation. Given that $I_2 = 50\mu A$, Find the values for R_1, R_2 and I_{OUT}. *(6 pts.) (Bulk of points goes into the solution).*

2. **More Current Mirrors**
In the particular current mirror shown in Fig. 3 below, all transistors have $V_{th} = 0.6V$, $k_{M1} = k_{M4} = 320\mu\frac{A}{V^2}$, $k_{M2} = k_{M3} = 3.2m\frac{A}{V^2}$ and $\lambda = 0.1V$. Also, $I_{REF} = 20\mu A$.

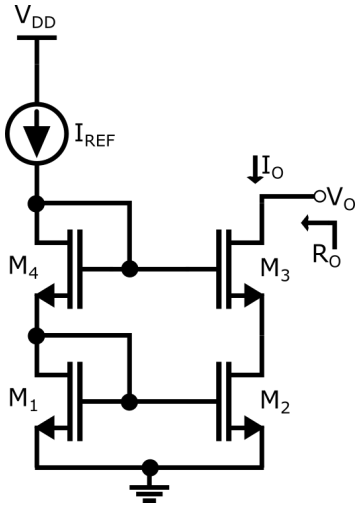

Figure 3: Cascoded MOS current mirror

For (a) and (b), you may ignore Early effect.

(a) Find the value of the output current, I_O. (1 pt)

(b) Determine the voltages at the gates of M2 and M3. (1 pt)

(c) Draw the small-signal model of the circuit. Label the transistor terminals, the transistor small-signal parameters, and their values. (2 pts)

(d) Determine the output resistance, R_O, of the current mirror. (2 pts)

For the following Wilson MOS current mirror shown in Fig. 4, assume that all the transistors are identical and that Early effect can be neglected.

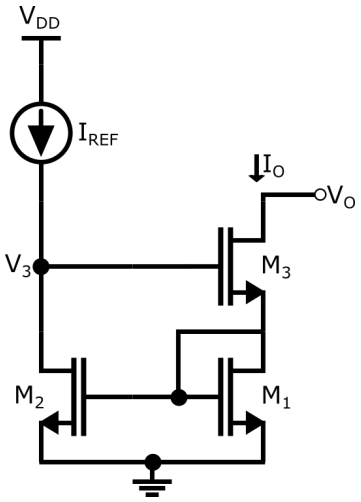

Figure 4: Wilson current mirror

(e) Find the input resistance, R_I, seen at node V_3. (2 pts)

For the circuit in Fig. 5, assume that all transistors have very high β and that $V_{BE} = 0.8V$ at $I_C = 1mA$.

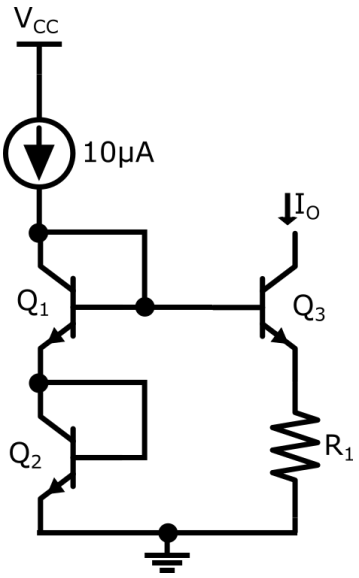

Figure 5: BJT current mirror circuit

(f) Find the value of the resistance R_1, such that the output current will be $I_O = 10\mu A$. (2 pts)

TOTAL: 20 points.