VE311 Electronic Circuit Homework 6

Due: **December 17th (no late submission)**

Note:

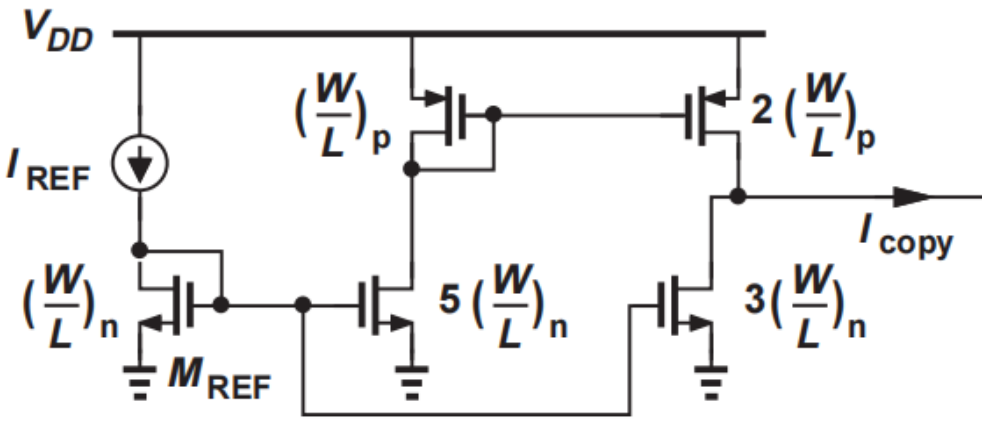
1) Please use A4 size paper or page.

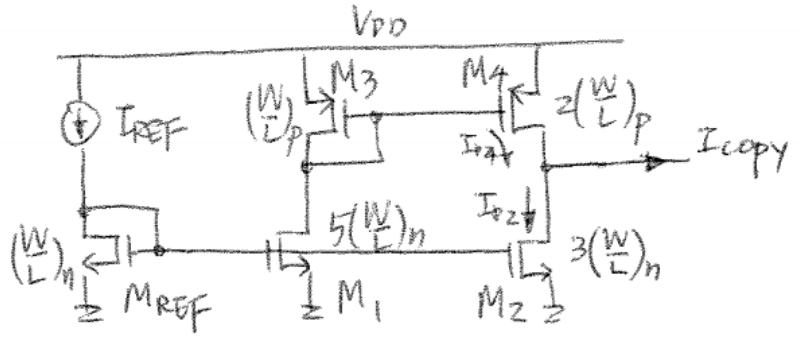
2) Please clearly state out your final result for each question.

3) Please attach the screenshot of Pspice simulation result if necessary.

Question 1. Current Mirror 1

[30pts] Calculate I_{copy} in the circuit shown below. Assume all the transistors operate in saturation.





$V_{GS,REF} = V_{GS,1} \therefore I_{D,1} = 5 I_{REF}$

$V_{GS,3} = V_{GS,4} \therefore I_{D4} = 2 I_{D3} = 2 I_{D,1} = 10 I_{REF}$

$V_{GS,REF} = V_{GS,2} \therefore I_{D2} = 3 I_{REF}$

$\therefore I_{COPY} = I_{D4} - I_{D2} = 7 I_{REF}.$

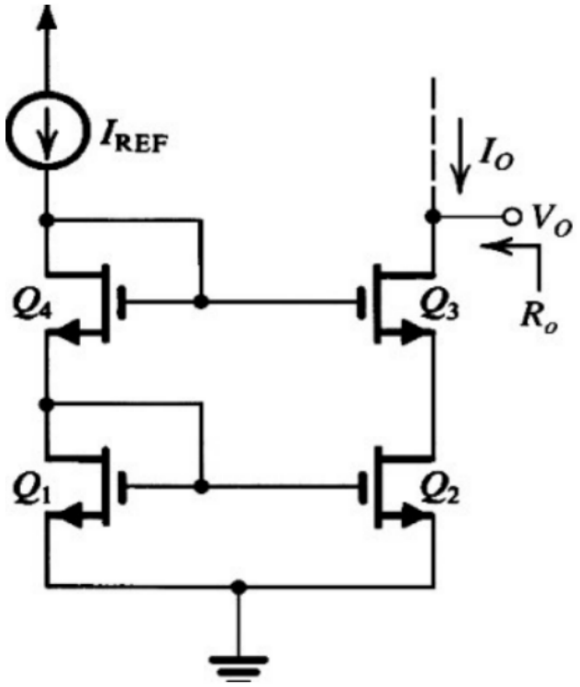
Question 2. Current Mirror 2

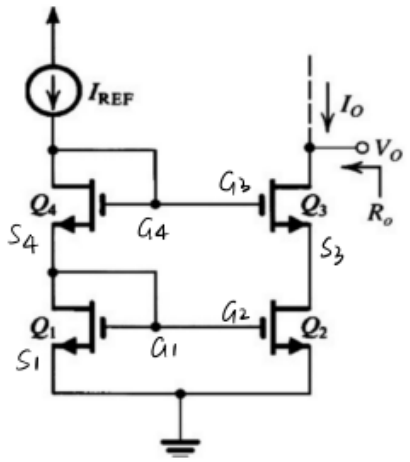
[70pts] In a particular cascaded current mirror shown below, assume all transistors have $V_{TH} = 0.7V$, $\mu_n C_{ox} = 160\mu A/V^2$, $L = 1\mu m$. For the widths, $W_1 = W_4 = 4\mu m$ and $W_2 = W_3 = 40\mu m$. The reference current $I_{REF} = 20\mu A$. No body effect.

(a) Assume $\lambda = 0$, what is the output current result I_O and the voltages at the gates of Q_2 and Q_3 ?

(b) Assume $\lambda = 0$, what is the lowest voltage at the output for which current-source operation is possible?

(c) Assume $\lambda = 0.1$ and the I_O keeps with the value that obtained from (a) and (b), what are the values of g_m and r_o of Q_2 and Q_3 ? What is the output resistance of the mirror?





(a). $I_{REF} = \frac{1}{2}\mu_n C_{ox}\frac{W_1}{L}(V_{GS1} - V_{TH})^2 = 20\,\mu A$.

$\Rightarrow V_{G1} = 0.95\,V$

$\therefore V_{G2} = V_{G1} = 0.95\,V$

$I_O = \frac{1}{2}\mu_n C_{ox}\frac{W_2}{L}(V_{GS2} - V_{TH})^2 = 200\,\mu A$

$\because I_{REF} = \frac{1}{2}\mu_n C_{ox}\frac{W_4}{L}(V_{GS4} - V_{TH})^2 = 20\,\mu A$

$\Rightarrow V_{GS4} = 0.95\,V$

$\because V_{S4} = V_{G1} = 0.95\,V \quad \therefore V_{G4} = 1.9\,V$

$\therefore V_{G3} = V_{G4} = 1.9\,V$

(b). $V_{DS3} \geq V_{GS4} - V_{TH}$

$V_O - V_{S3} \geq V_{G3} - V_{S3} - V_{TH}$

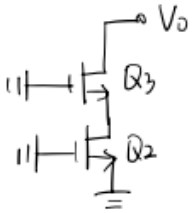
$\Rightarrow V_O \geq V_{G3} - V_{TH} = 1.2\,V$

(c). $g_{m2} = \frac{2I_O}{V_{GS2} - V_{TH}} = 1.6 \times 10^{-3}\,A/V = g_{m3}$

$V_{GS2} = 0.95V$ if Q_1, Q_4's $\lambda = 0$

$r_{O2} = \frac{1}{I_O \cdot \lambda} = 5 \times 10^4\,\Omega = r_{O3}$

Rout:



Cascode circuit without R_D and g_{mb},

Original formular: $R_{out} = [r_{O1} + r_{O2} + (g_{m2} + g_{mb2})r_{O1}r_{O2}] \,||\, R_D$

Ignore R_D and g_{mb}, we get:

$R_{out} = r_{O2} + r_{O3} + g_{m3}r_{O2}r_{O3} \simeq 4.1 \times 10^6\,\Omega$

If Q_1, Q_4's $\lambda = 0.1$, $I_{REF} = \frac{1}{2}\mu_n C_{ox}\frac{W_1}{L}(V_{GS1} - V_{TH})^2(1 + \lambda V_{DS1})$

$\Rightarrow V_{GS1} = V_{DS1} = V_{G1} = V_{G2} = 0.94V$

$\therefore g_{m2} = g_{m3} = \frac{2I_O}{V_{GS2} - V_{TH}} = 1.617 \times 10^{-3}\,A/V$

$\therefore r_{O2} = \frac{1}{I_O \lambda} = 5 \times 10^4\,\Omega = r_{O3}$

$R_{out} = r_{O2} + r_{O3} + g_{m3}r_{O2}r_{O3} = 4.28 \times 10^6\,\Omega$