Problem set #3
Reading: Lecture Notes #3 (available in the Lab or online)

Problem #1:

Consider the following OTA circuit. Assume the OTA power is supplied by ±15 V power supplies.

Calculate the output \( V_{\text{out}} \) as a function of \( V_x \) and \( V_y \).

\[
V_{\text{out}} = 0.19 \beta \left( \frac{3}{13} \right) V_x (V_y + 0.6)
\]

\[
V_{\text{out}} = 9 \cdot m (V_+ - V_-) 100 \Omega
\]

\[
= 19.2 J_{\text{ABC}} (V_+ - V_-) 100 \Omega
\]

\[
V_- = 0 \quad V_+ = V_x \left( \frac{3 \Omega}{3 \Omega + 10 \Omega} \right) = \frac{3}{13} V_x
\]

\[
V_{\text{out}} = 19.2 J_{\text{ABC}} \left( \frac{3}{13} \right) V_x 100 \Omega
\]

\[
V_G = 0.6 V \quad I_b = -V_y + 0.6 \quad J_{\text{ABC}} = \beta \frac{I_b}{10 k \Omega}
\]
Problem #2: Consider the above OTA circuit.

1. Calculate the current $I_1$ as a function of $V_0$ and $V_{control}$. Assume that $R_1$ and $R_2$ are chosen such that $I_2 < I_1$. $I_1 = -I_0 = -19.2I_{AC}(V_0 - V_c)$, but $V_c = 0$; $I_1 = V_0 (\frac{R_2}{R_{IN}})$.

2. Calculate the equivalent impedance $Z_{eq}$ across the terminals A and B. (Hint: Once you have completed part 1, this is a trivial calculation.)

3. A capacitor is attached to the circuit to make a simple RC filter, as diagrammed below. How does the filter cutoff frequency vary with $V_{control}$? (Hint: Use the impedance calculated above!)

$$Z_{eq} = \frac{V_c}{I_1} = \frac{R_c (R_1 + R_2)}{19.2(V_{control} - 11.4)R_2}$$

This is a Voltage controllable Reason.

$$\frac{V_{out}}{V_{in}} = \frac{Z_{eq}}{Z_{eq} + \frac{1}{C_0}} = \frac{C_0 Z_{eq}}{1 + C_0 Z_{eq}}$$

Filter cuts at

$$W = \frac{19.2(V_{control} - 11.4)R_2}{C R_c (R_1 + R_2)}$$

Voltage controllable

$$I_{s1} = \frac{1}{C Z_{eq}}$$
Problem #3: Consider the following OTA circuit. Assume the OTA power is supplied by ±15 V power supplies.

1. Calculate the output $V_{out}$ as a function of $V_{in}$, and $V_A$

Current mirror gives $I_{ABC} = \frac{V_A + 0.6V}{10k \Omega} = \frac{V_A}{10^4} + \frac{0.6}{10^4}$

$V_+ = \frac{50}{10k+50} V_\infty = \frac{V_\infty}{3}$

$V_{out} = 9m (V_+ - V_-) 100 \Omega$  \hspace{1cm} $V_- = 0$

$= 9m \left( \frac{V_\infty}{3} \right) 100 \Omega$

$9m = 19.2 I_{ABC} = \frac{19.2(V_A + 0.6)}{10^4}$

$V_{out} = \frac{19.2}{10^4} \left( \frac{V_A + 0.6}{3} \right) \frac{V_\infty (100)}{3} = \frac{19.2(V_A + 0.6) V_\infty}{300}$

$V_{out} = 0.064(V_a + 0.6) V_\infty$