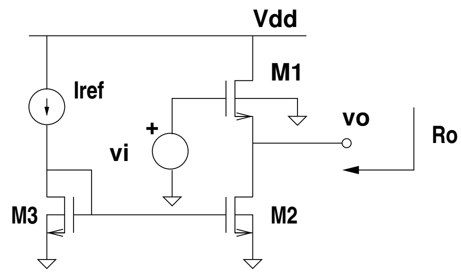
EELE 5131
Assignment 4 — Winter 2019

Use the following MOSFET parameters: $I_{SQn} = 100$ nA, $V_{thn} = 0.42$ V, $|\partial L/\partial V_{DS}|_n = 0.07$ μm/V, $I_{SQp} = 23$ nA, $V_{thp} = -0.43$ V, $|\partial L/\partial V_{DS}|_p = 0.07$ μm/V, $L_D = 20$ nm, $n_n = 1.3$ and $n_p = 1.32$. Minimum allowed channel length is 0.8 μm.

1. The supply voltage in the circuit below is $V_{DD} = 1.8$ V. Transistor aspect ratios are $(W/L)_1 = (15\mu\text{m}/1\mu\text{m})$ and $(W/L)_2 = (W/L)_3 = (6\mu\text{m}/1\mu\text{m})$. The reference current is $I_{ref} = 6$ μA.



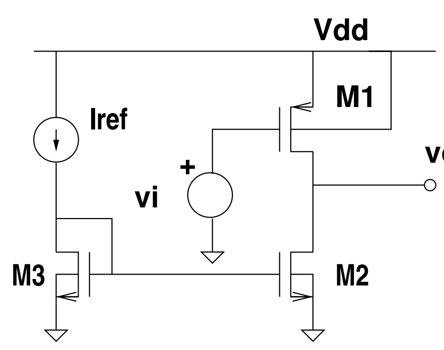
   (a) Symbolically, derive an expression for the large-signal output voltage (v_O) as a function of the input voltage (v_I) when both M1 and M2 are active (neglect channel-length modulation).

   (b) Calculate the maximum and minimum values of v_I to keep both M1 and M2 active.

   (c) Using the small-signal model (and considering transistor output resistances) derive analytic expressions for the voltage gain (v_o/v_i) and the output resistance of the circuit as shown in the diagram.

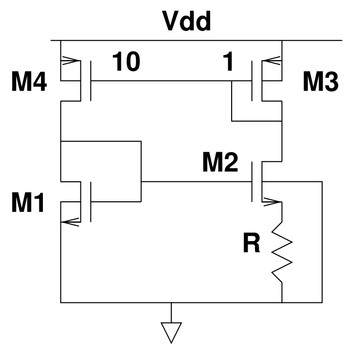
   (d) Numerically calculate the voltage gain and output resistance.

2. Based on the schematic shown below, design a common-source amplifier with a gain of at least 100, a total output voltage range that includes [0.25 V, 1.5 V], a minimum output slew-rate of 50 V/μs when the load is a 0.5 pF capacitor. Supply voltage is 1.8 V. Try to use the minimum possible current and gate area. Specify transistor dimensions and value of I_{ref}. Calculate the required DC component of the input voltage (referred to ground) for your design.



3. In the current source of the figure, all transistors are operating in weak inversion and $R = 100$ kΩ. Assume all transistors are active and neglect channel length modulation and M1=M2.

   (a) Derive a simple analytic expression for the voltage across the resistor as a function of the current mirror gain. How is the temperature dependence of this voltage.
   (b) Calculate the drain current in M2 at room temperature.
   (c) Calculate all transistor aspect ratios and the minimum supply voltage if i_{f1} and i_{f3} are set equal to 0.1.



4. The differential amplifier shown in the figure has been designed to operate as follows: $i_{f1} = i_{f2} = 20$, $i_{f3} = i_{f4} = 80$, $i_{f5} = 150$. Assume all transistors have $L = 2$ μm. Other circuit parameters: $V_{DD} = 1.8$ V, $C_L = 0.5$ pF.

   (a) Calculate the upper limit of the input common-mode voltage range.
   (b) Calculate the upper limit of the output voltage range when the input common-mode voltage is 0.2 V
   (c) Calculate all transistor widths for a slew rate equal to 200 V/μs.