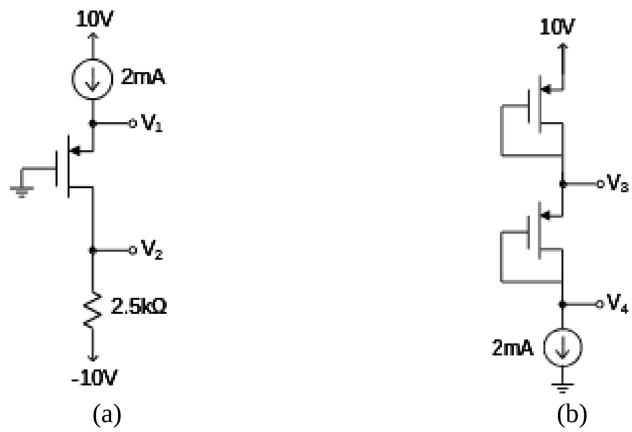
EECE 2412 – Homework 7 – Spring 2017

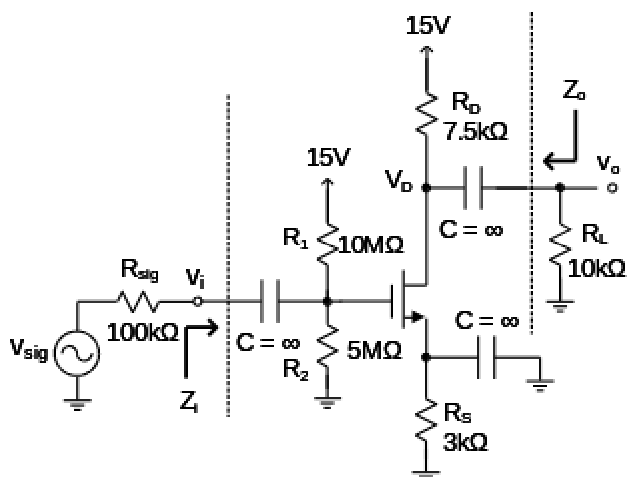
Due: Thursday, April 13, 2017

1) The PMOS transistors in the circuits below have V_{to} = -2V, $\mu_p \cdot C_{ox} \cdot (W/L)$ = 1mA/V^2, and λ is small enough to be approximated as $\lambda \approx 0$. Find the labeled voltages $V_1 - V_4$.



2) Problem 5.18 on page 335 of the textbook.

3) The NMOS transistor in the circuit below has the following parameters: V_{to} = 1V, K = (W/L)·(KP/2) =1mA/V^2, V_A = 100V
   a) Perform DC analysis to calculate the transistor's drain current, transconductance (g_m), and drain-source resistance (r_{ds}). Note: You can assume $\lambda = 0$ for the calculation of the drain current at the DC operating point, but use the given information to calculate r_{ds} at the operating point (with the calculated drain current value).
   b) Draw the small-signal equivalent circuit to write equations for the following voltage gains and to calculate their values: $A_v = v_o/v_i$ and $A_{vs} = v_o/v_{sig}$
      Note: Include the effect of r_{ds} in the small-signal analysis.
   c) What is the value of the amplifier's input impedance (Z_i)? Perform an analysis to obtain the equation before substituting values.
   d) What is the value of the amplifier's output impedance (Z_o)? Perform an analysis to obtain the equation before substituting values.



4) Setup the circuit from problem 3) in PSpice to verify your results. Use the MbreakN transistor model, and connect its bulk terminal to the source terminal. Select the MbreakN transistor in the

schematic and choose “edit → PSpice model” in the menu on the top. To specify its most relevant parameters, change the statement in the first line to:

.model Mbreakn NMOS VTO=0.9,KP=41.3E-6,W=20E-6,L=1E-6,LAMBDA=0.02

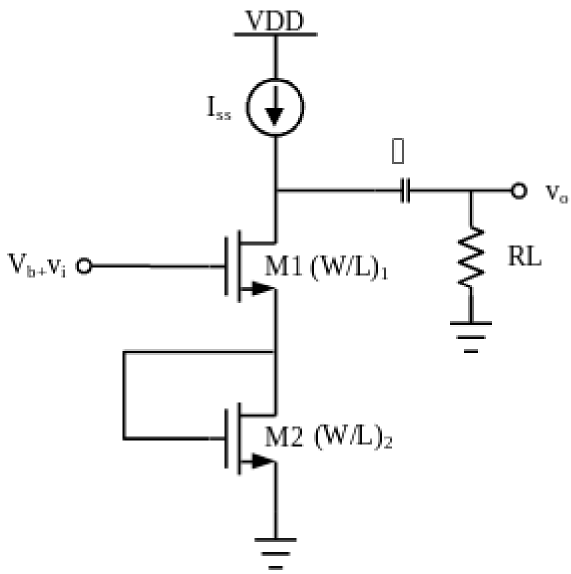
Hint: Choosing C = 100μF ensures that the impedances of the blocking capacitors at the signal frequency of interest are much smaller than the resistances in the circuit.

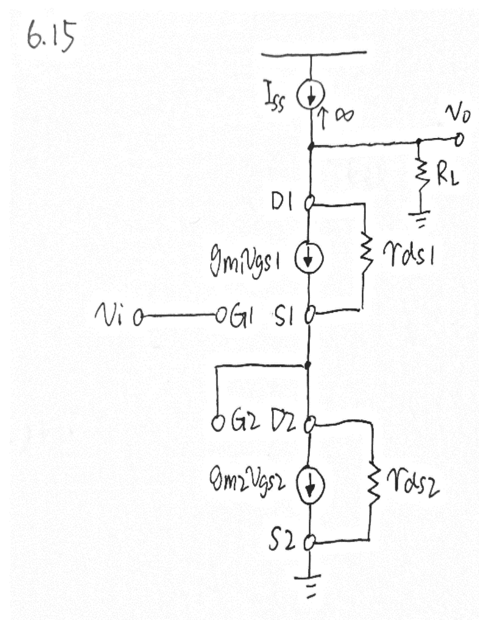
a) Run a DC bias point simulation to verify that your operating point is correct (the V_D error should be less than 3% in this case), and submit the schematic that shows all DC voltages and currents.
b) Print the DC operating point information for the transistors after the simulation in part a). Notice that GDS parameter is equal to $1/r_{ds}$. Compare the drain-source resistance value to the one from the analysis in problem 3).
c) Run an AC simulation to plot $A_{vs} = v_o/v_{sig}$. Label the midband gain in the plot before submitting it, and compare it to the hand calculation result.
d) Run a transient simulation with a sinusoidal input signal having an amplitude of 5mV and a frequency of 1MHz. Plot $v_i(t)$ and $v_o(t)$ vs. time. Mark the peak output voltages in the plot before printing it for submission. What is the voltage gain based on the transient simulation result?

5) A common-source amplifier with source degeneration is shown below, where a diode-connected transistor M2 (g_{m2}, r_{ds2}) is placed in series with the source of M1(g_{m1}, r_{ds1}). Draw the small-signal equivalent circuit and derive an equation of the small-signal voltage gain v_o/v_i in terms of g_{m1},

$$v_o/v_i$$

r_{ds1}, g_{m2}, r_{ds2}, and R_L. Assume that the output impedance of the ideal current source is high enough to be ignored, and that all capacitors behave as short circuits for the AC signal frequencies of interest.





$$\left(\frac{1}{r_{ds1}}+\frac{1}{R_L}\right)\cdot v_o-\frac{1}{r_{ds1}}\cdot v_{g2}+g_{m1}\cdot\left(v_i-v_{g2}\right)=0$$

$$\left(\frac{1}{r_{ds1}}+\frac{1}{r_{ds2}}\right)\cdot v_{g2}-\frac{1}{r_{ds1}}\cdot v_o-\frac{1}{r_{ds2}}\cdot 0+g_{m2}\cdot\left(v_{g2}-0\right)-g_{m1}\cdot\left(v_i-v_{g2}\right)=0$$

$$v_o/v_i=-\frac{g_{m1}r_{ds1}R_L(1+g_{m2}r_{ds2})}{r_{ds1}+r_{ds2}+R_L+g_{m1}r_{ds1}r_{ds2}+g_{m2}r_{ds2}(r_{ds1}+R_L)}$$