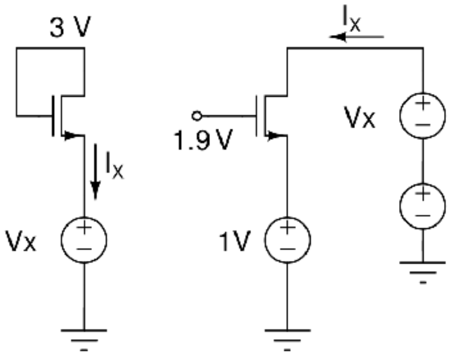
EC5135/EC3102: Analog Circuits
Tutorial 2

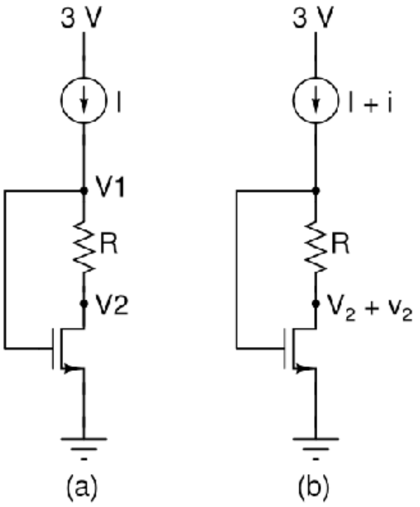
1) For each of the circuits shown below, plot Ix as Vx varies from 0-3V.



$k = \mu_n C_{ox} = 100\ \mu A/V^2$, $(W/L) = 10$, $V_T = 0.7$ V

Figure 1: Circuits for Problem 1

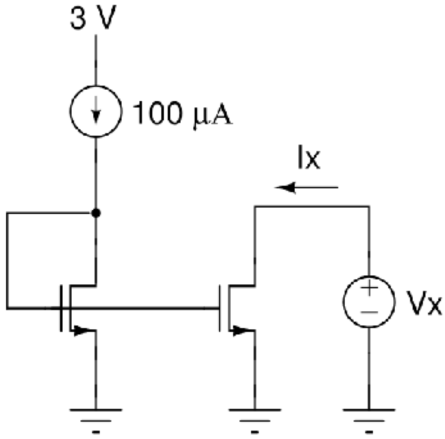
2) For the circuit (a) shown below, determine the minimum value of I required to make the MOSFET operate at the edge of the active region. In the circuit (b) shown below, determine the incremental voltage v_2 in terms of the incremental current i, assuming the device is in saturation. How will you choose R to make v_2 independent of i?



$k = \mu_n C_{ox} = 100\ \mu A/V^2$, $(W/L) = 10$, $V_T = 0.7$ V

Figure 2: Circuit for Problem 2

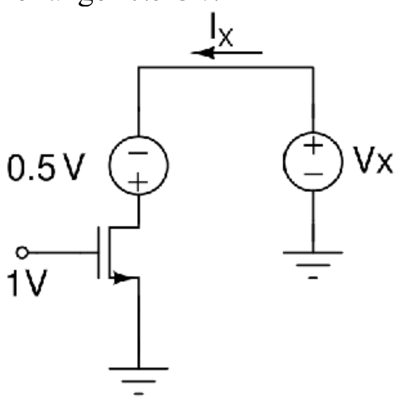
3) For the circuit shown below, sketch I_x as V_x varies in the range 0-3V.



$k = 100\ \mu A/V^2$, $(W/L) = 10$, $V_T = 0.7$ V

Figure 3: Circuit for Problem 3

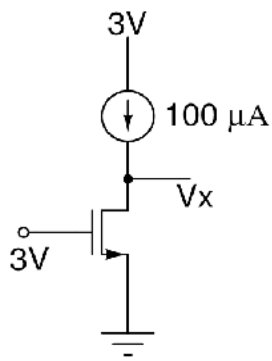
4) For the circuit shown below, sketch I_x as V_x varies in the range -0.5-3V.



$k = 100\ \mu A/V^2$, $(W/L) = 10$, $V_T = 0.7$ V

Figure 4: Circuit for Problem 4

5) For the circuit shown below, determine the region of operation of the transistor. Find V_x.



$k = 100\ \mu A/V^2$, $(W/L) = 10$, $V_T = 0.7$ V

Figure 5: Circuit for Problem 5

6) In the circuit shown below, it is known that both M1 & M2 operate in saturation. Further, k and W/L for both transistors is the same. The threshold voltage of M2 is *slightly* larger than that of M1, by an amount ΔV_T. Determine I_2. Assume $\Delta V_I \ll V_I$.

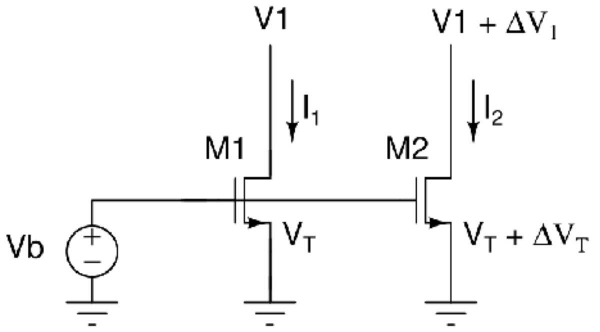


Figure 6: Circuit for Problem 6

7) The small signal equivalent circuit of an amplifier is shown below. M1 is assumed to be in saturation, with transconductance g_m and output conductance g_o. Determine the Norton equivalent looking in at A, as well as the Thevenin equivalent looking in at B. What happens to these equivalents when $g_m \rightarrow \infty$?

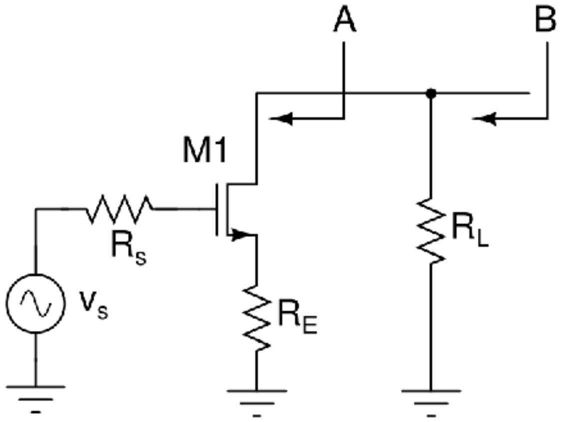


Figure 7: Circuit for Problem 7

8) Determine the quiescent operating point and small signal gain of the amplifier shown below. What is the maximum permissible amplitude of the sinewave input so that clipping of the output is avoided?

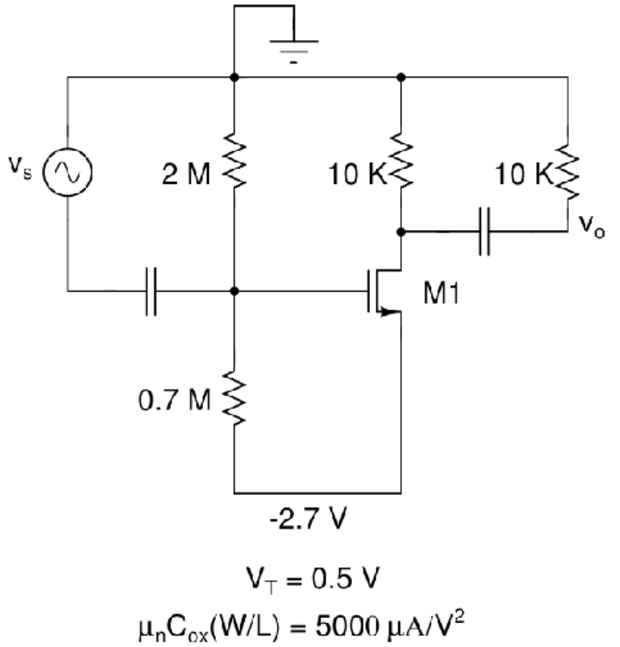


Figure 8: Circuit for Problem 8

9) The input to the amplifier shown below is a sinusoid of amplitude A. Determine R1, R2, A, Vdd and Vss in the circuit to achieve the following:

- There must be no quiescent current flowing through the load and source.
- The incremental gain must be -4.
- The output sinewave must begin to just begin to clip at both extremes.

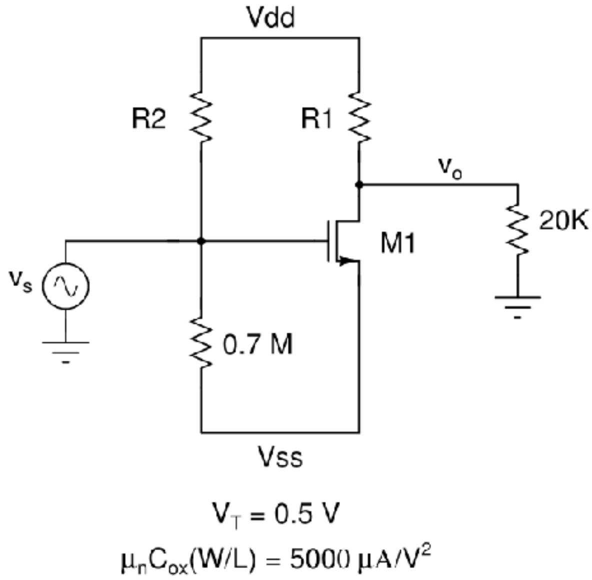


Figure 9: Circuit for Problem 9

10) A Bipolar Junction Transistor (BJT) is a 3-terminal semiconductor device that is used to design a wide variety of analog circuits. The symbol of an "NPN" BJT is shown below in Figure 10, with terminals marked B–Base, C–Collector and E–Emitter. As with the MOSFET, the arrow indicates the direction of current flow inside the device – inside the NPN BJT, current flows from collector to emitter. With respect to the external network, current flows into the base and collector nodes, and out of the emitter node (as shown in the figure). The operation of the BJT is described by the following simplified equations:

$I_C = I_{CS} \cdot \{\exp(V_{BE}/V_t)\} \cdot \{1+(V_{CE}/V_A)\}$
$I_C = \beta \cdot I_B$
$I_E = I_B + I_C$

where I_E, I_C, I_B are the emitter, collector and base currents respectively; V_t (=kT/q) is the thermal voltage; V_A is the "Early voltage" (typically a few 10's of V); β is the current gain of the transistor (typically a few 100's).

(a) Determine the small-signal equivalent circuit of the BJT (i.e. small-signal y-parameters).

(b) Assume that a BJT is used in a "common-emitter" amplifier configuration to drive a load resistance R_L, and that the input signal source has a thevenin resistance R_S. Determine the overall small-signal gain of the amplifier.

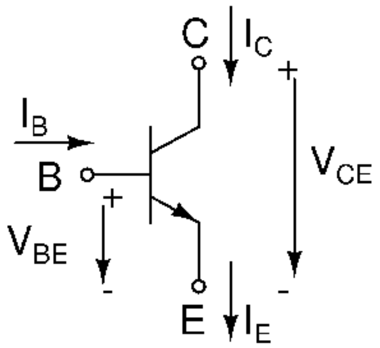


Figure 10: BJT symbol for Problem 10