Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits
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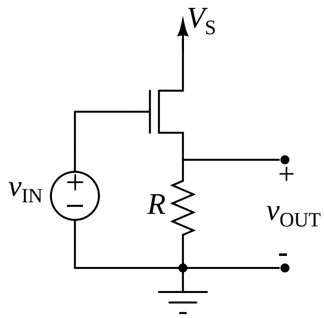
Homework #5

Issued 3/6/02 – Due 3/13/02

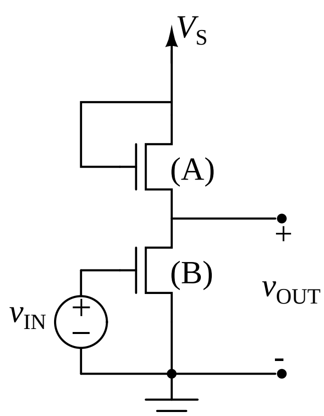
Exercise 5.1: This problem studies the MOSFET amplifier shown below. A saturation-region model for the MOSFET is also given below. Assuming that the MOSFET operates in its saturation region, determine v_{OUT} as a function of v_{IN}. Also, determine the range of v_{IN} and the corresponding range of v_{OUT} over which the MOSFET operates in its saturation region.



Saturation:

$0 \le (v_{GS} - V_T) \le v_{DS}$
$i_D = \frac{K}{2}(v_{GS} - V_T)^2$

Exercise 5.2: A “linear” MOSFET amplifier may be constructed using two MOSFETs as shown below. Note that the transconductances K_A and K_B, and the threshold voltages V_{TA} and V_{TB}, of the two MOSFETs are different. Assuming that both MOSFETs operate in their saturation regions, determine v_{OUT} as a function of v_{IN}. Also, determine the range of v_{IN} and the corresponding range of v_{OUT} over which both MOSFETs operate in their saturation region.



Saturation:

$0 \le (v_{GSA} - V_{TA}) \le v_{DSA}$
$i_{DA} = \frac{K_A}{2}(v_{GSA} - V_{TA})^2$
$0 \le (v_{GSB} - V_{TB}) \le v_{DSB}$
$i_{DB} = \frac{K_B}{2}(v_{GSB} - V_{TB})^2$

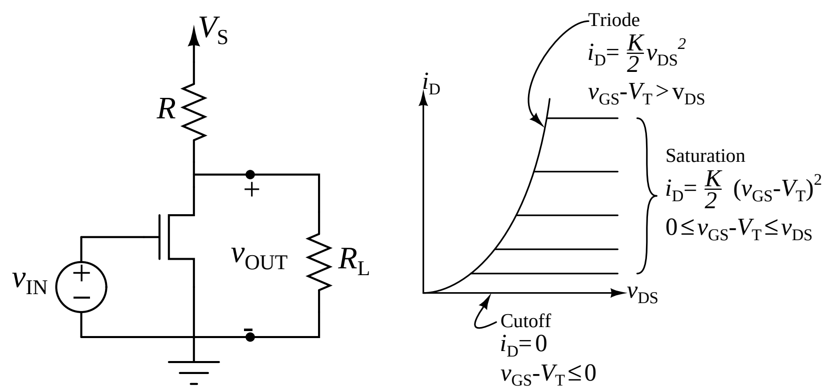
Problem 5.1: So far we have studied MOSFET amplifiers that have no load. That is, the current circulating through the output port of each amplifier was zero. For example, in Problem 4.3 the current out of the fist amplifier and into the second amplifier was zero because $i_G = 0$ for the second MOSFET. In this problem, which studies the amplifier shown below, the output current is no longer zero. The load below is a resistor that does draw current from the amplifier. Hint, in analyzing this amplifier, consider the use of both Thevenin equivalence and load line analysis to simplify the problem. Also, review your solution to Problem 4.3.

Once again, use a simplified model for the MOSFET as shown below. The simplification is again that the triode region of operation is compressed onto the curve $i_D = Kv_{DS}^2/2$, which becomes a common curve of operation for $v_{GS} - V_T > v_{DS}$.

(A) Determine the range of v_{IN} over which the MOSFET operates in cutoff. Also, determine v_{OUT} for this operating range.

(B) Assuming that the MOSFET operates in its saturation region, determine v_{OUT} as a function of v_{IN}. Also, determine the range of v_{OUT} and the range of v_{IN} that correspond to the saturated operation of the MOSFET.

(C) For values of v_{IN} that are above the range found in Part (B), the MOSFET operates in its triode region, which in the model below is compressed onto the curve $i_D = Kv_{DS}^2/2$. Determine v_{OUT} for v_{IN} in this range of operation.



Problem 5.2: This problem continues to study the two-stage amplifier studied first in Problem 4.3. In this problem, let $v_{IN} = V_{IN} + v_{in}$ and $v_{OUT} = V_{OUT} + v_{out}$, where V_{IN} and V_{OUT} are the large-signal components of v_{IN} and v_{OUT}, respectively, and v_{in} and v_{out} are the small-signal components of v_{IN} and v_{OUT}, respectively.

(A) Assume that both MOSFETs are biased so that they operate in their saturation regions. Develop a small-signal circuit model for the amplifier that can be used to determine v_{out} as a function of v_{in}. In doing so, assume that V_{IN} defines the operating point around which the small-signal model is constructed, and evaluate all small-signal model parameters in terms of V_{IN} as necessary.

(B) Use the small-signal model to determine v_{out} as a function of v_{in}.

(C) Compare the small-signal gain found in Part (B), defined as v_{out}/v_{in}, to that found in Part (E) of Problem 5.1. Explain any differences.

(D) Determine the small-signal Thevenin equivalent of the amplifier when it is viewed through its output port.

Problem 5.3: Consider again the amplifier described in Exercise 5.1. In this problem, let $v_{IN} = V_{IN} + v_{in}$ and $v_{OUT} = V_{OUT} + v_{out}$, where V_{IN} and V_{OUT} are the large-signal components of v_{IN} and v_{OUT}, respectively, and v_{in} and v_{out} are the small-signal components of v_{IN} and v_{OUT}, respectively.

(A) Using your result from Exercise 5.1, determine the small signal gain of the amplifier as a function of the input bias voltage v_{IN}. That is, determine $v_{out}/v_{in} = dv_{OUT}/dv_{IN}$ evaluated at V_{IN}.

(B) Again assume that the MOSFET is biased so that it operates in its saturation region. Develop a small-signal circuit model for the amplifier that can be used to determine v_{out} as a function of v_{in}. In doing so, assume that V_{IN} defines the operating point around which the small-signal model is constructed, and evaluate all small-signal model parameters in terms of V_{IN} as necessary.

(C) Use the small-signal model to determine the small-signal gain v_{out}/v_{in}. Compare this small-signal gain to that found in Part (A) and explain any differences.

(D) Determine the small-signal Thevenin equivalent of the amplifier.