

Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 - Electronic Circuits
Fall 2003

Homework #5
Handout F03-028

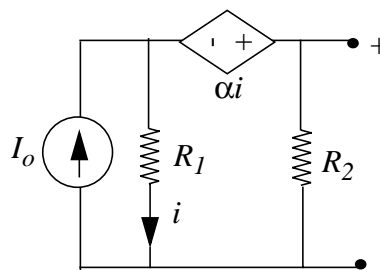
Issued 10/6/2005 - Due 10/19/2003

Helpful Readings for this Homework: Agarwal & Lang Chapter 7.1 - 7.7

Exercise 5.1: Do Exercise 7.1 in Agarwal & Lang, page 390.

Exercise 5.2: Do Exercise 7.3 in Agarwal & Lang, page 391.

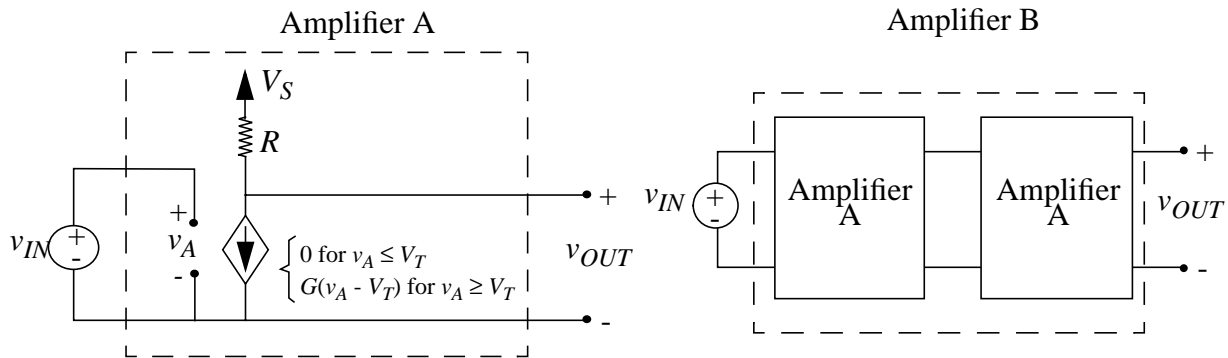
Exercise 5.3: Determine the Thevenin equivalent of the following circuit. Note that it contains a dependent voltage source, and that the parameter α has units of Ohms.



Problem 5.1: This problem studies the two amplifiers shown on the other side of the page. Amplifier A is a single-stage amplifier implemented with a voltage-dependent current source and a pull-up resistor. Assume that the current source parameters G and V_T satisfy $G > 0$ and $V_S > V_T > 0$. Also assume that $RG < \frac{V_S}{V_S - V_T}$. Amplifier B is a two-stage amplifier in which each stage is identical to Amplifier A.

- (A) Determine v_{OUT} as a function of v_{IN} for Amplifier A.
- (B) Sketch and clearly label a graph of the input-output relation found in Part (A).
- (C) Determine v_{OUT} as a function of v_{IN} for Amplifier B.
- (D) Sketch and clearly label a graph of the input-output relation found in Part (C).
- (E) Consider Amplifier A again. Show that the dependent current source sinks power for $v_{OUT} > 0$ and sources power for $v_{OUT} < 0$.

- (F) Dependent current sources are most often implemented with transistors that are passive devices, and hence not capable of sourcing power. In this case, the dependent current source in Amplifier A would saturate so that v_{OUT} actually never goes below 0 V. That is, the current through the dependent current source becomes constant and does not increase with a further increase in v_A once the voltage across the source reaches 0 V. Given this revised behavior for Amplifier A, sketch and clearly label a graph of the input-output behavior of Amplifier B for very large G .



Problem 5.2: Do Problem 7.5 from Agarwal & Lang, page 396-397.

Problem 5.3: Do Problem 7.11 from Agarwal & Lang, page 399-400.

Problem 5.4: For this problem, we will use Weblab to examine the characteristics of a typical MOSFET device, and see how it differs from our theoretical calculations.

- a) Go to <http://ilab.mit.edu> and login to your account.
 - Select the Microelectronics Weblab Graphical Client
 - Start the lab by clicking the Launch Lab button.
 - To view the laboratory equipment in real time, click the Launch Webcam button.
- b) Experiment Setup:
 - Select the 2N7000 nMOSFET from the Devices menu.
 - Click on SMU1
 - Name the current and voltage at this terminal and select the download option for each of them.
 - Do a voltage sweep (VAR1) from 0 to 5 V with a 200 mV step.
 - Set the compliance to 100 mA.
 - Click on SMU2
 - Name the current and voltage at this terminal and select the download option for the voltage.
 - (What do we expect the current into this terminal to be?)
 - Do a voltage sweep (VAR2) from 0 to 3 V with a 200 mV step.
 - Set the compliance to 1 mA.
 - Click on SMU3
 - Name the current and voltage at this terminal.
 - Set this node to be ground (COMM).
- c) Run Measurement
 - Select Run Measurement from the Measurement menu (or click the running man icon).

d) Results

- Select Download Data from the Results menu, and save it to the local machine.

e) Questions

- 1) Plot and print out the curves of drain current vs. drain-source voltage for the various values of gate-source voltage.
- 2) From the graphs, calculate the values of K and V_T for the MOSFET.
- 3) Calculate the small signal resistance in the triode (linear) region for each of the I_D vs. V_{GS} curves. Plot this resistance as a function of V_{DS} .
- 4) In our discussions of the MOSFET in saturation, we have modeled it as a current source. From the graphs of I_D vs. V_{GS} , we can see that it is not a perfect current source, as the curve is not completely horizontal. We can model this instead as a current source in parallel with some resistance. Calculate this resistance for each of the I_D vs. V_{GS} curves. Plot this resistance as a function of I_D .