Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 - Electronic Circuits
Fall 2003

Homework #5
Handout F03-028

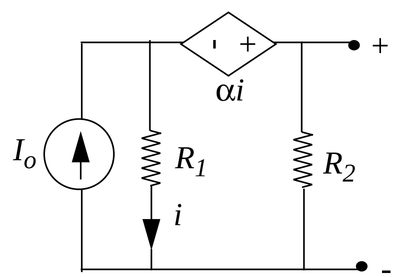
Issued 10/6/2005 - Due 10/19/2003

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.

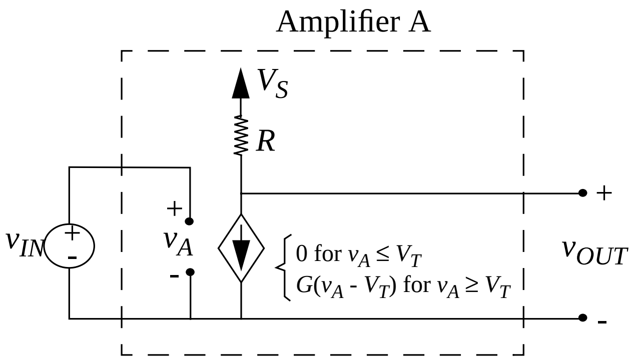
(B) Sketch and clearly label a graph of the input-output relation found in Part (A).

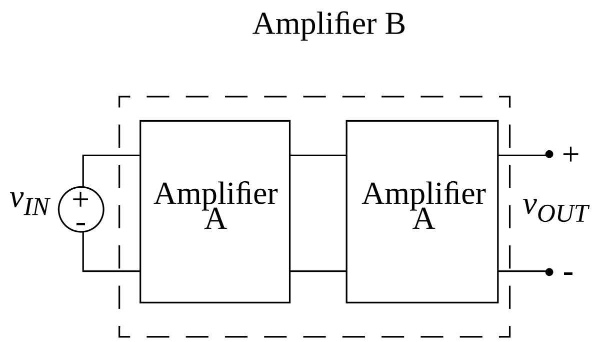
(C) Determine v_{OUT} as a function of v_{IN} for Amplifier B.

(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 $1/(V_{GS} - V_T)$.
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 $1/I_D$.