EECS 215: Introduction to Electronic Circuits WN 2010
Problem Set 5

Issued: 2/5/10

Due: 2/12/10, **9:30 AM**

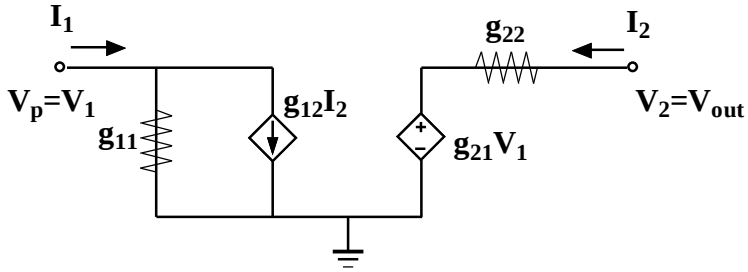
Note: Problem sets are DUE at the start of lecture on Friday mornings. Do not skip class to work on homework further. Your paper may not be accepted.

U&M refers to a problem from Ulaby and Maharb**iz**.

Some of these problems are pretty easy, some more involved. Problem 7, the non-book problem has a long statement, but is not bad. I do recommend starting early, however, in case you hit points of confusion and need assistance. Point assignments to each problem will be added by Monday.

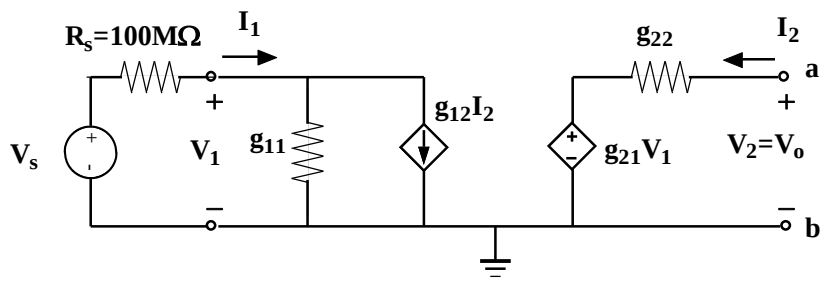
Problems:

1. U&M 3.77
2. U&M 4.10
3. U&M 4.11
4. U&M 4.32
5. U&M 4.42
6. U&M 4.43
7. *This problem will explore the results of non-ideal characteristics of op-amps. However, do the problem requires only the use of nodal or mesh analysis (nodal is recommended). It also shows some of the utility of Thevenin equivalent circuits.*
   We want to build a gain of 100 amplifier for to measure a weak signal from a sensor with a maximum output voltage of 1mV output and a series resistance of 100MΩ. We are going to use op-amps with the following characteristics:
   $$V_{offset} = 0 \quad R_i = 2M\Omega \quad R_o = 75\Omega \quad A = 2x10^5$$
   a. First we build a single stage op-amp using the non-inverting topology with R_1=990KΩ and R_2=10KΩ. Thus, the ideal gain is 100. Using nodal analysis, we can reduce the non-ideal op-amp problem to the network shown below:



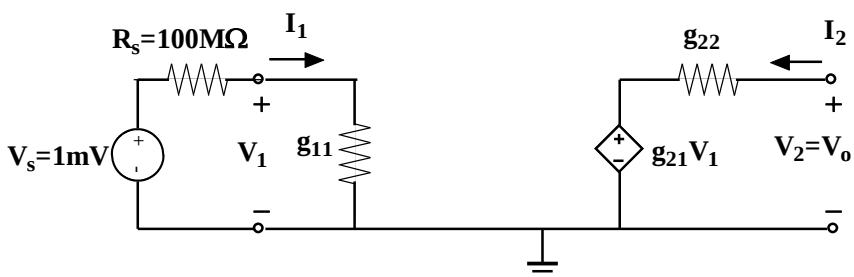
Where the parameters g_{11}, g_{12}, g_{22}, g_{21} ,g_{22} are given in Prof. Terry's lecture notes ("11-Op Amps 1" and on the following pages). A MATLAB function m-file is included on the course CTools site for computing the g-parameters

Thus the full circuit to model our problem is:



Find the Thevenin equivalent circuit seen at the terminals a&b. Find the gain of the full circuit ($G = V_o/V_s$). Also compute the percentage error vs. the ideal gain ($\%G_{error} = \left[\left(G - G_{ideal}\right)/G_{ideal}\right]*100$.

b. Repeat (a) but now ignore the effects of the output on the input (i.e. assume g_{12}=0). Is there any significant difference in your results using this simplified model?



c. To improve $\%G_{error}$, a smart 215 student decides to use a 2 stage design where stage 1 stage 1 is a unity gain buffer (a non-inverting op-amp amplifier with R_1=0, R_2=open circuit). Find the Thevenin equivalent circuit for this circuit. *Hint: You should be able to reuse your analysis work from (a) but the number will change.*

d. Now we complete the circuit with a 2nd stage using R_1=990KΩ and R_2=10KΩ. **Find the Thevenin equivalent as seen by the output terminals and the gain of the full circuit ($G = V_0/V_s$). Also compute the percentage error vs. the ideal gain ($\%G_{error} = \left[\left(G - G_{ideal}\right)/G_{ideal}\right]*100$..** *Hint: You should be able to reuse your analysis work from both (a) and (b).*

e. Compute G and $\%G_{error}$ if we now load the output of the circuit with a 1KΩ resistor.

g-Parameters for the Non-Inverting Op-Amp Amplifier

$$1/g_{11} = R_i + \frac{R_2\left(AR_i + R_1 + R_o\right)}{\left(R_1 + R_2 + R_o\right)}$$

$$= R_i\left(1 + A\frac{R_2}{\left(R_1 + R_2 + R_o\right)}\right) + \frac{R_2\left(R_1 + R_o\right)}{\left(R_1 + R_2 + R_o\right)}$$

$$g_{12} = -\frac{R_2 R_o}{R_i\left[\left(A+1\right)R_2 + R_1 + R_o\right] + R_2\left(R_1 + R_o\right)}$$

$$g_{21} = \frac{A\left(R_1 + R_2\right)R_i + R_2 R_o}{R_i\left[\left(A+1\right)R_2 + R_1 + R_o\right] + R_2\left(R_1 + R_o\right)}$$

$$g_{22} = \frac{\left[R_i\left(R_1 + R_2\right) + R_1 R_2\right]R_o}{R_i\left[\left(A+1\right)R_2 + R_1 + R_o\right] + R_2\left(R_1 + R_o\right)}$$