3: Transfer Functions, Parameters, and Equivalent Circuits of Linear Amplifiers: PART A

ECE 3200 Electronics II
updated 10 February 2021

Reference

1. A. S. Sedra and K. C. Smith, Microelectronic Circuits, 8th ed., Oxford University Press, 2019.

Objectives

1. To measure experimentally and confirm via simulation the static open circuit voltage transfer characteristic of a simple direct coupled linear amplifier. DO NOT DISASSEMBLE YOUR CIRCUIT AT THE CONCLUSION OF THIS LAB. YOU MAY NEED THIS CIRCUIT AT A LATER DATE.

2. To develop an acceptable method of organizing, describing, and recording experimental data as it is generated in the laboratory. NOTE: THIS GENERALLY MEANS THAT IT IS IMPERATIVE THAT DATA BE RECORDED IN YOUR LABORATORY NOTEBOOK, DURING THE LABORATORY SESSION, AT THE TIME THE OBSERVATIONS ARE MADE, AND NOT LATER.

Pre-Laboratory Assignment
(MUST BE COMPLETED INDIVIDUALLY)

COVID-19 Safety

1. Complete the COVID screening questionnaire here **PRIOR** to coming to campus. If you are not able to come to campus as a result of this screening process, a makeup lab will be arranged.

2. Review the *Bronco Student Pledge* here.

3. You will be required to wipe down your keyboard, monitor, mouse, work area, equipment buttons and knobs, components, cables, and any contacted items or surfaces using a disinfecting wipe at the start and end of lab. Be sure lab equipment is OFF when disinfecting.

4. **WASH YOUR HANDS** immediately after lab.

Simulation

5. Through simulation obtain a plot of the static open circuit voltage transfer function V_R vs. V_I of the circuit in Figure 1 (R_S = 0 and $R_L = \infty$. Hint: set R_S to 1fΩ and R_L to 1000MΩ to approximate a 0 and an infinite-valued resistor). The values of R_3, R_4, and R_5 will be provided prior to the lab. Use a DC SWEEP simulation to vary the value of V_I. Note that in LTspice® M=10^{-6} and MEG=10^6. Make sure that you vary V_I over a sufficient range to ensure that V_R reaches well into both the positive and negative saturation regions. From your plot determine the output offset

voltage (V_R when V_I=0 and the load is open), the region of linear operation, and the two saturation voltages. Find the open circuit voltage gain by measuring the slope of the transfer characteristic in the linear region. If you are unsure of the meaning of these terms, read through the laboratory procedure (which you should always do before coming to lab). Paste/tape a copy of your results in your laboratory notebook before coming to lab. YOU WILL LATER REPEAT THIS SIMULATION USING YOUR ACTUAL CIRCUIT COMPONENT AND VOLTAGE VALUES. BE SURE AND SAVE YOUR SIMULATION WORK FOR FUTURE USE. You will need to access your SPICE simulation file(s) in lab.

6. Consider the term "voltage transfer function"; how does the use of that term in part 1 of the pre-lab differ from the term "transfer function" used in say ECE 3100?

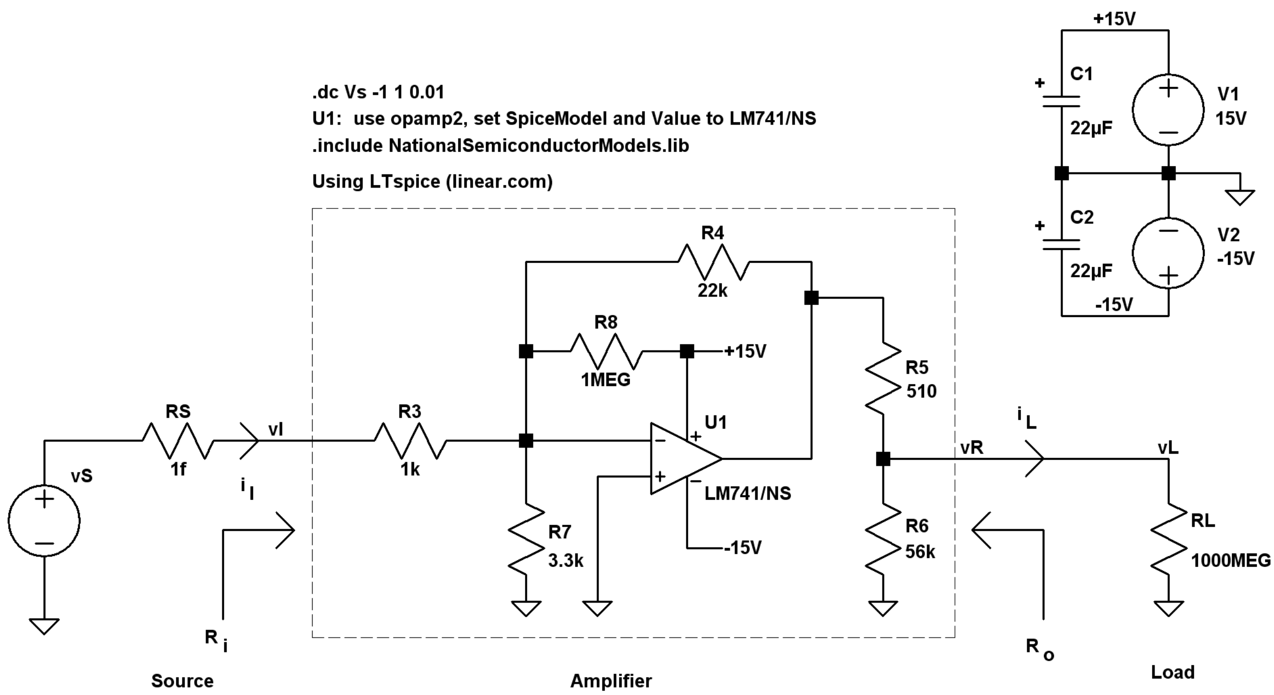

Figure 1. Amplifier Circuit

NOTE: Component values are for illustrative purposes only.

Procedures

1. Maintain social distancing during lab.

2. **BE SURE ALL EQUIPMENT IS OFF.**

   Wipe down the keyboard, monitor, mouse, work area, equipment buttons and knobs, components, cables, and any contacted items or surfaces with the provided disinfecting wipe.

3. Using a 741 integrated circuit, set up the amplifier circuit of Figure 1. Set R_S = 0 and R_L = ∞. Redraw the circuit in your LABORATORY NOTEBOOK and indicate on this drawing the measured values of the resistors and power supply voltages. Note which part of the circuit is the SOURCE, which is the AMPLIFIER, and which is the LOAD.

4. Measure and record the amplifier output offset voltage (V_{ROS}). NOTE: Monitor V_{ROS} on the oscilloscope, first DC coupled and then AC coupled (set oscilloscope sensitivity to about 5mV/div for the AC measurement). Record your observations. Several sentences and graphs may be needed to make the record. The entry in your laboratory notebook should appear something like that shown below. Note that the output offset voltage is the output voltage when the input voltage is zero and the load is open. To zero v_I, short the v_I node to ground. NOTE: never short a voltage source to ground; remove the source before shorting the node.

> *Procedure Part 2 V_{ROS} measurement*
>
> *Set v_I to zero, (Disconnect signal source and use shorting jumper from node v_I to ground)*
>
> *v_{ros} = xxx.xx volts peak-to-peak via O-scope*
>
> *V_{ROS} = xxx.xx volts DC via DMM, 200 millivolt full scale*
>
> *Observations of Scope display of v_{ROS} : v_{ROS} appeared to contain a lot of broadband noise with most of it at about 100 MHz. Also ....*

5. STATIC OPEN CIRCUIT VOLTAGE TRANSFER FUNCTION MEASUREMENT. Remove the input short. Place the oscilloscope in XY mode and monitor V_I on the abscissa and V_R on the ordinate. Use a variable bipolar DC source for V_S to vary V_I in about 0.1V increments over a range that insures that V_R varies from well into negative saturation to well into positive saturation. Use the scope (in XY mode) to detect saturation. Your data entry should look something like:

> *Procedure Part 3 Static Transfer Function Measurement*
>
> *Measure V_I and V_R using DMM in DC mode*
>
> | *Data Table I* | |
> |---|---|
> | *V_I(V)* | *V_R(V)* |
> | *xxx.x* | *xxx.x* |
> | *xxx.x* | *xxx.x* |
> | *xxx.x* | *xxx.x* |

6. Plot your experimentally obtained transfer function measurements ON THE SIMULATED TRANSFER FUNCTION generated in the pre-laboratory assignment. DO IT NOW! As always, be sure to label and enumerate the axis and entitle the graph. From your graph determine and record the following in your data record:

   a. the output offset voltage,
   b. the region of linear operation,
   c. the two saturation voltages, and

d. the open circuit voltage gain, i.e., the slope ($\Delta V_R / \Delta V_I$), in the linear region (of course). Note: Use linear least squares regression analysis to find a better estimate of the voltage gain.

Your data sheet entry should look something like that shown below.

<u>Procedure Part 4</u> From the graphed data, the:

a) linear region is bounded by xx.xx $\leq V_I \leq$ xx.xx and xx.xx $\leq V_R \leq$ xx.xx

b) "Positive" saturation is xx.x V
"Negative" saturation is xx.x V

c) Voltage Gain = ΔV_R / ΔV_I = (xx.xx - xx.xx) / (xx.xx - xx.xx) = xx.x V/V

7. **BE SURE ALL EQUIPMENT IS OFF.**

   Wipe down the keyboard, monitor, mouse, work area, equipment buttons and knobs, components, cables, and any contacted items or surfaces with the provided disinfecting wipe.

8. **Wash hands immediately after lab.**

Exercise

Redo the pre-lab assignment using your MEASURED resistor and voltage supply values. Plot your measurements obtained in procedure 3 on the resulting transfer function (do not "connect the dots"; see section 1.6). Use appropriate statistical measures (e.g. mean and variance) to characterize the error between the simulated and experimental transfer functions (in each region?). Provide your equations. What is an ideal mean and variance? Paste/tape a copy of the resulting graph in your lab notebook.

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