LABORATORY 3

ASSIGNED: 3/2/16

OBJECTIVE: The purpose of this lab is evaluating Thevenin equivalent circuits and the performance of various amplifier circuits using op-amps. You will evaluate operational constraints associated with rail-to-rail and non rail-to-rail op-amps in commonly used op-amp circuits.

MINIMUM EQUIPMENT LIST: You will need the following supplies to complete this lab, at a minimum:

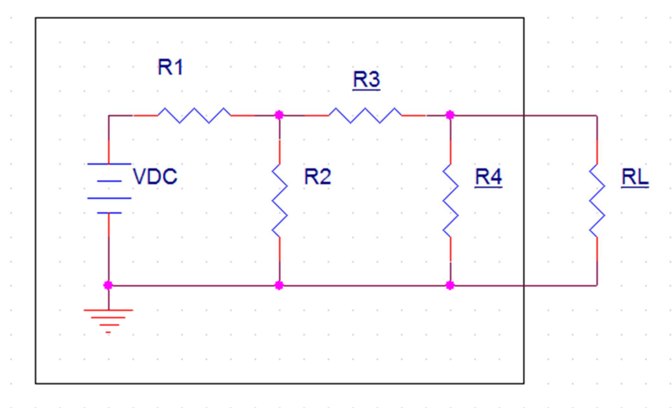
1. Your power supply circuit
2. Multi-meter
3. Test wires
4. Breadboard
5. Electronic Components:
    a. Op-amps:
        i. Rail-to-rail
        ii. Non rail-to-rail (LM741 or equivalent)
    b. Resistors

LAB 3A: THEVENIN EQUIVALENT CIRCUIT

You have learned in class that a more complicated circuit containing a collection of voltage sources and resistances can be represented by the Thevenin equivalent circuit containing a single voltage source and an equivalent resistance. This lab will allow you to demonstrate the equivalency of the two circuits.

Consider the baseline circuit shown below using the following component values:

VDC = 15V; R1 = R2 = R3 = R4 = 20k, $R_{L,1}$ = 12k, $R_{L,2}$ = 3.9k



QUESTIONS:

1. Considering that the main circuit is comprised of all elements except the load resistance "RL,1 or RL,2":
    a. Measure the open circuit voltage "Voc" and short circuit current "Isc" of the circuit
    b. Turn off your power supply and measure the equivalent resistance "Rth" of the circuit

2. Analytically calculate the Thevenin voltage "Vth", short circuit current "Isc" and resistance "Rth" for this circuit
    a. Calculate the percent difference between the measured and calculated values for all three parameters

3. With the load resistance "RL,1" installed:
    a. Measure the voltage across the load "VL"
    b. Calculate the voltage across the load "VL" using node or mesh analysis (and any network reduction technics you feel appropriate)

4. Build the Thevenin equivalent circuit utilizing the calculated resistance "Rth" and adjust your power supply to the Thevenin voltage "Vth" also previously calculated

5. Install your load resistance "RL,1" to the output of your Thevenin equivalent circuit and measure the voltage across the load "VL"
    a. Comparing your results from (2), does your equivalent circuit behave the same as the baseline circuit? Explain your results
    b. Calculate the percent difference between the measured and calculated values

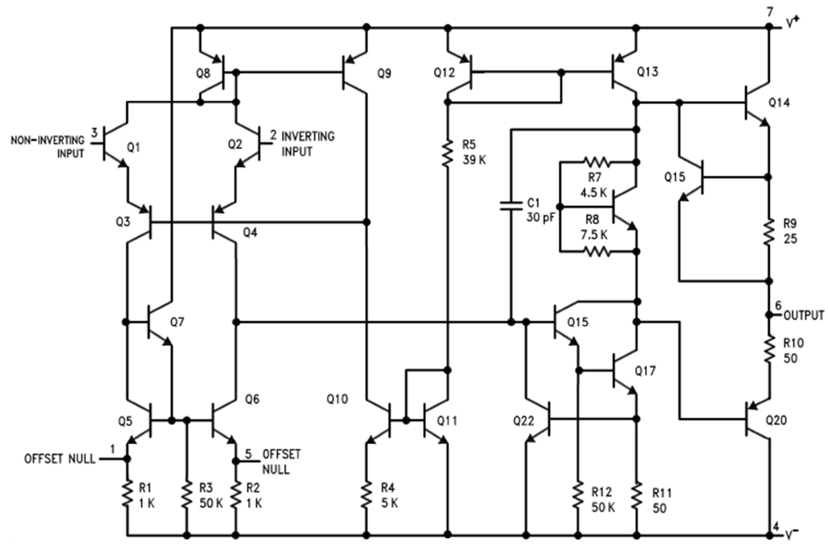
6. Construct the baseline circuit in LTSpice (or other Spice solver)
    a. Without the load resistance "RL,1", determine the open circuit voltage "Voc" and short circuit current "Isc"
    b. Do your calculations from (2) correlate to the simulated results?
    c. Install the load resistance "RL,1" and determine the voltage developed across the load "VL"

7. Construct the Thevenin equivalent circuit in LTSpice (or other Spice solver)
    a. Place "RL,1" in your equivalent circuit and determine the voltage developed across the load "VL"
    b. Does your equivalent circuit exhibit the same operating characteristics as measured in (4)?

8. Repeat (2) through (7) with "RL,2" and describe why there is a difference in results with your measurements with "RL,1"

LAB 3B: INVERTING OP-AMP

This part of the lab will familiarize you with using operational amplifiers (op-amps). There are generally two types of op-amps, rail-to-rail and non-rail-to-rail op-amps. For reference, the LM741 circuit schematic is shown below which details the collection of parts utilized inside the op-amp.



Texas Instruments LM741 – Op-Amp Schematic Block Diagram (From Datasheet)

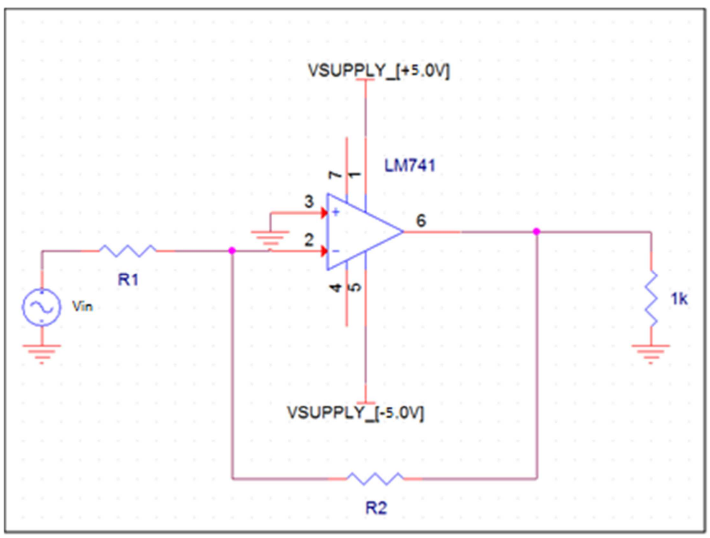
To get started, it is always useful to get an idea of the key operating requirements for the part you are going to use. Let's start using the LM741 op-amp as the active circuit element. Look at the datasheet and extract the key recommended and absolute maximum operating requirements. Be sure and define what each of the parameters tells you.

QUESTIONS:

1. Package Pinout: Draw the physical layout of the chip and label the function of each chip.
2. ABSOLUTE MAXIMUM CONDITIONS:
   a. Differential supply voltage limits
   b. Input pin voltage limits
   c. Output current limits
   d. Power dissipation limits
   e. Thermal resistance
   f. Junction temperature
3. RECOMMENDED CONDITIONS:
   a. Voltage gain
   b. Slew rate
   c. Gain-Bandwidth Product
   d. Supply current

The circuit shown below is an inverter because it samples the input voltage and changes the sign on the output and permits a configurable gain through resistances “R1” and “R2”. You can use your power supply circuit as the “VSUPPLY_+5.0V” source (from the DC-DC converter branch) and the “VSUPPLY_-5.0V” source (from the charge pump branch). For the input signal “Vin”, you can use the regulator branch of your power supply circuit.

Before you begin building your circuit, you will want to make sure that the circuit configuration you plan on using will not exceed the absolute maximum conditions. Verify that none of the parameters will be exceeded and build your op-amp circuit shown below on the breadboard. Configure the circuit with a gain of “Av = -2” using resistors obtained from the class stockroom. You will want to ensure that resistor values greater than “2K” are used to keep from loading the op-amp.



QUESTIONS:

1. Record the output voltage of your circuit when you vary the input voltage “Vin” in 0.5V increments between -2.5V through +2.5V
    a. Plot the data (by hand, Microsoft Excel or some other graphing program)
2. Determine the actual gain exhibit by your circuit:
    a. Based on the actual resistance values used in your feedback path
    b. Does this gain correspond to expected values?
3. What observations have you noticed about the response of the circuit
4. What are the input signal limitations to guarantee predictable results from your circuit (ie: annotate the knee and saturation points)

LAB 3C: INVERTING OP-AMP (RAIL-TO-RAIL OP-AMP)

Repeat LAB3B using a rail-to-rail op-amp