Physics 310
Lab 6 – Op Amps

Equipment: 741 Op-Amp, IC test clip, IC extractor, breadboard, silver mini-power supply, two function generators, oscilloscope, two 5.1 k's, 2.7 k, three 10 k's, 1 k, 100 k, LED, Heath kit power supply, two 10 k pots, photo-transistor, DMM

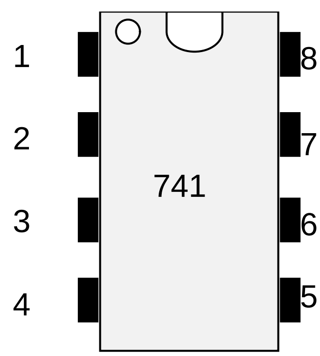
General Lab Notebook instructions (from syllabus)

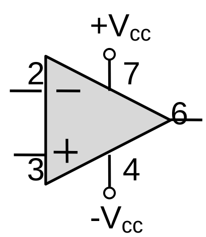
You should be sure to write down enough so that you can recall what you did several weeks later (it may come in handy when you're working on your final project.) The following information should be included:

1. Titles for labs and sections of labs.
2. Description of procedures followed (e.g. what was measured).
3. Well-labeled diagrams of circuits.
4. Record of observations and data (in tabular form when appropriate).
5. Analysis of data: computations and tables or graphs of results.
6. Comparison with theory: calculations and graphical or tabular comparison.
7. Answers to all questions.

General Procedures:

- Carefully place the 741 Op Amp on the breadboard so that it straddles one of the gaps. When properly installed, the breadboard will <u>not</u> connect any of its pins to each other.





1. Offset Null
2. Inverting Input (-)
3. Non-Inverting Input (+)
4. $-V_{CC}$
5. Offset Null
6. Output
7. $+V_{CC}$
8. No Connection

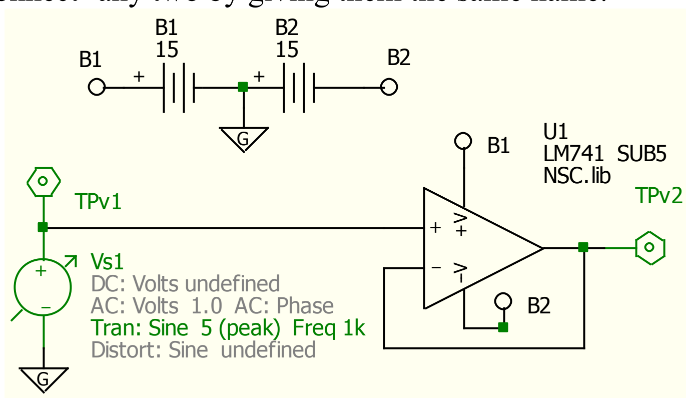
- A top view of the 741 is shown above (sometimes there will only be one of the marks shown on the left). Connect +15 V to the $+V_{CC}$ terminal and –15 V to the $-V_{CC}$ terminal. These connections will remain the same throughout the lab.
- The Offset Null terminals can be used to correct for the output being different than zero when the two inputs are the same. They will not be used in this lab.
- An IC test clip can be used to make connections for testing the voltage at the pins of an integrated circuit (IC). Using an IC extractor to remove the op amp will prevent damage to its pins.

6-1. Follower

Pre-Lab

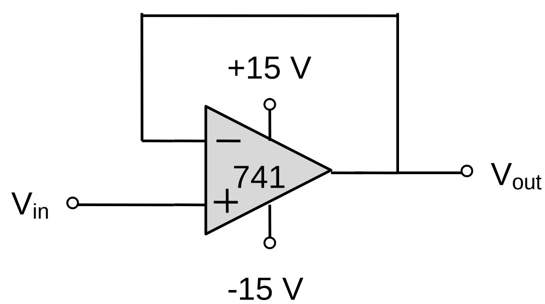
A. In 5Spice, construct the circuit shown below.

1. For the Op-Amp, go to the menu on the right with a similar icon, and then select the op-amp in the upper left of the menu, under the "sub-circuit" heading. To make it an "LM741", once you've placed it on the page, right-click on it, choose to "Edit Parameters…" and then search for LM741.
2. On either end of the two batteries you'll notice two circles labeled "B1" and "B2", and the same names on two more circles attached to the Op-Amp. These allow you to make connections without complicating the schematic with more wires. These circles can be found under the power-supply menu at the left; once you put them on the page, you can 'connect' any two by giving them the same name.



B. Plot the input and output voltages for 2 ms by following the same procedure that you did in the pre-lab for Lab 5.
Question: How are the input and output related to each other?

C. Construct the following circuit (observe that the + and – input terminals are switched relative to their positions in 5Spice, there's no fix convention for which is drawn on top and which is drawn on bottom, so pay close attention to which is which.)



D. Input a sine wave with an amplitude of 5 V and a frequency of about 1 kHz and observe the output.
Questions: How well does the output follow the input? Is the output phase shifted?

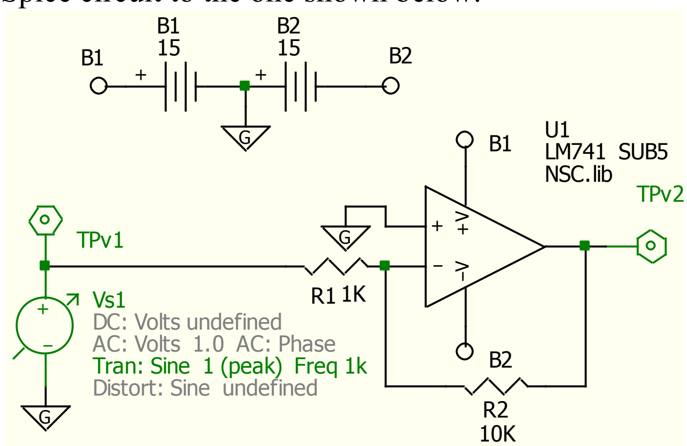
E. Build a voltage divider with two 5.1-kΩ resistors and input a sine wave with an amplitude of 5 V and a frequency of about 1 kHz. Measure the peak voltage of its output. Put a 2.7-kΩ load resistor across the output of the divider and measure the peak voltage across it. Next, connect the output of the divider to the input of the follower and put the 2.7-kΩ load resistor between the follower's output and ground. Measure the peak voltage across the load resistor again.

Question: Why does the follower make it easier to drive a load with the output of the voltage divider?

6-2. Inverting Amplifier

Pre-Lab

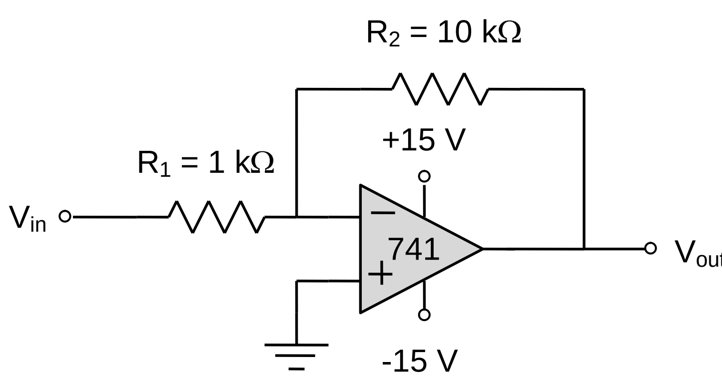
A. Change your 5Spice circuit to the one shown below.



B. Plot the input and output signals for 2 ms; print that out so you can tape it in your notebook where appropriate.

Question: What is the gain (sign and magnitude) and how does it compare with the theoretical value?

C. Construct the following amplifier circuit.



D. Input a sine wave with an amplitude of 1 V and a frequency of about 1 kHz and observe the output.

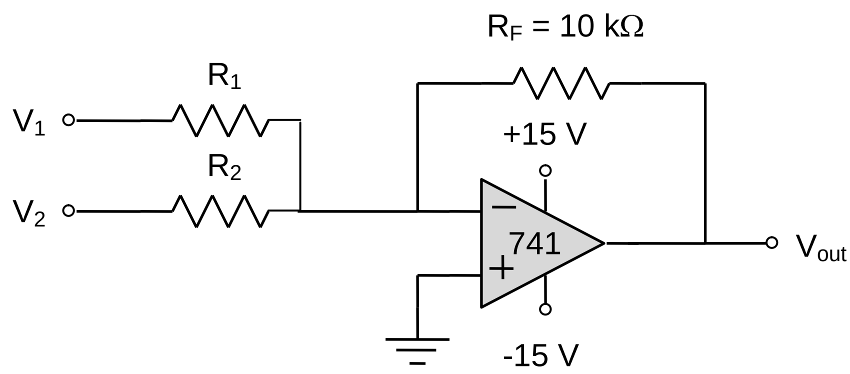
Questions: What is the gain and how does it compare to the theoretical value (calculate your theoretical value using the *measured* resistances of R_1 and R_2); what's the % difference? Is the output phase shifted?

Questions: What happens if the amplitude of the input is turned up to 5 V? Why?

Questions: Does the circuit perform well at all frequencies? If not, when does it work poorly?

6-3. Voltage Summer

A. Construct the following summer with 10-kΩ resistors for R_1 and R_2.



B. Input two different DC voltages for V_1 and V_2 (such that $|V_1+V_2|< 12V$ or the op-amp will max out) and measure the output.

Questions: Ignoring small errors because each "10-k" resistor has slightly different resistance, is the output the sum of the two inputs? If not, how does it differ?

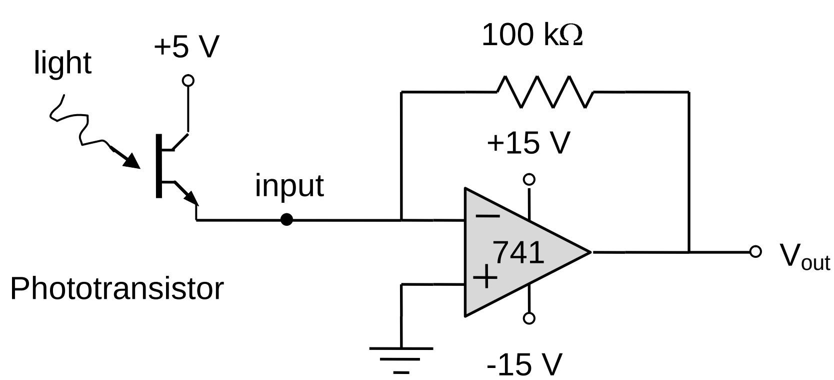
C. Substitute 10-kΩ potentiometers for R_1 and R_2.Wire them so that the resistances increase when the knobs are turned clockwise. Input sine waves with smallest amplitudes possible (remember to pull out the amplitude knob!) but a low frequency for the first input and a high frequency for the second.

Question: What effect does increasing the first resistance (R_1) have? Explain.

For kicks: You can *hear* this effect by attaching the output to a speaker; some should be on hand if you'd like to do this.

6-4. Current-to-Voltage Converter

A. Construct the following circuit to convert the current from a phototransistor into a voltage signal. Light acts as the "base current" for the phototransistor.



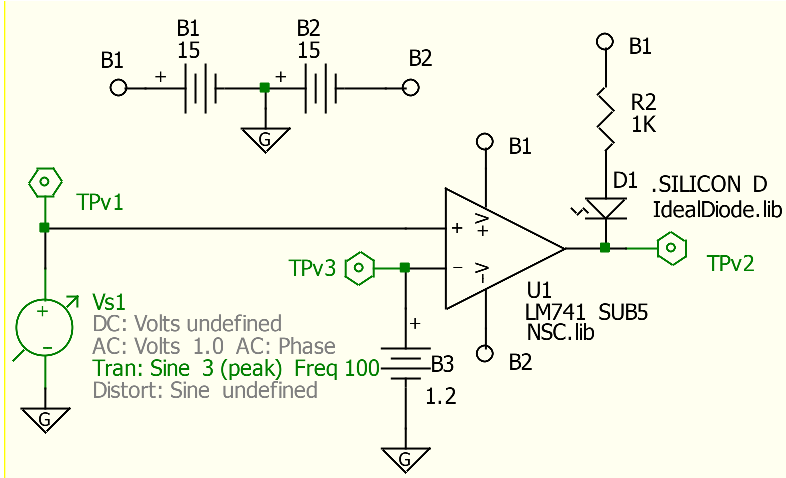
B. Observe what happens to the output voltage with a DMM as the phototransistor is covered and uncovered.

Questions: What is the relationship between the current flowing into the input and the output voltage? What is the maximum current that you experimentally get to flow from your phototransistor?

6-5. Comparator

Pre-Lab

A. In 5Spice, construct the circuit below.

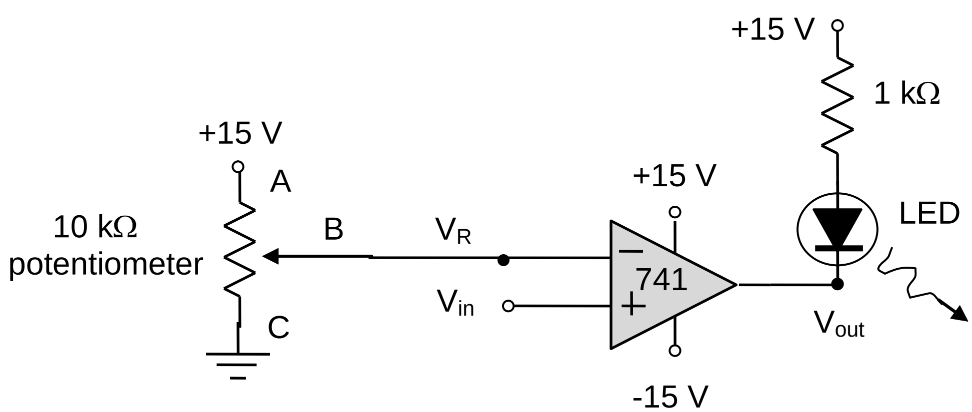


B. Generate a plot which shows all three test point voltages: TPv1, TPv2, and TPv3. Note that the Vs1's frequency is 100Hz, so in the analysis tab, you'll want to set it to run from 0 to 0.02 s.

C. Print the plot to affix in your notebook.

Question: According to your plot, what determines the whether the output voltage (TPv2) is large and positive or negative?

D. Construct the following comparator circuit. Use all three terminals of the potentiometers as labeled to make an adjustable voltage divider for setting the reference voltage (V_R). The middle terminal (B) of the potentiometer connects to the op amp's inverting input. The LED connected to the output will be used as a visual indicator (and the 1-kΩ resistor limits the current).



E. Set the reference voltage to about 5 V. Use another 10k pot to input an adjustable DC voltage.

Question: How does the output vary with the input? (The LED will indicate whether the output voltage is high or low.)

F. Now use a10-kΩ resistor and a 10-kΩ thermistor to modify the circuit so that the LED lights up whenever the temperature drops too low. (If the LED were replaced with a heater, this would be a thermostat since the potentiometer allows you to adjust the desired temperature.) This can be achieved by replacing the V_{in} pot with a voltage divider constructed of the resistor and thermistor. Recall that the resistance of the thermistor drops as the temperature rises. Draw the circuit that you designed.

Note: As discussed in the textbook, it is often better to use a comparator with positive feedback (a Schmidt trigger) to keep the output from oscillating between low and high when the inputs are nearly the same. Alternatively, a comparator IC such as the LM311 could be used.