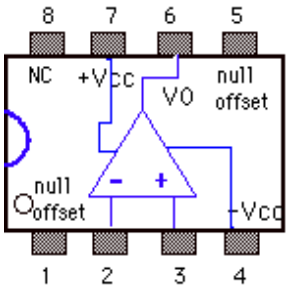
# ELE 215 – Lab 4 – Op Amps

## Objectives

- Build and test an op amp based inverting amplifier.

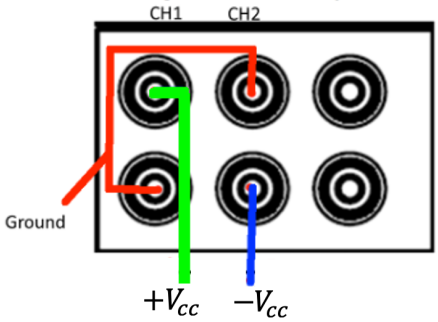
## Notes

- This laboratory is based on the 741 op amp; its pin-out for the standard dual-in-line (DIP) package is shown to the right.




- To power the device, we combine the two channels of the power supply in series, connecting one positive and one negative input together as shown to the right (the heavy red lines) and calling this ground; the other two terminals become the positive (green) and negative (blue) power connections, respectively. Here are the words from the power supply's manual for setting this up:

Figure 9: Series setup




1. Wire the outputs in series (i.e. attach the red wire), as shown in the figure.
2. Push Menu.
3. Use the arrow keys to select Combine CH1+CH2.
4. Push Enter.
5. Push the down arrow key to select V1+V2 Series
6. Push Enter. The screen will return to meter mode. Check that the indicator Series appears on the display, replacing the Channel 2 voltage and current readings. This indicates that the power supply is in the V1 + V2 Series state. The total output voltage is displayed on Channel 1; the Channel 2 values stays at zero.
7. Set the channel 1 voltage to the desired voltage value.
8. Use the ON/OFF button to enable the power. Note that the display will show <OFF> for Channel 2.

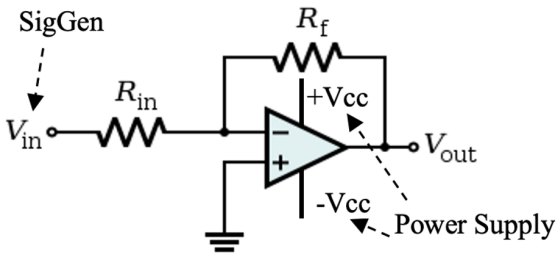
For use in this lab, set the voltage to be 20 volts for $\pm 10$ sources.

## Procedure

1. <u>Build the inverting amplifier</u>:

   a) Select two resistors from the bins, one chosen from between 1 and 10 k Ω for $R_{in}$ and the other resistor 10 times larger for $R_f$. Measure the resistances using the DMM and record the values on the summary sheet (don't forget units!).

   b) Using a breadboard, build the gain 10, inverting amplifier circuit show on the next page:




- Use the power supply connections for $+V_{cc}$, $-V_{cc}$, and ground (pins 7, 4 and 3 on the op amp, respectively).
- The feedback resistor should be the larger resistor.
- Connect the signal generator for $V_{in}$; set if for a 1000 Hz sinusoid with amplitude of 0.5 volts. Connect the ground of the signal generator to the circuit ground (pin 3).
- Connect two channels of the oscilloscope to measure both Vin and Vout. Connect the scope's ground to pin 3 of the op amp as well (it's important that all the components have the same ground). Set up the measurement menu on the scope to show the amplitudes and frequencies of the two signals.
- Assuming that the power is on and that you have built this correctly, you should see two sinusoids on the scope with the output being approximately 10 times as large as the input (5 volts versus 0.5 volts) and also with a 180 degrees phase shift (the inverting part). Call the TA over to see this.

2. Saturation:

a) Increase the signal generator's amplitude until the op amp is just a little bit "saturated," that the top and/or bottom of the output sinusoid is just flattened out a bit. Adjust the DC bias (called "offset") on the signal generator to balance the op amp to make the picture symmetric (i.e. approximately the same flattening on top and bottom of the output sinusoid).

b) Demonstrate your saturation to the TA.

3. Gain-bandwidth product estimation:

a) Decrease the amplitude of the input to eliminate the saturation effect. Record the two amplitudes into the table on your summary sheet, they should both have units of volts. Compute the gain (equal to the ratio of the amplitudes, output divided by input; this should be unitless), it should be about 10, and record it in the next to last column.

b) Increase the frequency of the input sinusoid until the amplitude ratio drops to about 9. Depending upon your specific device, this should be in the 10-30 kHz range. Record the frequency and the two amplitudes in the second row of the table on your summary sheet. Compute the actual gain and, finally, the product of the gain and the frequency (this last column does not need any units).

c) Increase the frequency further until the amplitude ratio drops to about 8. Record the frequency and the two amplitudes in the third row of the table on your summary sheet. Once again, compute and enter the actual gain and then the product of the gain and the frequency. Note that due to other limitations of the op amp the output sinusoid will start to distort in shape and look more triangular; that's okay for this part of the experiment.

d) Repeat step c for desired gains of 7, 6, 5, 4, 3, 2 and 1, respectively. Demonstrate this last result (unity gain) to the TA

e) Complete your table. If you've done things correctly you should see roughly constant values in that last column (especially for the higher frequencies); the closed loop gain-bandwidth (or gain-frequency) product for the device

4. Reporting: Submit one summary sheet per team using Brightspace in the usual way. For example, the file might be named

Lab_4_321_789.pdf