NOTE: You must do parts P1 – P4 PRIOR to coming to the lab session.

EE101 Laboratory 7 (FL03) Name ______________________________

Date ______________________ Partner's name ______________________________

Instructional Objectives (at the end of this lab you should be able to:)

- Follow a wiring diagram to properly construct a prototype circuit containing an operational amplifier.
- Apply a DC voltage signal to this circuit and measure the output signal using the multimeter.
- Understand and explain the concept of signal amplification.
- Be able to calculate expected output signals from basic amplifier circuits with known input signals.

Description and Background

Operational amplifiers are electronic integrated circuits (ICs) that can provide amplification and are designed specifically to be building blocks within a more complex electronic design. Many different operational amplifiers are available to meet a wide range of needs. IC electronics are placed in packages (typically plastic housings) since the electronic circuits themselves are physically very fragile. Data sheets, available on the web for a wide range of IC devices, provide operating information and various application circuit diagrams. One example of a web site for IC information is National Semiconductor at http://www.national.com/

Operational amplifiers have two inputs, inverting (-) and non-inverting (+), and a single output. In order for the amplifier to work, a separate DC voltage supply is required to power the internal circuitry of the integrated circuit. Sometimes the external DC voltage supply is not shown explicitly on circuit diagrams, but it must be included in all op amp projects.

Op amps have a voltage "gain" or amplification factor which is very large – on the order of 100,000 – and this allows some interesting and very useful applications, nearly all of which involve negative "feedback." Feedback means that there is a signal path deliberately connected between the output and the input in such a way that it "feeds back" a negative signal from the output to the input. Detailed analysis of feedback structures shows that a wide variety of useful circuits can be constructed using the feedback principle. In particular, feedback often allows the overall circuit to be highly tolerant of gain variations and other practical limitations of electronic components. This is an attractive property since it often means that the normal manufacturing variations (tolerances) of individual components become insignificant in the performance of the overall circuit. Thus, meeting the desired overall performance specifications becomes readily achievable.

Op amps are designed to have a very high input resistance and a very low output resistance. This means that the inputs of the op amp require essentially no input current and the output is able to drive a wide range of resistances. You will have many opportunities to analyze op amp circuits in the following ECE courses.

Operational amplifiers in the LM158 series (LM158 or 258 or 358) are packaged two to a package. This dual-amplifier package consists of two independent, high gain, internally frequency compensated operational amplifiers which are designed specifically to operate from a single power supply over a wide range of voltages. You will be using the LM358 dual op amp in this experiment and also as a building block in several of the following experiments.

Equipment

Your own circuit prototype board, your own lab kit containing resistors and capacitors (and other components), your own resistor color code chart, alligator clips from your lab kit, lab DC power supplies, and lab digital multimeter, plus meter cables furnished in the lab for connecting to the signal generator.

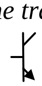
Procedures

You are to complete Procedures P1 through P4 PRIOR to coming to your lab session.

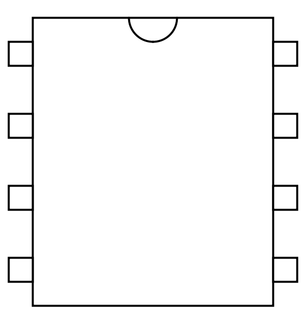
P1. Find the Data Sheet for the LM358 Operational Amplifier on the National Semiconductor web site by (a) going to www.national.com, (b) search by the part number LM358, (c) click on Datasheet, (d) then choose either view online, download, or receive via email.

P2. → Complete Table 1 using the data from the Data Sheet for the LM358A Operational Amplifier and include the page number where you found each requested item. Be sure you are looking at the proper column (LM358A) for these values.

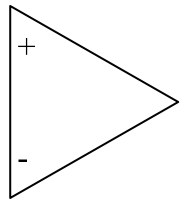
TABLE 1

Information Needed for the LM358A	**Value from Datasheet** (be sure to include **units**)	**Page Number**
Operating Temperature Range, LM358:		
Supply current, typical (typ.) value, for power supply voltage V+ = 5V:		
Large Signal Voltage Gain, typical (typ.) value *(this is the "open loop" gain, without feedback)*		
Output current , typical value, source *("source" means op amp can supply this much output current)*		
Output current , typical value, sink, for $V_O = 2V$ *("sink" means op amp can receive this much current in the output pin)*		
Number of transistors in the internal schematic diagram for one operational amplifier. *Note that the transistors are labeled Q and have three terminals:*  *or*  .		

P3. → Complete the internal connection diagram below for the DIP (dual in-line package) configuration, including pin numbers and pin names. Note that the notch matches with that on the actual chip.



P4. → Sketch the external circuit diagram for the non-inverting DC Gain operational amplifier circuit found in the data sheet, including +10V and ground connections and write the pin numbers on your circuit diagram.



P5. Now in the lab, construct the non-inverting DC Gain operational amplifier circuit you sketched in P4, but using R1 = 39 kΩ and R2 = 7.7 kΩ (4.7 kΩ in series with 3 kΩ). Also remember that you will need to connect +10 volts between the V+ and GND pins on the op amp package.

Set one of the DC power supplies to +10 volts, then use the other DC power supply for the input signal V_{IN}. **Be sure to wire the amplifier circuit correctly and set the DC voltages before connecting the power supplies to your circuit**.

Then **after verifying your circuit wiring**, connect the +10V power supply **first**, then connect the input signal V_{IN} .

→ Make measurements on your circuit and complete Table 2.

TABLE 2

Input voltage, V_{IN}	**Measured output voltage, V_O**	**Calculated gain, V_O/V_{IN}**
0.1 V		
0.5 V		
2 V		
3 V		
5 V		
7 V		

P6. → What is the average gain of your amplifier circuit, averaged over the six gain calculations from Table 2?

P7.

→ Sketch a graph with V_o on the y-axis and V_{in} on the x-axis. Draw a "best fit" straight line through the data points. Remember to label the axes and include a graph title.

→ Now measure V_o for V_{in} = 8 volts and V_{in} = 9 volts. Show the new points on the same graph.

→ Why aren't the new points on the same line as the original measurements? Comment on the results.