**Electronic Instrumentation**

**Name ________________ ENGR-4300 Spring 2002 Section _____________**

# Homework #4
## Introduction to Op Amps

*Due: Tuesday, Februrary 19th*

Fig. 1 shows a standard op-amp configuration known as an inverting amplifier. For this case, we have $V_{out} = -4.7\ V_{in}$. That is, the output voltage is equal to minus the input voltage times the ratio of the feedback resistor to the input resistor. Feedback resistors feed the output voltage back to the inverting input. Essentially anything that connects the output terminal of the op-amp to the inverting input terminal will provide feedback.

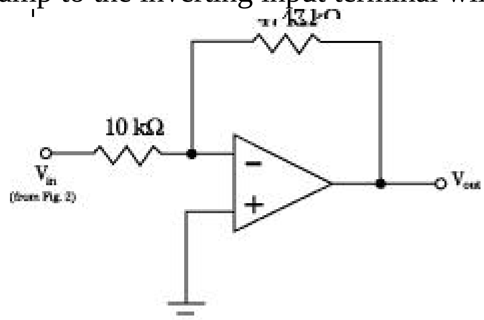


Figure 1

In Fig. 2 we have another op-amp configuration known as a non-inverting amplifier. Here we have $V_{out} \cong 2\ V_{in}$. That is, the output voltage is equal to the input voltage times one plus the ratio of the feedback resistor to the resistor connecting the inverting input to ground.

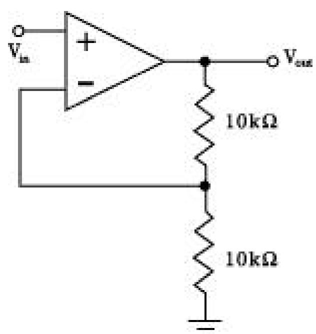


Figure 2

The more commonly used configuration is the inverting op-amp, which means that, much of the time, the output will be negative if the input is positive.

The mysterious properties of the op-amp are actually quite easy to understand. When connected correctly, an op-amp is a circuit with a very, very large voltage gain, where voltage gain is defined as the ratio of the output voltage to the input voltage of the op-amp itself. The input voltage is the difference between the voltage connected to the plus terminal and the voltage connected to the minus terminal. If we call these $V_+$ and $V_-$, the gain is defined as

$$A = V_{out}/(V_+ - V_-) \rightarrow \infty$$

Typical values for this gain can be 100,000, so it is indeed a very large number. If the voltage at the output terminal is the order of a volt or so, then the difference between $V_+$ and $V_-$ must be very, very small.

It is important to realize that there are two kinds of gains we will be using. There is the gain just mentioned that characterizes the op-amp device itself. Usually, we will not be too interested in this gain, since we will just assume that it is so big that we can assume it is infinite. The other more useful gain is the amplification of the circuit configuration (i.e. inverting or non-inverting op-amp) in which the op-amp is used. Unless we indicate otherwise, we will only use the word *gain* when we refer to the total configuration, not just the op-amp itself. We will probably refer to the latter as the *intrinsic gain.*

If we connect an op-amp into either of these or other standard configurations, it will do a very good job of following what are known as the *golden rules for op-amps.* There are two such rules:

First, since the voltage gain of the op-amp itself is so high, a fraction of a millivolt between the input terminals will swing the output voltage over its entire range, so we ignore that small voltage and state that

*I. The output attempts to do whatever is necessary to make the voltage difference between the two inputs zero.*

Second, op-amps draw very little input current (0.08µA for the 741; picoamps for FET-input types); we round this off, stating that

*II. The inputs draw no current*

1. Apply these two rules to the circuits in Figures 3 and 4 and produce a simplified circuit with no op-amp in it. Then analyze the circuit to show that the gains given above are correct. Instead of using actual numbers for the resistors, label them $R_1$ and $R_2$ for the resistor connected to the minus input and the feedback resistor, respectively.
(6 points)

2. The inverting op-amp configuration negates the signal and multiplies it by a gain. The non-inverting op-amp configuration multiplies the signal by a gain without negating it. What does the differential op-amp configuration in experiment 4 do to the two input signals? (1 point)

3. For experiment 5, you will need to understand and use voltage signals represented by complex numbers. Look through http://www.geom.umn.edu/~laurence/welcome.html. Note that in electrical circuits, i is always written as j. Answer the following questions: (3 points)

a) What is "j" ?
b) What is "$j^2$"?
c) Sketch a plot with the points (3+j4), (3-j4), (-3+j4), and (-3-j4) clearly labeled.
d) The magnitude of a complex number is the square root of the sum of the squares of the real and imaginary parts. What is the magnitude of (3+j4)?
e) The phasor of a complex number is the inverse tangent of the imaginary part divided by the real part. The phasor is given by $\angle$. What is $\angle$(3+j4)?
f) What is the phasor of the following for all real values:
- a positive real number (with no imaginary part) ie. 3
- a negatve real number (with no imaginary part) ie. –3
- a positive imaginary number (with no real part) ie. j3
- a negative imaginary number (with no real part) ie. –j3