Pre-lab assignment:
Read the Basic Oscilloscope Features

Objectives:
1. Review of Lab procedures and equipment
2. Experimental verification of the LF356 op-amp PSpice model - comparison of experimental and simulation results

Lab procedure and post-lab report:
The inverting op-amp amplifier having an ideal gain of -10 is shown in Figure 1:

Figure 1: Inverting op-amp amplifier and LF356 pinout.

The LF356 data sheet is provided on the website.

The same amplifier has been tested using PSpice in Lab 1: the PSpice deck is example2.cir. The .dc, .tran and .ac analyses have been used to determine dc transfer characteristic, step transient responses, and frequency responses. In Lab 2 your task is to perform the same tests experimentally and to compare the experimental results to the results obtained by PSpice simulations.

For each of the experiments performed, your post-lab report should include:

a) Detailed circuit diagram of the experimental circuit annotated with component names and values, and signal names. A sketch by hand is fine.

b) Relevant equipment setup data:
   - Oscilloscope: probe coupling, vertical and horizontal scales (volts per division and seconds per division), trigger setting
   - Signal generator: type of waveform, offset, amplitude, frequency
c) Experimental results; scope waveforms (sketch by hand is fine) should be annotated with signal names that should match the names shown in the schematic, and scales (volts per division and seconds per division).

d) Comparison of the experimental results with the results obtained by simulation

Perform the experiments necessary to get the following results:

**DC transfer characteristic:**

(a) The maximum Vomax and the minimum Vomin DC output voltage the amplifier can produce for the given supply voltages;

(b) the range of input voltages, Vin,min < Vin < Vin,max where the DC characteristic of the amplifier is very close to the ideal (Vout = -10 Vin).

This DC transfer characteristic experiment can be performed in two different ways:

1.1 Using a DC voltage source as the input Vin, and a DC voltmeter to measure the output voltage
1.2 Using a signal generator to sweep Vin (at low frequency), and a scope with two probes (to sense the input voltage and the output voltage) in XY mode to display the complete DC transfer characteristic

Do both 1.1 and 1.2.

**Step transient responses:**

The rise time tr and the propagation delay tp of the amplifier for the step input specified in the PSpice deck. Include an annotated sketch of the scope waveform in your report.

**Frequency responses:**

Print out the magnitude and phase responses obtained by PSpice simulation and use this sheet to label measured magnitude and phase of the amplifier at several frequencies. The objective is to find out how well the frequency response of the amplifier is modeled in simulation. In this experiment, the input signal should be a sine-wave with 0.1 V peak-to-peak amplitude. Find the experimental -3dB bandwidth frequency fbw of the amplifier and compare it to the result obtained by simulation.

**Extra credit:**

Repeat the test to find the -3dB bandwidth frequency for different values of the input signal amplitude. With a linear amplifier, the frequency responses and therefore the bandwidth should be independent of the signal amplitude. With the real op-amp, however, you will find that the "large-signal" bandwidth drops as the amplitude signal increases, which is due to the "slew-rate" limitation of the op-amp. Collect the data to plot the "large-signal" bandwidth as a function of the output signal amplitude.

The post-lab report is due one week after the lab is completed unless posted otherwise.