Lab 2 – Signal Conditioning

**Format**

This lab will be conducted during your regularly scheduled lab time in a group format. Each student is responsible for learning all of the material, so I strongly recommend that you rotate roles during the lab. You may ask the lab instructor for assistance if needed, but successful completion of the lab is your responsibility.

**Report**

An individual, short report is due at NOON on the **Friday** February 3, 2006. You are strongly encouraged to finish your report early so that you can focus on Lab 3, which is a formal lab (worth **FOUR** informal labs). Follow the guidelines found on Lab 1-1. An optional template is available on [http://www.me.ua.edu/me360/](http://www.me.ua.edu/me360/). Please note that it comes with no warranties – and has not been verified to contain a marker for every piece of information needed for a good grade.

**Caveat**

Typos slip past and equipment malfunctions. If circumstances require it, the TA’s are authorized to modify procedures. Just proceed as directed and note the changes in your report.

**Introduction**

Often the output signal of an electronic transducer must be conditioned prior to being transmitted. An example is the amplification of a low-level signal from a transducer to a higher level for readout. Another example is the reduction or elimination of noise or unwanted frequencies in an output signal via filtering.

2.1 Test a Single Input, Inverting Op-amp Circuit

In the first experiment, two 741 operational amplifiers (op amps) are used to build a circuit for amplifying voltage. The voltage follower circuit has a fixed gain of 1, while the gain of the inverting op-amp can be changed to a desired value. The voltage follower shown in Figure L2-1 is used to “isolate” the output of the potentiometer from the input of the inverting op-amp.

![Diagram of Inverting Op-Amp Circuit](image)

Figure L2-1. Inverting Op-Amp Circuit.
Procedure:

1. Your lab instructors will provide you with the circuit shown in Figure L2-1 (possibly with some small changes). Verify the connections and note any differences. Refer to the 741 data sheets in your class notes for information on the pin connections.

2. Connect the ±12 volt bipolar power supply to the op amp. Connect power supply to the op amp only after the rest of the circuit has been properly connected and checked.

   **ALWAYS DISCONNECT THE POWER SUPPLY before making or changing any connection on an op-amp circuit.**

3. Adjust the 10kΩ potentiometer to within ±0.1 volt of the nominal values for \( E_{in} \) shown in Table L2-1 below. It is not necessary to get exactly the voltage noted in the table. Measure \( V_{in} \) and \( V_{out} \) with the DMM at the locations shown in Figure L2-1.

   **Table L2-1. Input Voltages for Lab Exercise 2.1**

<table>
<thead>
<tr>
<th>1.0 volts</th>
<th>2.0 volts</th>
<th>3.0 volts</th>
<th>4.0 volts</th>
<th>5.5 volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0 volts</td>
<td>9.5 volts</td>
<td>0.0 volts</td>
<td>-1.0 volts</td>
<td>-2.0 volts</td>
</tr>
<tr>
<td>-3.0 volts</td>
<td>-4.0 volts</td>
<td>-5.5 volts</td>
<td>-7.0 volts</td>
<td>-9.5 volts</td>
</tr>
</tbody>
</table>

4. Repeat step #3 with different students setting the input voltage and reading data.

5. After collecting two sets of data, remove the resistors \( R_1 \) and \( R_2 \) from the board and measure their resistances. These resistance values are used in the formula to compute the ideal gain for the op-amp circuit.

Outside Lab:

6. Plot measured \( V_{out} \) vs. \( V_{in} \) with all of your data points.

7. Identify the linear region on the plot of experimental data.

8. Find the experimental gain for each set of data in the linear region except for the 0.0 volt input set,

   \[
   G_{exp} = \frac{V_{out}}{V_{in}}
   \]

9. Compare experimentally measured gains to the theoretical gain, where

   \[
   G_{theo} = -\frac{R_2}{R_1}
   \]
2.2 Measure RC Filter Response

This exercise involves the testing of a passive RC (resistor-capacitor) filter supplied by your lab instructor.

Procedure:

1. A low-pass filter will be assigned to your group. The output of the function generator will be “buffered” with a voltage follower, which will serve as the input to your passive filter. *Make sure you understand the connections on the breadboard; if in doubt, ask the lab instructor.*

2. Use the function generator to input a 5.0 $V_{pp}$ (volts peak-to-peak) *sine* wave to the low-pass filter at the nominal frequencies given in Table L2.1. It is not critical that you get exactly the frequency listed, ±10 Hz is close enough.

3. For each input sine wave frequency generated by the function generator, record the measured frequency, $E_{in}$ (input amplitude) and $E_{out}$ (output amplitude) with the *VirtualScope*.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>400 Hz</th>
<th>450 Hz</th>
<th>500 Hz</th>
<th>550 Hz</th>
<th>600 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Hz</td>
<td>150 Hz</td>
<td>200 Hz</td>
<td>280 Hz</td>
<td>350 Hz</td>
<td></td>
</tr>
<tr>
<td>650 Hz</td>
<td>700 Hz</td>
<td>750 Hz</td>
<td>800 Hz</td>
<td>900 Hz</td>
<td></td>
</tr>
<tr>
<td>1.0 kHz</td>
<td>1.3 kHz</td>
<td>1.6 kHz</td>
<td>2.0 kHz</td>
<td>2.5 kHz</td>
<td></td>
</tr>
</tbody>
</table>

4. Repeat step #2 with different students setting frequencies and reading data.

5. Pull the resistor and capacitor from the circuit and measure their values. Use these measured values in the equations of the textbook for the theoretical values of gain.

*Outside Lab:*

6. Plot the experimental gains (dB) against the input frequency $\omega$ (in rad/sec). Note that the gain (in dB) is on the y axis, which has a normal linear scale, and the frequency is on the x axis, which has a log (base 10) scale.

7. Plot the *theoretical* frequency response of your filter (plotted as a solid line) on the same plot as the experimental values (plotted as points). Comment on any discrepancies.
2.3 Build and Measure First-Order Butterworth (RC) Filter
This exercise requires your group to design, build and test an active, low-pass RC (resistor-capacitor) Butterworth filter. An example of this type of filter is shown in your text in Figure 3.21. Break frequencies $f_c$ and gains $G$ will be assigned in lab.

Procedure:

1. Select components (1 or 2 capacitors and 2 or 3 resistors - either series or parallel connection) for the filter assigned to your group. Your designed break frequency should be within $\pm 5\%$ of the assigned break frequency.

2. Measure the resistance and capacitance of the selected components. Calculate the theoretical break frequency, $f_c$, for your selected components.

3. Build the low pass filter on the breadboard and make the necessary connections to the input (function generator) and output (scope), similar to those of the second exercise.

4. Use the function generator to create a 4.0 volt (peak-to-peak) input sine wave at the frequencies listed in Table L2.2. It is not critical that you get exactly the frequency listed, $\pm 10$ Hz is close enough.

5. Verify the frequency generated with the *VirtualScope*.

<table>
<thead>
<tr>
<th>Table L2.2. Input Frequencies for Lab Exercise 2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 $f_c$</td>
</tr>
</tbody>
</table>

6. Save the data (both channels) collected from *VirtualScope* for each input sine wave frequency generated by the function generator. Use filenames that identify the input frequency tested.

7. Repeat steps #3-5 with different students setting frequencies and reading data. You will now have 2 sets of experimental data for your filter.

**Outside Lab:**

8. Determine the experimental gain (output amplitude / input amplitude) and the phase angle (delay between input and output signals) for the filter as a function of frequency.

9. Use the measured values for resistance and capacitance to calculate theoretical gains and phase angles for the filter. Plot these theoretical values (as lines) on the same plot as the experimental values (as points) and comment on any differences.