Mechatronics I Laboratory Exercise: Operational Amplifiers

Operational amplifier (op-amps) is one of the most useful integrated circuits available. The schematic of an op-amp consists of three connections (see Figure 1): the inverting input (-), the non-inverting input (+), and the output.

There are two main assumptions: the internal-gain of the amplifier and its input impedance is high that you can consider it to be infinite. These two assumptions allows the following simple design rules, which are approximations that suffice for our purposes:

1. The voltage at the inverting input point , "-", is the same as the voltage at the non-inverting input point "+". For example, if the point "+" is connected to ground (as shown in Figure 1) then this potential can be considered as zero. Then this statement says that the potential at point "-" is also zero.

2. The current flow between - and + is zero. Hence Kirchoff's current law states that the sum of the currents entering node 1 (see Figure 1) is zero.

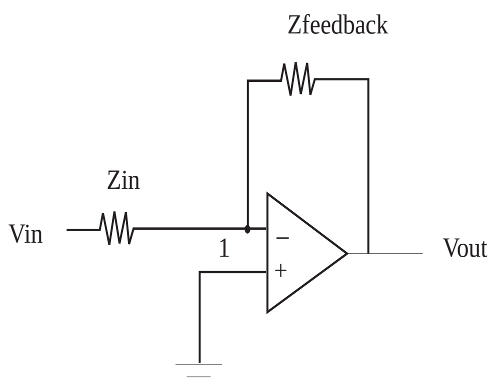

Figure 1: Schematic of an inverting amplifier circuit.

Using the two simplifying assumptions, the circuit can be simplified to the circuit shown in Figure 2.

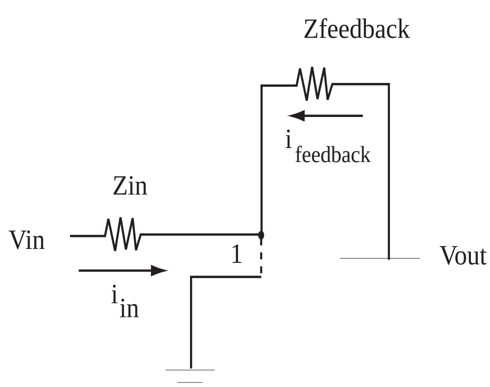

Figure 2: Simplified circuit.

The dashed line indicates a virtual ground at the inverting input since the first design rule says that the voltages are equal at the two input points. Summing currents at node 1, results in Equation 1.

$$i_{in} = -i_{feedback} \tag{1}$$

Putting in the relationships for the currents results in Equation 2.

$$\frac{V_{in}}{Z_{in}} = -\frac{V_{out}}{Z_{feedback}} \tag{2}$$

Or:

$$V_{out} = -\frac{R_{feedback}}{R_{in}} V_{in} \tag{3}$$

Pre-lab Report

Consider a sinusoidal input signal with frequency 2Hz and amplitude 1Volt. The objective is to differentiate a signal and to record it using computer data acquisition system. Keep in mind that the A/D system saturates at ±5 volts. Consider saturation in your design. You will first buffer the signal using a voltage follower (Figure 3), then differentiate (Figure 4) the signal and later amplify it appropriately (to maximize resolution) before passing it into the A/D. Design and analyze the circuit you designed using the resistor and capacitor values listed below. Resistors must be chosen from: 1K, 2.2K, 3.3K, 10K, 33K, 68K, 100K, 200K and 500K (ohms). Consider A/D saturation in your design! Capacitors can only be: 0.1mF, .01mF, .001mF, and 1nF.

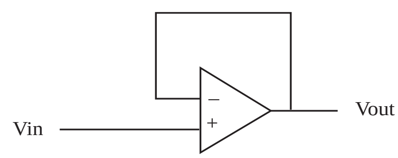

Figure 3: Voltage Follower.

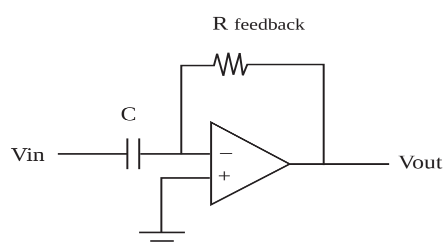

Figure 4: Differentiator Circuit.

Laboratory Excerise

Equipment Needed: Breadboard, function generator, and oscilloscope.

1. Build the circuit you designed in the prelab. To verify the input and output relationship for your circuit, start LabWindows CVI and load the project "OP_AMP.PRJ" from "C:\CVI\PROGRAMS\LABS\OP-_AMP" folder. Take the output from your circuit (op-amp signal) and connect it to AI CHO on the A/D board. Using a function generator, apply a 2Volt amplitude, 5 Hz sinusoidal input to your circuit. Connect the output from the function generator to AI_CH1 (input signal). Verify the sine wave using the oscilloscope. Set the appropriate sampling rate and number of samples and start the program. There should be two waveforms captured by CVI, one is the output from your circuit (op-amp signal) and the other is the input sine wave (input signal). Save the file and show the plot in your report. The data file contains three columns. First column is time, second column is op-amp output signal, and third column is input signal. How does the output look? Why?

2. Add a capacitor across the feedback resistor in your differentiator circuit (see Figure 4). Make sure that the product of your feedback resistor and the added capacitor is around 0.001. Set the appropriate sampling rate and number of samples and start the program. Save the file and show the plot in your report.

3. How does the output signal change? Find the phase delay and amplitude gain?

4. Apply a 2 Volt 500 Hz signal as input to the circuit. Set the appropriate sampling rate and number of samples and start the program. Save the file and show the plot in your report. How does the output change?

Post-Lab Report

What is the input-to-output transfer function for your circuit (without the extra capacitor)? How does the transfer function change when you added the capacitor? Analytically (using Laplace Transforms techniques) predict the output for the two inputs you tried in the Lab. Compare the results with your observations in the lab. Include all relevant circuit diagrams and plots. Make sure you answer all questions from Laboratory Exercise steps 1-4.