Operational Amplifiers: Part I

Sping 2015

Objectives

- To demonstrate the principle of superposition by examining the characteristics of a weighted summer op amp configuration.
- To observe the effects of non-ideal amplifier characteristics, including finite input resistance, finite open-loop gain, and systematic offset voltages.
- To demonstrate methods of offset cancellation via capacitive coupling.

Parts and Equipment Required

Components and Materials Needed:

- 741 Operational amplifiers (2).
- 10nF capacitor (1).
- 10kΩ resistors (5).
- 10kΩ potentiometer (1).
- Breadboard and hookup wire.

Equipment to be Used:

- Banana cable sets (4).
- Oscilloscope probes (2).
- Potentiometer adjustment tool (1).

- BNC-to-BNC cable (1)
- BNC-to-alligator cable (1)

1 Pre-Lab Exercises

Exercise 1. Consider the inverting weighted summer circuit shown in Fig. 1. Using only parallel combinations of 10kΩ resistors, design the amplifier stage to implement the function $v_{\text{out}} = -v_1 - 2v_2$. (You will use a total four 10 kΩ resistors). Predict the input resistances seen at terminals v_1 and v_2.

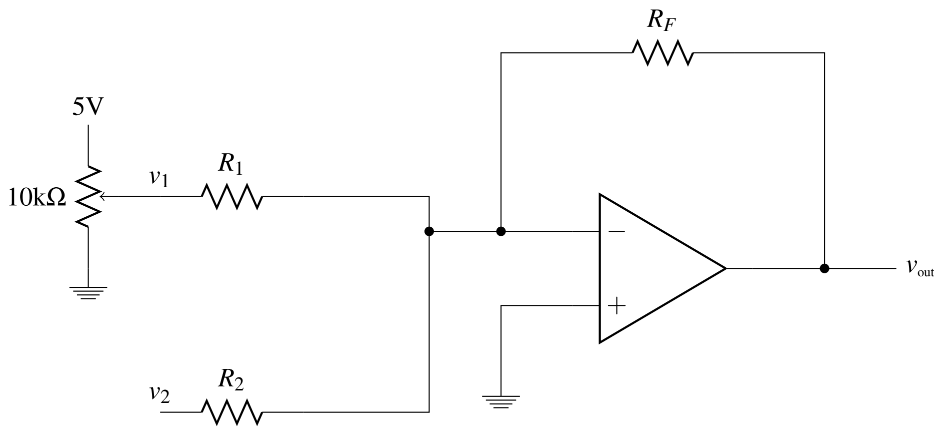

Figure 1: Circuit for Exercise 1.

Exercise 2. Consider the revised weighted summer circuit shown in Fig. 2. In this circuit, an AC coupling capacitor, $C = 10\text{nF}$, is inserted in the signal path of v_2. This creates a high-pass filter which rejects the DC offset of v_2, allowing only the AC part to be summed with v_1. What is the cutoff frequency (i.e. the *lowest* frequency that will be passed) for this high-pass configuration?

Exercise 3. Consider another circuit, shown in Fig. 3, which is similar to the circuit from Exercise 2. In this circuit, a unity-gain follower is used to isolate the high-pass offset-reject filter from the input resistance in the second stage. Note that a 10MΩ resistor is inserted with the coupling capacitor in order to pass the op amp's non-ideal bias current. Predict the high-pass cutoff frequency for this two-stage configuration.

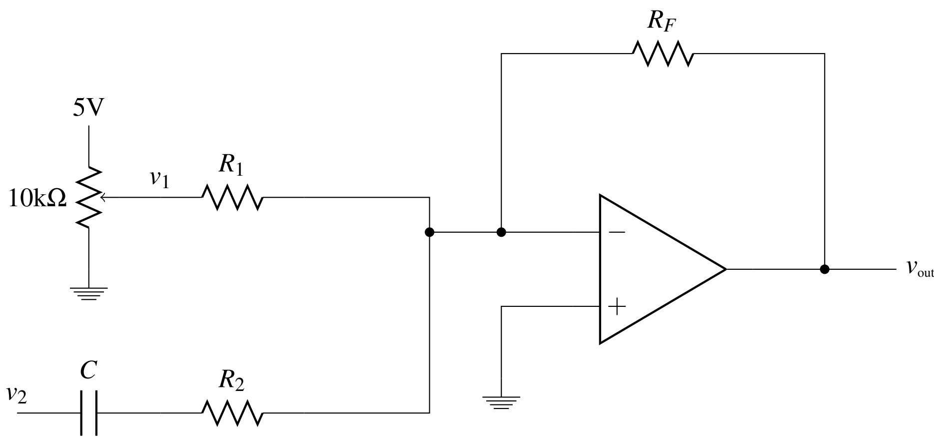

Figure 2: Circuit for Exercise 2.

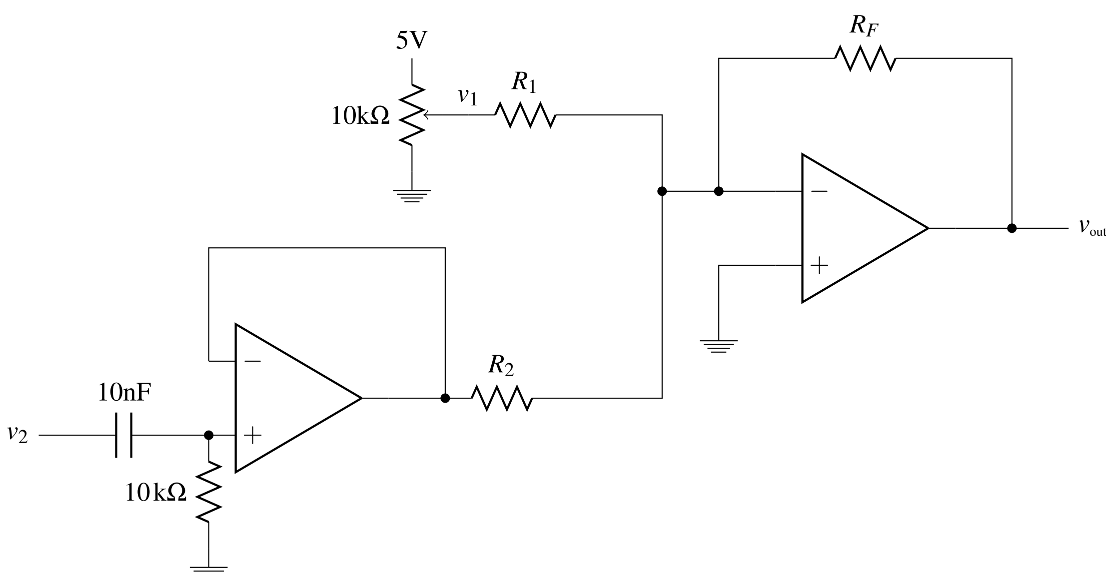

Figure 3: Circuit for Exercise 3.

2 Physical Experiments

Procedure 1. Using a breadboard, construct the circuit described in Fig. 1. Use $+15$V and -15V for the 741's power supplies. Perform the following experiments:

Step A. Adjust the potentiometer so that $v_1 = 1$V. Connect v_2 to the 5V supply. Measure the precise value of v_2 using the DMM, since it won't be exactly 5 V. Predict the amplifier's output for these input values. Measure the actual input and output values using the digital multimeter. How closely do the values match? Offer explanations for any discrepancy.

Step B. Connect v_2 to ground (zero potential). By adjusting the potentiometer, vary v_1 from 1 V to 2 V in steps of 0.25 V. Record a table that includes precise measurements of both v_1 and v_{out}. In your table, also record the expected value of v_{out} for each measured v_1, and record the error (i.e. the difference between the expected and measured v_{out}).

Step C. Record two plots in your lab note book. In both plots, let the horizontal (x) axis be the input voltage v_1. In the first plot, draw graphs showing the measured and expected values of v_{out} for each measured v_1. In the second plot, draw a graph of the error. Answer the following questions, and justify your answers using features from your graphs:

i Does the circuit's gain differ from the designed value?

ii Does the op amp exhibit a systematic offset voltage?

Procedure 2. Construct the circuit described in Fig. 2. Using a BNC-to-alligator cable, connect the function generator's output to the circuit's input at v_2. Perform the following experiments.

Step A. Offset Cancellation:

i Set the function generator to provide a sinusoidal waveform with 1V peak-to-peak amplitude and 50kHz frequency. Use the 0–2 V range setting on the function generator.

ii Using an oscilloscope probe, record a precise measurement of the peak-to-peak amplitude and offset voltage at v_2 and at v_{out}. You will need to use AC coupling in the `Channel` settings to get an accurate amplitude measurement, and DC coupling to get an accurate offset measurement.

iii What is the gain at this frequency? Is it the same as the DC gain measured in Proc. 1?

iv Vary the function generator's DC offset and describe how v_2 and v_{out} respond. Note: you may need to *pull out* the offset adjustment knob in order to change the setting. Make sure both `Channel` settings are configured for DC coupling.

v While keeping the function generator's offset voltage fixed, vary v_1 by adjusting the potentiometer. For three separate values of v_1, record measured values for v_1, and predict the effect that the value will have on v_{out}. Using the oscilloscope, measure and record the offset voltage of v_{out} at each value. Do the measured values agree with your predictions? Offer explanations for any discrepancies.

Step B. Frequency Response:

i Using the FFT procedure that you practiced in Lab 1, measure the 3 dB cutoff frequencies of the circuit. Due to the capacitor C, there will be two cutoff frequencies, one at a low frequency (f_{low}) and another at a high frequency (f_{high}). The transfer function is maximized for frequencies between f_{low} and f_{high}. You may need to use different sampling rate settings to measure the high and low frequencies.

Procedure 3. Construct the circuit shown in Fig. 3. Repeat the frequency-sweep measurement described in Proc. 2 B. After completing the measurement, explain any observed differences between the measured frequency responses, the cutoff frequencies, and the bandwidth of these two circuits.

3 Post-Lab

In your lab book, write a brief summary of your findings. Prepare a formal report describing the objectives, methods and major findings of this lab experience. Your report should compare results from pre-lab analyses, SPICE simulations and physical experiments. Submit this report online in Canvas, and have the TA examine and grade your lab book.