EE43/100--Lab #6
Op Amps Guide

Motivation / Objectives

In this lab, we will be learning about operational amplifiers (op amps), and simple circuits involving op amps. We will compare the op amp theoretical analysis developed in the lectures with actual measured values, and real-world (non-ideal) op amps. In addition, the circuits used in this lab will also reinforce previous concepts, such as voltage dividers and superposition.

Important Notes

- Please set the current limit on the DC power supply to 300mA or less, on both the 6V and ±25V outputs, to prevent damage to the op amps.
- These circuits are complicated. Good breadboard practices will be key in completing this lab.

Part 1: Op Amp Setup

1. Set the current limit on the 6V, 25V, and -25V outputs of the DC power supply to 300mA. Set the power supply to have outputs of +5V, +10V, and -10V. Be sure to use the same ground node for the ground of the 6V and ±25V outputs.

2. We will be using the LM741 op amp. The pinout of the LM741 package is shown in Figure 1.

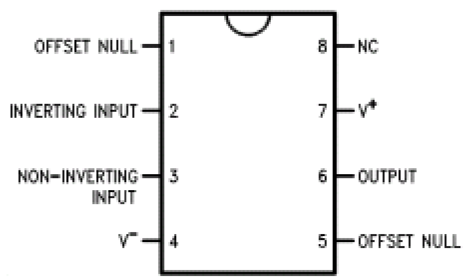

Figure 1: Pinout of LM741 package (Source: National Semiconductor LM741 datasheet)

Part 2: The Voltage Follower

3. On your breadboard, build the op amp circuit shown in Figure 2. The numbers correspond to the appropriate pin of the LM741. $\mathbf{V_{DD}}$ and $\mathbf{V_{SS}}$ will be supplied by the DC power supply. Set $\mathbf{V_{DD}}$ = 10V and $\mathbf{V_{SS}}$ = -10V.

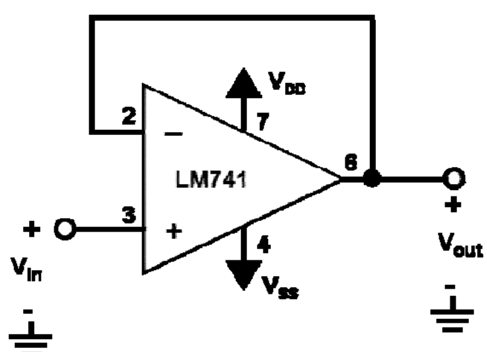

Figure 2: The voltage follower

4. Apply a 5V DC voltage to $\mathbf{v_{in}}$. Measure this value using the DMM. What is the expected value of $\mathbf{v_{out}}$? Verify by measuring $\mathbf{v_{out}}$ with the DMM.

Part 3: The Inverting Amplifier

5. On your breadboard, build the op amp circuit shown in Figure 3. The numbers correspond to the appropriate pin of the LM741. The circuit element labeled **R** is an adjustable resistor, which is realized by using a potentiometer.

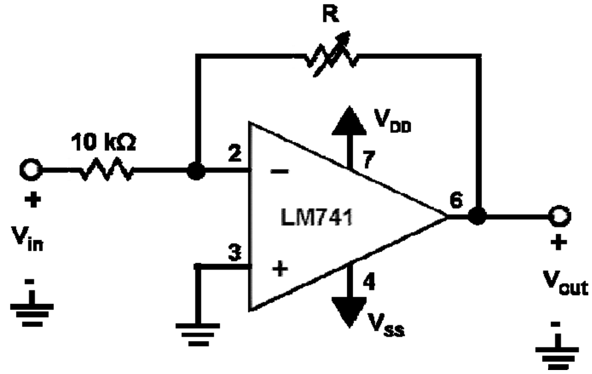

Figure 3: The inverting amplifier

6. Set **R** to approximately 20kΩ. Use the DMM to measure the exact value of **R**. Using the 6V output of the DC power supply, apply a 1V DC signal at $\mathbf{v_{in}}$. Using the measured value of **R**, calculate the expected value of $\mathbf{v_{out}}$. Verify by measuring the value of $\mathbf{v_{out}}$ using the DMM. What is the gain of this circuit?
7. Increase **R** to approximately 50kΩ. Use the DMM to measure the exact value of **R**. Using the measured value of **R**, calculate the expected value of $\mathbf{v_{out}}$. Verify by measuring the value of $\mathbf{v_{out}}$ using the DMM. What is the gain of this circuit?
8. Disconnect the 1V DC input. Use the function generator to apply a 1kHz, 0.5Vpp sine wave to $\mathbf{v_{in}}$. Measure $\mathbf{v_{in}}$ using the oscilloscope to obtain a more precise value. Using the measured value of $\mathbf{v_{in}}$, what should $\mathbf{v_{out}}$ be? Using the second channel of the oscilloscope, measure $\mathbf{v_{out}}$ and display it on the screen along with $\mathbf{v_{in}}$. Plot the input and output waveforms (using the same scales for both signals). What is the gain of this circuit?

Part 4: The Non-inverting Amplifier

9. On your breadboard, build the op amp circuit shown in Figure 4.

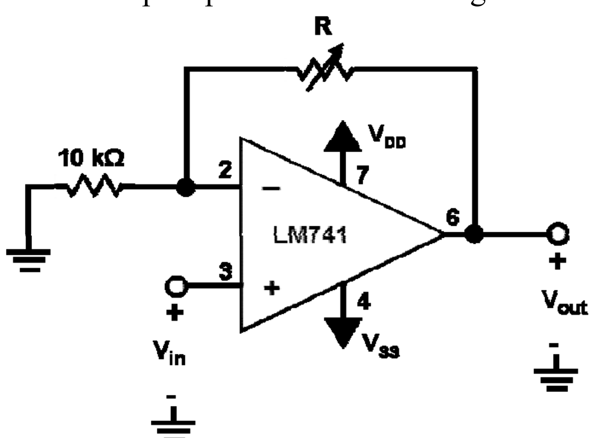

Figure 4: The non-inverting amplifier

10. Set **R** to approximately 20kΩ. Use the DMM to measure the exact value of **R**. Using the 6V output of the DC power supply, apply a 1V DC signal at $\mathbf{v_{in}}$. Using the measured value of **R**, calculate the expected value of $\mathbf{v_{out}}$. Verify by measuring the value of $\mathbf{v_{out}}$ using the DMM. What is the gain of this circuit?
11. Increase **R** to approximately 50kΩ. Use the DMM to measure the exact value of **R**. Using the measured value of **R**, calculate the expected value of $\mathbf{v_{out}}$. Verify by measuring the value of $\mathbf{v_{out}}$ using the DMM. What is the gain of this circuit?
12. Disconnect the 1V DC input. Use the function generator to apply a 1kHz, 0.5Vpp sine wave to $\mathbf{v_{in}}$. Measure $\mathbf{v_{in}}$ using the oscilloscope to obtain a more precise value. Using the measured value of $\mathbf{v_{in}}$, what should $\mathbf{v_{out}}$ be? Using the second channel of the oscilloscope, measure $\mathbf{v_{out}}$ and display it on the screen along with $\mathbf{v_{in}}$. Plot the input and output waveforms (using the same scales for both signals). What is the gain of this circuit?

Part 5: The Summing Amplifier

13. On your breadboard, build the op amp circuit shown in Figure 5.

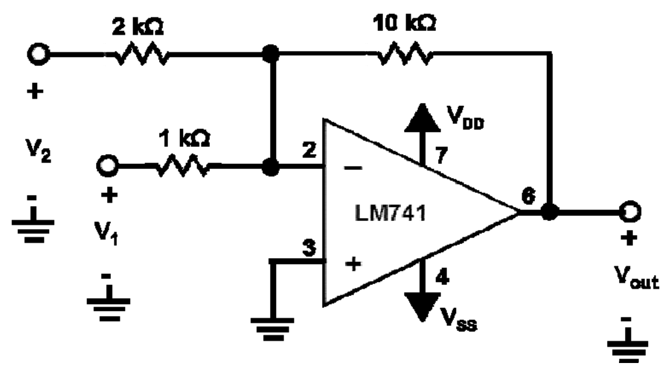

Figure 5: The summing amplifier

14. Leaving $\mathbf{v_2}$ disconnected, use the 6V output of the DC power supply to apply a 0.5V DC signal to $\mathbf{v_1}$. What value do you expect for $\mathbf{v_{out}}$? Verify by measuring the value of $\mathbf{v_{out}}$ using the DMM.
15. Now disconnect $\mathbf{v_1}$, and use the 6V output of the DC power supply to apply a 0.5V DC signal to $\mathbf{v_2}$. What value do you expect for $\mathbf{v_{out}}$? Verify by measuring the value of $\mathbf{v_{out}}$ using the DMM.
16. Use the superposition principle to calculate $\mathbf{v_{out}}$ for the case where $\mathbf{v_1} = \mathbf{v_2} = 0.5V$. Apply a 0.5V signal to both $\mathbf{v_1}$ and $\mathbf{v_2}$. Measure the value of $\mathbf{v_{out}}$ using the DMM. You have now witnessed the superposition principle in practice.

Part 6: The Non-Ideal Op Amp

17. One condition of the ideal op amp is that the open-loop gain is infinite. Let's see how a real op amp behaves. Build the circuit shown in Figure 6.

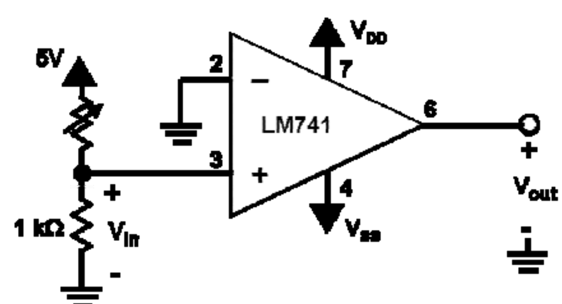

Figure 6: Open-loop op amp

18. Set **R** = 4 kΩ. Use the DMM to measure the exact value of **R**. Using the measured value of **R**, calculate the expected value of $\mathbf{v_{in}}$. Verify by measuring the value of $\mathbf{v_{in}}$ using the DMM. What is the expected value of $\mathbf{v_{out}}$? Measure the actual value of $\mathbf{v_{out}}$ using the DMM.
19. Set **R** = 1 kΩ. Use the DMM to measure the exact value of **R**. Using the measured value of **R**, calculate the expected value of $\mathbf{v_{in}}$. Verify by measuring the value of $\mathbf{v_{in}}$ using the DMM. What is the expected value of $\mathbf{v_{out}}$? Measure the actual value of $\mathbf{v_{out}}$ using the DMM. Review your results for **R** = 4 kΩ and **R** = 1 kΩ. Why is the measured value of $\mathbf{v_{out}}$ not equal to the expected value?

Part 7: The Differential Amplifier

20. Build the op amp circuit show in Figure 7.

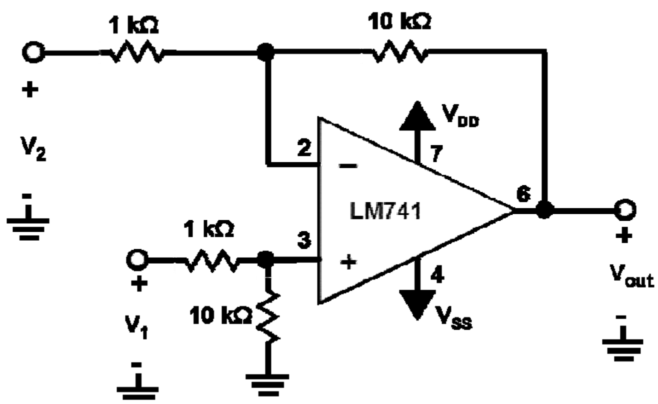

Figure 7: The differential amplifier

21. Using the 6V output of the DC power supply, apply a 1V DC signal to $\mathbf{v_1}$. Using the function generator, apply a 1kHz, 1Vpp sine wave to $\mathbf{v_2}$. What do you expect the output of the differential amplifier to be?
22. Measure the output of the differential amplifier using the oscilloscope. Plot the output waveform.