

California State University, Fresno

Department of Electrical and Computer Engineering

ECE 90L Principles of Electronic Circuits Laboratory

Experiment No. 6: Operational Amplifiers*

Objective

The operational amplifier, or op-amp for short, has many applications in electronic circuits. In this laboratory you will gain experience using op-amps to create a number of useful circuits, including an inverter, non-inverter, summer, and cascaded amplifier.

Prelab

- 1.) Design each of the circuits specified in the Procedure section of this lab. Your design should attempt to get within $\pm 5\%$ of the specified gain. All designs are to use standard commercial 5% resistors. You may only use a single resistor for each calculated value. Complete all work in your laboratory journal.
- 2.) The theoretical input resistance of an operational amplifier is infinite. Power supplies, however, are typically designed to provide a source voltage for a finite load resistance. Therefore, it is often necessary to connect a $50\ \Omega$ resistor to ground between the output of the power supply providing the input voltage, and the input of the operational amplifier circuit. Draw a circuit diagram showing the connection between the input voltage supply, the $50\ \Omega$ resistor, and your operational amplifier designs.
- 3.) What is the maximum output voltage that an operational amplifier can supply? Why?

Procedure

The op-amp chip that you will be using, the *LM747*, comes in a 14-pin DIP PACKAGE, which stands for dual in-line pin package. The two rows of seven pins are arranged with 0.1 inches between pins and 0.3 inches between rows. The pin-out diagram is shown in Figure 1. This diagram illustrates the top view of the chip. The end of the chip with the #1 pin is identified by both the notch and the dot.

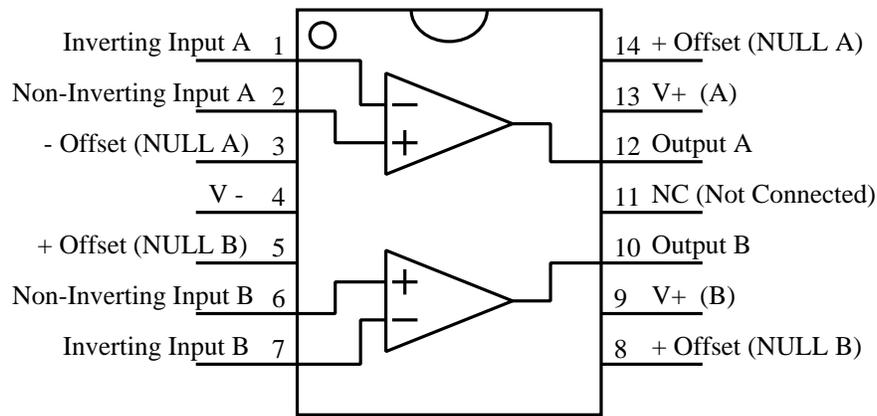


Figure 1: LM 747 Pin-out

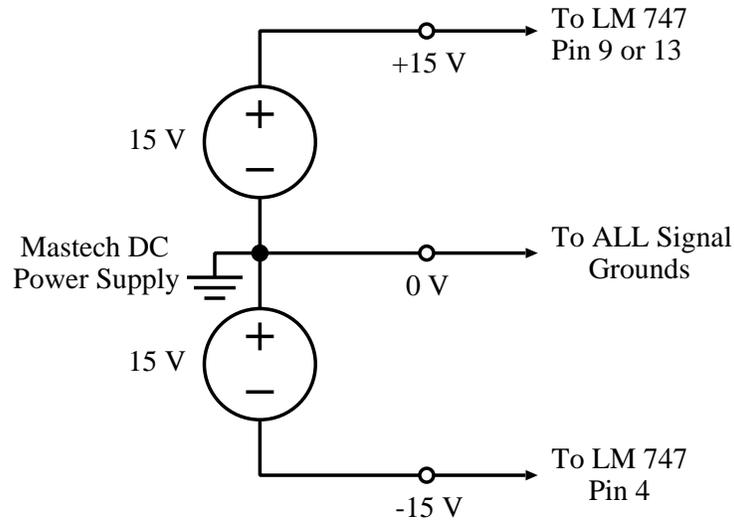


Figure 2: Power supply hook up using the Mastech DC Power Supply

The *LM747* requires a dual power supply in most applications. A positive voltage with respect to ground is supplied to the $V+$ pins and a negative voltage with respect to ground to the single $V-$ pin. The power supply ground, by itself, is not needed by the chip. It will be used, however, as a reference for your signals. The proper power connections are illustrated in Figure 2.

When you test each of your designs, measure the gain using a DC input voltage. Be careful that the output of the op-amp is not being saturated. You can check this by cutting the input by a factor of, say, two, and verifying that the output is reduced by the same factor. If the relationship does not hold, you are saturating the output by applying too strong of an input signal to the amplifier. Use the white breadboards to build your circuits.

Secondly, test the gain of each circuit using a 1 kHz, AC signal. Again, watch for saturation, but this time increase the input until the output obviously saturates. Then reduce the input enough to have a “clean” output.

- 1.) **Inverter** — Design, build, and test an inverter that has a gain of -15 and an input resistance of at least 1 k Ω . Orderliness of your wiring is important. If you are not careful, you will have a non-working circuit or even a dead op-amp. The chips are easy to burn out via electro-static discharge, and do not do anything spectacular when they go (such as smoke).
- 2.) **Non-inverter** — Design, build, and test a non-inverting circuit with a gain of 15 and an input resistance of at least 1 k Ω .
- 3.) **Summer** — Design, build, and test a summing amplifier that produces an output of $Input_1 + 2 \cdot Input_2$. The input resistance of each input should be at least 2 k Ω . Use a DC voltage for $Input_1$, and the 1 kHz AC voltage for $Input_2$.
- 4.) **Cascaded Amplifier** — Design, build, and test a non-inverting amplifier with a gain of 25 and an input resistance of at least 50 k Ω . Do this without using any outlandish resistors. (For example, try cascading two op-amps together, each with a smaller gain.)

Conclusion

Briefly discuss your conclusions regarding the relationship between linearity and operational amplifiers. What are their limits? When does saturation occur, and why? What kind of mathematical functions could you perform when building an op-amp circuit?

Acknowledgments

*This lab has been adapted from Dr. Wm. J. Eccles' Circuits & Systems I laboratory on Operational Amplifiers.

Group Report

- 1.) Compare the measured values of the voltage gain in your circuit with your theoretical values, accounting for the actual, measured values of resistance. How accurate is the amplification?
- 2.) Describe how you could implement voltage addition, subtraction, multiplication, and division using op-amps.