Mixed Electronics Lab 3
Operational Amplifiers

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1 Introduction

The students will build and test a transimpedance amplifier, a differential amplifier, and a comparator. The applications of these circuit types will be discussed, and students will be asked to design op-amp circuits to accomplish generalized tasks. What students learn in this lab will be a foundation for later projects, when they will be asked to amplify and process analog signals.

1.1 Background

Unlike the passive circuit components used so far, operational amplifiers require a power supply to operate. The amount of amplification is referred to as the gain, and is a simple ratio of V_{out} over V_{in}. The combination of passive elements around an op-amp determine the gain across the op-amp. The ideal op-amp has equivalent voltages at the positive and negative node, and supplies no current from the output. The specific behavior of an op amp can be found on its data sheet. The output of an op-amp is limited by the power supplied to it.

In this lab, students will design and build op-amps to address specific tasks. The circuit responses will be characterized based on ideal assumptions, and measured values will be compared against them in order to determine experimental error.

1.2 Transimpedence Amplifier

Consider a sensor that produces a DC output with a current between 0 and 100 mA, but your existing analog circuitry requires a DC signal between 0 and 5V. You have a wide set of resistors available and two op-amps available. Create a transimpedence amplifier system to amplify your DC input.

1. How much gain do you require?
2. What limits can you expect from the op-amp?
3. Is it possible to accomplish your goal with only 1 op-amp? Discuss the pros and cons of this arrangement.

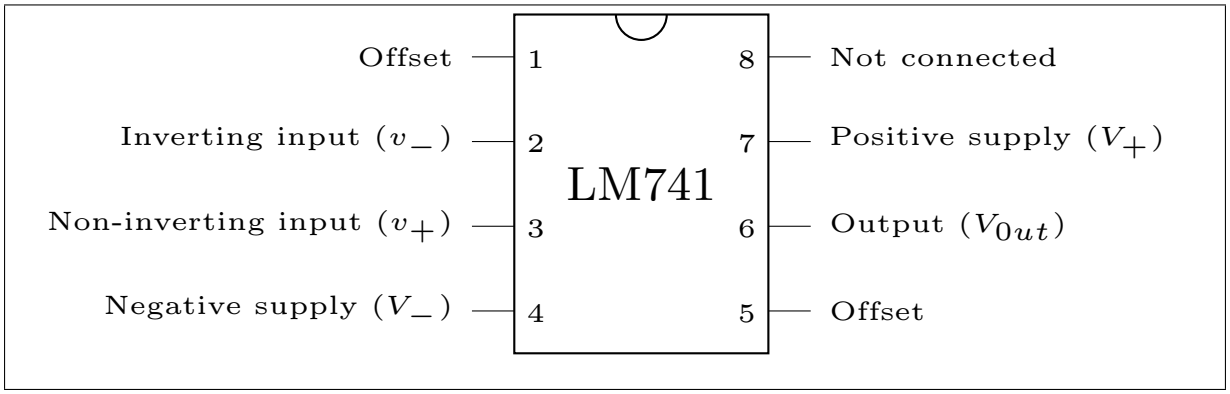

Figure 1: The configuration of pins for a LM741 Op-Amp in a DIP format

4. Using the power supply to simulate a DC signal, test your design.

5. Does your design meet the expected specifications? How were specifications determined?

6. How could you use capacitors to implement a low-pass filter, and limit high frequency noise?

1.3 Differential Amplifiers

Consider a sensor whose output is affected by the ambient temperature as well as another variable of particular interest, such as light level or air pressure. In order to isolate changes in the signal corresponding to the variable of interest, a second sensor is established as a control. By taking the difference of outputs, the effect of the second variable on the primary sensor's output is able to be isolated. Using a range of resistors and a single op-amp, design a differential amplifier system with 2 inputs. Use a power supply to simulate a .75V DC control, and use the function generator to simulate a sinusoidal sensor output, with a 1 Vpp output. The output of the system should be bound between 0 and 3.3 V.

1. What is the ideal gain of your system, and how can you control it?

2. This particular system is often modified into an instrumentation circuit. Determine how and why an instrumentation circuit would be used.

3. Determine the difference between an instrumentation amplifier and a differential amplifier. Discuss what additions would be necessary to the existing circuit

1.4 Comparator

In order to extract relevant information from an analog signal, comparisons against a reference value can be performed to process the information digitally. A cascade of comparators can be used to set and evaluate a range of thresholds, as utilized in an analog-to-digital converter. While it is possible to utilize dedicated hardware cooperators, an op-amp can be configured to serve as a comparator.

Consider the Wheatstone bridge built in the first week of labs. Comparing the voltages at two nodes allows for determining the value of a unknown resistor. A comparator can be used to show when the resistor in question is matched to the reference components.

1. Design a comparator system that indicates when a Wheatstone bridge is balanced, it may require multiple cooperators.

2. How accurate can the system be made to be?

3. How large is your error and what are the sources of error?

1.5 Questions to Consider

1. What characteristics would be useful in an op-amp for measuring a signal from an ultrasonic source?

2. What characteristics would be useful in an op-amp for measuring a signal from an very quiet source?

3. What characteristics would be useful in an op-amp for measuring a very fast signal?