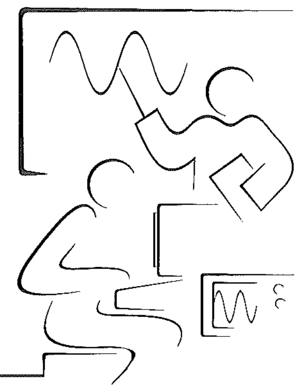

Lab 5
Operational Amplifiers

In this exercise you will learn how an operational amplifier (Op-amp) functions in simple circuits. You will investigate a *voltage follower*, a *summing amplifier*, a *differential amplifier*, and a *differentiator.*

Reading Assignment

Building Scientific Apparatus by J. H. Moore, C. C. Davis, and M. A. Coplan (Addison-Wesley, NY 1989). Section 6.4.2 *General Transistor Amplifier Operating Principles* (pages 398-402) and Section 6.4.3 *Operational Amplifier Circuit Analysis* (pages 402-406).

Materials Required

Heathkit ET-1000 Circuit Design Trainer (1); Operational amplifier: OP97FP (1); Resistors @ 1/4 W: 1 kΩ (1), 10 kΩ (4); Capacitor, ceramic, 0.1 μF (1); Diode, 1N4002 (2); Hookup wire; Digital multimeter: 4 1/2 digit (1); Oscilloscope (1).

I. Introduction

The OP97FP is a precision operational amplifier manufactured by Analog Devices. The Op-amp is supplied in an 8-pin Dual-In-Line Package (DIP). Pay particular attention to the pin assignments as shown in Figure 5-1. Locate and identify each pin on the actual IC package. Notice that some of the pins are not used. Although the OP97FP is relatively insensitive to destruction by static electricity, it is a good practice to handle all Op-Amps with care. In particular, do *not* touch the pins with your fingers! Insert the Op-Amp near the center of the breadboard in the Heathkit Circuit Design Trainer. Wire protection diodes to the Op-Amp as shown below. In your lab report, describe how the protection circuit functions. Insure that the positive and negative terminals of the power supply connections are correct, the voltages are set to within one volt of their nominal values, and the polarities are correct. Take your time. If the Op-Amp or power supply leads are wired incorrectly the Op-Amp could be destroyed!

Caution Supply V_{CC} and V_{EE} to the Op-Amp simultaneously. If this is not possible, supply the positive bias first, and then the negative bias.

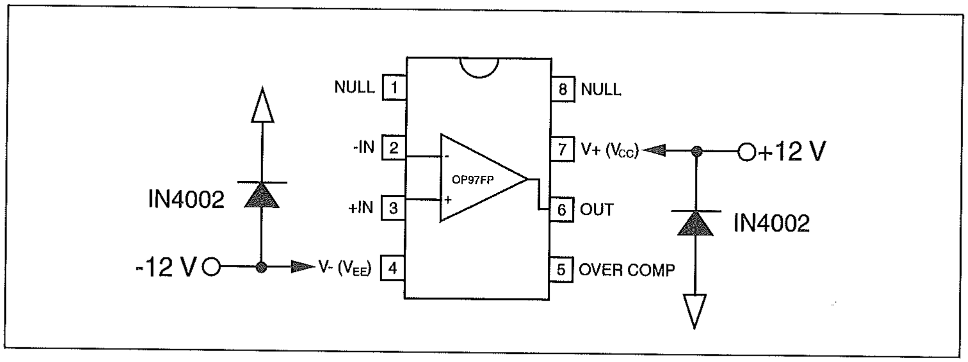

Figure 5-1. Pin-out for an OP97FP Operational Amplifier

II. Voltage Follower

Construct the circuit voltage follower shown in Figure 5-2. Remember to check and double-check the magnitude of each power supply voltage *and its polarity*. Before applying V_{CC} and V_{EE}, calculate the voltage gain (the ratio of the output to the input voltage). Turn on the power supply voltages noting the caution outlined above.

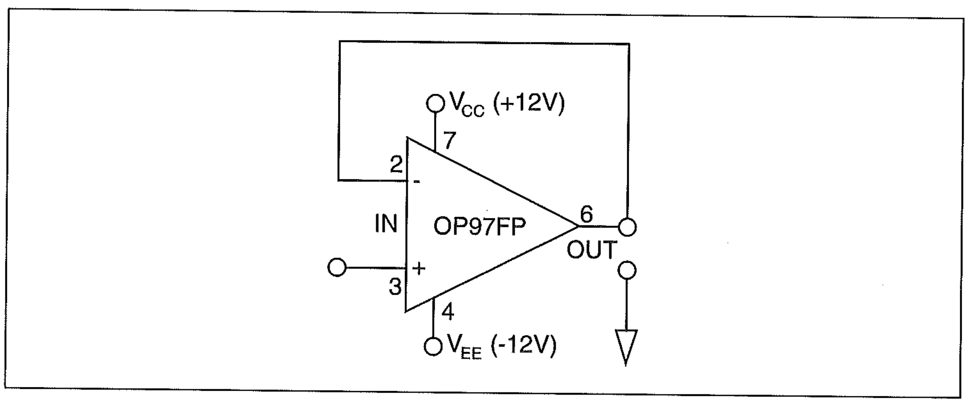

Figure 5-2. Voltage Follower

Apply a sine wave to the input, and measure the voltage gain. Use the dual trace capability of the oscilloscope for your measurement. Calculate the percent difference between the calculated and measured values of the voltage gain. Estimate (within an order of magnitude) the input impedance of the amplifier. Is this a useful property? Why?

III. Summing Amplifier

As its name suggests, the output of this amplifier is the sum of its inputs. In your lab report use circuit analysis to show why this is true. This circuit can be used to change the DC offset of an input signal. How? Construct the summing amplifier shown in Figure 5-3.

Apply a 2 V (peak-to-peak) sine wave to one input, and a DC voltage to the other. Adjust the DC voltage to produce a sine wave that is centered at +3 V. Now adjust the DC voltage until the positive peaks of the sine wave just begin to clip. Record the DC voltage. Explain in your lab report how your observations define a limit on the amplitude of the input signals.

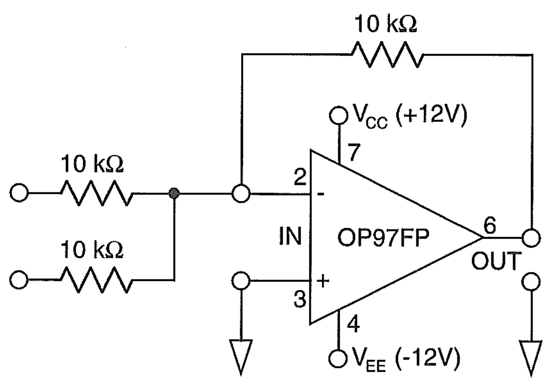

Figure 5-3. A Summing Amplifier

IV. Differential Amplifier

In experimental physics, one often needs to detect small signals in the presence of an electrically noisy environment. You probably noticed a 60 cycle AC noise signal in many of the circuits you constructed. A differential amplifier provides a way to minimize noise that is picked up on cables or wires that carry a signal. A true signal creates a *voltage difference* between two conductors. In contrast, noise is generally present on both conductors (particularly when the noise is induced by a time-varying electromagnetic field). If an identical noise signal appears on two conductors it is called a *common mode* signal. When the common mode signal becomes more positive on one of the conductors, it also becomes more positive on the other conductor. A differential amplifier will subtract out the common noise signal at its input, and amplifies the remaining signal that is to be measured. A differential amplifier has a greater gain for differential signals than it does for common mode signals.

Construct the differential amplifier shown in Figure 5-4. Begin by measuring the two different gains of the differential amplifier. Apply a differential signal across inputs V1 and V2 by connecting the ground lead of the sine wave generator to one input and the signal lead to the other. Measure the differential gain. Now apply a common mode signal to the inputs by applying the signal lead of the sine wave generator to both V1 and V2. Measure the common mode gain of the amplifier. Calculate the ratio of the differential gain to the common mode gain. This is called the common mode rejection ratio (CMRR) of the amplifier. A perfect differential amplifier would have CMRR = ∞. In your circuit there is common mode rejection, but it is certainly not infinite! Matched resistors can be used to improve the CMRR of a differential amplifier. In your lab report explain why mismatched resistors could lead to a poor CMRR.

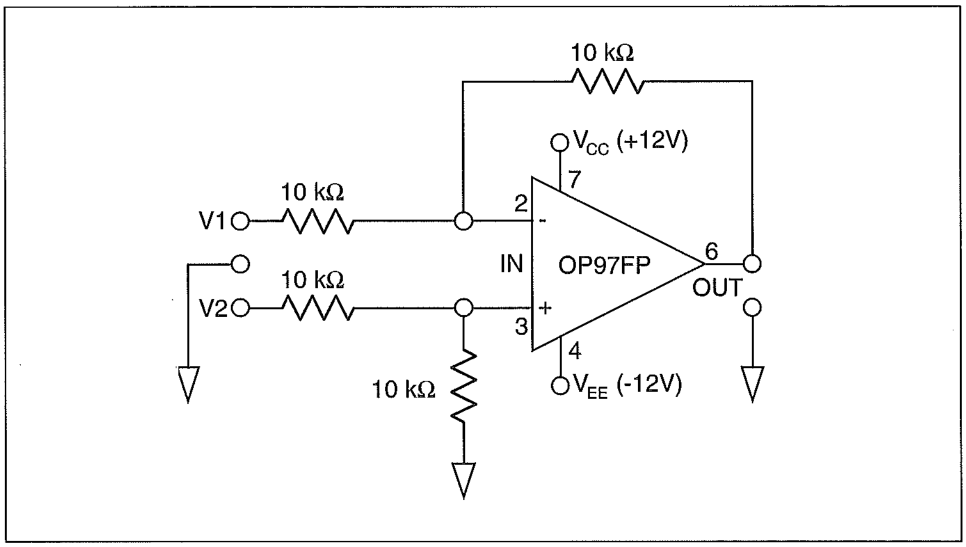

Figure 5-4. A Differential Amplifier

V. Differentiator (Optional)

A differentiator is different from the previous circuits you examined because a capacitor is present at the input. With a capacitor in the circuit, the output signal is proportional to the rate-of-change of the input voltage. Why? Since the output voltage is proportional to the time derivative of the input voltage the circuit appears to differentiate the input signal.

Construct the differentiator shown in Figure 5-5. Before you investigate its properties, draw the output signal you would expect for three different inputs: a sine wave, a square wave, and a triangular wave.

Apply power to the circuit and then apply a sine wave, a square wave, and a triangular wave to the input. Use a frequency of 100 Hz. Compare the input and output signals using the dual trace oscilloscope. Trigger the oscilloscope from one of the signals to observe the relative phase between the input and output signals. Draw the input and output signals you observe. Include the drawings of the input and output signals in your lab report, and explain why each input produces the corresponding output.

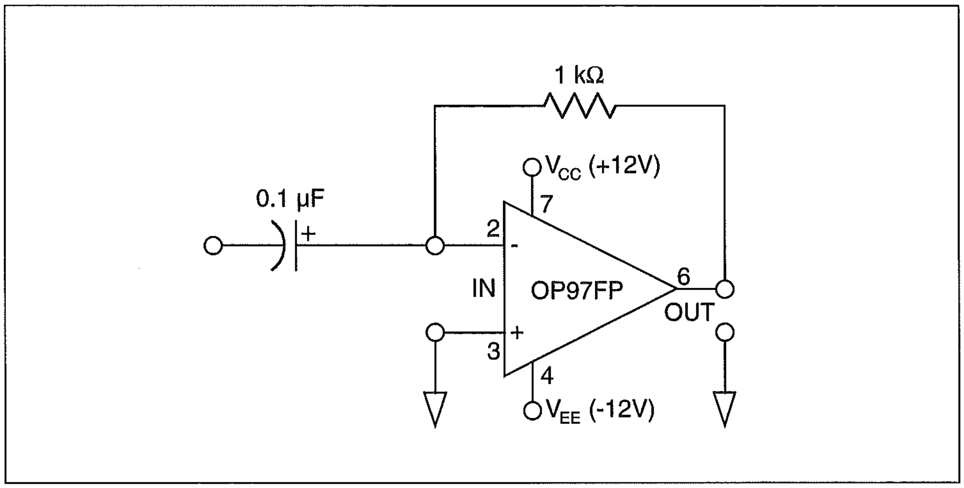

Figure 5-5. A Differentiator

Homework Assignment

Prepare a laboratory report in the form of a short paper. The paper should include the usual sections and the answers to any questions posed in this laboratory handout.