

**CENG4480 Embedded System Development and Applications**  
**The Chinese University of Hong Kong**  
Laboratory 1: Op Amp – 1

Student ID:

2019 Fall

## 1 Introduction

This lab session introduces some very basic concepts of operational amplifier “op amp” that every engineering student should know about. The op amp IC used in this lab is LM324. LM324 contains 4 op amps, we only use one of them.

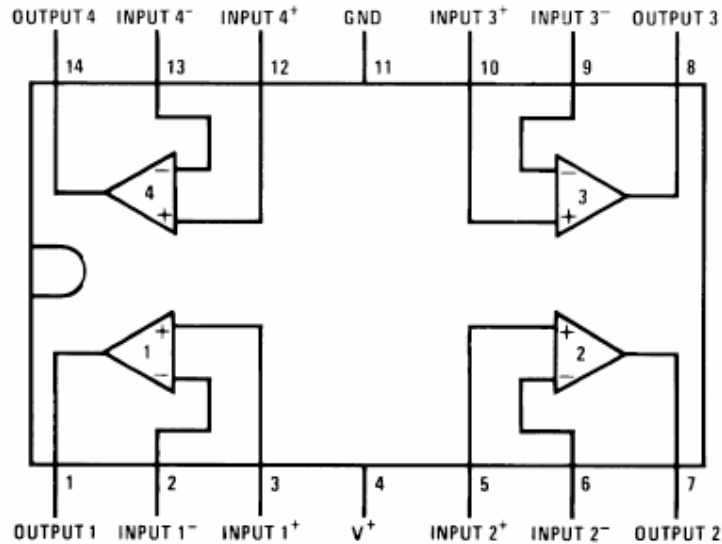


Figure 1: Pinout for the LM324.

### Objectives

By completing this lab session, you should know:

- 1) how to use op amp circuits to interface between sensors and MCU;
- 2) how to design amplifier circuit using op amp and
- 3) how to design integrator and differentiator circuit using an op amp.

## Procedures

Follow the procedures of each experiment. Write your result in a report sheet with your name and student ID. Submit the report sheet to the tutor after the lab.

## 2 Experiment 1. Inverting Amplifier

In this experiment, you will construct and observe the inverting amplifier. Record the input and output waveforms. The following apparatus will be provided:

- 1) a power supply;
- 2) an oscilloscope;
- 3) a breadboard;
- 4) resistors:  $2 \times 1K\Omega$ ,  $1 \times 2K\Omega$ ;
- 5) one LM324 IC.

## Procedures

- 1) Use pinout diagram for LM324 op amp IC shown in Figure 1 to construct the inverting amplifier circuit as shown in Figure 2.
- 2) Configure the waveform generator on the oscilloscope with following settings:
  - Waveform=Sine
  - Frequency= $1KHz$
  - Amplitude= $500mV$  p-p
  - Offset= $-250mV$
- 3) Connect the waveform generator output to the input of inverting amplifier;
- 4) Connect channel 1 input ( $X$ ) of the oscilloscope to the output of inverting amplifier and connect channel 2 ( $Y$ ) input of the oscilloscope to the input of inverting amplifier.
- 5) Record the input and output waveforms displayed on the oscilloscope.
- 6) In your lab report, give your derivation and compare the calculated with measured output voltages. Why is this called an inverting amp?

## 3 Experiment 2. Non-inverting Amplifier

In this experiment, you will construct and observe the non-inverting amplifier. Record the input and output waveforms. The following apparatus will be provided:

- 1) a power supply;
- 2) an oscilloscope;

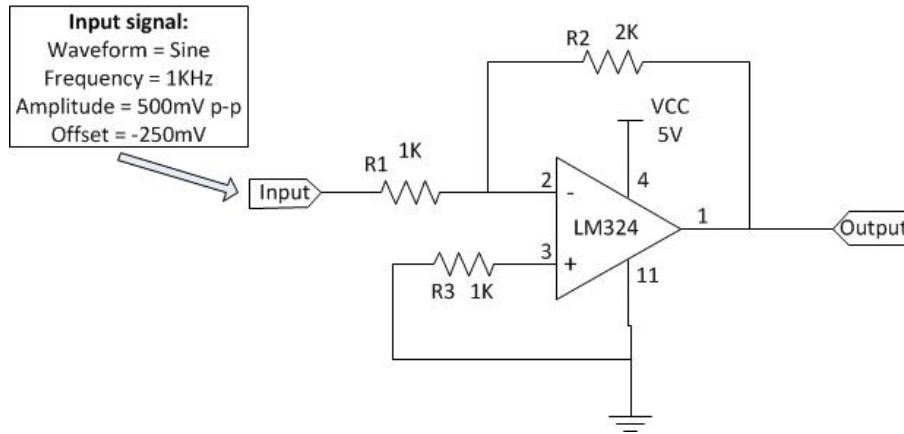


Figure 2: Inverting amplifier.

- 3) a breadboard;
- 4) resistors:  $1 \times 1K\Omega$ ,  $1 \times 2K\Omega$ ;
- 5) one LM324 IC.

### Procedures:

- 1) Use pinout diagram for LM324 op amp IC shown in Figure 1 to construct the non-inverting amplifier circuit as shown in Figure 3.
- 2) Configure the waveform generator on the oscilloscope with following settings:
  - Waveform=Sine
  - Frequency=1KHz
  - Amplitude=500mV p-p
  - Offset=-250mV
- 3) Connect the waveform generator output to the input of non-inverting amplifier.
- 4) Connect channel 1 input (X) of the oscilloscope to the output of non-inverting amplifier and connect channel 2 (Y) input of the oscilloscope to the input of non-inverting amplifier.
- 5) Record the input and output waveforms displayed on the oscilloscope.
- 6) In your lab report, give your derivation and compare the calculated with measured output voltages. Verify the gain relation of the non-inverting amplifier.

$$\frac{V_o}{V_{in}} \approx 1 + \frac{R2}{R1} \quad (1)$$

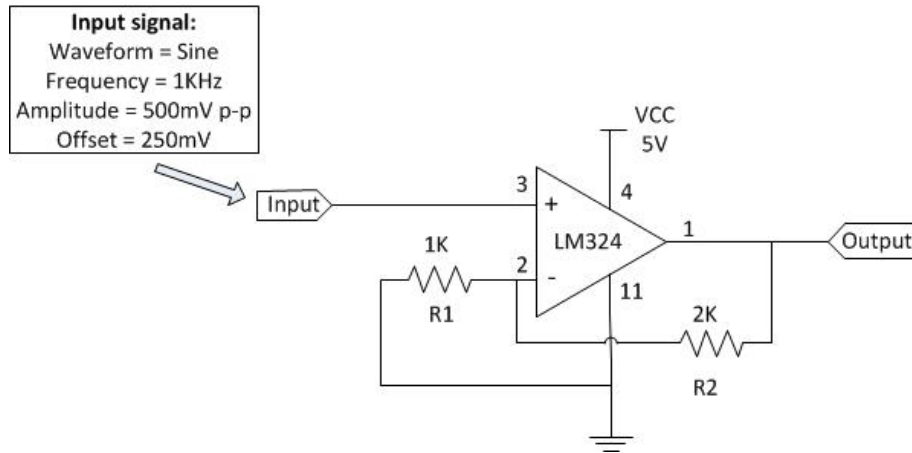


Figure 3: Non-inverting amplifier.

## 4 Experiment 3. Differential Amplifier

In this experiment, you will construct and observe the differential amplifier. Record the input and output waveforms. The following apparatus will be provided:

- 1) a power supply;
- 2) an oscilloscope;
- 3) a breadboard;
- 4) resistors:  $2 \times 1K\Omega$ ,  $2 \times 2K\Omega$ ;
- 5) one LM324 IC.

### Procedures:

- 1) Use pinout diagram for LM324 op amp IC shown in Figure 1 to construct the differential amplifier circuit as shown in Figure 4.
- 2) Configure the waveform generator on the oscilloscope with following settings:
  - Waveform=Sine
  - Frequency=1KHz
  - Amplitude=500mV p-p
  - Offset=-250mV
- 3) Connect the waveform generator output to the input 1 of differential amplifier.
- 4) Connect 1 V dc from power supply to the input 2 of differential amplifier.
- 5) Connect channel 1 input ( $X$ ) of the oscilloscope to the output of differential amplifier and connect channel 2 ( $Y$ ) input of the oscilloscope to the input 1 of differential amplifier.
- 6) Record the input and output waveforms displayed on the oscilloscope.

- 7) In your lab report, give your derivation and compare the calculated with measured output voltages.

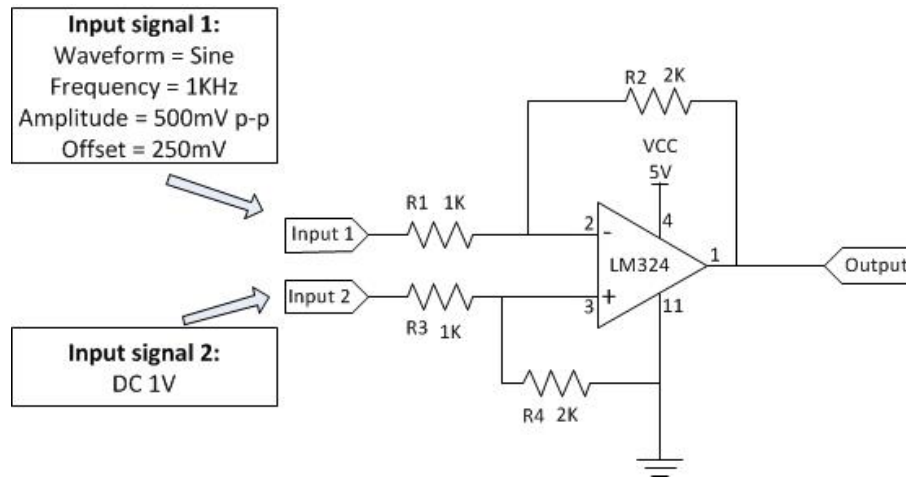


Figure 4: Differential amplifier.

## 5 Experiment 4. Voltage follower

In this experiment, you will construct and observe the voltage follower. Record the input and output waveforms. The following apparatus will be provided:

- 1) a power supply;
- 2) an oscilloscope;
- 3) a breadboard;
- 4) resistors:  $1 \times 2K\Omega$ ;
- 5) one LM324 IC.

### Procedures:

- 1) Use pinout diagram for LM324 op amp IC shown in Figure 1 to construct the voltage follower circuit as shown in Figure 5.
- 2) Configure the waveform generator on the oscilloscope with following settings:
  - Waveform=Sine
  - Frequency=1KHz
  - Amplitude=500mV p-p
  - Offset=-250mV
- 3) Connect the waveform generator output to the input of voltage follower.

- 4) Connect channel 1 input ( $X$ ) of the oscilloscope to the output of voltage follower and connect channel 2 ( $Y$ ) input of the oscilloscope to the input of voltage follower.
- 5) Record the input and output waveforms displayed on the oscilloscope.
- 6) In your lab report, state what is the relation between the output and input voltages of the voltage follower.

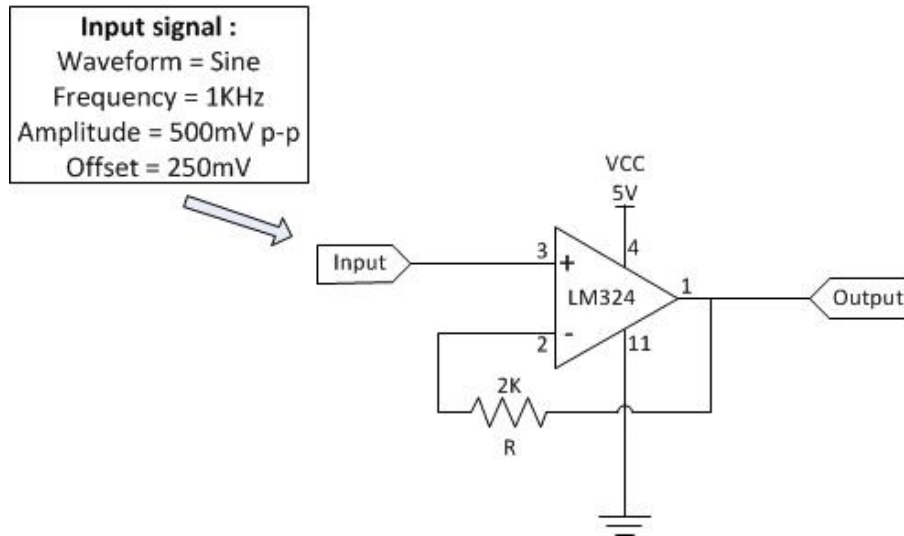


Figure 5: Voltage follower.