

# Op-Amp Differential Amplifier Introduction

EET-210 Digital & Linear Circuits

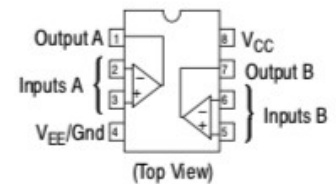
Objective:

To investigate the basic construction and operation of integrated circuit based differential amplifiers (D.A.'s). Investigative emphasis will be placed on the operating characteristics of differential-mode gain ( $A_{DM}$ ), common-mode gain ( $A_{CM}$ ) and the determination of the common-mode rejection ratio (CMRR).

Equipment: LM358 (or better) op-amps  
Various 5% tolerance ½ Watt resistors  
Variable Regulated Power Supply  
DMM

LM358

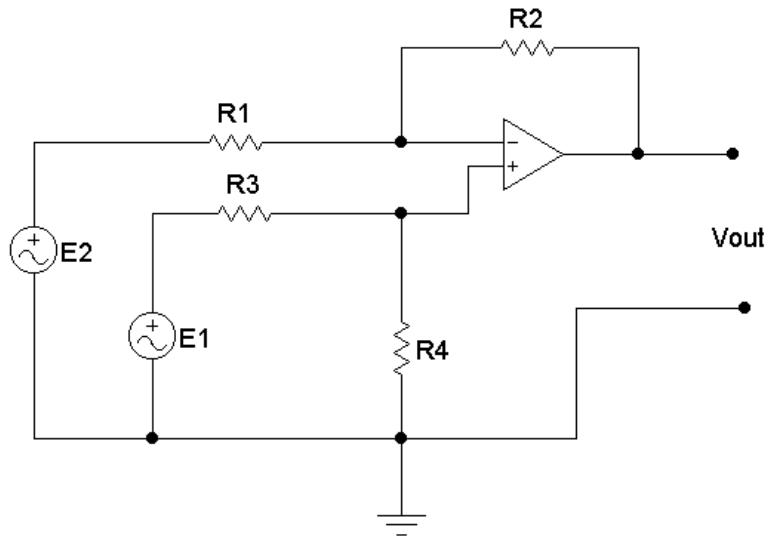
**PIN CONNECTIONS**



Theory:

The standard op-amp based differential amplifier shown below has a gain expression given by:

$$V_{out} = E_1(R_4/(R_3+R_4))(1+R_2/R_1) - E_2(R_2/R_1)$$



The differential-mode gain,  $A_{DM}$ , is the circuit gain measured with respect to the difference in potential between  $E_1$  and  $E_2$ .

$$A_{DM} = V_{out}/(E_1-E_2) \quad A_{DM}(dB) = 20*\log(V_{out}/(E_1-E_2))$$

The common-mode gain,  $A_{CM}$ , is the circuit gain measured with respect to the common or “same” potential placed at the inputs to the circuit,  $E_{CM}$ .

$$A_{CM} = V_{out}/E_{CM} \quad A_{CM}(dB) = 20 \cdot \log(V_{out}/E_{CM})$$

Together, these two gains constitute the figure of merit for differential amplifiers known as the common mode rejection ration, CMRR. The CMRR is given by:

$$CMRR = A_{DM}/A_{CM} \quad CMRR(dB) = 20 \cdot \log(A_{DM}/A_{CM})$$

For an ideal differential amplifier, the common mode gain is zero. However, practical limitations in construction of the circuits will prevent this number from being exactly zero. As we will see in subsequent work, high quality integrated circuit differential amplifiers are available with a very small common-mode gain and hence a large common-mode rejection ratio.

### PROCEDURE

- 1.) Measure all of your components accurately. Make and record each measurement as accurately as possible. Construct the circuit shown below. One of the goals of these experiments is to derive the highest CMRR possible. This will require that resistors be selected and trimmed as accurately as possible. **You can use D.C. sources** for the differential and common mode gain measurements. **When measuring the common-mode gain, connect the same potential to points  $E_1$  and  $E_2$  on the circuit.**

Construct the circuit on the next page. However, we are going to simplify that circuit due to the constrains of the 2020 Fall semester schedule and COVID related issues.

For Step #1: Be sure to use the LM358 Op-Amp, NOT the 741 as shown.

Make  $R_1 = R_2 = R_3 = R_4$  equal 1 k-ohm, 5% resistors. Ignore the 10 k-ohm resistor notation. Keep  $R_L = 10$  k-ohm. You DO NOT NEED to use the trim-pots for these experiment.

Record your resistor values as accurately as your DMM will allow:

$R_1 =$  \_\_\_\_\_  $R_2 =$  \_\_\_\_\_  $R_3 =$  \_\_\_\_\_  $R_4 =$  \_\_\_\_\_

Calculate the expected  $A_{DM}$  for this circuit.  $A_{DM} =$  \_\_\_\_\_

Record your Input and Output Measurements here:

$E1(DM) =$  \_\_\_\_\_  $E2(DM) =$  \_\_\_\_\_  $V_{out}(DM) =$  \_\_\_\_\_

$E1(CM) = E2(CM) =$  \_\_\_\_\_  $V_{out}(CM) =$  \_\_\_\_\_

Measured  $A_{DM} =$  \_\_\_\_\_

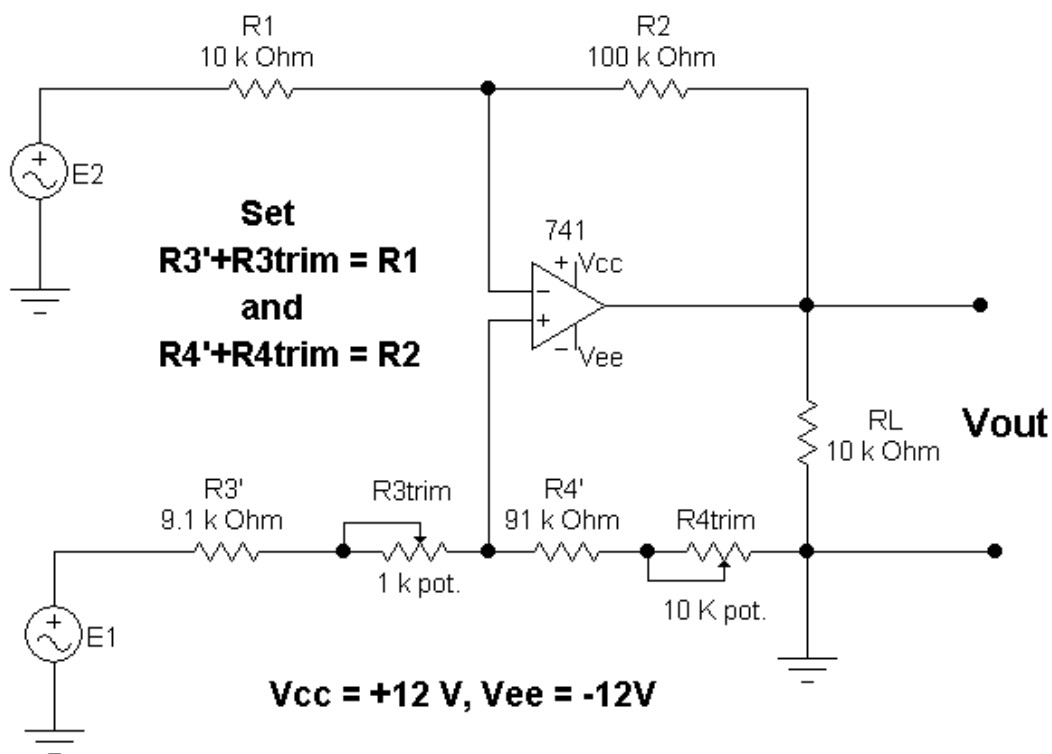
Measured  $A_{DM}(dB) =$  \_\_\_\_\_

Measured  $A_{CM} =$  \_\_\_\_\_

Measured  $A_{CM}(dB) =$  \_\_\_\_\_

Measured CMRR = \_\_\_\_\_

Measured CMRR (dB) = \_\_\_\_\_



2.) Perform the modifications necessary on the circuit above to get a differential-mode gain of approximately 100. (HINT: Keep  $R_1=R_3 = 1 \text{ k-ohm}$ , Make  $R_2=R_4=100 \text{ k-ohm}$ ). Make sure you choose 5% resistors.

Repeat the measurements made in step #1.

Record your resistor values as accurately as your DMM will allow:

$R_1 =$  \_\_\_\_\_  $R_2 =$  \_\_\_\_\_  $R_3 =$  \_\_\_\_\_  $R_4 =$  \_\_\_\_\_

Calculate the Expected  $A_{DM} =$  \_\_\_\_\_

Record your Input and Output Measurements here:

$E_1(DM) =$  \_\_\_\_\_  $E_2(DM) =$  \_\_\_\_\_  $V_{out} (DM) =$  \_\_\_\_\_

$E_1(CM) = E_2(CM) =$  \_\_\_\_\_  $V_{out}(CM) =$  \_\_\_\_\_

Measured  $A_{DM} =$  \_\_\_\_\_

Measured  $A_{DM} \text{ (dB)} =$  \_\_\_\_\_

Measured  $A_{CM} =$  \_\_\_\_\_

Measured  $A_{CM} \text{ (dB)} =$  \_\_\_\_\_

Measured CMRR = \_\_\_\_\_

Measured CMRR (dB) = \_\_\_\_\_

Do you observe the same effects as in the first circuit? Do you notice any differences?

## QUESTIONS

- 1.) Did each of your circuits perform as expected? If not, try to explain any sources of error.
- 2.) Use the Excel Sheet posted on the Forums and presented in the Zoom Lecture on 12/9 to verify your gain measurements with each of your resistor combinations. For each circuit, was the Excel simulation accurately reflects the the circuit operation you observed? If so, why? If not, why not?