

# ELE2EMI 2007

## Laboratory 5: Instrumentation Amplifier

### Equipment and Parts

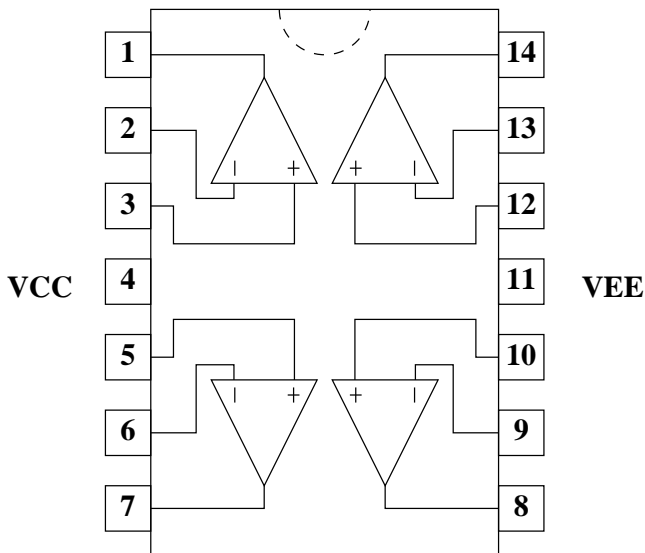
1. One LM324 operational amplifier chip
2. One 10  $\Omega$  resistor
3. One 3.3 k $\Omega$  resistor
4. Two 4.7 k $\Omega$  resistors
5. One 5.6 k $\Omega$  resistor
6. Seven 10 k $\Omega$  resistors
7. Two 22 k $\Omega$  resistors
8. Two 33 k $\Omega$  resistors
9. One 10 nF *nonpolar* polyester capacitor
10. 5V, 12V, -12V power supply
11. Protoboard
12. Single strand hook-up wire

### Aim

The aim of this laboratory is to gain a deeper understanding of the structure and operation of an instrumentation amplifier (IA). The common mode rejection (CMR) of an IA is compared with that of a simple differential amplifier. A simple way to control the CMR is tried. The practical limitations of an IA are studied.

The op-amp used in this lab is the LM324, a quadruple (quad) op-amp IC, with the following layout:

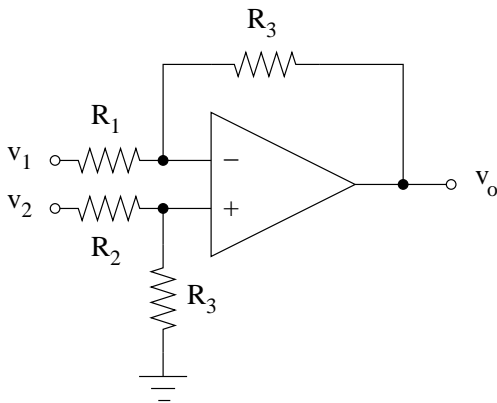
# LM324



## 1 Simple amplifier

### 1.1 Construction

Construct the following circuit.



### 1.2 Common Mode Voltage

Connect both inputs ( $v_1$  and  $v_2$ ) to ground.

Measure the common mode output voltages ('common mode' means that  $v_1 = v_2$ ) by using  $R = 10\text{ k}\Omega$ ,  $22\text{ k}\Omega$ , and  $33\text{ k}\Omega$ , in turn. Record your results in this table:

R (k $\Omega$ )	CM Voltage (V)
10	
22	
33	

### 1.3 Differential Mode Gain

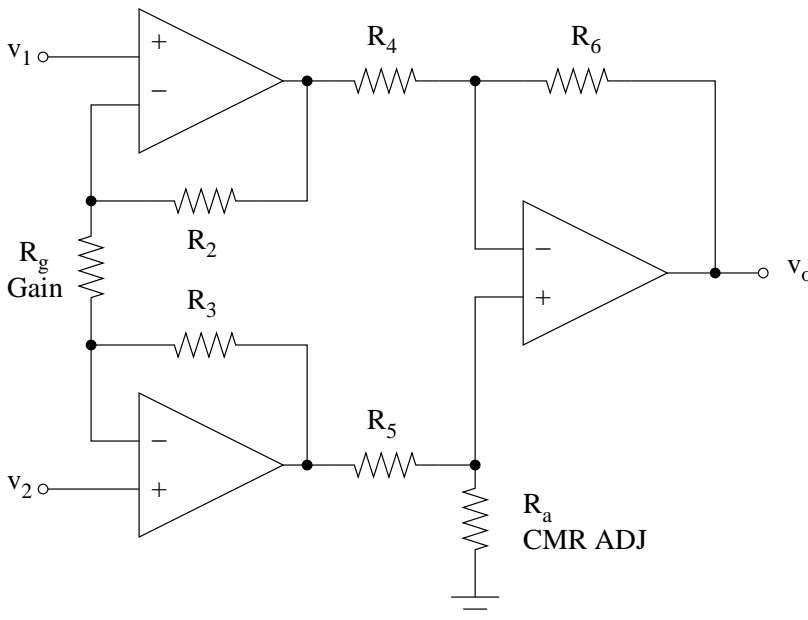
Connect a signal generator (at about 100 Hz or 1 kHz, at your discretion) to  $v_1$ , set  $v_2$  to ground, and use an oscilloscope to measure the differential mode gain of the circuit, for the same three values of  $R$ .

R (k $\Omega$ )	$v_1$ (V)	$v_o$ (V)	DM Gain $\frac{v_o}{v_1}$
10			
22			
33			

## 2 Instrumentation Amplifier

### 2.1 Construction

Construct the following circuit.



### 2.2 Common Mode Voltage

Connect both inputs  $v_1$  and  $v_2$  to ground.

Measure the common mode output voltages for  $R = 4.7 \text{ k}\Omega$ ,  $10 \text{ k}\Omega$ , and  $22 \text{ k}\Omega$ , in turn.

R (k $\Omega$ )	CM Voltage (V)
4.7	
10	
22	

## 2.3 Differential Mode Gain

Using a signal generator and an oscilloscope as before, measure the differential mode gain for  $R = 4.7 \text{ k}\Omega$ ,  $10 \text{ k}\Omega$ , and  $22 \text{ k}\Omega$ , in turn.

## 3 Questions

1. What is the ideal value of the common mode voltage for a differential amplifier?
2. *For roughly the same gain*, which of the two circuits produces a lower common mode voltage?
3. In both cases, how does the common mode voltage vary as gain is increased?

## 4 CMR Adjustment

In the instrumentation amplifier, the common mode voltage can be reduced by changing the value of resistor  $R_a$ .

Setting  $R=10 \text{ k}\Omega$ , and using  $R_a= 3.3 \text{ k}\Omega$ ,  $4.7 \text{ k}\Omega$ , and  $5.6 \text{ k}\Omega$ , in turn, measure the common mode voltage.

$R_a$ (k $\Omega$ )	CM Voltage (V)
3.3	
4.7	
5.6	

## 5 Operation of an Instrumentation Amplifier

### 5.1 Frequency response of the LM324

The op-amps in the LM324 do not have a very wide bandwidth. Therefore, they might have problems operating at high frequencies.

Using the same instrumentation amplifier circuit as above, with  $R = R_a = 10 \text{ k}\Omega$ , connect input  $v_1$  to ground, and input  $v_2$  to a signal generator. Display the output in an oscilloscope.

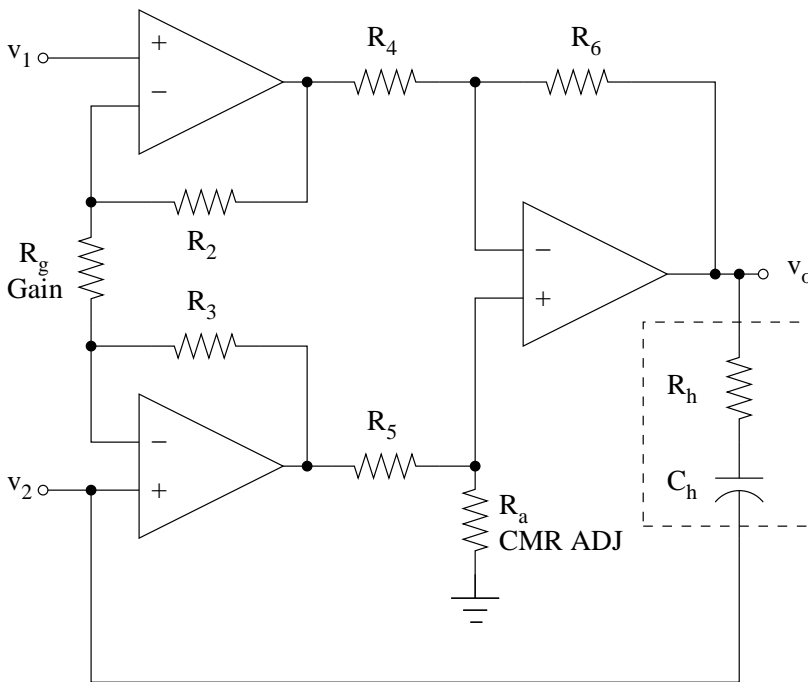
Start from a low frequency, say  $100 \text{ Hz}$ , and observe the output for both sinusoidal and square wave inputs.

Slowly increase the frequency, and observe the distortion at high frequency.

For frequencies of  $100 \text{ Hz}$ ,  $1 \text{ kHz}$ ,  $10 \text{ kHz}$ , and  $100 \text{ kHz}$ , sketch the output waveforms on separate graphs for both sine and square wave inputs. (This will require eight graphs.)

## 5.2 High Frequency Compensation

In Carr's book (page 303), a high frequency compensation control circuit is added, as indicated by the dotted box in the following circuit diagram.



Add this to your circuit.

Turn off the signal generator. You will observe that the amplifier is an oscillator!

**Question:** Explain why this happens.

Turn on the signal generator, and examine the output for both sine and square wave inputs. You will see that the output is the *sum* of an amplified input signal *plus* a high frequency signal.

Therefore, such a high frequency compensation circuit should be used with great care.

## 6 Report

Your laboratory report should show:

1. All experimental details, including:
  - (a) Each circuit diagram;
  - (b) each set of input and output waveforms on the same set of axes;
  - (c) the measured voltages.
2. Your answers to all the questions.

**Your report is due by the start of the next laboratory session.**