17.368 Data Conversion and Lab
Lab 1
Fall 2013

Operational Amplifiers

Lab Report

See separate report form located on the course webpage. This form should be completed during the performance of this lab.

Objectives

1) To construct and operate a comparator circuit using an operational amplifier.
2) To construct and operate an inverting operational amplifier.
3) To construct and operate a summing operational amplifier.

Materials

General Material

☐ 1	Breadboard	
☐ 1	Dual Power Supply (+15 V and –15 V)	
☐ 1	Voltmeter	

Amplifier Circuits

☐ 1	741 Linear IC	
☐ 1	2 k ohm Resistor	(Red – Black – Red)
☐ 3	10 k ohm Resistors	(Brown – Black – Orange)
☐ 4	20 k ohm Resistors	(Red – Black – Orange)
☐ 1	24 k ohm Resistor	(Red – Yellow – Orange)
☐ 2	10 k ohm Potentiometers	

WARNINGS AND PRECAUTIONS

1) Do not construct circuits while energized

2) Follow electrical safety precautions

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Background Information

Digital circuits function by using signals that are at one of two distinct voltage levels. The other classification of electronic circuits is the analog circuit. These devices function by operating with signals that vary anywhere between the low and high extreme voltages supplied by the power supply. Because these devices produce an output that is directly proportional to the input, they are known as linear circuits. One type of linear circuit commonly used with digital circuits is the operational amplifier. Also known as an op-amp, it is capable of performing many types of functions. Two functions, comparing and amplifying, will be examined. Figure 1 shows the symbol of an op-amp. It has two inputs. One of them is called an inverting input and is labeled with a minus sign. The other is called a non-inverting input and is labeled with a positive sign. The output lead is located at the apex of the triangle. Figure 2 is the pin-out for the 741 operational amplifier.

Pre-Lab Preparation

1. Download Lab # 1 from the course website. Read and understand the lab.

Procedure

Objective 1. COMPARATOR CIRCUIT

a. The op-amp in Figure 3a is capable of comparing the voltage applied to one input to the voltage applied to the other input. When the voltage at the non-inverting terminal is greater than the voltage at the inverting terminal, the output will go to an approximate positive 5 V saturation potential. When the voltage at input (-) is greater than the voltage at input (+), the output will go to an approximate negative 5 V saturation level. When the voltage at both input terminals is the same, the output will go to 0 V.

b. Assemble the circuit shown in Figure 3(a). **NOTE: Ensure that you connect the power supply common to power supply ground in order for the 741 to operate correctly.**

c. Fill in the output portion of the table in Figure 3(b) by applying the voltages listed in the input section.

OBJECTIVE 2. INVERTING OPERATIONAL AMPLIFIER

a. The op-amp in Figure 4(a) shows an inverting op-amp. An input resistor (R_{IN}) is connected between the input terminal and the (-) op-amp lead, and the feedback resistor (R_F) is connected between the output and the (-) input. The name of the op-amp circuit is derived from the way in which it operates. When a voltage is applied to the (-) input lead, a voltage of the opposite polarity develops at the output. The gain of the inverting op-amp is determined by the resistance ratio of RF compared to R_{IN}. The larger R_F becomes compared to R_{IN}, the larger the gain.

b. The output voltage can be determined by the following formula:

$$V_{OUT} = -\frac{V_{IN}}{R_{IN}} * R_F$$

where,

R_F = feedback resistor
R_{IN} = input resistor
V_{IN} = input voltage

c. Assemble the circuit in Figure 4(a).

R_{IN} = 2k

R_F = 10k

d. Fill in the output portion of the table in Figure 4(b) by applying the voltages listed in the input section. Use the formula to verify that the measured voltages are correct.

e. Change R_F in Figure 4(a) to 25 k ohm and R_{IN} to 10 k ohm.

f. Fill in the output portion of the table in Figure 4(c) by applying the voltages listed in the input section. Use the formula to verify that the measured voltages are correct.

OBJECTIVE 3. SUMMING AMPLIFIER

a. The circuit in Figure 5(a) shows an op-amp circuit with more than one input tied at its inverting input lead. Called a *summing* amplifier, it is capable of adding the algebraic sum of all the input voltages applied. The sum of these voltages is inverted to the opposite polarity. Each of the summing input resistors are tied together and a 20 k ohm feedback resistor is used. The following calculations show how to determine the voltage at the output terminal:

$$I_{R1} = \frac{V_{R1}}{R_1} = \frac{2V}{20k\Omega} = 0.1mA$$

$$I_{R2} = \frac{V_{R2}}{R_2} = \frac{1V}{20k\Omega} = 0.05mA$$

$$I_{R3} = \frac{V_{R3}}{R_3} = \frac{3V}{20k\Omega} = 0.15mA$$

$$I_{RF} = 0.1mA + 0.05mA + 0.15mA = 0.3mA$$

$$V_{OUT} = I_{RF} * R_F = 0.3mA * 20k\Omega = -6.0V$$

b. Assemble the circuit shown in Figure 5(a). Use the following values ...

$R_1 = R_2 = R_n = R_F = 20k$ ohms

c. Fill in the output portion of the table in Figure 5(b) labeled measured by applying the voltages listed in the input section. Measure V_{OUT} to ground.

d. Using the formula to determine the output of a summing amplifier, verify that the measured values are correct and place the answers in the column labeled “Calculated”.

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SUMMARY:

You have just developed your first analog circuits. They were the comparator, the inverting operational amplifier, and the summing amplifier. This should have provided an insight into how analog circuits functions. These circuits are the foundation for data conversion.

Lab Notebook Requirements:

1. Ensure that you have recorded all the data requested during the lab in your lab notebook as well as your lab report.

Lab Report:

1. Use template provided on the Class Web Site.

Lab Questions:

1. A/n _____ (analog, digital) signal can vary at any value between the low and high voltage range supplied by the power supply.

2. A _____ (linear, digital) circuit produces signals that are analog.

3. When the voltage applied to the non-inverting terminal of an op-amp comparator is _____ (less, greater) than the voltage at the inverting input, the output will be driven into positive saturation.

4. If –2 V is applied to an inverting op-amp that has an input resistance of 2 k ohm and a feedback resistance of 5 k ohm, the voltage at the output is _____ volts, and the polarity is
_____ (+,-).

5. The summing op-amp of Figure 5(a) has the following applied to the inputs: +2 V, +3 V, and –1 V. What is the output voltage?

Figure 1 – Op Amp Symbol

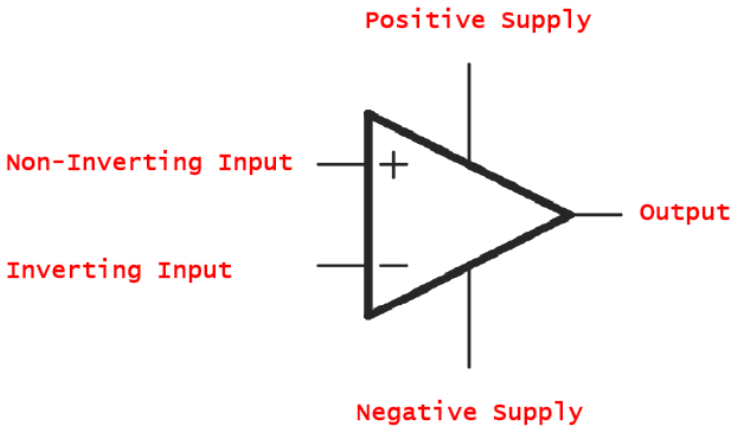


Figure 2 – 741 Operational Amplifier Pin-Out

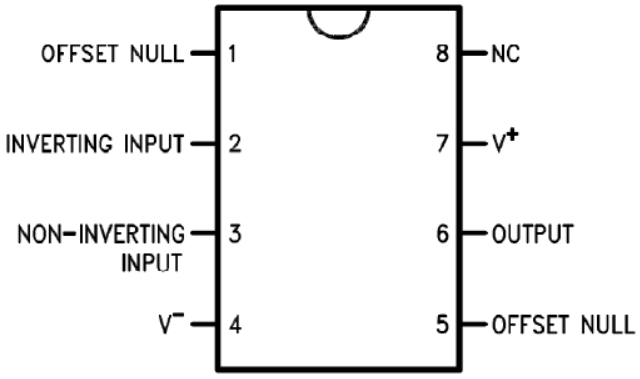
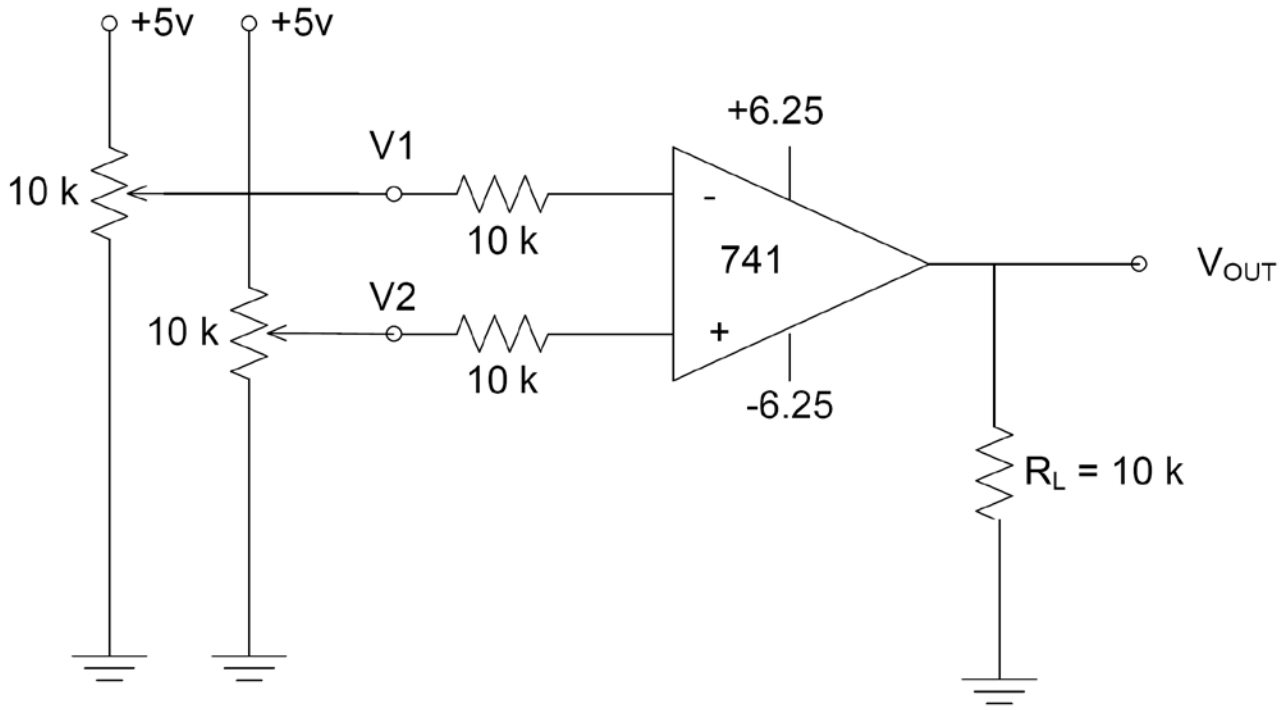


Figure 3 – COMPARATOR CIRCUIT

(a)

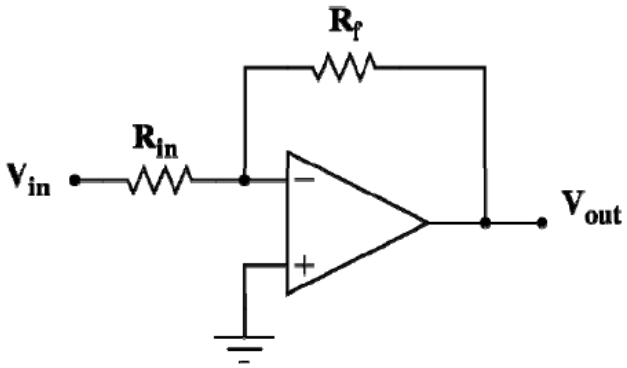


(b)

Input		Output
V1 (-)	V2 (+)	V_{OUT} (V)
+4 V	+1V	
+2 V	+3 V	
+1 V	0 V	
+4 V	+4 V	
0 V	+1 V	
+3 V	+2 V	

Figure 4 - Inverting Operational Amplifier

(a)



(b)

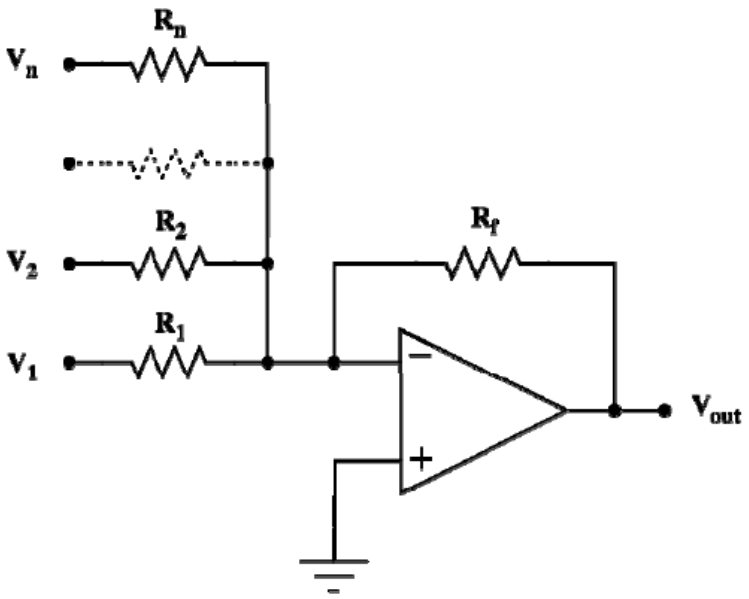
V_{IN}	V_{OUT}
+ 0.2 V	
- 0.3 V	
0 V	
+ 0.32 V	

(c)

V_{IN}	V_{OUT}
+ 0.3 V	
- 0.25 V	
- 0.2 V	
+ 0.4 V	

Figure 5 – Summing Amplifier

(a)



(b)

Input Voltage				Output Voltage	
V1	V2	Vn		Measured	Calculated
+ 1 v	+ 1 v	+ 1 v			
- 1 v	- 1 v	+ 1 v			
- 1 v	- 1 v	+ 2 v			
+ 3 v	- 3 v	- 3 v			
- 2 v	+ 1 v	- 2 v			