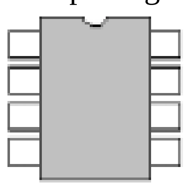
LAB 8. Operational Amplifier I

Objective:
1. Introduction of OP Amp
2. Implementation of OP amp circuits using 741

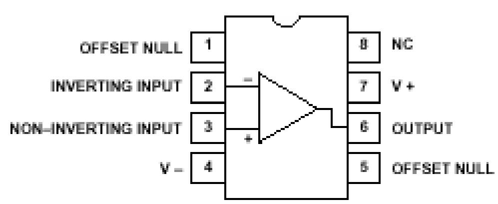
OP AMP Fundamentals

A. Introduction
1. The *operational amplifier* or *op amp* for short, is a versatile circuit building block.
2. The *op amp* is an electronic unit that behaves like a voltage-controlled voltage source.
3. The *op amp* may also be regarded as a voltage amplifier with very high gain.
4. An op amp can sum signals, amplify a signal, integrate it, or differentiate it. The ability of the op amp to perform these mathematical operations is the main reason it is called an operational amplifier.
5. The term *operational amplifier* was introduced by John Regazzini and his colleagues, in their work on analog computers for the National Defense Research Council during World War II. The first op amps used vacuum tubes rather transistors.

B. OP AMP Package
1. The op amp is an electronic device consisting of a complex arrangement of resistors, transistors, capacitors, and diodes.
2. Op amps are commercially available in integrated circuit (IC) packages in several forms. A typical one is the 8-pin single or dual in-line package (DIP) shown below.



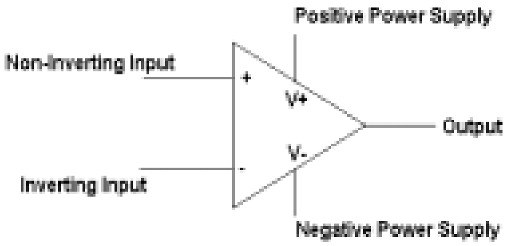
3. For a single DIP op amp (typically uA741)**, pin or terminal 8 is unused (NC), and terminals 1 and 5 are of little concern to us.**

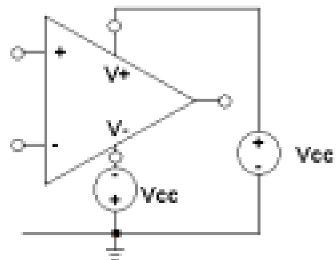


C. Symbols and terminal Behaviors
1. The five important terminals in an op amp are:
   (a) Inverting input (-)
   (b) Noninverting input (+)
   (c) Output
   (d) Positive power supply, V+ (or Vcc)

(e) Negative power supply, V- (or -Vcc)

2. The circuit symbol for the op amp is the triangle.
3. An input applied to the noninverting terminal appears with the same polarity at the output.
4. An input applied to the inverting terminal appears inverted at the output.
5. The op amp must be powered by a voltage supply.





6. Output voltage limitation: The magnitude of the output voltage cannot exceed $|V_{cc}|$. Depending on the power supply voltage and the differential input voltage $v_d=v_p-v_n$, op amp can operate in three modes:
   - (a) Positive saturation: $v_o = V_{cc}$
   - (b) Linear region: $-V_{cc} \le v_o \le V_{cc}$
   - (c) Negative saturation: $v_o = -V_{cc}$
7. The voltage transfer characteristics combine the three regions of mode.

$$v_o = \begin{cases} -V_{cc} & if \quad A(v_p - v_n) < -V_{cc} \\ A(v_p - v_n) & if \quad -V_{cc} \le A(v_p - v_n) \le +V_{cc} \\ +V_{cc} & if \quad A(v_p - v_n) > +V_{cc} \end{cases}$$

D. Ideal OP AMP Model

1. An op amp is ideal if it has the following characteristics:
   - (a) Infinite open-loop gain, i.e., $A = \infty$
   - (b) Infinite input resistance, i.e., $R_i=\infty\ \Omega$
   - (c) Zero output resistance, i.e., $R_o= 0\ \Omega$
2. Two important characteristics of the ideal op amp for circuit analysis:
   - (a) The current into both input terminals are zero, i.e., $i_p=i_n=0$. This is due to infinite input resistance: an open circuit exists between two terminals and current cannot flow through.
   - (b) The voltage across the input terminals is negligibly small, i.e., $v_p=v_n$.. This is due to infinite open-loop gain. In the linear region, the magnitude of the output voltage must be less than the supply power voltage, i.e., $-V_{cc} \le A(v_p - v_n) \le V_{cc}$. Even for a practical op amp, the gain A is about the 10^5, and the V_{cc} is just about 24V. Therefore, to satisfy the inequality for the linear region mode, $(v_p - v_n) \le \frac{24}{10^5} = 0.24 \times 10^{-3} = 0.24$ [mV], or zero.

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1. In the following circuits, assuming ideal OP Amps, describe output voltage in terms of input voltage.

Fig.1(a)

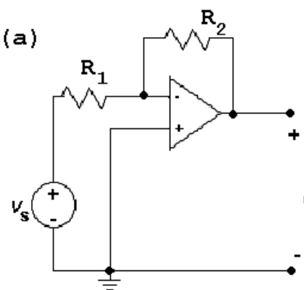


Fig.(b)

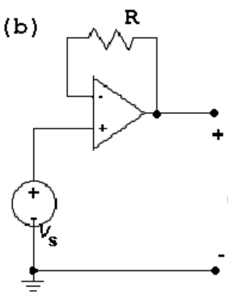
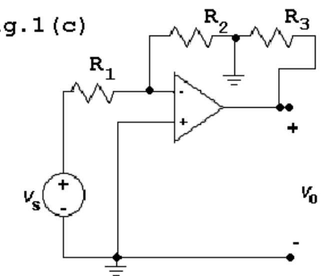


Fig.1(c)



2. For the circuit shown below:

(a) Express output voltage in terms of two input voltages.

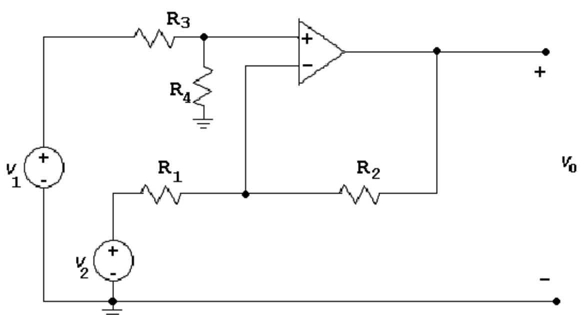
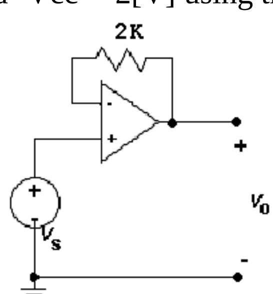


Fig.2

(b) Simplify the expression for output voltage if R_3=R_1 and R_2=R_4, and guess the function of the circuit.

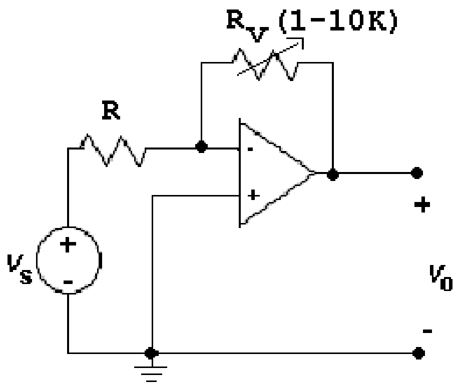
3. Draw a wiring (or connection) diagram of the circuit below using 741 Op Amp. Also, indicate how you apply Vcc=4[V] and -Vcc= -2[V] using the dual power supply.



4. From the circuit above, what would be the output voltage V_o if the input voltage is fed by a sinusoidal voltage source with $V_s = 5\cos wt$. Sketch V_s and V_o.

LAB PROCEDURE

1. Draw an implement (wiring) diagram next to the following circuit with 741 OP Amp. For the variable resistor, use a 1- 10KΩ variable resistor. Apply Vcc=+5V and -Vcc=-5V. Choose any resistor in the range of [1 - 4 K] for the resistor **R**.



Draw Wiring Diagram Here with Selected Value of *R*

2. Once the circuit is implement on a broad board, apply a DC source of Vs= 1[V], and measure using a DMM the output voltage Vo, while changing the value of the variable resistor. At each wiper position of the variable resistor, also measure using the DMM the resistance of the variable resistor. Fill the table below.

Vs = [V]				R = [Ω]			
Rv [Ω]							
Vo [V]							

3. Explain and justify the results obtained from the above table.

4. Now, instead of DC voltage of 1[V], apply **a sinusoidal source with magnitude of 1[V] with frequency of 1000Hz** using a function generator. Measure, using a Scope, V_o (channel 2 of the scope) and V_s (channel 1 of the scope) for the following 3 wiper positions of the variable resistor: left most, center, and right most positions. Plot V_o and V_s below for the 3 variable resistor positions.

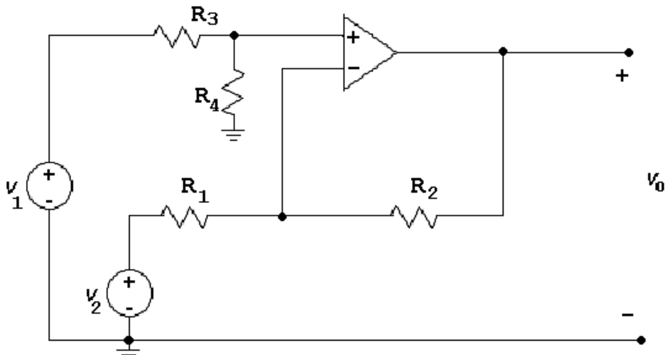
Wiper in Left Most Position

Wiper in Center Position

Wiper in Right Most Position

5. Explain the differences in the plots obtained above.

6. Our next experiment is of the circuit shown below left. For V_1 we plan to apply **a sinusoidal source with magnitude of 2V and frequency of 1KHz**. We will connect +5V for Vcc and -15V for -Vcc. Draw an implementation diagram with Op Amp 741. **For resistors, R_1=R_3=[1K - 2KΩ], and R_2=R_4=[2K - 4KΩ], while satisfying that $R_2 = 2*R_1$.**



R1= Ω R2= Ω R3= Ω R4= Ω

Implementation Diagram with all the resistance values

7. Once the circuit is implemented, apply a sinusoidal source with magnitude of 2[V] and frequency of 1KHz as V_1, and a DC voltage with magnitude of 1[V] as V_2. Do not forget to supply Vcc+ and Vcc- to the OP Amp. Using a scope, measure the output voltage, and plot V_1, V_2, and V_o. Draw also Vcc and -Vcc on the plot.

8. Explain and justify the results obtained above.