

# **Assignment-1**

## **Electronics Engineering(KOE-048)**

### **Unit - 4**

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#### **About**

This assignmet contains information about  
**OPERATIONAL AMPLIFIER**  
All the questions are catagorized section and  
subsectionwise

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# 1 What is Operational Amplifier?

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The *operational amplifier* is a direct coupled, *high gain, negative feedback* amplifier.

Op-Amp is a *high gain* differential amplifier. It has high input impedance(ideally infinites) and low output impedance.

**Type:** - Discrete Circuit Integrated Circuit

**Invented:** - Karl D. Swartzel Jr.

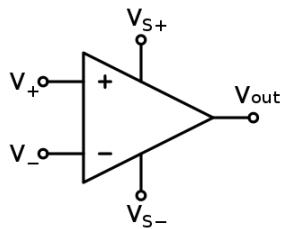


Figure 1: Circuit Diagram for an op-amp. Pins are labeled below

**V<sub>1</sub>** = Input voltage at non-inverting terminal

**V<sub>2</sub>** = Input voltage at inverting terminal

**V<sub>0</sub>** = Output Voltage

(+) = Non-inverting input point

(-) = Inverting input terminal

+V<sub>cc</sub> = Positive Voltage Supply

-V<sub>ee</sub> = Negative supply

**V<sub>id</sub>** = Differential input = (V<sub>1</sub> – V<sub>2</sub>)

The power supply pins +V<sub>cc</sub> and -V<sub>ee</sub> can also be labeled in different ways. As shown in **Figure: 1**

## 1.1 Operation

The amplifier's differential inputs consist of a non-inverting input(+) with voltage V<sub>+</sub> an inverting input(–) with Voltage V<sub>-</sub>; ideally the op-amp amplifies only the difference in voltage between the two, which is called the **differential input voltage**. The output voltage of the op-amp V<sub>out</sub> is given in the equation

$$V_{\text{out}} = A_{\text{OL}}(V_+ - V_-)$$

where A<sub>OL</sub> is the **open-loop** gain of the amplifier (the term “open-loop” refers to the absence of a feed-back loop from the output to the input)

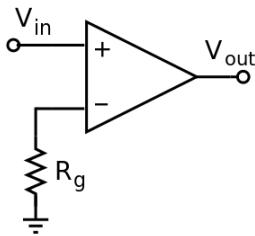


Figure 2: An op-amp without negative feedback

## 1.2 Classification

Op-amps may be classified by their construction:

- discrete (built from individual [transistors](#) or [tubes/valves](#))
- IC (fabricated in an [Integrated Circuit](#)) - most common
- hybrid

## 1.3 Applications

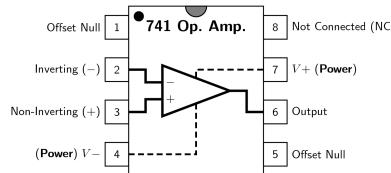


Figure 3: [DIP pinout](#) for 741-type operational amplifier

### 1.3.1 Use in electronics system design

The use of op-amps as circuit blocks is much easier and clearer than specifying all their individual circuit elements(transistors, resistors, etc.), whether the amplifiers used are integrated or discrete circuits.

Circuit design follows the same lines for all electronic circuits. A specification is drawn governing what the circuit is required to do, with allowable limits. For example, the gain may be required to be 100 times, with a tolerance of 5% but drift of less than 1% in a specified temperature range; the input impedance not less than one megohm; etc.

### 1.3.2 Other applications

- audio- and video-frequency [pre-amplifiers](#) and [buffers](#)

- differential amplifiers
- differentiators and integrators
- filters
- precision peak detectors
- volatage and current regulators
- analog calculators
- analog-to-digital convertors
- digital-to-analog convertors
- Voltage clamping
- oscillators and waveform generators
- clipper
- clamp( dc inserter or restorer)
- LOG and ANITLOG amplifiers

Most single, dual and quad op-amps available have a standardized pin-out which permits one type to be substituted for another without writing changes.

## 2 Explain IC 741

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The short form of the operational amplifier is op-amp, is a one kind of solid state IC. The first operational amplifier is designed by **Fairchild Semiconductors** in the year **1963**.

These ICs uses an exterior feedback to regulate its functions and these components are used as a multipurpose device in various electronic instruments. It consists of two inputs and two outputs, namely inverting and non-inverting terminals. The main intention of this 741 op amp is to strength AC & DC signals and for mathematical operations. It's **applications** mainly involves in filter, comparators, pulse generators, oscillators, etc.

### 2.1 IC 741 Operational Amplifier

The **IC 741 operational amplifier** looks like a small chip. The representation of 741 IC op-amp is given below that comprises of eight pins. The most significant pins are **2, 3 and 6**, where pin 2 and 3 are pin 2 and 3 denote inverting & non-inverting terminals and pin 6 denotes output voltage. The triangular form in the IC signifies an op-amp integrated circuit. The main function of this IC 741 is to do mathematical operations in various circuits. IC 741 op amp is made from various stages of transistor which commonly have three stages like differential i/p, a push-pull o/p and an intermediate gain stage. The differential op-amps **comprises of a set of FETs or BJTs**.

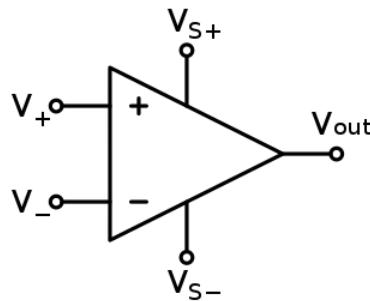


Figure 4: IC 741 Op-Amp

### 2.2 Pin Diagram of IC 741 Op-Amp

The **pin configuration of the IC 741 operational amplifier** is shown below. It comprises of eight pins where the function of each pin is discussed below.

- Pin-1 is Offset null.

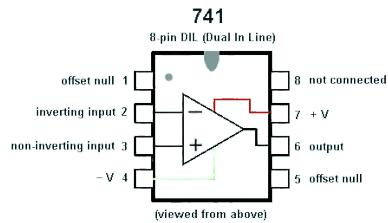


Figure 5: Pin Diagram of IC 741 Op-Amp

- Pin-2 is Inverting (-) i/p terminal
- Pin-3 is a non-inverting (+) i/p terminal
- Pin-4 is -Ve voltage supply (Vcc)
- Pin-5 is offset null
- Pin-6 is the o/p voltage.
- Pin-7 is +ve voltage supply (+Vcc)
- Pin-8 is not connected.

The IC 741 operation amplifier is used in two methods such as an inverting(-) and a non inverting(+)

Whenever any input voltage is applied at the non-inverting input terminal, the output voltage waveform phase does not change. (No phase shift is obtained between output and input) (0° or 360° phase shift is obtained)

When input voltage is applied at inverting terminal, 180° phase shift is obtained at the output waveform.

### 3 Operation Amplifier Characteristics

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In the table given below, ideal and practical characteristics of an op-amp are listed:

<b>Parameter</b>	<b>Ideal</b>	<b>Practical</b>
<b>Op Amp</b>	$V_{id}$ $(V_1 - V_2)$	$(V_1 - V_2)$ $\frac{1}{2}(V_1 - V_2)$
<b>Gain</b>	$\infty(A_d)$	Finite, Very large $A_d \rightarrow$ very large, $A_c \rightarrow$ very small
<b>Input resistance</b> <b>R<sub>in</sub></b>	$\infty$	Very high (in $M\Omega$ )
<b>Output resistance</b> <b>R<sub>out</sub></b>	0	Very Small
<b><math>A_d/A_c = CMRR</math></b>	$\infty$	very large
<b>Slow Rate</b>	$\infty$	Finite Very large
<b>Bandwidth</b>	$\infty$	High/large
<b>Input Offset voltage</b>	0	Very low
<b>Input Offset current</b>	0	Very low

Table 1: characteristics of op-amp

#### 3.1 Block Diagram of an Op-Amp

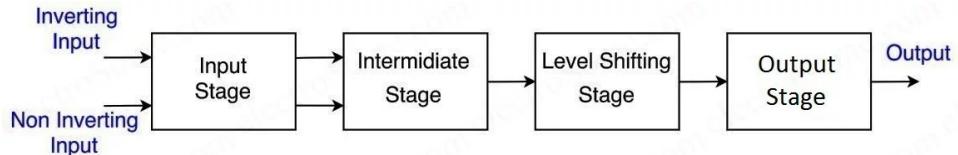


Figure 6: block diagram of an Op-Amp

1. Dual i/p balanced o/p differential amplifier
2. Dual i/p unbalanced o/p differential amplifier
3. Emitter follows with constant current source
4. Push-Pull Amplifier

## 4 Differential gain and Common-mode gain

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### 4.1 Differential Amplifier

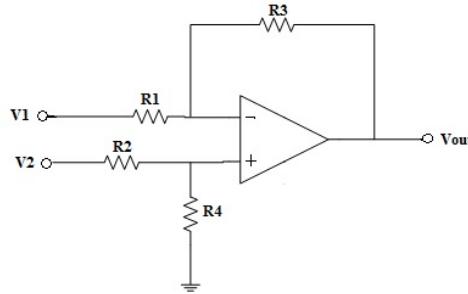


Fig.- Differential Amplifier Circuit

The difference amplifier shown in the circuit is a combination of both inverting and non - inverting amplifiers. If the non-inverting terminal is connected to ground, the circuit operates an inverting amplifier and the input signal  $V_1$  is amplified by  $(R_3/R_1)$ .

Similarly, if the inverting input terminal is connected to ground, the circuit behaves as a non-inverting amplifier. With the inverting input terminal grounded,  $R_3$  and  $R_1$  function as the feedback components of a non-inverting amplifier.

Input  $V_2$  is potentially divided across resistors  $R_2$  and  $R_4$  to give  $V_{R4}$ , and then  $V_{R4}$  is amplified by  $(R_3 + R_1)/R_1$ .

With  $V_2 = 0$ ,

$$V_{O1} = -(R_3/R_1) * V_1$$

With  $V_1 = 0$ ,

$$V_{R4} = \{R_4/(R_2 + R_4)\} * V_2$$

and

$$V_{O2} = \{R_1 + (R_3/R_1)\} * V_{R4}$$

Therefore,

$$V_{O2} = \{R_1 + (R_3/R_1)\} * \{R_1 + (R_3/R_1)\} * V_{R4}$$

If the input resistance are chosen such that,  $R_2 = R_1$  and  $R_4 = R_3$ , then

$$V_{O2} = \{R_3/R_1\} * V_2$$

Now, according to superposition principle if both the input signals  $V_1$  and  $V_2$  are present, then the output voltage is

$$\begin{aligned} V_O &= V_{O1} + V_{O2} \\ &= \{-(R_3/R_1) * V_1\} + \{R_3/R_1\} * V_2 \end{aligned}$$

Which results in,

$$V_0 = (R_3/R_1) * \{V_2 - V_1\}$$

When the resistors  $R_3$  and  $R_1$  are of the same value, the output is the direct difference of the input voltages applied. By selecting  $R_3$  greater than  $R_1$ , the output can be made an amplified version of the difference of the input voltages.

## 4.2 Differential Gain

The differential gain of a difference amplifier **4.1** is defined as the gain obtained at the output signal with respect to the difference in the input signals applied.

The output voltage of a difference amplifier is given as,

$$V_O = A_D(V_1 - V_2)$$

where,  $A_D = -(R_3/R_1)$  is the differential gain of the amplifier.

## 4.3 Common-mode gain

A perfect operational amplifier amplifies only the voltage difference between its two inputs, completely rejecting all voltages that are common to both. However, the differential input stage of an operational amplifier is never perfect, leading to the amplification of these common voltages to some degree. The standard measure of this defect is called the common-mode rejection ratio (denoted CMRR). Minimization of common mode gain is usually important in non-inverting amplifiers (described below) that operate at high amplification.

## 5 Question 1

Determine the output voltage of an op-amp for the input voltage of  $300\mu\text{V}$  and  $240\mu\text{V}$ . The differential gain of the amplifier is 5000 and the value of CMRR is  $10^5$ .

The solution is provided in the image below:

ques 7) Determine the output voltage of an op-amp for the input voltage of  $300\mu\text{V}$  and  $240\mu\text{V}$ . The differential gain of the amplifiers is 5000 and the value of CMRR is  $10^5$ .  
Formulas can be given as  
 $v_1 = 240\mu\text{V}$ ,  $v_2 = 300\mu\text{V}$   
 $A_d = 5000$ ,  $\text{CMRR} = 10^5$

$$\text{CMRR} = \frac{A_d}{A_c} \Rightarrow A_c = \frac{5000}{10^5} = 0.05$$
$$v_d = v_2 - v_1 = 60\mu\text{V}$$
$$v_c = \frac{1}{2}(v_2 + v_1) = \frac{1}{2}(300 + 240) = 270\mu\text{V}$$
$$v_o = v_d A_d + v_c A_c$$
$$= 60 \times 5000 + 270 \times 0.05$$
$$= 300000 + 13.5$$
$$= 300013.5\mu\text{V} = 300.0135\text{mV}$$

Figure 7: solution for ques. 1

## 6 Question 2

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Find the slow rate of an op-amp, if maximum change in output voltage is 0.25 volt for a time duration of  $20\mu\text{sec}$ .

### 6.1 Slow Rate

Slow rate is defined as maximum rate of change of output voltage with respect to time

$$S.R. = \frac{dV_o}{dt} \Big|_{\max}$$

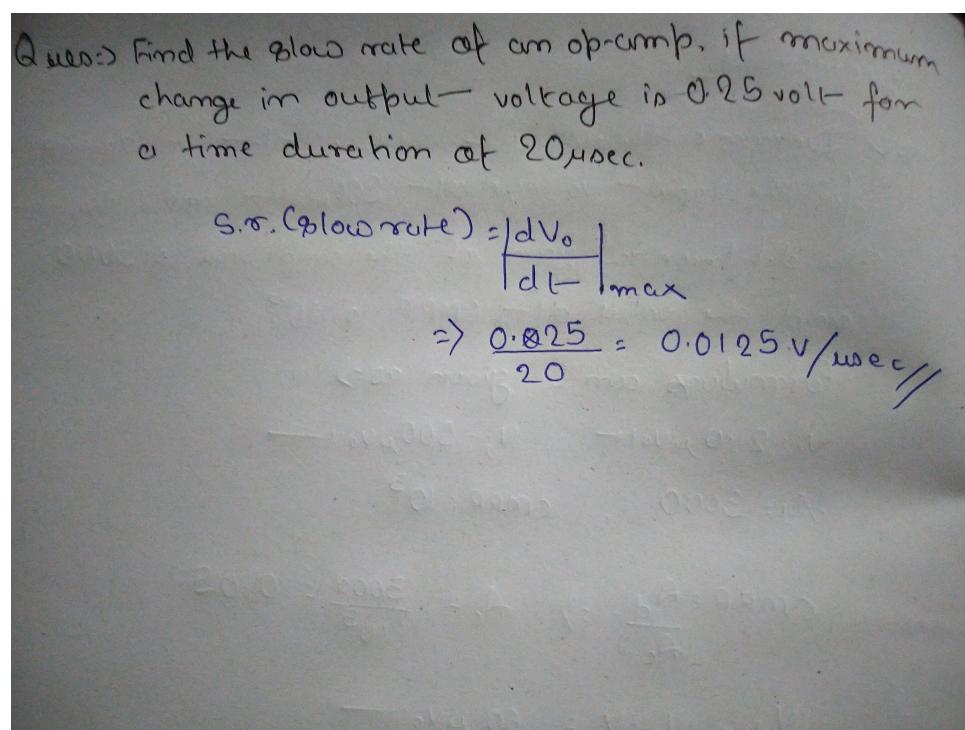


Figure 8: solution of question. 2

## 7 Input Impdence, Output Impedance, Offset Voltage

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### 7.1 Input Impdence( $Z_{in}$ )

Input Impedance is defined as the input voltage by the **input current**. The input impedance of an ideal op amp is  $\infty$ . That is there no current flowing in the input circuit. However, an ideal op amp has certain current flowing in the input circuit of the magnitude of few pico-amps to a few milli-amps.

### 7.2 Output Impedance( $Z_{out}$ )

Output impedance is defined as the ratio of the output voltage to the input current. The output impedance of an ideal op amp is 0, however, real **op amps** have an output impedance of 10-20  $k\Omega$ . An **ideal op amp** behaves like a perfect **voltage source** delivering current without any internal losses. The internal resistance reduce the voltage available to the load.

### 7.3 Offset Voltage( $V_{io}$ )

The offset voltage of an **ideal op amp** is zero, which means that the output voltage will be zero if the difference between the inverting and non-inverting terminal is zero. If both the terminals are grounded, the output voltage will be zero. But real **op amps** have an offset voltage.

## **8 Differentiate Pin 2 and Pin 3 in IC741**

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Pin 2 and Pin 3 are **input** pins of IC. Pin 2 is **inverting input** pin and pin 3 is **non inverting input** pin. If the voltage in pin 2 is greater than voltage of pin 3, i.e., the voltage at inverting input is higher, the output signal stays low. Similarly, the voltage in pin 3 is greater than the voltage at pin 2, i.e., the voltage in non-inverting input is high, the output goes high.