American International University- Bangladesh

Department of Electrical and Electronic Engineering

EEE2210: Analog Electronics 1 Laboratory

Title: Study of Operational Amplifier, Various Types of Comparators, Integrator and Differentiator.

Abstract:
This experiment deals with the basic operations of an operational amplifier (op-amp). The voltage level detectors constructed with op-amp have been studied.

Introduction:

An operational amplifier (op-amp) is a DC coupled high gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.

The op-amps had their origins in analog computers, where they were used to do mathematical operations in many linear, non-linear and frequency-dependent circuits. Characteristics of a circuit using an op-amp are set by external components with little dependence on temperature changes or manufacturing variations in the op-amp itself, which makes op-amps popular building blocks for circuit design. The details Pin Configuration of IC µA741 is shown in **Fig. 1**.

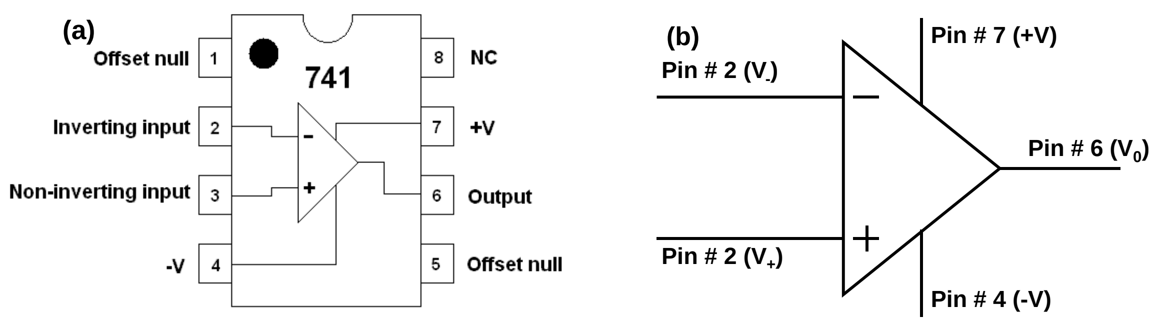


Fig. 1. Pin Configuration of an op-amp (µA741)

The objectives of this experiment are:

- To get familiarized with op-amp and its open and closed loop operations.
- Different types of comparator circuits such as zero crossing, positive level, and negative level detectors with inverting and non-inverting configurations will be experimented.
- To observe the outputs of amplifiers, integrator and differentiator.

Theory and Methodology:

In an op-amp there are two terminals, labeled (-) and (+). They are called differential input terminals because output voltage, V_0 depends on the difference in voltage between them, E_d and the gain of the amplifier, A. The output voltage, V_0 can be determined by E_d and the open loop gain, A. The A is called voltage gain.

Open loop voltage gain

Systems in which the output quantity has no effect upon the input to the control process are called open-loop control systems, and that open-loop systems are just that, open ended non-feedback systems. For an open loop op-amp system V_0 is expressed by the following relationship

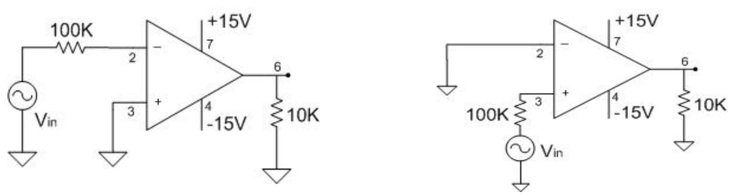
$$\text{Output Voltage } (V_0) = \text{Differential Input Voltage } (E_d) \times \text{Open Loop Gain } (A_{OL})$$

Here A_{OL} is called open loop voltage gain. The value of A_{OL} is extremely large, often 200,000 or more whereas the hence V_0 becomes limited between $+V_{sat}$ and $-V_{sat}$ because it can never exceed the positive or negative saturation voltage. Different types of comparator circuits are the example of op-amps open loop operation.

In electronics, a comparator is a device that compares two voltages or currents. It has two analog input terminals V_+ and V- and one output V_0. A standard op-amp operating in open-loop configuration (without negative feedback) may be used as a low-performance comparator. When the non-inverting input (V_+) is at a higher voltage than the inverting input (V_-), the high gain of the op-amp causes the output to saturate at the highest positive voltage. When the non-inverting input (V_+) drops below the inverting input (V_-), the output saturates at the most negative voltage. The op-amp's output voltage is limited by the supply voltage.

A **zero crossing detector** is a comparator with the reference level set at zero. It is used for detecting the zero crossings of ac signals. It can be made from an operational amplifier with an input voltage at its positive input or negative input which are shown in **Fig. 2(a)** and **Fig. 2(b)**, respectively.

In a non-inverting zero crossing detector when the input voltage is positive, the output voltage is a positive value, when the input voltage is negative, the output voltage is a negative value. In the inverting positive level detector when the input voltage is positive, the output voltage is a negative value and when the input voltage is negative, the output voltage is a positive value.



(a) (b)

Fig 2 (a) Inverting Zero Crossing Detector and **(b)** Non- inverting Zero Crossing Detector

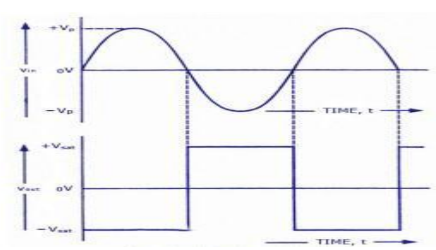
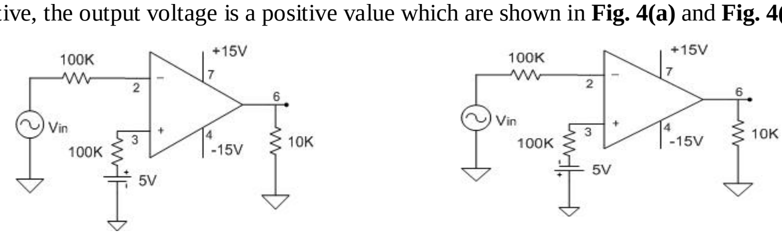


Fig 3 Input output wave shapes of an Inverting zero crossing detector

A **positive level detector** is a comparator with the reference level set at some constant positive voltage. It is used for detecting the positive level crossing of ac signals. In a non-inverting positive level detector when the input voltage is positive, the output voltage is a positive value, when the input voltage is negative, the output voltage is a negative value. In the inverting zero crossing detector when the input voltage is positive, the output voltage is a negative value and when the input voltage is negative, the output voltage is a positive value which are shown in **Fig. 4(a)** and **Fig. 4(b)**.



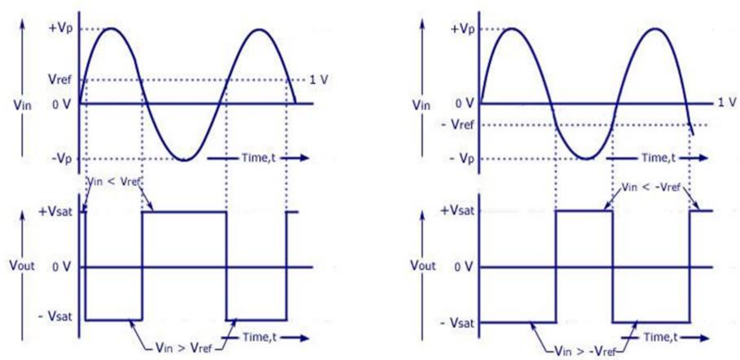
(a) **(b)**

Fig 4 (a) Inverting positive level detector and **(b)** Inverting positive level detector

Condition for inverting configuration:

(i) If $E_i > V_{ref}$, then $V_0 = -V_{sat}$

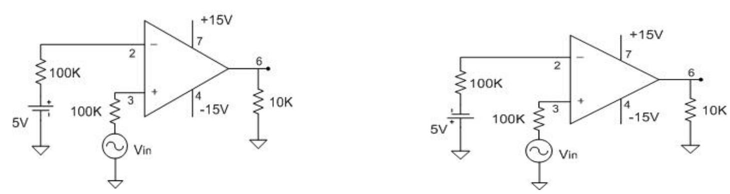
(ii) If $E_i < V_{ref}$, then $V_0 = +V_{sat}$



(a) (b)

Fig. 5. Input output wave shapes of an inverting detector. (a) Positive Level and (b) Negative Level

A **negative level detector** is a comparator with the reference level set at some constant negative voltage. It is used for detecting the negative level crossing of AC signals. In a non-inverting negative level detector when the input voltage is positive, the output voltage is a positive value, when the input voltage is negative, the output voltage is a negative value. In the inverting negative level detector when the input voltage is positive, the output voltage is a negative value and when the input voltage is negative, the output voltage is a positive value. The wave shapes are shown in **Fig. 6(a)** and **Fig. 6(b)**.



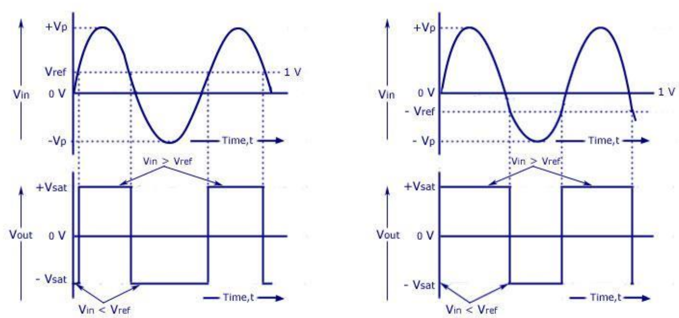
(a) **(b)**

Fig 6 (a) Non-inverting positive level and **(b)** Non- inverting negative level

Condition for non-inverting configuration:

(i) If $E_i > V_{ref}$, then $V_0 = +V_{sat}$

(ii) If $E_i < V_{ref}$, then $V_0 = -V_{sat}$



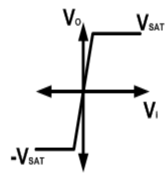
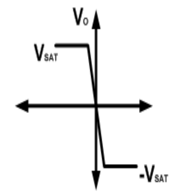
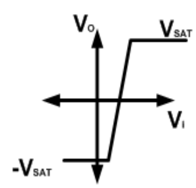
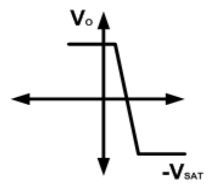
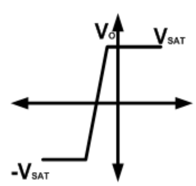
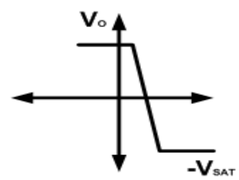
(a) (b)

Fig. 7. Input output wave shapes of a non-inverting detector. (a) Positive Level and (b) Negative Level

Transfer Characteristic Graphs

Transfer characteristic of a comparator is a graph where input and output relationship of that specific comparator can be represented.

Table 1: Transfer characteristics of different types of comparator circuits.

Types of Comparator	Non-Inverting	Inverting
Zero Crossing Detector		
Positive Level Detector		
Negative Level Detector		

Closed loop voltage gain

The very high gain of an open loop op-amp system is of no real use as it makes the amplifier both unstable and hard to control. The smallest of input signals, just a few micro-volts, (μV) would be enough to cause the output voltage to saturate and swing towards one or the other of the voltage supply rails losing complete control of the output. A resistor or other components are used to reduce the gain of the system by feeding back a portion of the output voltage to the input. This type of circuit is called a closed loop amplifier because a closed circuit path exists between the output and the input. Integrator and differentiator are the example of closed loop operation.

Op-amp **Integrator** is an operational amplifier circuit that performs the mathematical operation of Integration which ensures an output voltage which is proportional to the integral of the input voltage. In other words the magnitude of the output signal is determined by closed loop gain of the circuit which is$A_{CL} = -\frac{1}{R_{in}C_f}$ and the input current through the feedback loop charges or discharges the capacitor as the required negative feedback occurs through the capacitor.

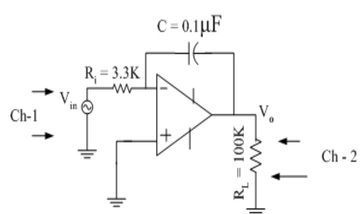


Fig 8 Op-Amp Integrator

The input signal to the **differentiator** is applied to the capacitor. The capacitor blocks any DC content so there is no current flow to the amplifier summing point, X resulting in zero output voltage. The capacitor only allows AC type input voltage changes to pass through and whose frequency is dependent on the rate of change of the input signal. The magnitude of the output signal is determined by the closed loop gain of the circuit which is $A_{CL} = -R_f C_i$

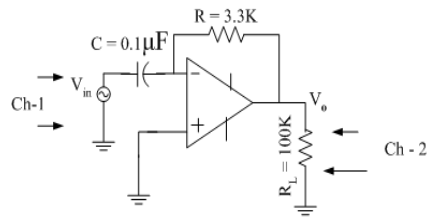


Fig 9: Op-amp Differentiator

Pre-Lab Homework:

Read the characteristics of the different types of detectors, amplifiers, integrator and differentiator from "Operational Amplifiers and Linear Integrated Circuits" by Robert F. Coughlin. PSpice should be used to prepare the output of the circuits provided in this lab sheet. Compare the results with the waveforms given in the text book. Save the simulation results and attach them in the lab report.

Apparatus:

1. IC-µA741-(quantity: 1)
2. Resistor 100K, 10K, 3.3 kΩ, 47 kΩ - (quantity: 2, 1)
3. Capacitor 0.1 uf. – (quantity: 1)
4. Bread Broad-(quantity: 1)
5. DC power supply- ± 30 V (quantity: 1)
6. Function Generator- 25V_{p-p}, 1 MHz (quantity: 1)
7. Oscilloscope- 20MHz/100MHz, 2 Ch, 400 V_{p-p} (quantity: 1)
8. Connecting wires-(quantity: 10)
9. Multimeter-(quantity: 1)

Precautions:

Biasing of the op-amps should be done carefully and oscilloscopes should be properly calibrated using the information provided at the calibration port before obtaining the wave shapes using the experimental set up.

Experimental Procedure:

Detectors

1. Implement the circuit as shown in the Fig. 2.
2. Use sinusoidal signal of 1 kHz as input signal. Adjust the amplitude of input signal to 10V_{p-p}.
3. Observe both input and output signals simultaneously on the oscilloscope.
4. Draw the wave shapes on graph paper properly identifying the cross over points.
5. Repeat steps 1 to 4 for circuits shown in Fig. 4 and Fig. 6 above in the theory section.

Integrator and Differentiator

1. Implement the circuit shown in Fig. 9
2. Use a sinusoidal voltage of 1KHz, 500 mV_p as input signal.
3. Observe both input and output voltages simultaneously with oscilloscope.

4. Draw the wave shapes on graph paper.
5. Repeat step 1 to 3 with a square wave.
6. Repeat steps 1 to 5 for circuit shown in Fig. 10.

Reports:

1. Write down the applications of op-amp which are used in your daily life.
2. Write down the application of a zero crossing detector.
3. How do you use the comparator in Analog to Digital Converter?
4. What are the applications of a voltage level detector?
5. Write down the application of inverting and non-inverting amplifiers.
6. Write down the application of integrator and differentiator.

Discussion and Conclusion:

Interpret the data/findings and determine the extent to which the experiment was successful in complying with the goal that was initially set. Discuss any mistake you might have made while conducting the investigation and describe ways the study could have been improved.

References:

1. Op-amp comparator, http://www.circuitstoday.com/op-amp-comparator
2. Robert F. Coughlin, Frederick F. Driscoll, "Operational amplifiers and linear integrated circuits", Prentice-Hall, 1982, 2nd Edition, The University of Michigan, 10 Dec 2007
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