Gokaraju Rangaraju
Institute of Engineering and Technology
(Autonomous Institution under JNTU Hyderabad)

Principles of Analog Electronics
Lab Record

Name:

Roll No:

Course: B.Tech. II Yr I Semester

Branch: EEE

CERTIFICATE

This is to certify that a bonafide record of practical work done

*by Mr. /Ms.*_____

*Reg. No.*_____*in the PRINCIPLES OF ANALOG*

ELECTRONICS LABORATORY in the II Year I Semester during

20____ - 20____.

Internal Examiner   External Examiner
Signature   Signature

PRINCIPLES OF ANALOG ELECTRONICS LAB

II Year I Semester

Course Objectives:

After completion of this course, Students must be able to

1. Classify the types of active components.

2. Describe the operations of Diode and BJT

3. Analyze different Configuration types of Operational Amplifier.

4. Implement the mathematical operation on signals.

5. Make conversant with Oscillator principle

Course Outcomes:

After completion of this course, Students will be able to

1. Recall types of active components.

2. Illustrate the characteristics of Diode and BJT

3. Design Operational Amplifiers as inverting and non-inverting amplifier

4. Apply mathematical operation on signals using Operational Amplifier
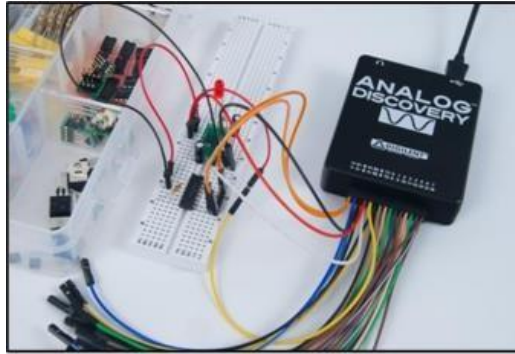
5. Design Oscillator circuit

CONTENTS

INTRODUCTION TO ANALOG DISCOVERY KIT

Overview

The Digilent Analog Discovery , developed in conjunction with Analog Devices Inc., is a multi-function instrument that can measure, record and generate analog and digital signals.


Figure: Analog Discovery used in a circuit design experiment

The small, portable and low-cost Analog Discovery (above Figure) was created so that engineering students could work with analog and digital circuits anytime, anywhere - right from their PC. The Analog Discovery's analog and digital inputs and outputs connect to a circuit using simple wire probes. Inputs and outputs are controlled using the free PC- based Waveforms software that can configure the Discovery to work as any one of several traditional instruments. Instruments include:

- Two channel oscilloscope (1MΩ, ±25V, differential, 14 bit, 100Msample/sec, 5MHz bandwidth);
- Two channel arbitrary function generator (22Ω, ±5V, 14 bit, 100Msample/sec, 5MHz bandwidth);
- Stereo audio amplifier to drive external headphones or speakers with replicated AWG signals;
- 16-channel digital logic analyzer (3.3V CMOS, 100Msample/sec)*;
- 16-channel pattern generator (3.3V CMOS, 100Msample/sec)*;
- 16-channel virtual digital I/O including buttons, switches and LEDs –good for logic trainer applications*;
- Two input/output digital trigger signals for linking multiple instruments (3.3V CMOS);
- Two power supplies (+5V at 50mA, -5V at 50mA).
- Single channel voltmeter (AC, DC, ±25V);
- Network analyzer – Bode, Nyquist, Nichols transfer diagrams of a circuit. Range: 1Hz to 10MHz;
- Spectrum Analyzer - power spectrum and spectral measurements (noise floor, SFDR, SNR, THD, etc.);
- Digital Bus Analyzers (SPI, I2C, UART, Parallel);

The Analog Discovery was designed for students in typical university-based circuits and electronics classes. Its features and specifications, including operating from USB power, a small and portable form factor, and the ability to be used by students in a variety of environments at low cost, are based directly on inputs from many professors at many universities. Meeting all the requirements proved challenging, and resulted in some new and innovative circuits. This document is a reference for the Analog Discovery's electrical functions and operations. This reference also provides a description of the hardware's features and limitations. It is not intended to provide enough information to enable complete duplication of the Analog Discovery, or to allow users to design custom configurations for programmable parts in the design.

The pin-out terminals of Analog Discovery Kit (AD Kit) is shown below
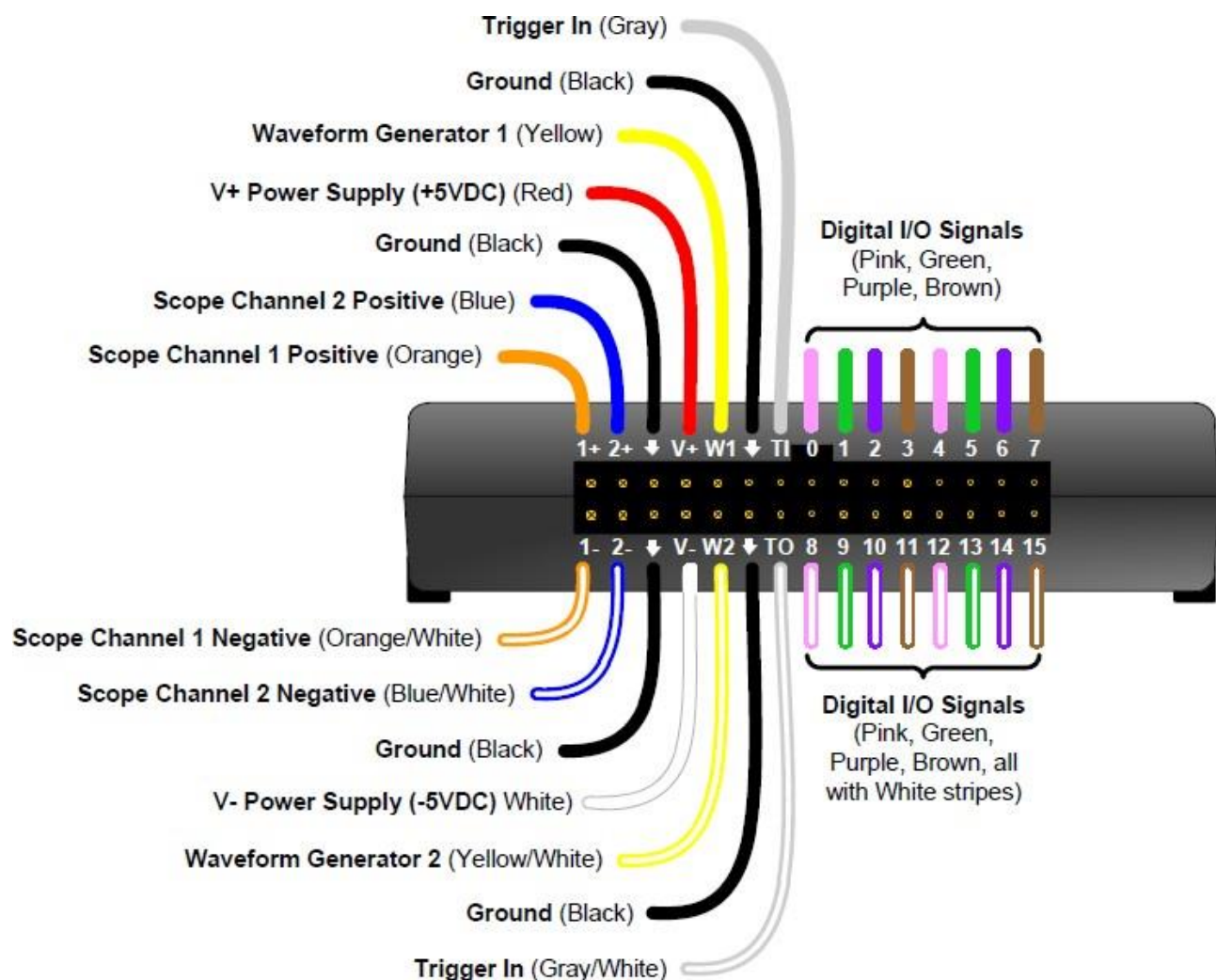
STEPS TO RUN WAVEFORM SOFTWARE

Step1: Open the "Waveform" software from the start menu of the windows desktop
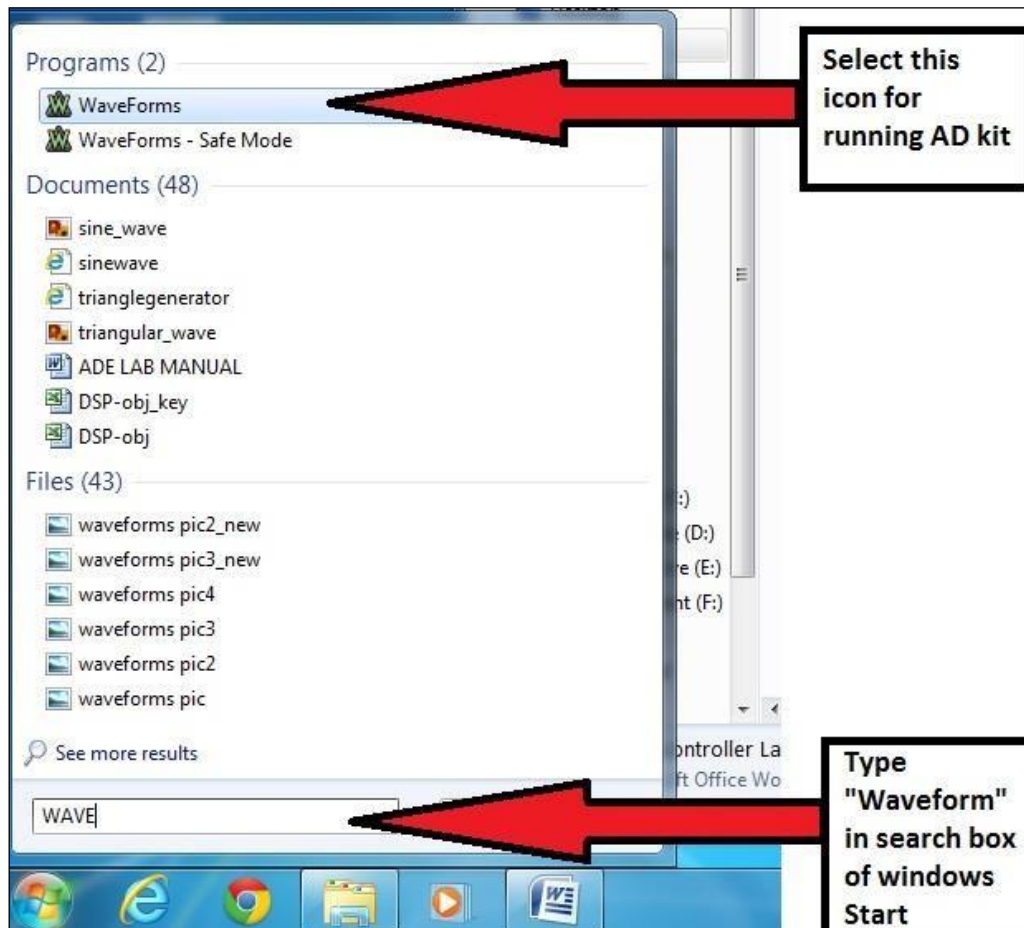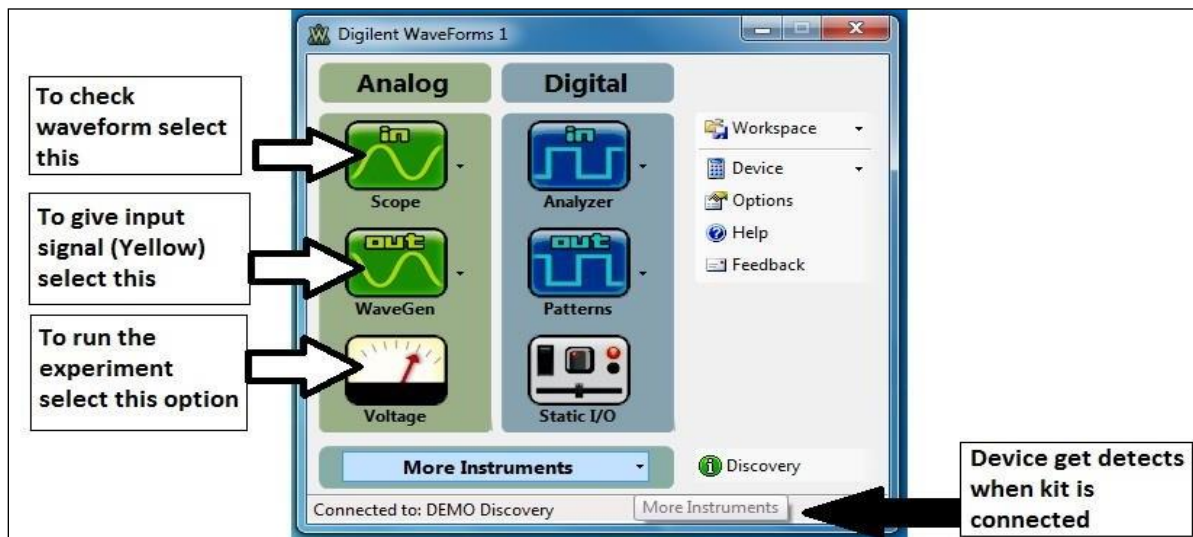

Figure: Showing the selection of Waveform software from the start menu

Step2: Each block representation of Waveform software

"in" -To check waveforms at the output terminals of the hardware connections done on Bread board "in" is selected

"out"- To give different input signals to the circuit done on the Bread board "out" is selected

"voltage"-This option is selected to apply +Vcc and –Vcc to the circuit connections done on Bread board

Figure: showing the Window of Waveform software

Step 3: The window shown below is obtained when "in" is selected from the "Waveform" software. Two waveforms can be seen at one time (one is "orange" and the other is "Blue"). The right side window shows the settings of different waveforms who's Y and X axis can be set. After selecting the required options, click the "Run" button on Top left side of the Window to see the obtained output of the circuit connected on the Bread board.
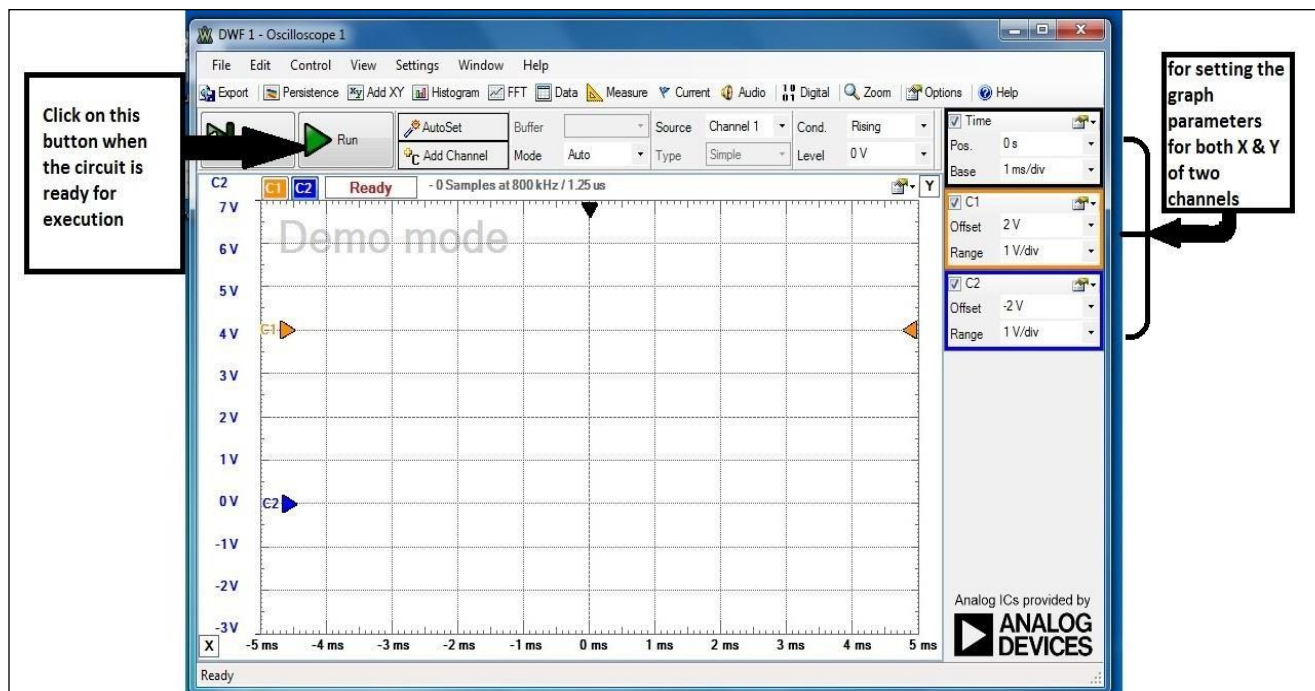

Figure: Shows the "in" window of "Waveform" software

Step4: "Out" tab of Waveform software is used for selecting the types of waveforms like-sinusoidal, square, triangular, trapezoidal, random signal of different frequencies from this window. The signal

selected from this window is given as input signal to the circuit connected on the Bread board. After making the required settings click on the "Run AWG1" option from the window.
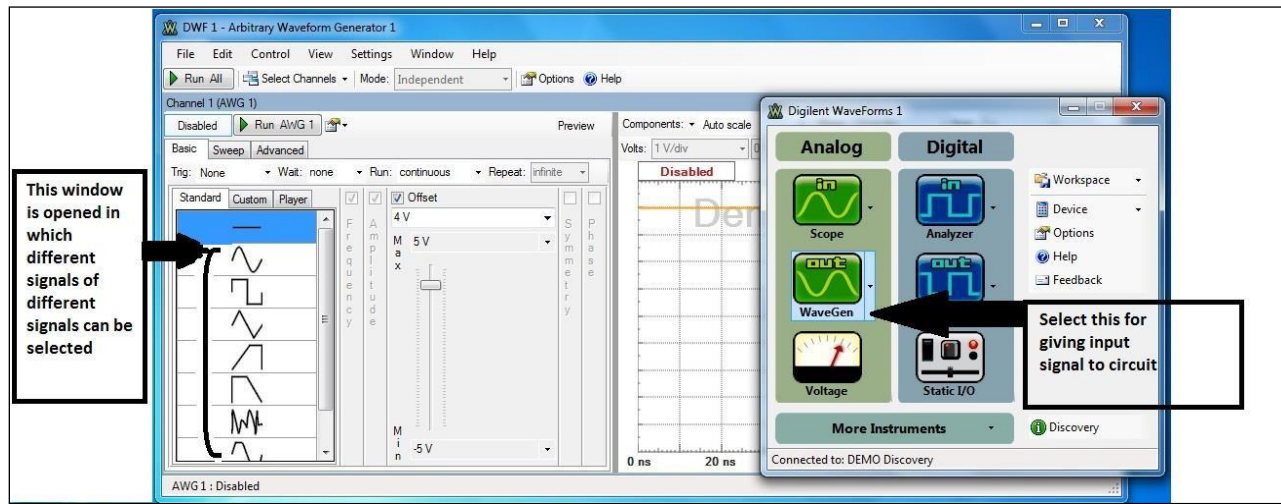
Figure: The "Out" window of Waveform in which different waveforms can be given as input

Step5: "Voltage" is selected for giving the input voltage of either +Vcc (Constant +5V) or –Vcc (Constant -5V) or both. When the "Power is ON/OFF" is selected the respective voltages are applied to the circuit connected.
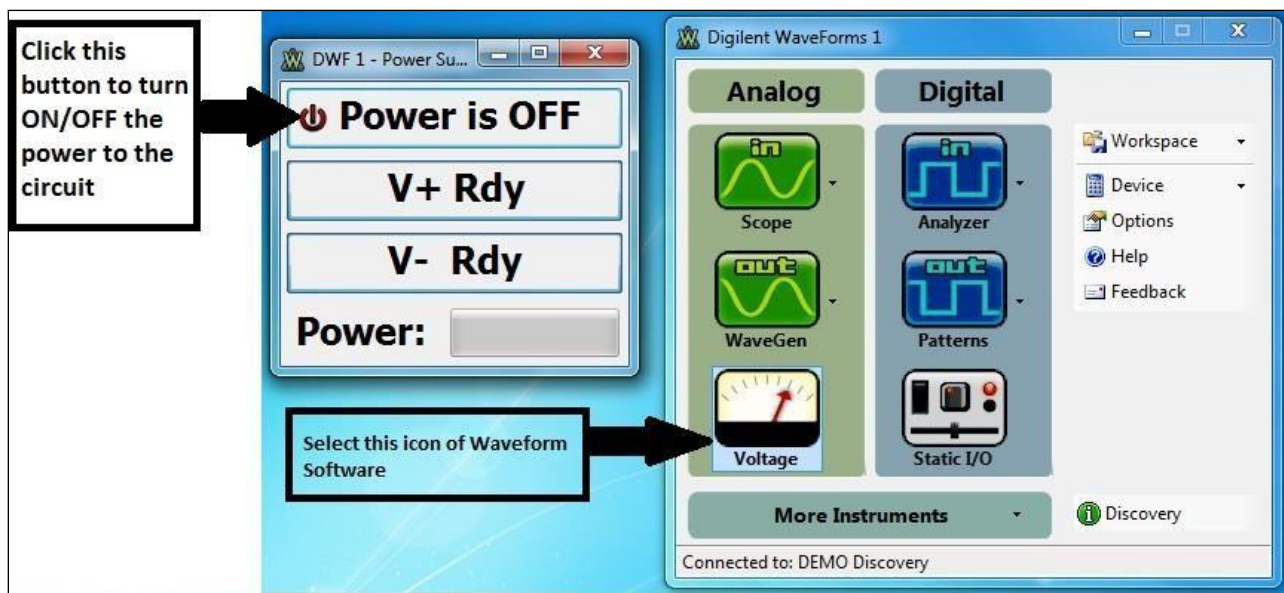
Figure: The "Voltage" window of Waveform helps to run the ADE kit

EXPERIMENT-1
DIODE CHARACTERISTICS

AIM: To study and verify the PN Junction Diode characteristics

APPARATUS:

Resistors (1 KΩ) – 1
Diode (1N4007) – 1
Analog Discovery Kit / ESIM Software / EC Studio Software
Connecting wires
Bread board

THEORY:

- **Biasing of PN junction Diode:**

Forward bias operation: The P-N junction supports uni-directional current flow. If +ve terminal of the input supply is connected to p-side and –ve terminal is connected the n-side, then diode is said to be forward biased condition. In this condition the height of the potential barrier at the junction is lowered by an amount equal to given forward biasing voltage. Both the holes from p-side and electrons from n-side cross the junction simultaneously thereby decreasing the depleted region. This constitutes a forward current (majority carrier movement – diffusion current). Assuming current flowing through the diode to be very large, the diode can be approximated as short-circuited switch. Diode offers a very small resistance called **Forward resistance** (few ohms).

Reverse bias operation If negative terminal of the input supply is connected to p-side and –ve terminal is connected to n-side then the diode is said to be reverse biased. In this condition an amount equal to reverse biasing voltage increases the height of the potential barrier at the junction. Both the holes on P-side and electrons on N-side tend to move away from the junction there by increasing the depleted region. However, the process cannot continue indefinitely, thus a small current called reverse saturation current continues to flow in the diode. This current is negligible; the diode can be approximated as an open circuited switch it offers a very high resistance called **Reverse resistance** (few Kiloohms)

Static Resistance: The opposition offered by a diode to the direct current flowing forward bias condition is known as its DC forward resistance or Static Resistance. It is measured by taking the ratio of DC voltage across the diode to the DC current flowing through it at an operating point.

Dynamic Resistance: The opposition offered by a diode to the changing current flow I forward bias condition is known as its AC Forward Resistance. It is measured by a ratio of change in voltage across the diode to the resulting change in current through it for an operating point P.

Average Resistance: Same as dynamic resistance but measured between extremities. Diode current equation

The volt-ampere characteristics of a diode explained by the following equations:

$$I = I_0(e^{\frac{V}{\eta V_T}} - 1)$$

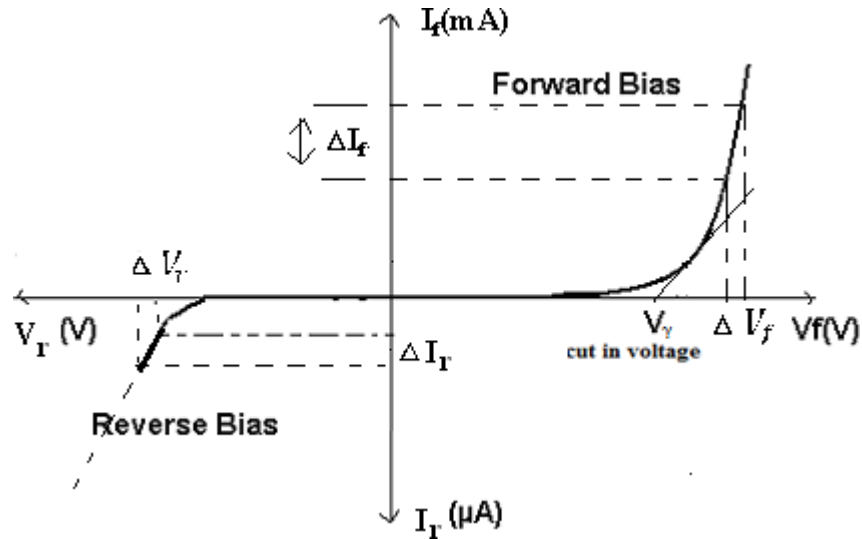Where I = current flowing in the diode,

I_0 = reverse saturation current

V = voltage applied to the diode,

V_T = volt- equivalent of temperature = k T/q = T/ 11,600 = 26mV (@ room temp)

η=1 (for Ge) and 2 (for Si)

Ideal Characteristics of Diode:

<u>Calculations from Graph:</u>

Cutin Voltage V_γ=

Static forward Resistance $R_{dc} = V_f/I_f \Omega$

Dynamic Forward Resistance $r_{ac} = \Delta V_f/\Delta I_f \Omega$

Static Reverse Resistance $R_{dc} = V_r/I_r \Omega$

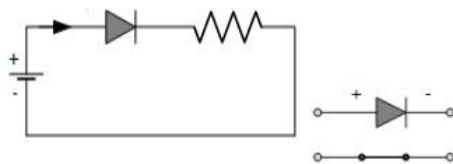Dynamic Reverse Resistance $r_{ac} = \Delta V_r/\Delta I_r \Omega$

CIRCUIT DIAGRAM:

Fig. 1: Forward Bias Condition   Fig. 2: Reverse Bias Condition
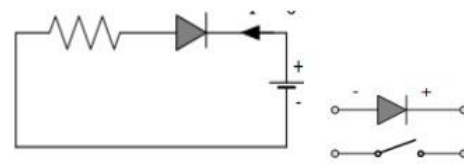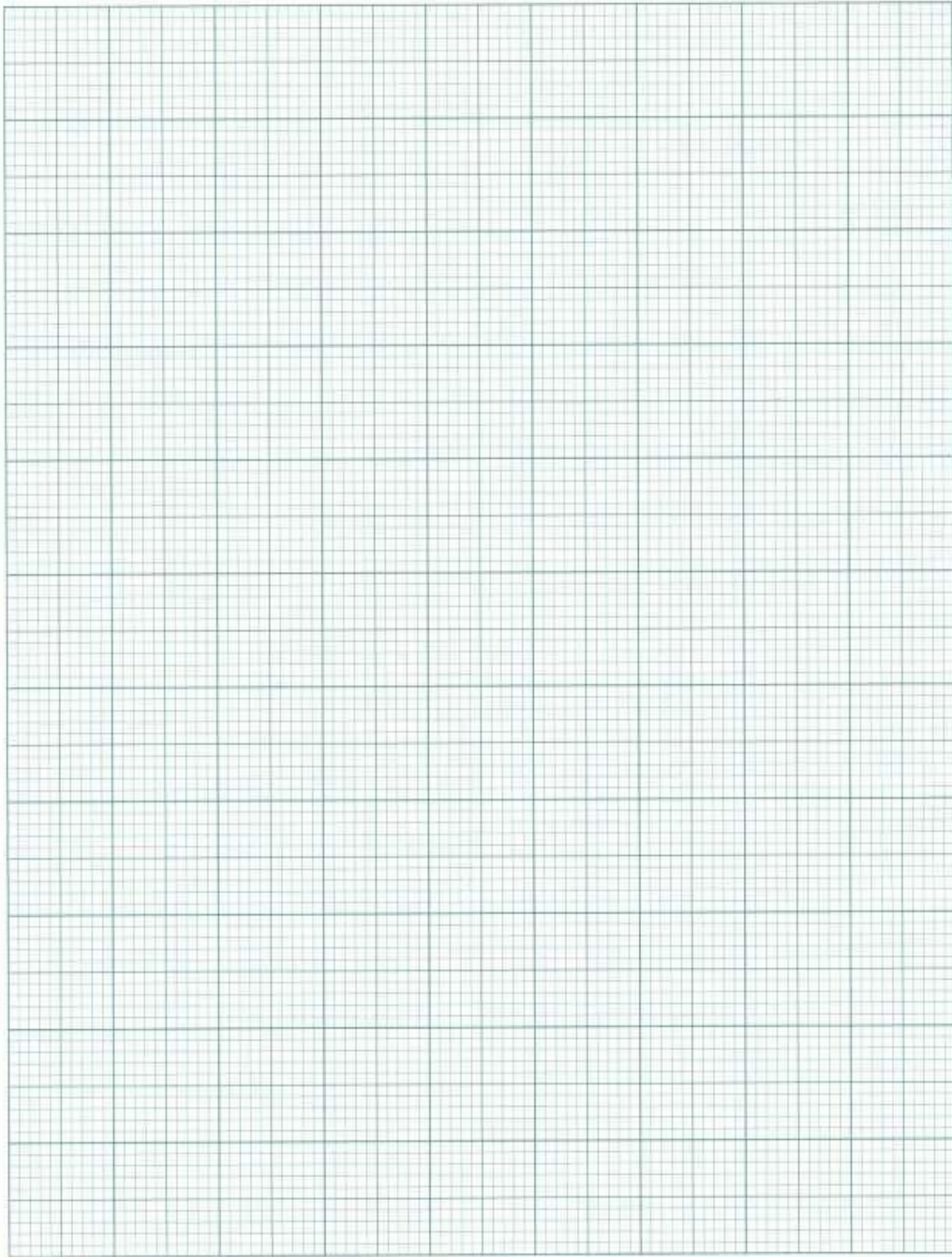
PROCEDURE:

(A) FORWARD BIAS CONDITION:

1. Connect the circuit as shown in Fig.1 (PN Junction diode with milli-ammeter in series with the diode).
2. Initially vary Regulated Power Supply (RPS) voltage V_s in steps of 0.1 V. Once the current starts increasing vary V_s in steps of 0.02V and note down the corresponding readings V_f and I_f.
3. Tabulate different forward currents obtained for different forward voltages.
4. Plot the V-I characteristics and calculate the resistance levels
5. Compare the theoretical and practical values (cut-in voltage and resistances).

(B) REVERSE BIAS CONDITION:

1. Connect the circuit as shown in Fig.2 (Point contact diode in series with micro ammeter).
2. Vary V_s in the Regulated Power Supply (RPS) gradually in steps of 1V from 0V to 5V and note down the corresponding readings V_r and I_r.
3. Tabulate different reverse currents obtained for different reverse voltages.
4. Plot the V-I characteristics and calculate the resistance levels.
5. Compare the theoretical and practical values.

Forward Bias		Reverse Bias	
V_f(volts)	I_f (mA)	V_r(volts)	I_r (µA)

GRAPH:

RESULT:

9

EXPERIMENT-2
HALF WAVE RECTIFIER USING DIODE

AIM: To design a Half Wave Rectifier circuit

APPARATUS:

Resistors (5 KΩ) – 1
Diode (1N4007) – 1
Analog Discovery Kit / ESIM Software / EC Studio Software
Connecting wires
Bread board

THEORY:

The conversion of AC into DC is called Rectification. Electronic devices can convert AC power into DC power with high efficiency. During the positive half cycle, the diode is forward biased and it conducts and hence a current flow through the load resistor. During the negative half cycle, the diode is reverse biased and it is equivalent to an open circuit, hence the current through the load resistance is zero. Thus the diode conducts only for one half cycle and results in half wave rectification. The input and output voltage waveform may be analytically written as:

$$V_{in} = V_p sin\omega t \, , 0 \le t \le T$$

and

$$V_{out} = V_{pl} sin\omega t \, , 0 \le t \le T/2$$

$$V_{out} = 0 \, , T/2 < t \le T$$

where

$$Peak \, Value = V_{pl} = V_p - V_\gamma$$

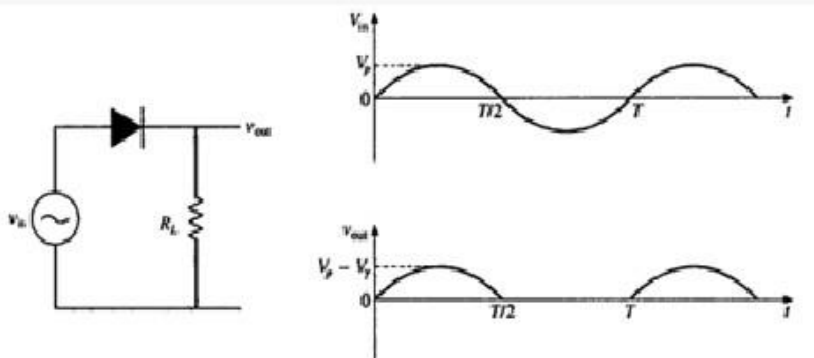and V_γ is cut-in voltage of the diode.
The average (dc) value of half wave rectified sine wave voltage is represented by

$$V_{avg} = V_{dc} = \frac{V_{pl}}{\pi}$$

RMS voltage at the load resistance can be calculated as

CIRCUIT DIAGRAM:

PROCEDURE:

1. Connect the circuit as shown in the circuit diagram.
2. Give the input signal as specified.
3. Switch on the power supply.
4. Note down the value of AC and DC voltages from the Waveform software
5. Draw the necessary waveforms on the graph sheet.

CALCULATIONS:

Average Voltage (V$_{dc}$): $V_{avg} = V_{dc} = \dfrac{V_{pl}}{\pi}$

RMS Voltage (V$_{RMS}$): $V_{rms} = \dfrac{V_{pl}}{2}$

Form Factor (FF): $FF = \dfrac{RMS\ Value}{Average\ Value} = \dfrac{V_{RMS}}{V_{dc}}$

Ripple Factor: Ripple factor is defined as the ratio of effective value of AC component to the average DC value. Ripple Factor (r),
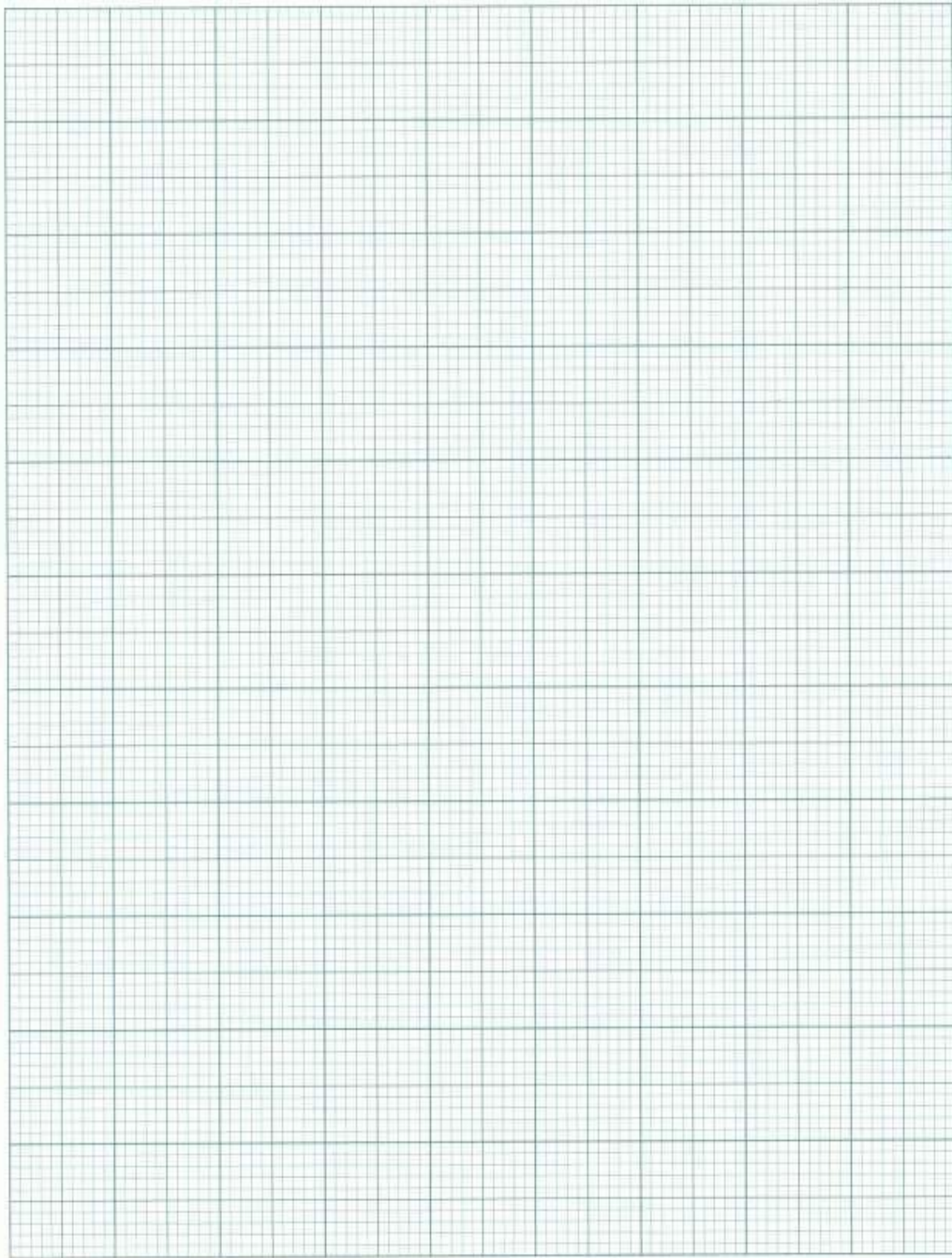
$$r = \sqrt{(FF)^2 - 1}$$

Efficiency: $\eta = \dfrac{dc\ output\ power}{ac\ input\ power} = \dfrac{P_{dc}}{P_{ac}} = \dfrac{(V_{dc}{}^2)/R_L}{(V_{RMS}{}^2)/R_L}$

Peak Factor: $PF = \dfrac{Peak\ Value}{RMS\ Value}$

11

GRAPH:

RESULT:

EXPERIMENT-3
CLIPPING CIRCUITS

AIM: To design Non- linear wave shaping circuits: Clipping Circuits.

APPARATUS:

Resistors (2.2 KΩ) – 2 Nos
Diode (1N4007) – 2 Nos
Analog Discovery Kit / ESIM Software / EC Studio Software
Connecting wires
Bread board

THEORY:

The process whereby the form of sinusoidal signals is going to be altered by transmitting through a non-linear network is called non-linear wave shaping. Non-linear elements (like diodes, transistors) in combination with resistors can function as clipper circuit.

Clipping circuits are used to select transmission of that part of an arbitrary wave form which lies above or below some particular reference voltage level. Clipping circuits are also referred to as Limiters, Amplitude selectors or Slicers.

Clipping circuits are constructed using a combination of resistors, diodes or transistor and reference voltage. Clipping circuits are classified based on the position of diode as

  i.   Series diode clipper
 ii.   Shunt diode clipper

and further they are classified as, with '0' reference, with +ve reference, with –ve reference; also as positive clipper , negative clipper.

PROCEDURE:

1. Connect the circuit as shown in the figures given below.
2. In each case, apply 10 V_{P-P}, 1 KHz Sine wave.
3. Observe the Output waveform (V_O in the circuit) and compare it with Input waveform.
4. Sketch the Input as well as Output waveforms and mark the voltage levels.
5. Note the changes in the Output due to variations in the reference voltage $V_R = 0V$, 2V, etc.
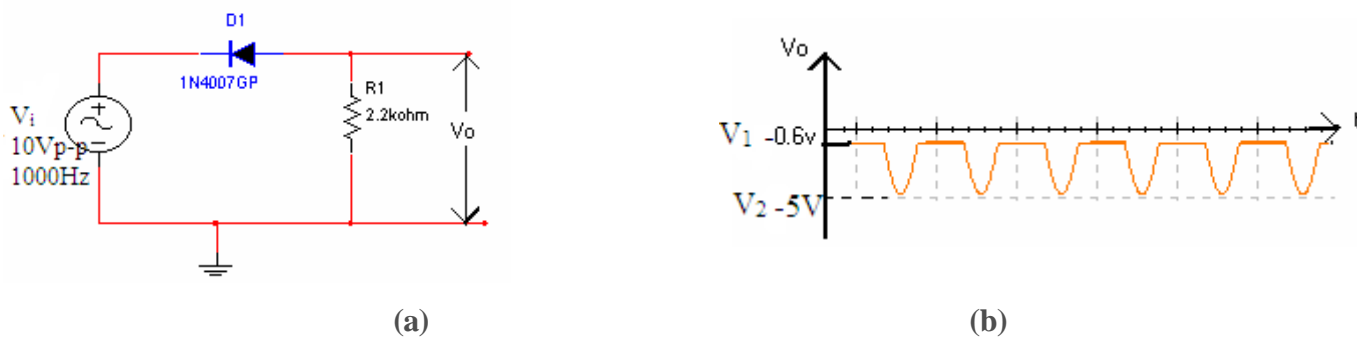6. Repeat the above steps for all the clipping circuits.

CIRCUIT DIAGRAMS:

Input Signal

(a)   (b)

TRANSFER CHARACTERISTICS:

(c)
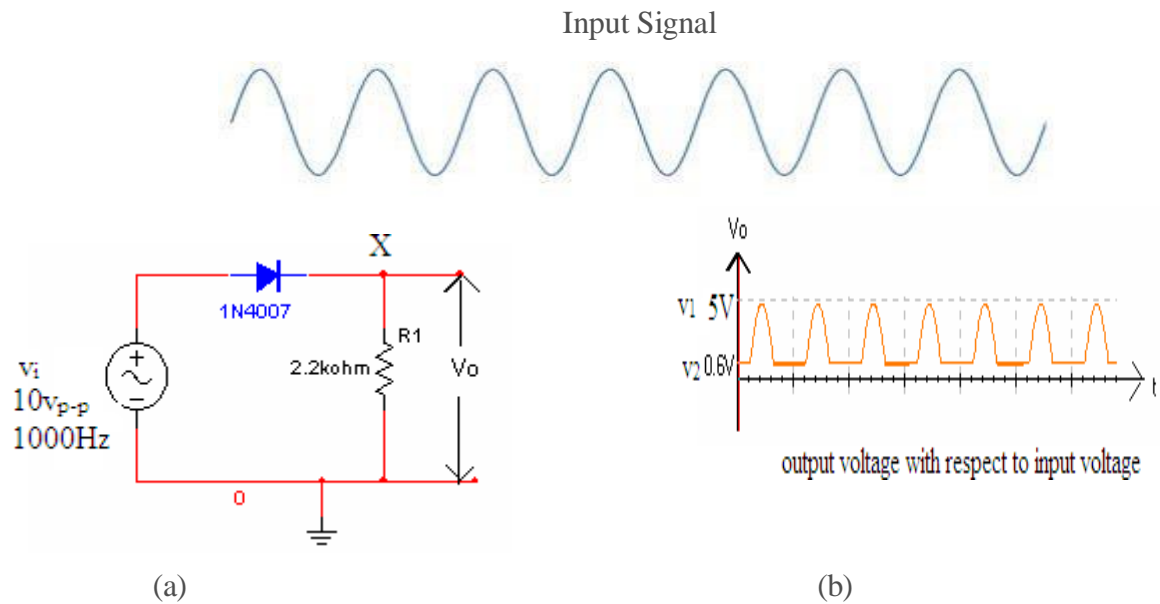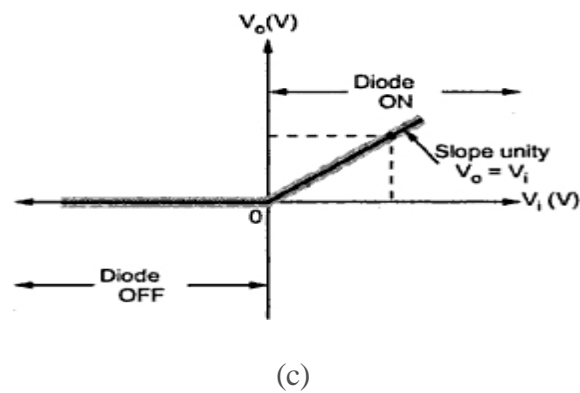
Fig 2.1 (a) Negative clipper with zero reference (Series clipper) (b) Waveforms, (c) Input Voltage vs Output Voltage graph

(a)   (b)

TRANSFER CHARACTERISTICS:

(c)

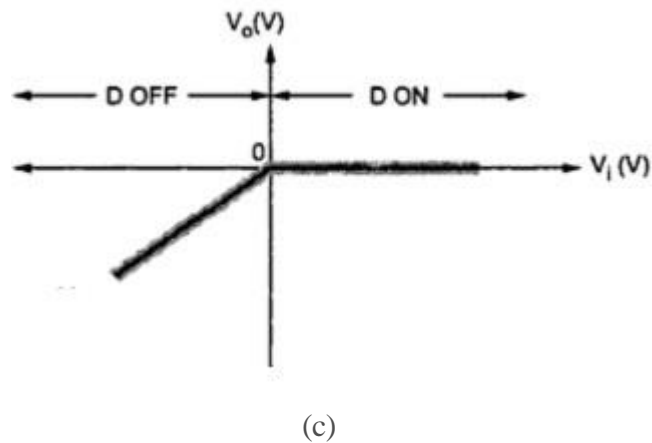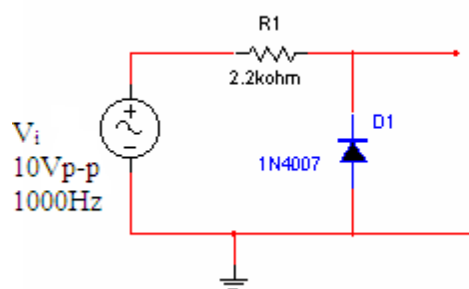**Fig 2.2 (a) Positive clipper with zero reference (Series clipper), (b) Waveforms and (c) Input Voltage vs Output Voltage graph**

(a)   **(b)**

TRANSFER CHARACTERISTICS:

(c)

Fig 2.3 (a) Negative clipper with zero reference (Shunt clipper), (b) Waveforms and (c) Input Voltage vs Output Voltage graph

15

(a)

(b)

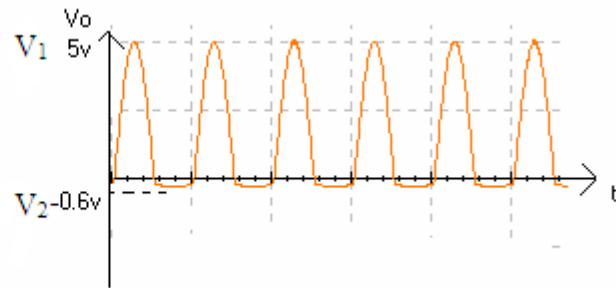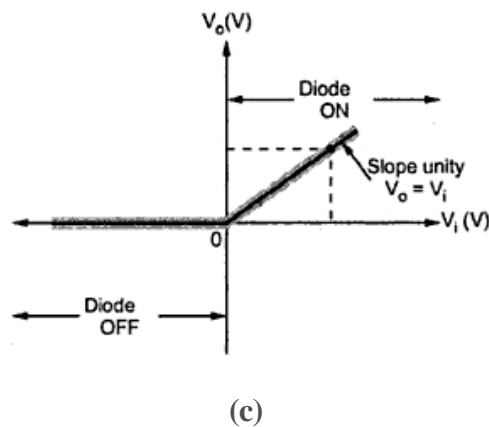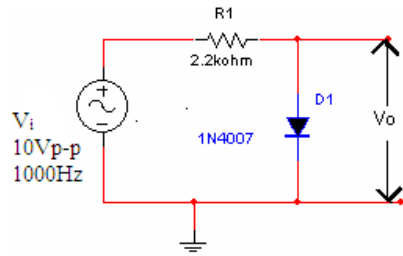**TRANSFER CHARACTERISTICS:**

(c)

Fig 2.4 (a) Positive clipper with zero reference (Shunt clipper), (b) Waveforms and (c) Input Voltage vs Output Voltage graph

(a)

(b)

TRANSFER CHARACTERISTICS:
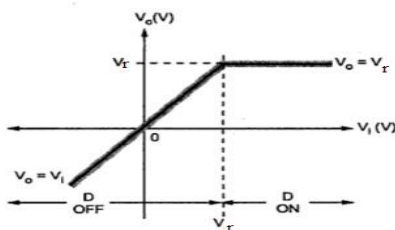
(c)

Fig. 2.5 (a) Positive clipper with positive reference (Series clipper) , (b) Waveforms and (c) Input Voltage vs Output Voltage graph

16

(a)   (b)
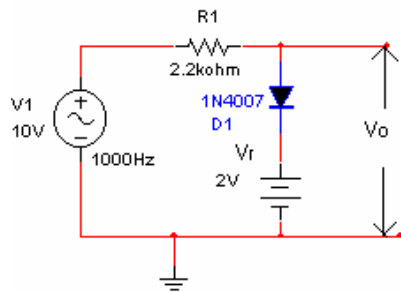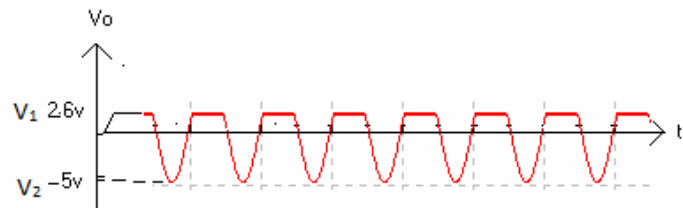
Transfer characteristics:
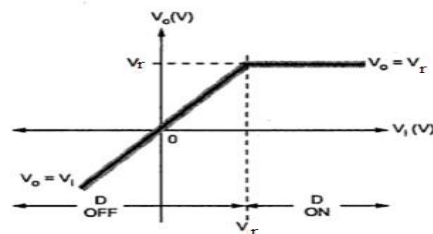
(c)

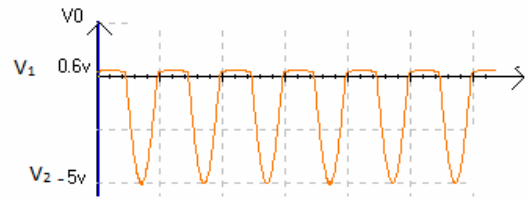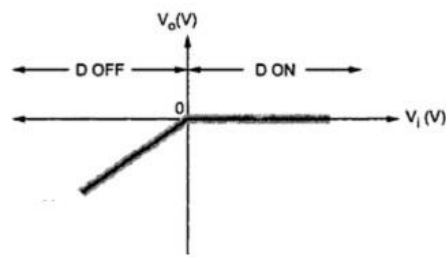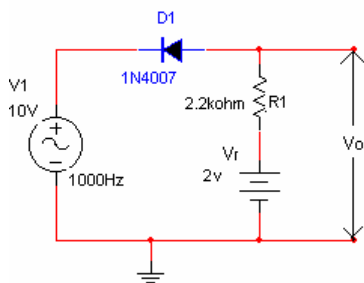**Fig. 2.6 (a) Positive clipper with positive reference (Shunt clipper), (b) Waveforms and (c) Input Voltage vs Output Voltage graph**

(a)   (b)
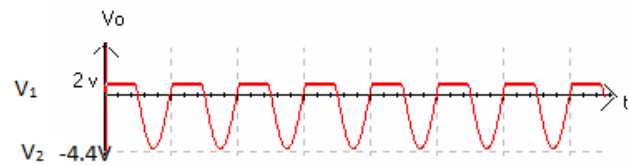
Transfer characteristics:

(c)

17
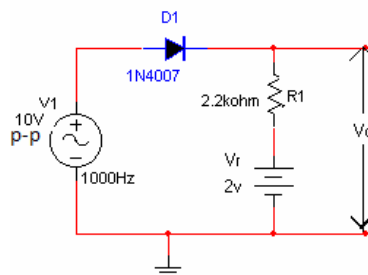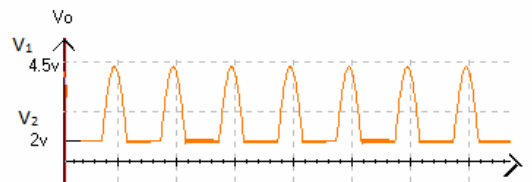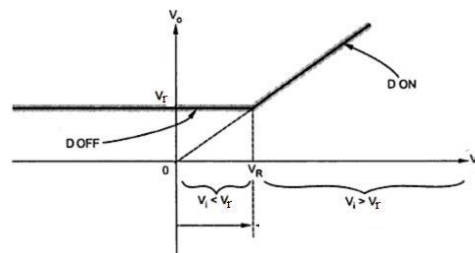
Fig. 2.7 (a) Negative clipper with positive reference (Series clipper) , (b) Waveforms and (c) Input Voltage vs Output Voltage graph

(a)

(b)
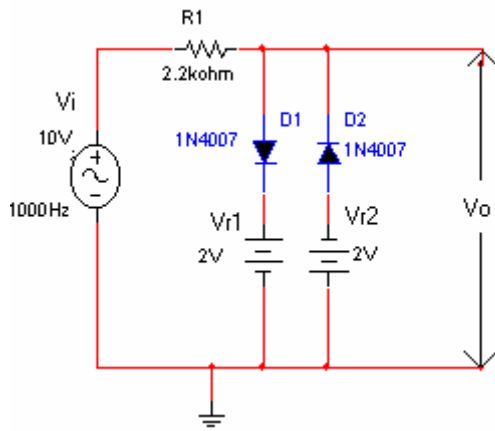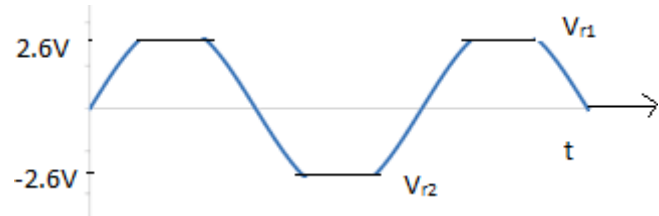
Transfer characteristics:
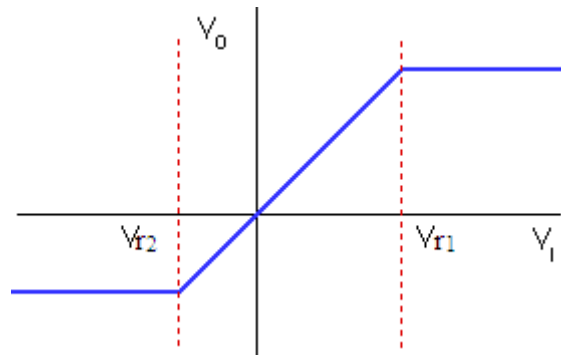
(c)

Fig.2.9 (a) Clipping at two independent levels, (b) Waveforms and (c) Input Voltage vs Output Voltage graph

OBSERVATIONS:

S.No.	Type of Clipper	Reference Voltage	Practical Clipping Voltage levels	
1	Series Positive Clipper	0V	V1	
			V2	
		2V	V1	
			V2	

S.No.	Type of Clipper	Reference Voltage	Practical Clipping Voltage levels	
2	Series Negative Clipper	0V	V1	
			V2	
		2V	V1	
			V2	
3	Shunt Positive Clipper	0V	V1	
			V2	
		2V	V1	
			V2	
4	Shunt Negative Clipper	0V	V1	
			V2	
		2V	V1	
			V2	
5	Two level clipper		V1	
			V2	

GRAPH:
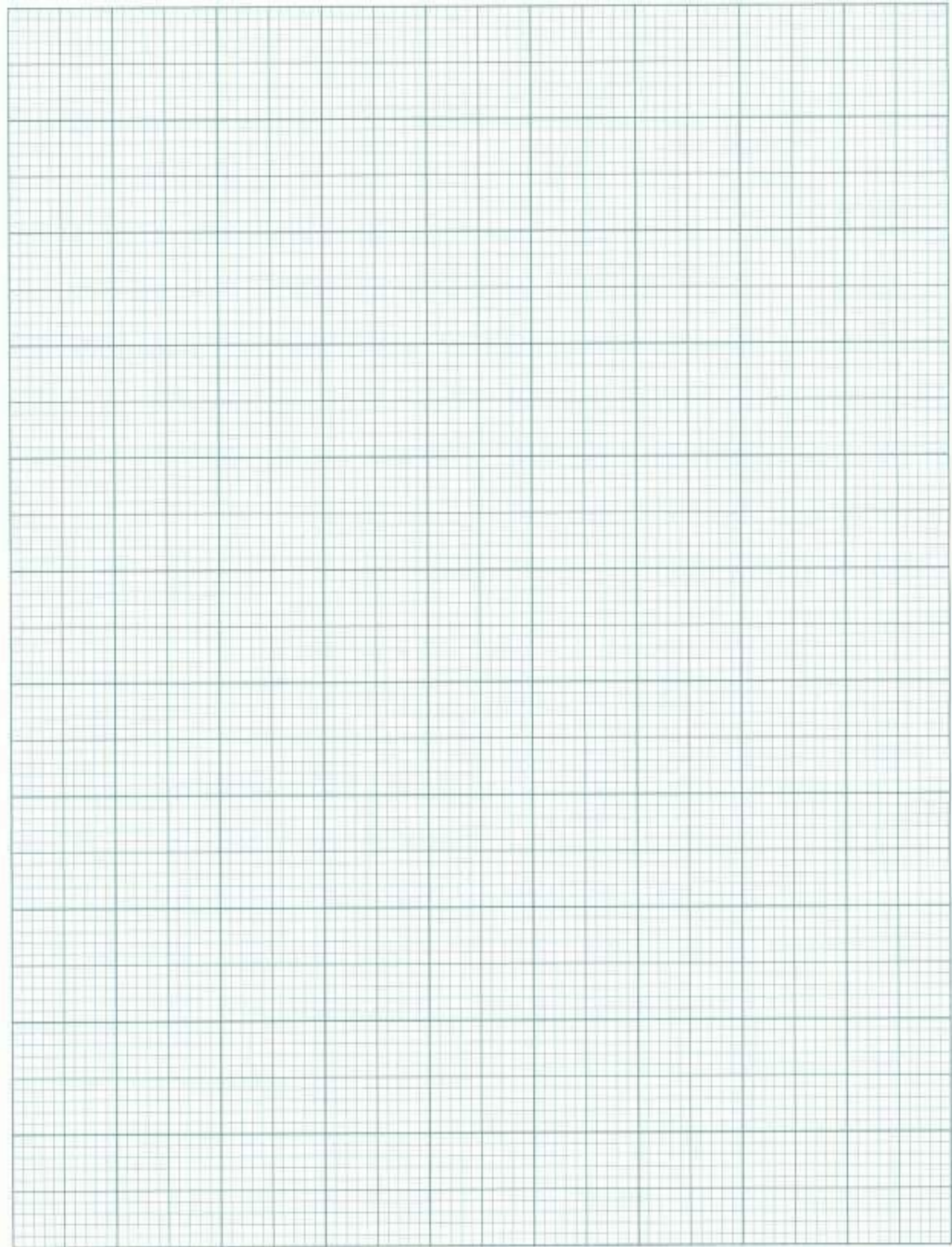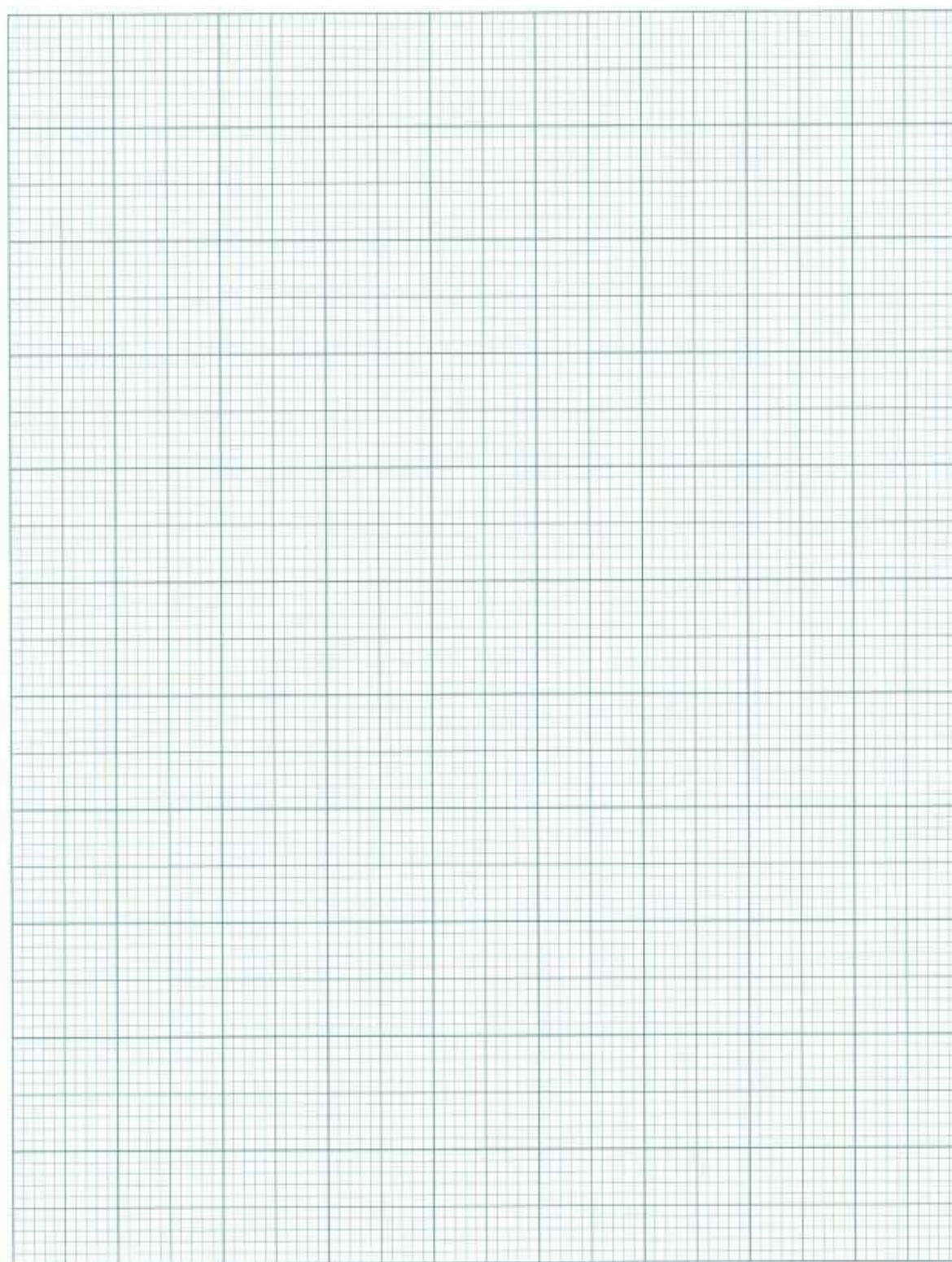
RESULT:

EXPERIMENT-4
CLAMPING CIRCUITS

AIM: To design Non- linear wave shaping circuits: Clamping circuits.

APPARATUS:

Resistors (100KΩ) – 1 No
Diode (1N4007) – 1 No
Capacitor (0.lpF) – 1 No
Analog Discovery Kit / ESIM Software / EC Studio Software
Connecting wires
Bread board

Theory:

The process where sinusoidal signals are going to be altered by transmitting through a non-linear network is called non-linear wave shaping. Non-linear elements (like diodes) in combination with resistors and capacitors can function as clamping circuit.

Clamping circuits add a DC level to an AC signal. A clamper is also referred to as DC restorer or DC re-inserter. The Clampers clamp the given waveform either above or below the reference level, which are known as positive or negative clampers respectively.

Clamping circuits are classified as two types.

i.   Negative Clampers
ii. Positive Clampers

Procedure:

1. Connect the circuit as shown in the figure 3.1 below.
2. Apply a Sine wave of 10V $_{P-P}$, 1KHz at the input terminals.
3. Observe the I/P & O/P waveforms on CRO and plot the waveforms and mark the values with $V_R = 0V$, 3V, etc.
4. Output is taken across the load RL.
5. Repeat the above steps for all clamping circuits (fig 3.2 to fig 3.6) as shown.
6. Draw the waveforms, assuming the diode is practical.

Circuit diagrams:

Input Signal
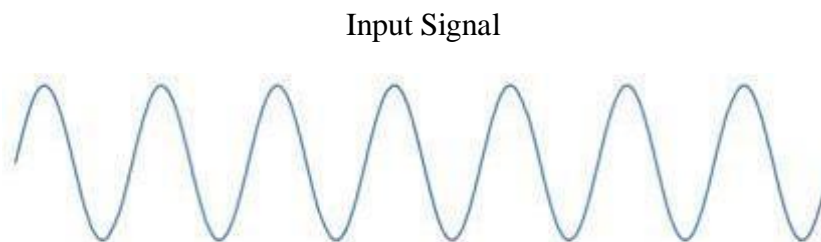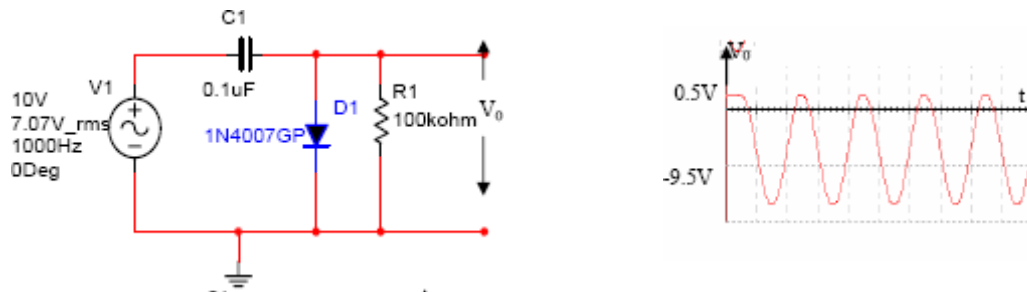
Fig.3.1 Negative clamping with zero reference voltage
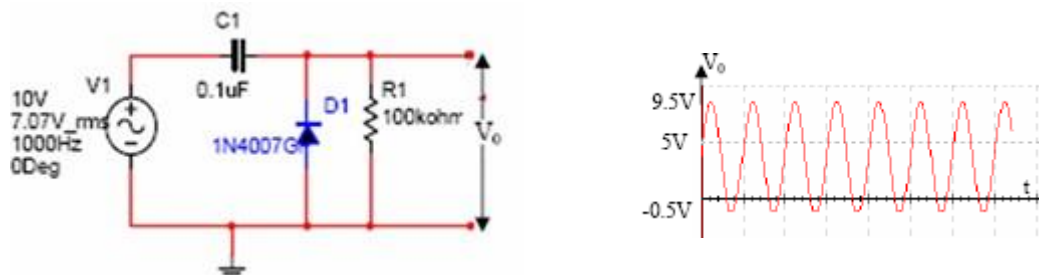
Fig.3.2 positive clamping with zero reference voltage
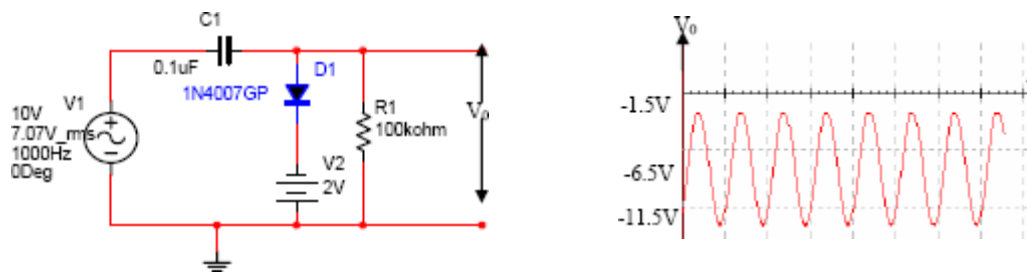
Fig.3.3 Negative clamping with Negative reference voltage
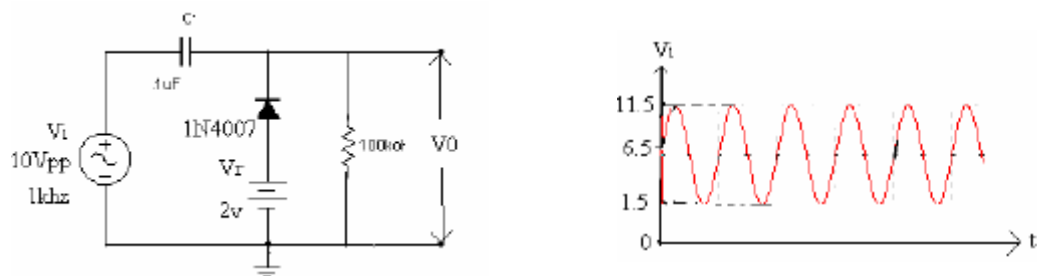
Fig.3.4 positive clamping positive reference voltage

23
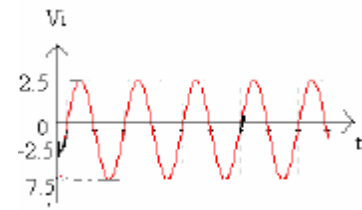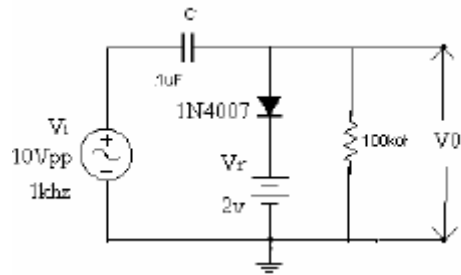
Fig.3.5 Negative clamping with Positive reference voltage
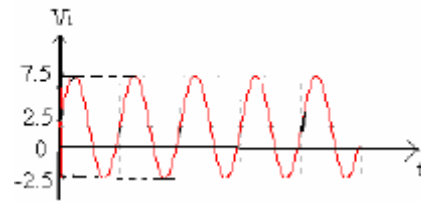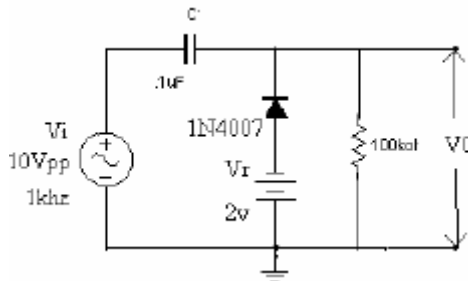
Fig.3.6 Positive clamping with Negative reference voltage

Observations:

S.No.	Type of Clamper	Ref. Voltage	Practicle clamping ref.voltage levels	
1.	Positive Clamper	0V	V1	
			V2	
		2V	V1	
			V2	
		-2V	V1	
			V2	
2.	Negative Clamper	0V	V1	
			V2	
		2V	V1	
			V2	
		-2V	V1	
			V2	

24

GRAPH:
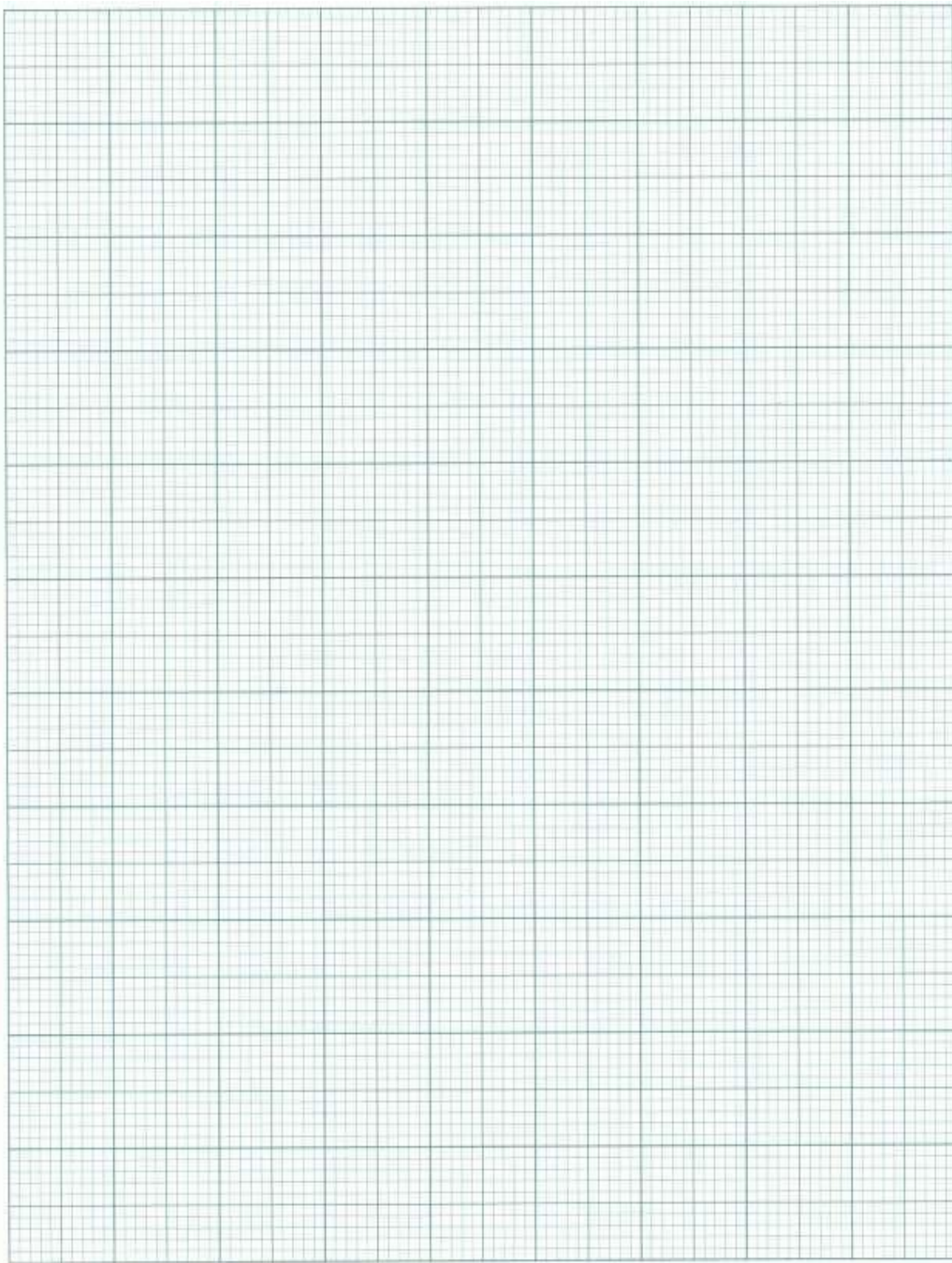
RESULT:

EXPERIMENT-5
BJT Input and Output Characteristics

AIM: To study BJT CE (Common Emitter) and CB (Common Base) Configurations

APPARATUS:

>BJT (NPN) – CK 100 or its equivalent – 1 No.
>BJT (PNP) – BC 107 or its equivalent – 1 No.
>Resistors – 2.2KΩ – 2 No(s).
>Analog Discovery Kit / ESIM Software / EC Studio Software
>Connecting wires
>Bread board

THEORY:

A Bipolar Junction Transistor, or BJT is a three terminal device having two PN-junctions connected together in series. Each terminal is given a name to identify it and these are known as the Emitter (E), Base (B) and Collector (C). There are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the Ptype and N-type semiconductor materials from which they are made. Bipolar Transistors are "CURRENT" Amplifying or current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing current applied to their base terminal. The principle of operation of the two transistor types NPN and PNP, is exactly the same the only difference being in the biasing (base current) and the polarity of the power supply for each type.
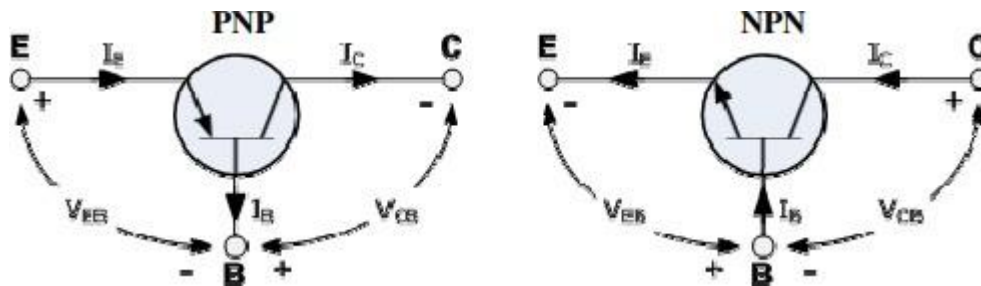
The symbols for both the NPN and PNP bipolar transistor are shown above along with the direction of conventional current flow. The direction of the arrow in the symbol shows current flow between the base and emitter terminal, pointing from the positive P-type region to the negative N-type region, like the standard diode symbol. For normal operation, the emitter-base junction is forward-biased, and the collector-base junction is reverse-biased. Transistor Configurations There are three possible configurations possible when a transistor is connected in a circuit: (a) Common base, (b) Common emitter (c) Common collector. We will be focusing on the first two configurations in this experiment. The behavior of a transistor can be represented by d.c. current-voltage (I-V) curves, called the static characteristic curves of the device. The three important characteristics of a transistor are: (i) Input characteristics, (ii) Output characteristics and (iii) Transfer Characteristics. These characteristics give information about various transistor parameters, e.g., input and out dynamic resistance, current amplification factors, etc.

Common Base Transistor Characteristics

In common base configuration, the base is made common to both input and output as shown in its circuit diagram.

(1) Input Characteristics: The input characteristics is obtained by plotting a curve between I_E and V_{EB} keeping voltage V_{CB} constant. This is very similar to that of a forward-biased diode and the slope of the plot at a given operating point gives information about its input dynamic resistance.

Input Dynamic Resistance (r_i) This is defined as the ratio of change in base emitter voltage (ΔV_{EB}) to the resulting change in emitter current (ΔI_E) at constant collector-emitter voltage (V_{CB}). This is dynamic as its value varies with the operating current in the transistor.

$$r_i = \frac{\Delta V_{EB}}{\Delta I_E}\bigg|_{V_{CB}}$$

(2) Output Characteristics: The output characteristic curves are plotted between I_C and V_{CB}, keeping I_E constant. The output characteristics are controlled by the input characteristics. Since I_C changes with I_E, there will be different output characteristics corresponding to different values of I_E. These curves are almost horizontal. This shows that the output dynamic resistance, defined below, is very high.

Output Dynamic Resistance (r_o): This is defined as the ratio of change in collector-base voltage (ΔV_{CB}) to the change in collector current (ΔI_C) at a constant base current I_E.

$$r_o = \frac{\Delta V_{CB}}{\Delta I_C}\bigg|_{I_E}$$

(3) Transfer Characteristics: The transfer characteristics are plotted between the input and output currents (I_E versus I_C).

Current amplification factor (α)

This is defined as the ratio of the change in collector current to the change in emitter current at a constant collector-base voltage (V_{CB}) when the transistor is in active state.

$$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}\bigg|_{V_{CB}}$$

This is also known as small signal current gain and its value is very large. The ratio of I_C and I_E is called α_{dc} of the transistor. Hence,

$$\alpha_{dc} = \frac{I_C}{I_E}\bigg|_{V_{CB}}$$

Since I_C increases with I_E almost linearly, the values of both α_{dc} and α_{ac} are nearly equal.

Common Emitter Transistor Characteristics:
In a common emitter configuration, emitter is common to both input and output as shown in its circuit diagram.

(1) Input Characteristics: The variation of the base current I_B with the base-emitter voltage V_{BE} keeping the collector-emitter voltage V_{CE} fixed, gives the input characteristic in CE mode.

      Input Dynamic Resistance (r_i): This is defined as the ratio of change in base emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}). This is dynamic and it can be seen from the input characteristic, its value varies with the operating current in the transistor:

$$r_i = \frac{\Delta V_{BE}}{\Delta I_B}\bigg|_{V_{CE}}$$

The value of r_i can be anything from a few hundreds to a few thousand ohms.

(2) Output Characteristics: The variation of the collector current I_C with the collector-emitter voltage V_{CE} is called the output characteristic. The plot of I_C versus V_{CE} for different fixed values of IB gives one output characteristic. Since the collector current changes with the base current, there will be different output characteristics corresponding to different values of I_B.

      Output Dynamic Resistance (r_o): This is defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current I_B.

$$r_o = \frac{\Delta V_{CE}}{\Delta I_C}\bigg|_{I_B}$$

The high magnitude of the output resistance (of the order of 100 kW) is due to the reverse biased state of this diode.

(3) Transfer Characteristics: The transfer characteristics are plotted between the input and output currents (I_B versus I_C). Both I_B and I_C increase proportionately.

Current amplification factor (β): This is defined as the ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}) when the transistor is in active state.

$$\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}\bigg|_{V_{CE}}$$

This is also known as small signal current gain and its value is very large. The ratio of I_C and I_B we get what is called β_{dc} of the transistor. Hence,

$$\beta_{dc} = \frac{I_C}{I_B}\bigg|_{V_{CE}}$$

Since I_C increases with I_B almost linearly, the values of both β_{dc} and βac are nearly equal.

CIRCUIT DIAGRAM:
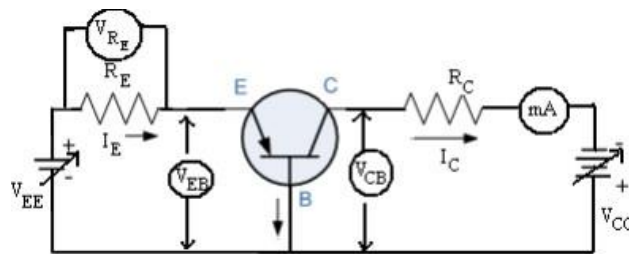
PNP transistor in CB configuration
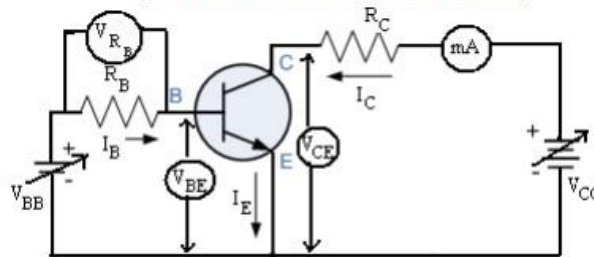
NPN transistor in CE configuration

PROCEDURE:

1. Note down the type number of both the transistors.

2. Identify different terminals (E, B and C) and the type (PNP/NPN) of the transistors. For any specific information refer the datasheet of the transistors.

(I) PNP Common Base (CB) characteristics

1. Configure CB circuit using the PNP transistor as per the circuit diagram. Use RE = RC = 150 Ω.

2. For input characteristics, first fix the voltage V_{CB} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{EB} slowly (say, in steps of 0.05V) by varying V_{EE}. Measure V_{EB} using a AD Kit. If V_{CB} varies during measurement bring it back to the initial set value To determine I_E, measure V_{RE} across the resistor R_E and use the relation $I_E = V_{RE}/R_E$.

3. Repeat the above step for another value of V_{CB} say, 2V.

4. Take out the AD Kit at V_{EB} and connect in series with the output circuit to measure I_C. For output characteristics, first fix $I_E = 0$, i.e. $V_{RE} = 0$. By adjusting V_{CC}, vary the collector voltage V_{CB} in steps of say 1V and measure V_{CB} and the corresponding I_C using AD Kits. After acquiring sufficient readings, bring back V_{CB} to 0 and reduce it further to get negative values. Vary V_{CB} in negative direction and measure both V_{CB} and I_C, till you get 0 current.

5. Repeat the above step for at least 5 different values of I_E by adjusting V_{EE}. You may need to adjust V_{EE} continuously during measurement to maintain a constant I_E.

6. Plot the input and output characteristics by using the readings taken above and determine the input and output dynamic resistance.

7. To plot transfer characteristics, select a suitable voltage V_{CB} well within the active region of the output characteristics, which you have tabulated already. Plot a graph between I_C and the corresponding I_E at the chosen voltage V_{CB}. Determine αac from the slope of this graph.

(II) NPN Common Emitter (CE) characteristics

1. Now configure CE circuit using the NPN transistor as per the circuit diagram. Use $R_B = 100k\Omega$ and $R_C = 1$ kΩ. 2. For input characteristics, first fix the voltage V_{CE} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{BE} slowly (say, in steps of 0.05V) by varying V_{BB}. Measure V_{BE} using AD Kit. If V_{CE} varies during measurement bring it back to the set value to determine I_B, measure V_{RB} across the resistor R_B and use the relation $I_B = V_{RB}/R_B$.

3. Repeat the above step for another value of V_{CE} say, 2V.

4. For output characteristics, first fix $I_B = 0$, i.e. $V_{RB} = 0$. By adjusting V_{CC}, vary the collector voltage V_{CE} in steps of say 1V and measure V_{CE} and the corresponding I_C using AD Kit. If needed vary V_{CE} in negative direction as described for CB configuration and measure both V_{CE} and I_C, till you get 0 current.

5. Repeat the above step for at least 5 different values of I_B by adjusting V_{BB}. You may need to adjust V_{BB} continuously during measurement to maintain a constant I_B.

6. Plot the input and output characteristics by using the readings taken above and determine the input and output dynamic resistance.

7. Plot the transfer characteristics between I_C and I_B as described for CB configuration for a suitable voltage of V_{CE} on the output characteristics. Determine βac from the slope of this graph.

Observations:

CB configuration:

Transistor code: _____ , Transistor type: _____(PNP/NPN) R_E = _____ , R_C = _____ .

Table (1): Input Characteristics

S. No	V_{CB}=____V			V_{CB}=____V		
	V_{EB} (V)	V_{RE} (V)	I_E(mA)	V_{EB} (V)	V_{RE} (V)	I_E(mA)

Table (2): Output Characteristics

S. NO	I_{E1}=0		I_{E2}=___		I_{E3}=___		I_{E4}=___		I_{E5}=___	
	V_{CB}(V)	I_C(mA)	V_{CB}(V)	I_C(mA)	V_{CB}(V)	I_C(mA)	V_{CB}(V)	I_C(mA)	V_{CB}(V)	I_C(mA)

Table (3): Transfer Characteristics: V_{CB} = _____ V

S. NO	I_E(mA)	I_C(mA)

CE configuration:

Transistor code: _____, Transistor type: _____(PNP/NPN) R_B = _____, R_C = _____.

Table (1): Input Characteristics

S. No	V_{CE}=_____V			V_{CE}=_____V		
	V_{BE} (V)	V_{RB} (V)	I_B(µA)	V_{BE} (V)	V_{RB} (V)	I_B(µA)

Table (2): Output Characteristics

S. NO	I_{B1}=0		I_{B2}=____		I_{B3}=____		I_{B4}=____		I_{B5}=____	
	V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)

Table (3): Transfer Characteristics: V_{CE} = _____V

S. NO	$I_B(\mu A)$	$I_C(mA)$

Graphs: Plot the input, output and transfer characteristics for each configuration.

CB configuration:

(1) **Input characteristics:** Plot $V_{EB} \sim I_E$, for different V_{CB} and determine the input dynamic resistance in each case at suitable operating points.

(2) **Output characteristics:** Plot $V_{CB} \sim I_C$, for different I_E and determine the output dynamic resistance in each case at suitable operating points in the active region.

(3) **Transfer characteristics:** Plot $I_E \sim I_C$, for a fixed V_{CB} and determine α_{ac}.
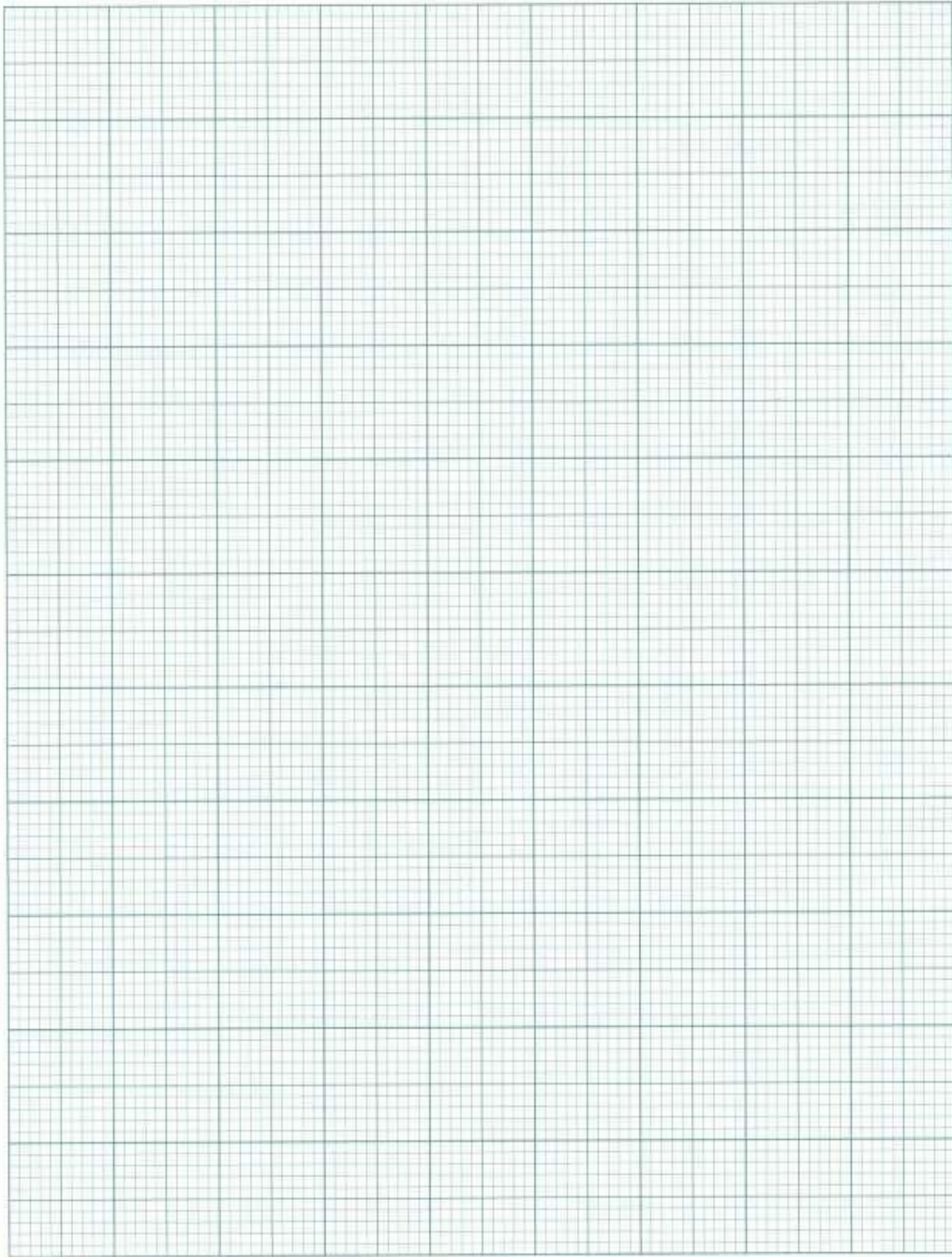
CE configuration:

(1) Input characteristics: Plot $V_{BE} \sim I_B$, for different V_{CE} and determine the input dynamic resistance in each case at suitable operating points.

(2) **Output characteristics:** Plot $V_{CE} \sim I_C$, for different I_B and determine the output dynamic resistance in each case at suitable operating points in the active region.

(3) **Transfer characteristics:** Plot $I_B \sim I_C$, for a fixed V_{CE} and determine β_{ac}.

GRAPH:

RESULT:

EXPERIMENT-7

JFET Characteristics

AIM:

To study Drain Characteristics of a Junction Field Effect Transistor (JFET).

APPARATUS:

JFET (2N547N or its equivalent) – 1 No.
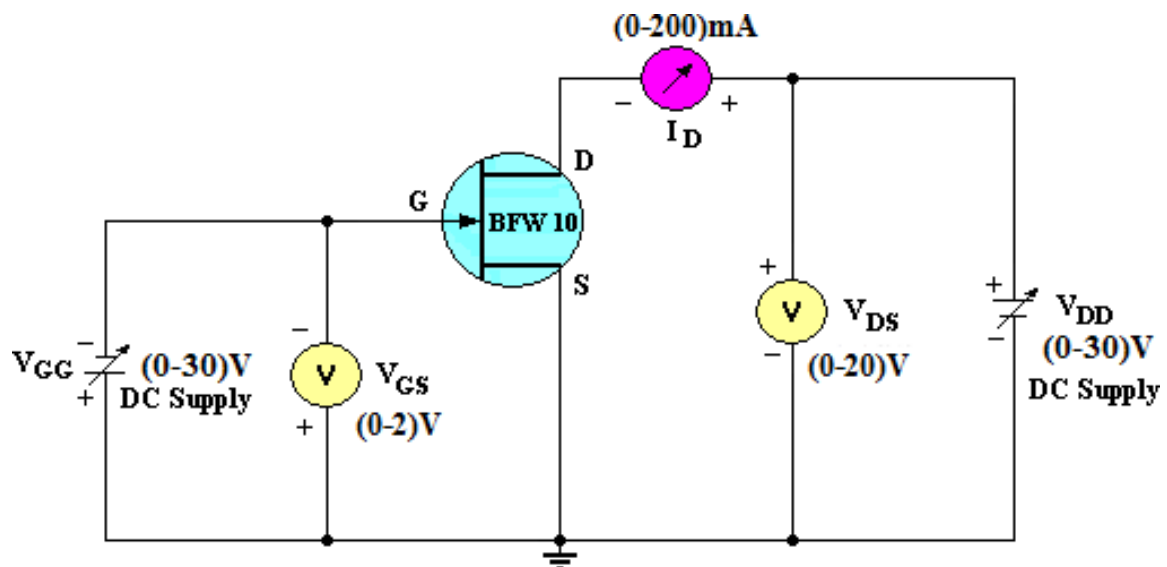
Resistor (1KΩ, 100KΩ)

Analog Discovery Kit/ESIM Software / EC Studio

Software Connecting wires

Bread board

CIRCUIT DIAGRAM:

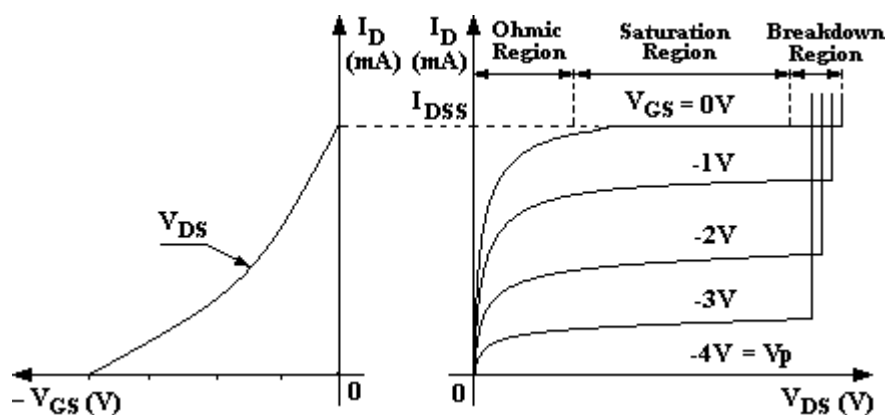**MODEL GRAPH:**

FET Transfer Characteristics   **FET Drain Characteristics**

THEORY:

Introduction:

N-channel FET

The field effect transistor (FET) is made of a bar of N type material called the SUBSTRATE with a P type junction (the gate) diffused into it. With a positive voltage on the drain, with respect to the source, electron current flows from source to drain through the CHANNEL.

If the gate is made negative with respect to the source, an electrostatic field is created which squeezes the channel and reduces the current. If the gate voltage is high enough the channel will be "pinched off" and the current will be zero. The FET is voltage controlled, unlike the transistor which is current controlled. This device is sometimes called the junction FET or IGFET or JFET.

If the FET is accidentally forward biased, gate current will flow and the FET will be destroyed. To avoid this, an extremely thin insulating layer of silicon oxide is placed between the gate and the channel and the device is then known as an insulated gate FET, or IGFET or metal oxide semiconductor FET (MOSFET) Drain characteristics are obtained between the drain to source voltage (V_{DS}) and drain current (I_D) taking gate to source voltage (V_{GS}) as the parameter. Transfer characteristics are obtained between the gate to source voltage (V_{GS}) and Drain current (I_D) taking drain to source voltage (V_{DS}) as parameter

PROCEDURE:

DRAIN CHARACTERISTICS:

1. Connect the circuit as per the Fig. 1 and start with V_{GG} and V_{DD} keeping at zero volts.
2. Keep V_{GG} such that $V_{GS} = 0$ volts, Now vary V_{DD} such that V_{DS} Varies in steps of 1 volt up to 10 volts. And Note down the corresponding Drain current I_D
3. Repeat the above experiment with $V_{GS} = $ -1V and -2V and tabulate the readings.

35

4. Draw a graph V_{DS} Vs I_D against V_{GS} as parameter on graph.

5. From the above graph calculate r_d and note down the corresponding diode current against the voltage in the tabular form.

6. Draw the graph between voltage across the Diode Vs Current through the diode in the first quadrant as shown in fig.

TABULAR FORM:

DRAIN CHARACTERISTICS:

S.No		$V_{GS} = 0$ volts	$V_{GS} = -1V$	$V_{GS} = -2V$
	V_{DS} (V)	I_D (mA)	I_D (mA)	I_D (mA)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				

INVERTING AMPLIFIER

AIM: To design an Inverting Amplifier Circuit using Op-Amp.

APPARATUS:　　LM324AD/741/OP27 IC or its equivalent
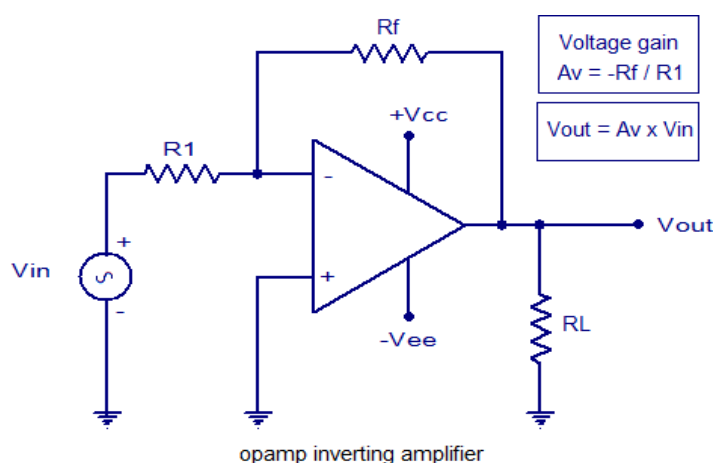
R_f, R_1 resistors (select R_f and R_1 such that $R_f \gg R_1$

Analog Discovery Kit (AD Kit) / ESIM Software / EC Studio Software

Connecting wires

Breadboard

CIRCUIT DIAGRAM:

opamp inverting amplifier

Figure: Inverting Amplifier

THEORY:

As the open loop DC gain of an Operational Amplifiers is extremely high we can therefore afford to lose some of this high gain by connecting a suitable resistor across the amplifier from the output terminal back to the inverting input terminal to both reduce and control the overall gain of the amplifier. This then produces and effect known commonly as Negative Feedback, and thus produces a very stable Operational Amplifier based system.

Negative Feedback is the process of "feeding back" a fraction of the output signal back to the input, but to make the feedback negative, we must feed it back to the negative or "inverting input" terminal of the op-amp using an external Feedback Resistor called Rf. This feedback connection between the output and the inverting input terminal forces the differential input voltage towards zero.

This effect produces a closed loop circuit to the amplifier resulting in the gain of the amplifier now being called its Closed-loop Gain. Then a closed-loop inverting amplifier uses negative feedback to accurately control the overall gain of the amplifier, but at a cost in the reduction of the amplifiers gain. This negative feedback results in the inverting input terminal having a different signal on it than the actual input voltage as it will be the sum of the input voltage plus the negative feedback voltage

giving it the label or term of a *Summing Point*. We must therefore separate the real input signal from the inverting input by using an Input Resistor, Rin.

In this Inverting Amplifier circuit the operational amplifier is connected with feedback to produce a closed loop operation. When dealing with operational amplifiers there are two very important rules to remember about inverting amplifiers, these are: "No current flows into the input terminal"and that "V1 always equals V2". However, in real world op-amp circuits both of these rules are slightly broken.

This is because the junction of the input and feedback signal (X) is at the same potential as the positive (+) input which is at zero volts or ground then, the junction is a "Virtual Earth". Because of this virtual earth node the input resistance of the amplifier is equal to the value of the input resistor, Rin and the closed loop gain of the inverting amplifier can be set by the ratio of the two external resistors.

We said above that there are two very important rules to remember about Inverting Amplifiers or any operational amplifier for that matter and these are.

1. No Current Flows into the Input Terminals
2. The Differential Input Voltage is Zero as V1 = V2 = 0 (Virtual Earth)

$$\boxed{\mathrm{Vout} = -\frac{\mathrm{Rf}}{\mathrm{Rin}} \times \mathrm{Vin}}$$

PROCEDURE:

1. Connect the components as per the circuit diagram on the Bread board
2. The color terminals represent the connections made with respect to the Analog Discovery kit at the respective terminals on the Bread board
3. Adjust the input voltage starting with 500mv and find the output voltage.
4. Repeat the above steps for different voltages by taking different input signals
5. Draw the graph between input and output voltages for the values obtained from the table.

TABULAR COLUMN:

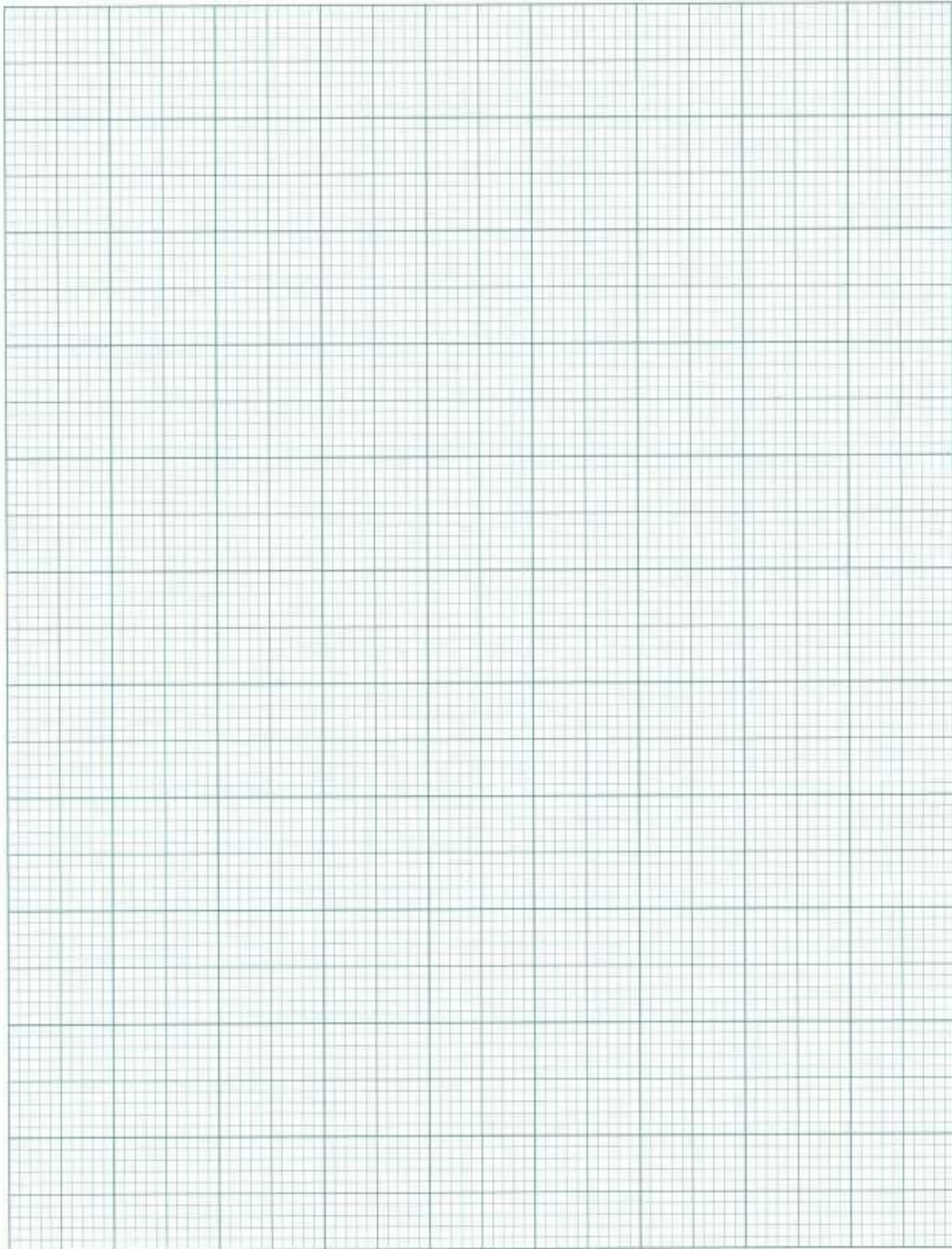| S. No	V_{in}	V_{out}	V_{out}/V_{in}

Theoretical Calculations:
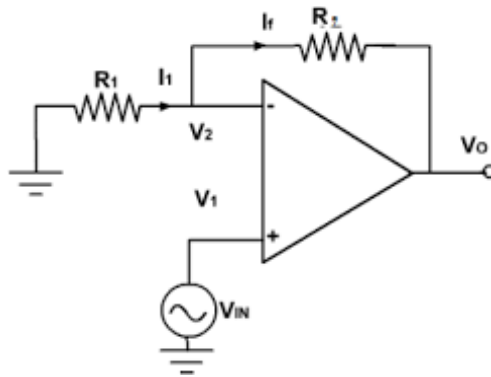
MODEL GRAPH:
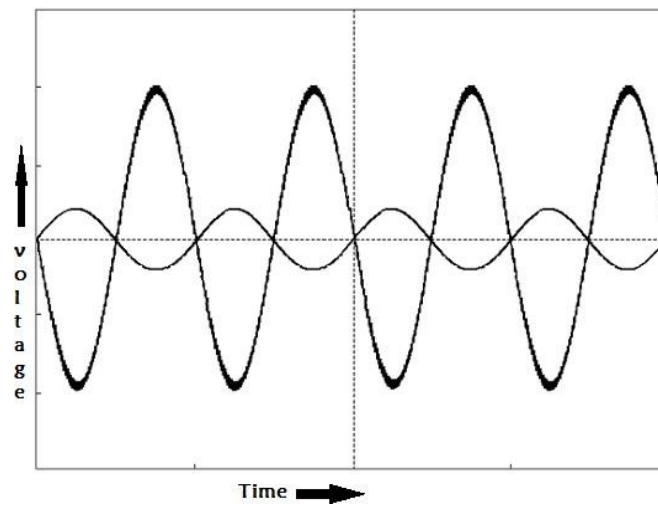
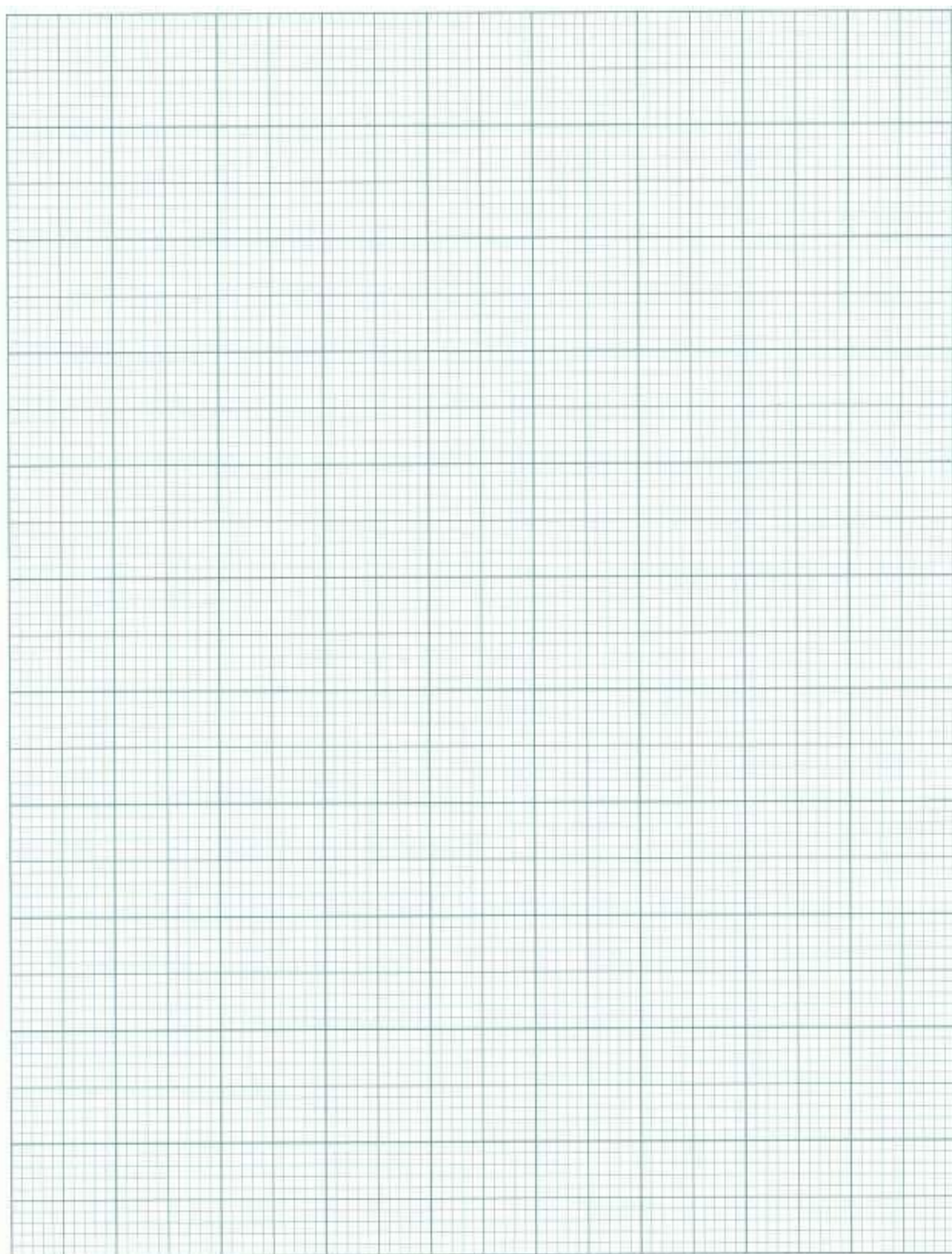**GRAPH SHEET:**

RESULT:

EXERCISE:

1. Execute the following "Non inverting Amplifier" circuit with different values of R_f resistances.

2. List the applications of Inverting and Non Inverting Amplifier.

GRAPH SHEET:

RESULT:

EXPERIMENT: 9
SUBTRACTOR CIRCUIT

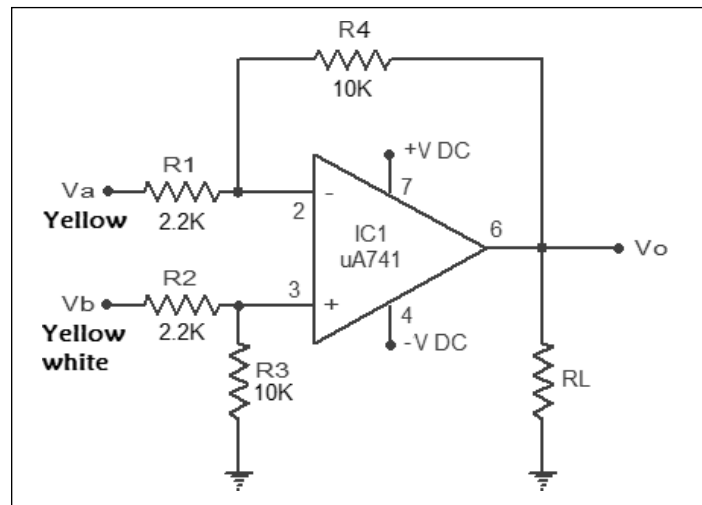**AIM:** To design a Subtractor Circuit using Op-Amp.

APPARATUS: LM324AD/741/OP27 IC or its equivalent

Resistors 2.2KΩ, 10KΩ

Analog Discovery Kit (AD Kit) / ESIM Software / EC Studio Software

Connecting Wires, Breadboard

CIRCUIT DIAGRAM:

Figure: Subtractor/Difference Circuit

THEORY:

The *differential amplifiers* amplify the difference between two voltages making this type of operational amplifier circuit a Subtractor unlike a summing amplifier which adds or sums together the input voltages. This type of operational amplifier circuit is commonly known as a Differential Amplifier configuration.

By connecting each input in turn to 0v ground we can use superposition to solve for the output voltage V_{out}. Then the transfer function for a Differential Amplifier circuit is given as:

$$V_{out} = -V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_4}{R_2+R_4}\right)\left(\frac{R_1+R_3}{R_1}\right)$$

When resistors, $R_1 = R_2$ and $R_3 = R_4$ the above transfer function for the differential amplifier can be simplified to the following expression:

$$V_{OUT} = \frac{R_3}{R_1} \left(V_2 - V_1 \right)$$

If all the resistors are all of the same ohmic value, that is: $R_1 = R_2 = R_3 = R_4 = R$ then the circuit will become a **Unity Gain Differential Amplifier** and the voltage gain of the amplifier will be exactly one or unity. Then the output expression would simply be $V_{out} = V_2 - V_1$. Also note that if input V_1 is higher than input V_2 the output voltage sum will be negative, and if V_2 is higher than V_1, the output voltage sum will be positive.

The Differential Amplifier circuit is a very useful op-amp circuit and by adding more resistors in parallel with the input resistors R_1 and R_3, the resultant circuit can be made to either "Add" or "Subtract" the voltages applied to their respective inputs. One of the most common ways of doing this is to connect a "Resistive Bridge" commonly called a *Wheatstone Bridge.*

PROCEDURE:

1. Connect the relevant circuit for the difference configuration as shown in the circuit diagram.
2. Measure the output voltage V_o from AD Kit.
3. Observe the waveforms at V_1, V_2, and V_o.
4. Note the phase of the output voltage V_o with respect to the input voltage.
5. Set different values of two input voltages, and find the output voltage
6. Repeat the steps 3, 4, and 5.
7. The waveforms are to be plotted.

TABULAR COLUMN:

S.No	V_{in1}	V_{in2}	V_{out}

THEORITICAL CALCULATIONS:

GRAPH SHEET:
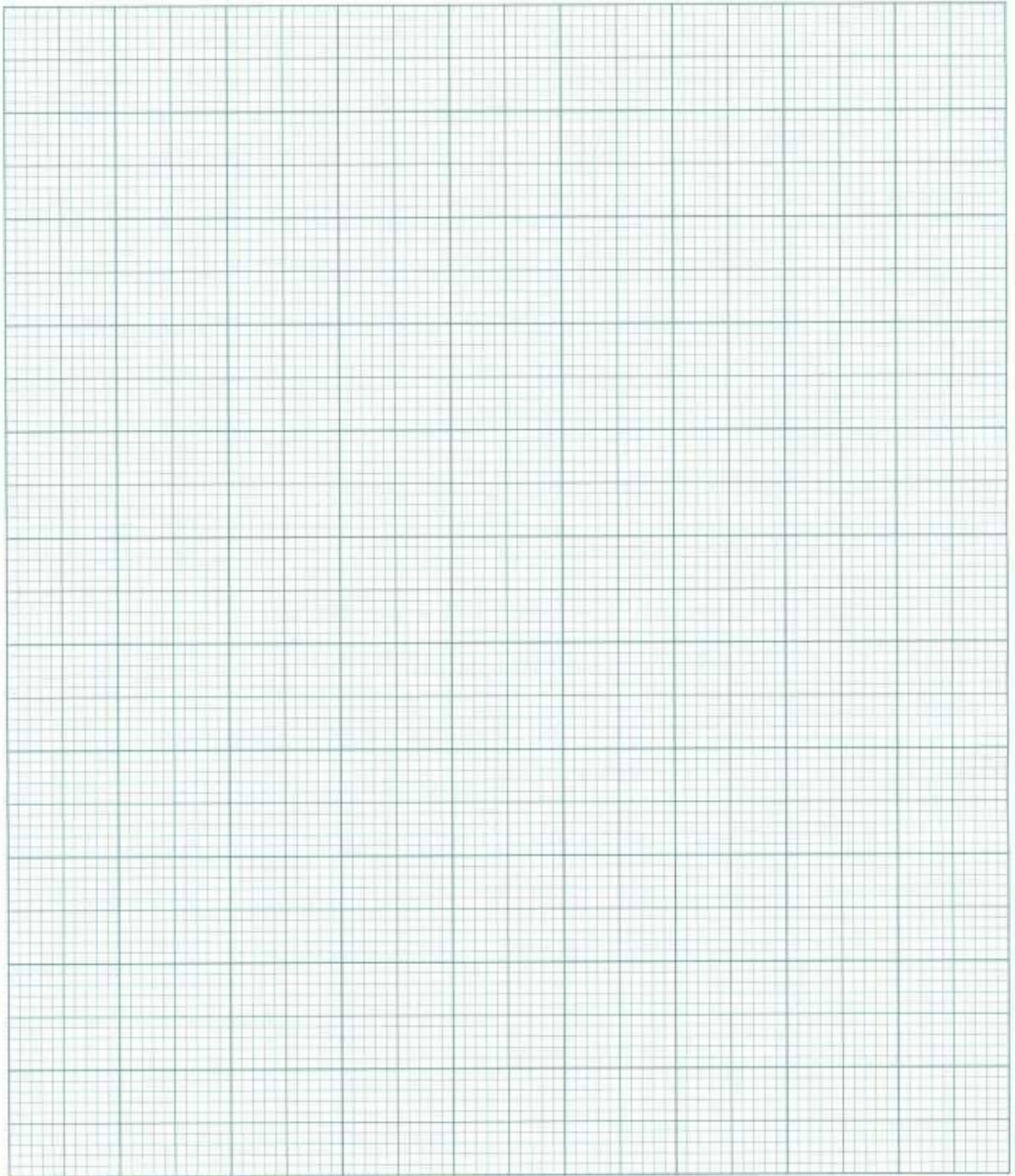
RESULT:

Exercise: Derive the expression for the Difference Amplifier. List the applications of Differential amplifier.

INTEGRATOR CIRCUIT

-

AIM: To design an Integrator Circuit using Op-Amp

APPARATUS: LM324AD/741/OP27 IC or its equivalent

    10 KΩ, 1KΩ Resistor

    100nF Capacitor

    Analog Discovery Kit (AD Kit) / ESIM Software / EC Studio Software

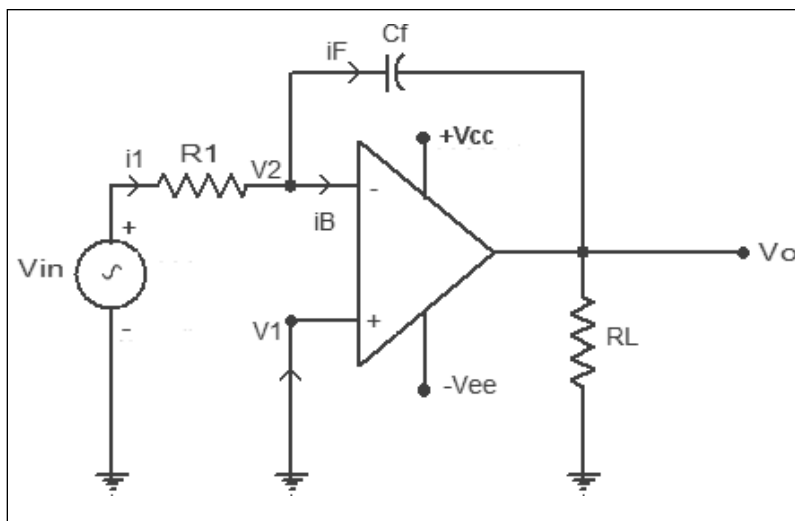   Breadboard

CIRCUIT DIAGRAM:

Figure: shows the Integrator

THEORY:

It is a low pass RC filter circuit. It can work as an integrator when time constant is very large. This requires very large values of R and C by Miller's theorem the effective input capacitance becomes C!(1-Av)where Av is the gain of the op-amp. The gain Av is infinite for an ideal op-amp.so, the effective time constant of the op-amp becomes large which results in perfect integration. The output voltage of an integrator is shown below

$$Vo = \frac{-1}{R1 \, Cf} \int_{0}^{t} Vin \, dt + C$$

PROCEDURE:

1. Connect the circuit as shown in the circuit diagram.
2. Suitable R_f and C_1 are chosen such that the output of the circuit is the integral of the input voltage.
3. Apply square wave or sine wave input voltage (V) or any other type of signal at the input terminal.
4. Observe the output voltage waveform on the CRO and note down the corresponding values.
5. The time constant R_fC_1 is changed by changing the values of R_f or C_1 and the corresponding output waveforms are noted.
6. The connection of R_L is optional.

MODEL GRAPH:

Input Signal	Output Signal
Square Wave	Triangular Wave
Sine Wave	Inverted Sine
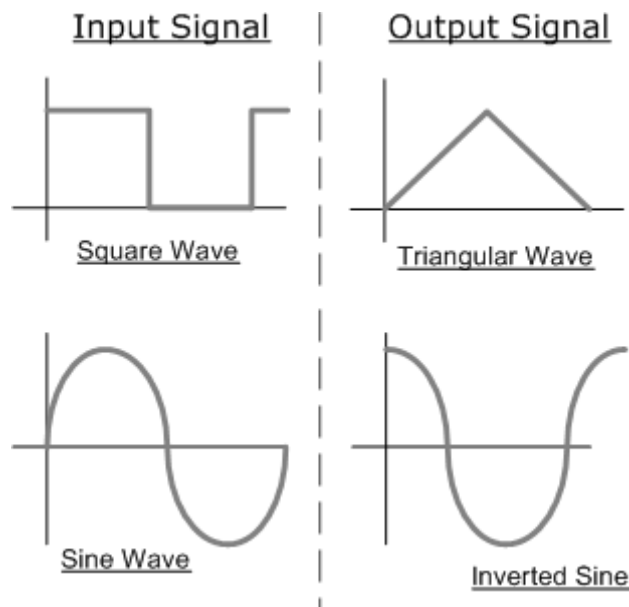
Figure: showing the output waveforms for different input waveforms

THEORETICAL CALCULATIONS:

THEORETICAL CALCULATIONS:

GRAPH SHEET:
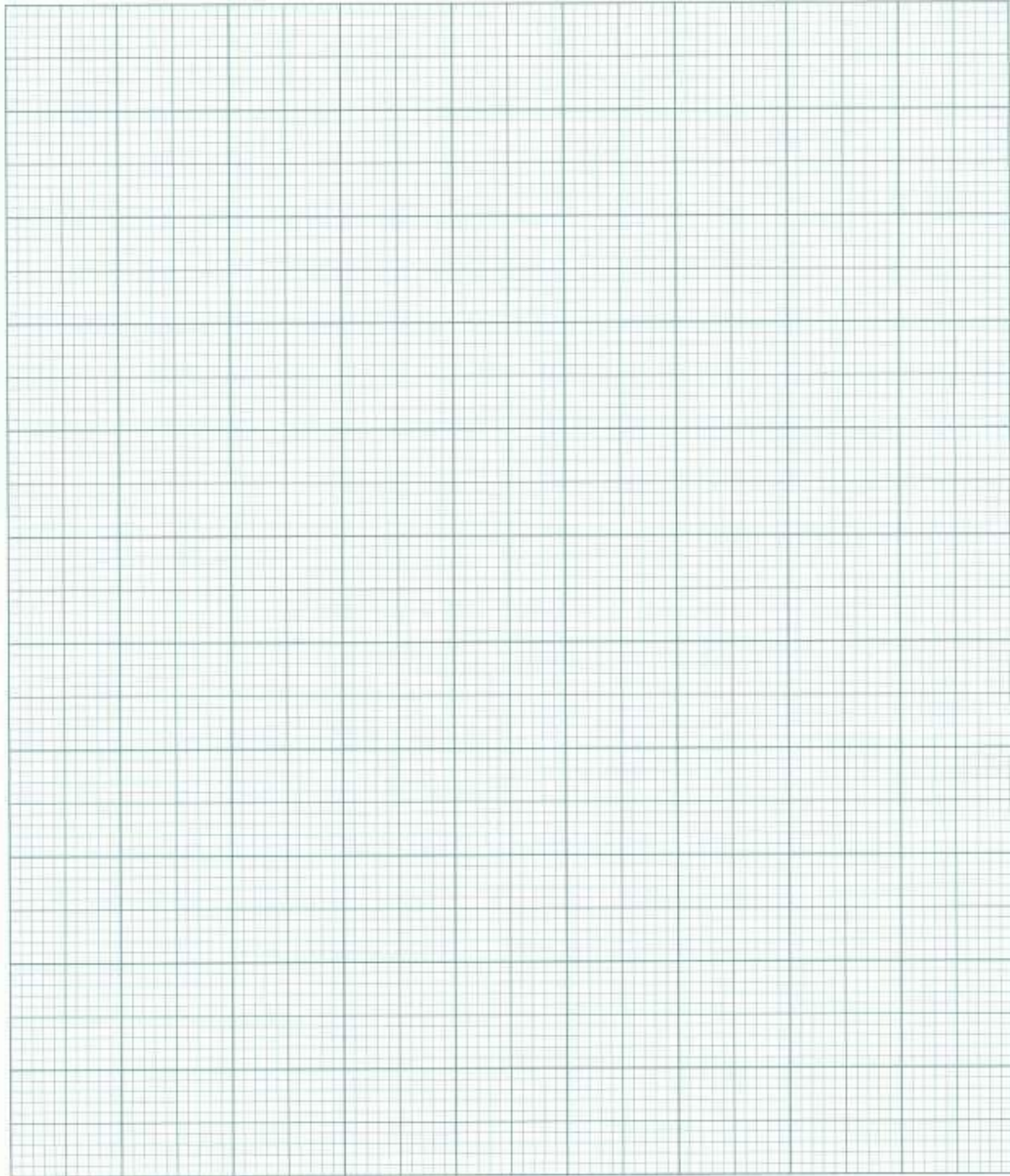
RESULT:

Exercise: List the applications of integrating amplifier and derive the expression of Integrating Amplifier
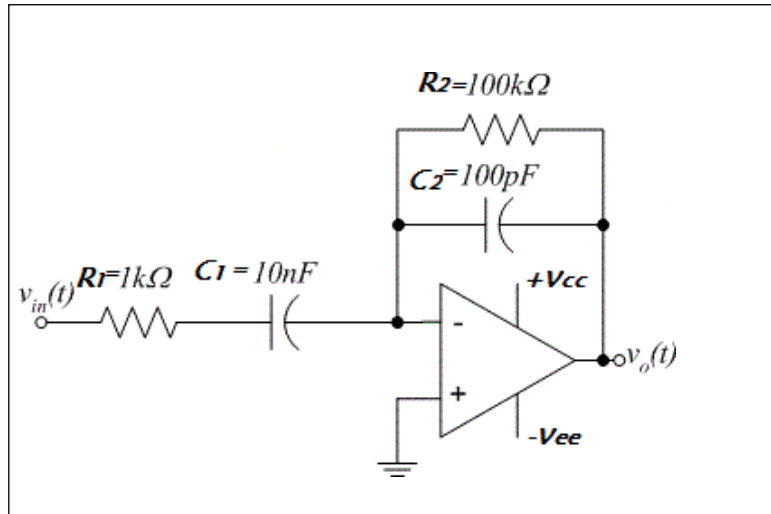
<div align="center">

EXPERIMENT: 11

DIFFERENTIATOR CIRCUIT

</div>

AIM: To design a Differentiator Amplifier Circuit using Op-Amp.

APPARATUS: LM324AD/741/OP27 IC or its equivalent

100 KΩ, 1 KΩ Resistors

10nF, 100pF Capacitor

Analog Discovery Kit (AD Kit) / ESIM Software / EC Studio Software

Connecting Wires and Breadboard

CIRCUIT DIAGRAM:

<div align="center">

Figure: Differentiator

</div>

THEORY:

It consists of a high pass RC filter. It acts as a differentiator for low values of time constant. Here the output is the derivative of the input signal.

Thus, output is not only the derivative of the input but also out of phase by 180° with respect to the input.

$$V_{out} = -RC\frac{dV_{in}}{dt}$$

Here $R_2 = R$ and $C_1 = C$

PROCEDURE:

1. Connect the circuit as shown in the circuit diagram.

2. Suitable values of R_1, R_2, C_1, C_2 are chosen such that the output of the circuit is the integral of the input voltage.

3. A square wave input voltage (V) is applied at the input terminal.

4. Observe the output voltage waveform on the CRO and note down the corresponding values.

5. The time constant R_2C_1 is changed by changing the values of R_2 or

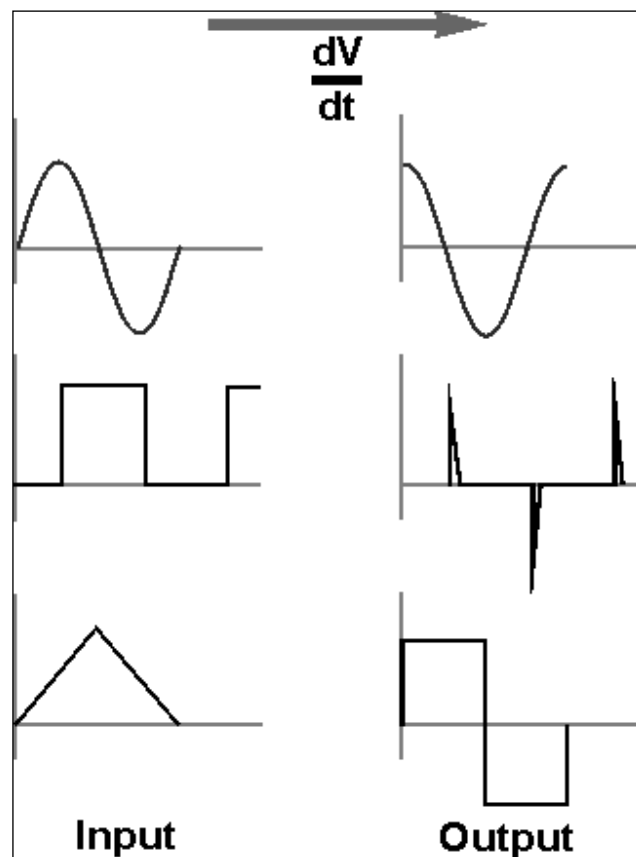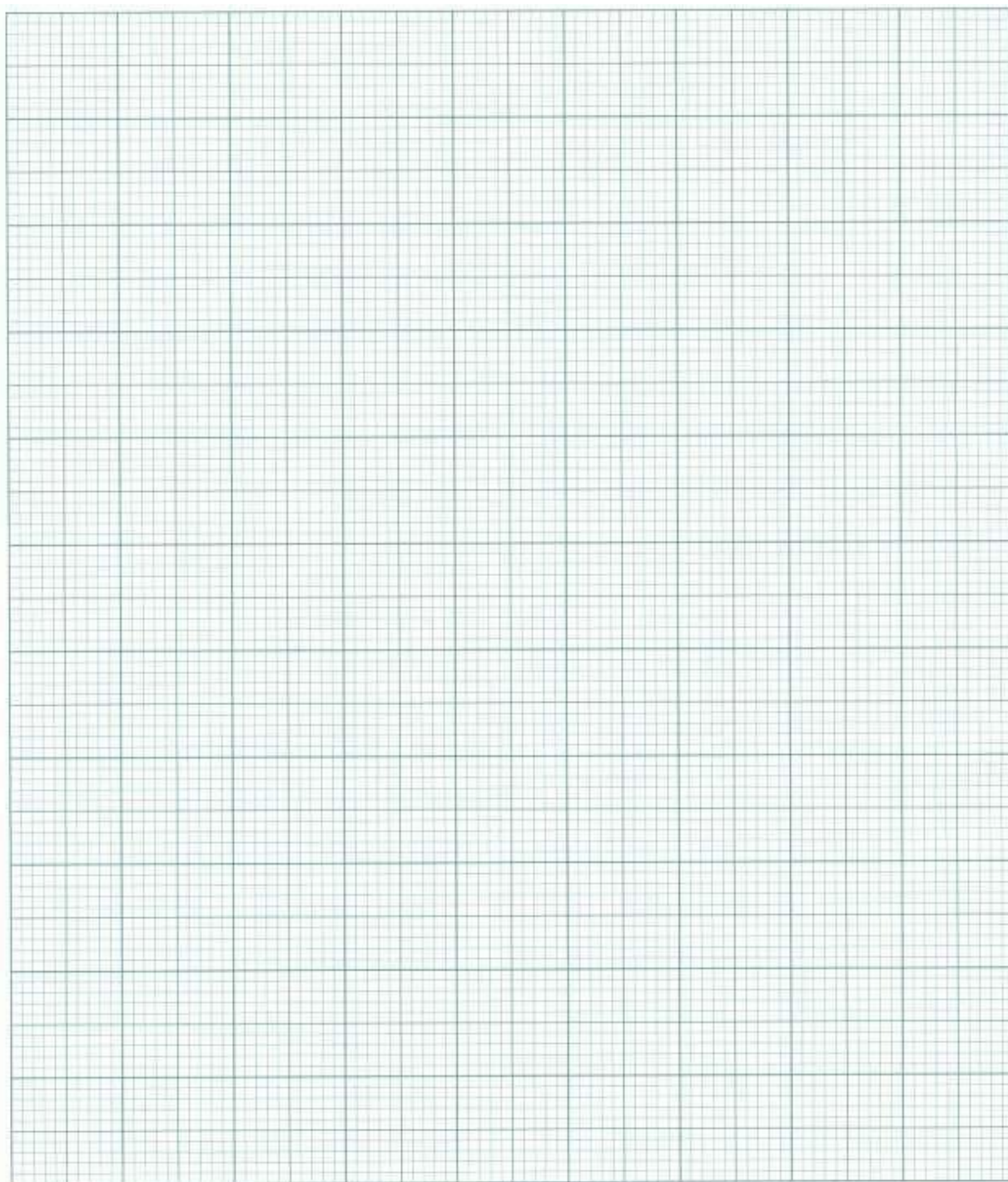C_1 and the corresponding output waveforms are noted.

MODEL GRAPHS:

Figure: Model output waveforms for different

input signals THEORETICAL CALCULATIONS:

52

GRAPH SHEET:

RESULT:

<p style="text-align:center">**EXPERIMENT: 12**</p>

RC PHASE SHIFT OSCILLATOR CIRCUIT

AIM: To design an RC Phase Shift oscillator using op-amp for a given frequency of 1kH̄z.

APPARATUS: LM324AD/741

OP27 IC or

equivalent

10 KΩ,

1KΩ Resistor

100nF Capacitor

Analog Discovery Kit (AD Kit) / ESIM Software /

EC Studio Software Breadboard

THEORY

An oscillator is a circuit that produces a periodic waveform on its output with only the dc supply voltage as a required input. A repetitive input signal is not required but is sometimes used to synchronize oscillations. The output voltage can be either sinusoidal or non-sinusoidal, depending on the type of oscillator. Two major classifications for oscillators are feedback oscillator and relaxation oscillators.

Conditions for oscillation

1. The phase shift around the feedback loop must be effectively zero degrees.
2. The voltage gain, A_{CL} around the feedback loop (loop gain) must equal to (or greater than) one.

The voltage gain around the closed feedback loop, A_{CL}, is the product of the amplifier gain, A_v, and the attenuation, B of the feedback circuit.

$$A_{CL}=A_v B$$

RC phase-shift oscillator is a linear electronic oscillator circuit that produces a sine wave output. It consists of an inverting amplifier element such as a transistor or op-amp with its output fed back to its input through a phase-shift network consisting of resistors and capacitors in a ladder network. Each of the three RC networks in the

<p style="text-align:center">54</p>

feedback loop can provide a maximum phase shift approaching 90 degrees. Oscillation occurs at the frequency where the total phase shift through the three RC network is 180 degrees. Inversion output at the output of op-amp itself produces the additional 180 degree to meet the requirement for oscillation of 360 degrees (or zero degree) phase shift around the feedback loop.

DESIGN

The attenuation B of the three section RC feedback network is $B = 1/29$

To meet the greater than unity loop gain requirement, the closed loop voltage gain of op-ampmust be greater than 29.

Given frequency, $f = 1$ kHz.　　We have $f = \dfrac{1}{2\pi RC\sqrt{6}}$

Let $R_1 = R_2 = R_3 = R$ and $C_1 = C_2 = C_3 = C$

Select nearest
value of 220 kΩ for
Rf

Assume $C = 0.01\mu F$.

$$R = \frac{1}{2\pi f\, C\sqrt{6}}$$

$$= \frac{1}{2\pi \times 10^3 \times 0.01\times10^{-6} \sqrt[]{6}}$$

$$= 6.5\ k\Omega$$

Select nearest value of 6.8 kΩ for R

$$R_f = A_{CL}\, R_1 \quad = 29 \times 6.8\times10^3 = 197.2\ k\Omega$$

R_f 220 kΩ

R_1
6.8 kΩ

2 −
7
+12V
LM 741
6
3 +
4
−12V

V_o

C_1 0.01μF C_2 0.01μF C_3 0.01μF

R_2
6.8 kΩ

R_3
6.8 kΩ