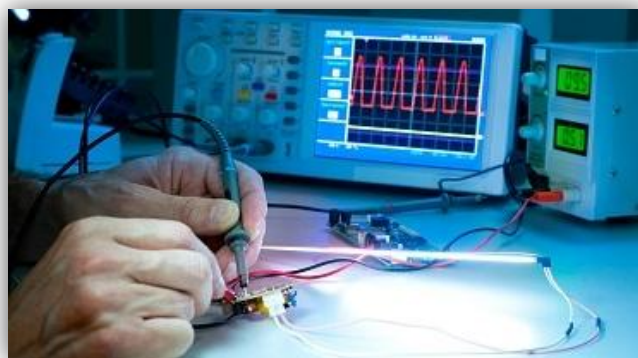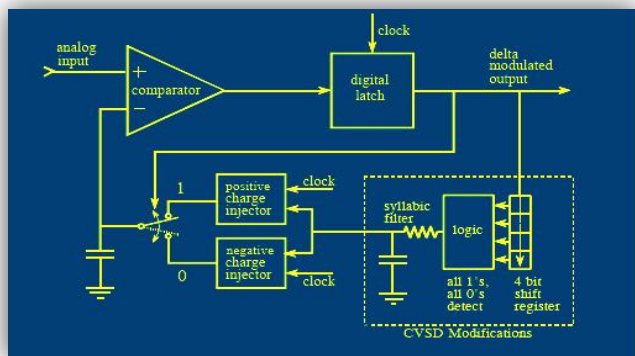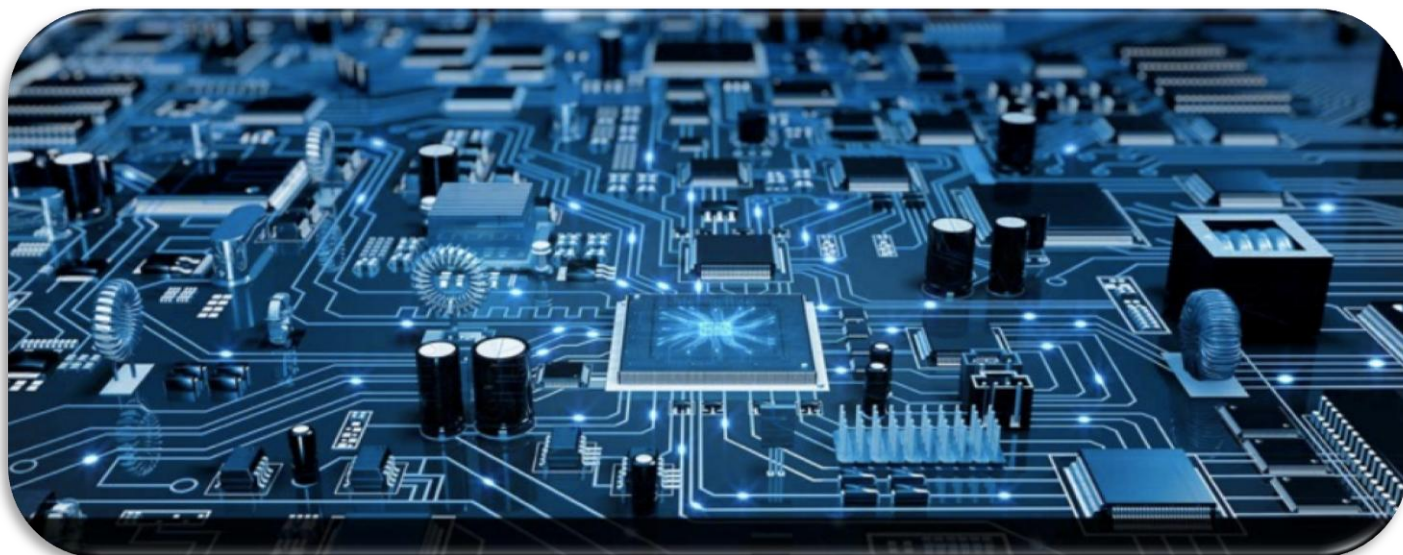# PRINCIPLES OF ANALOG ELECTRONICS LAB

Department of Electrical and Electronics Engineering

GOKARAJU RANGARAJU

Institute of Engineering and Technology

(Autonomous)

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

- Classify the types of active components.

- Describe the operations of Diode, BJT and MOSFET

- Analyse different Configuration types of Operational Amplifier.

- Implement the mathematical operation on signals.

- Make conversant with Digital to Analog and Analog to Digital Converters

Course Outcomes:

After completion of this course, Students will be able to

- Recall types of active components.

- Draw characteristics of Diode, BJT and MOSFET

- Design Operational Amplifiers as inverting and non-inverting amplifier

- Apply mathematical operation on signals using Operational Amplifier

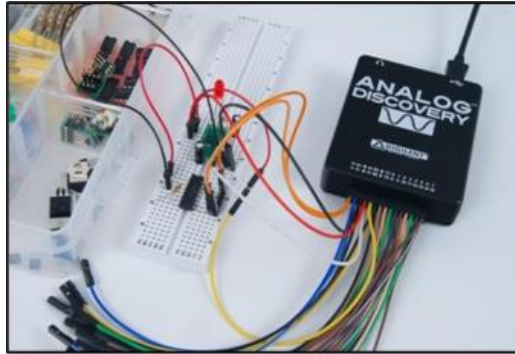- Explain operation of Analog to Digital Conversion (ADC) and Digital to Analog Conversion (DAC)

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
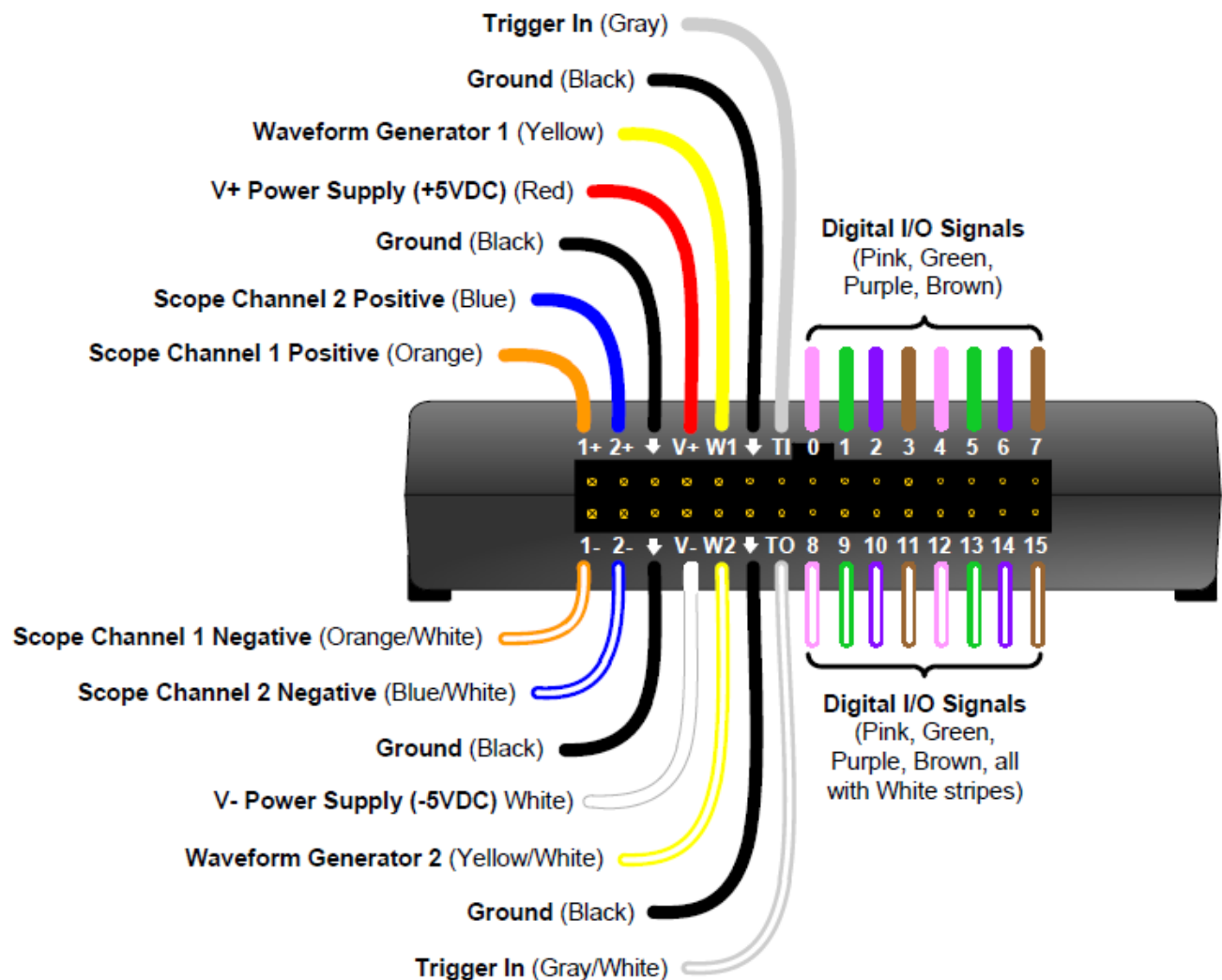
STEPS TO RUN WAVEFORM SOFTWARE

Step1: Open the "Waveform" software from the start menu of the windows desktop
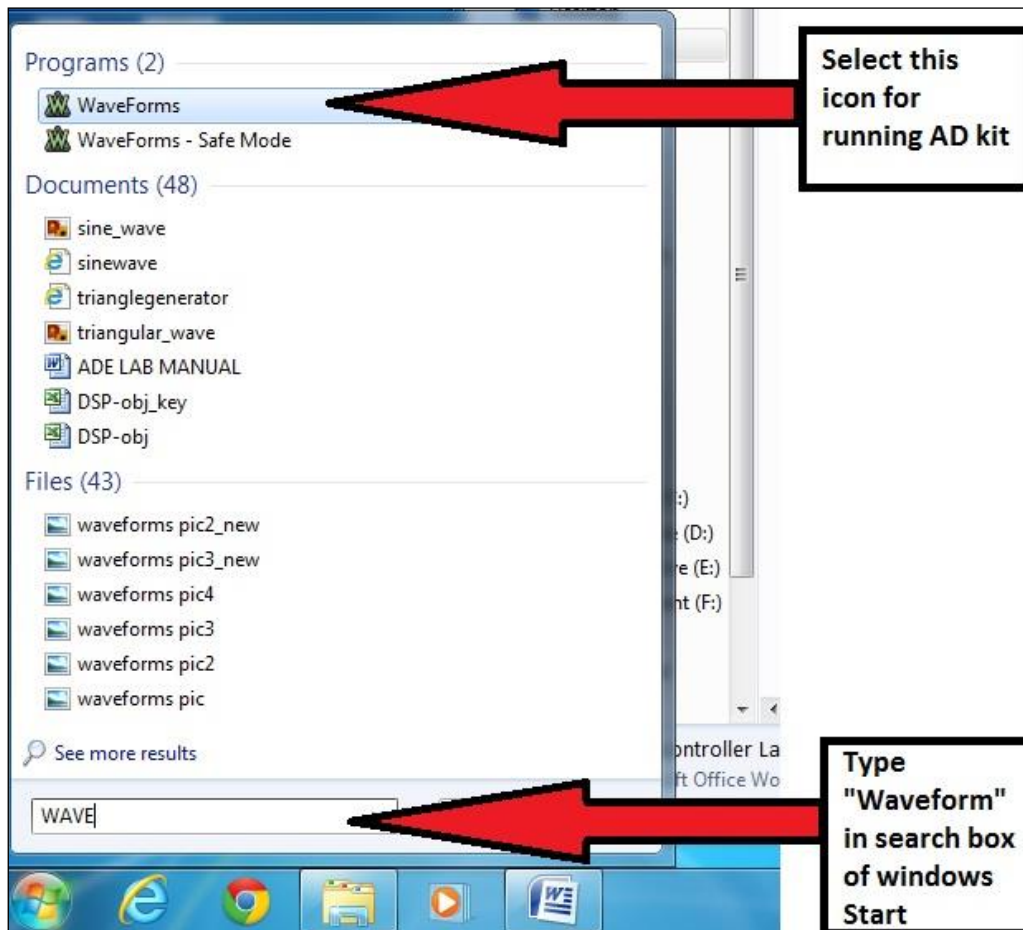
Figure: Showing the selection of Waveform software from the start menu
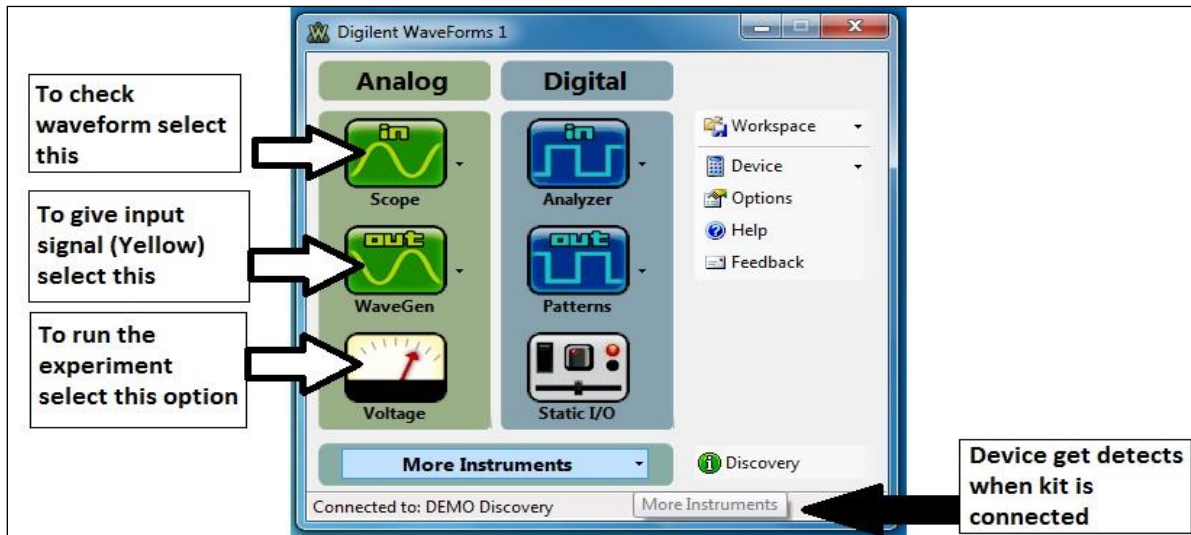
Step2: Each block representation of Waveform software

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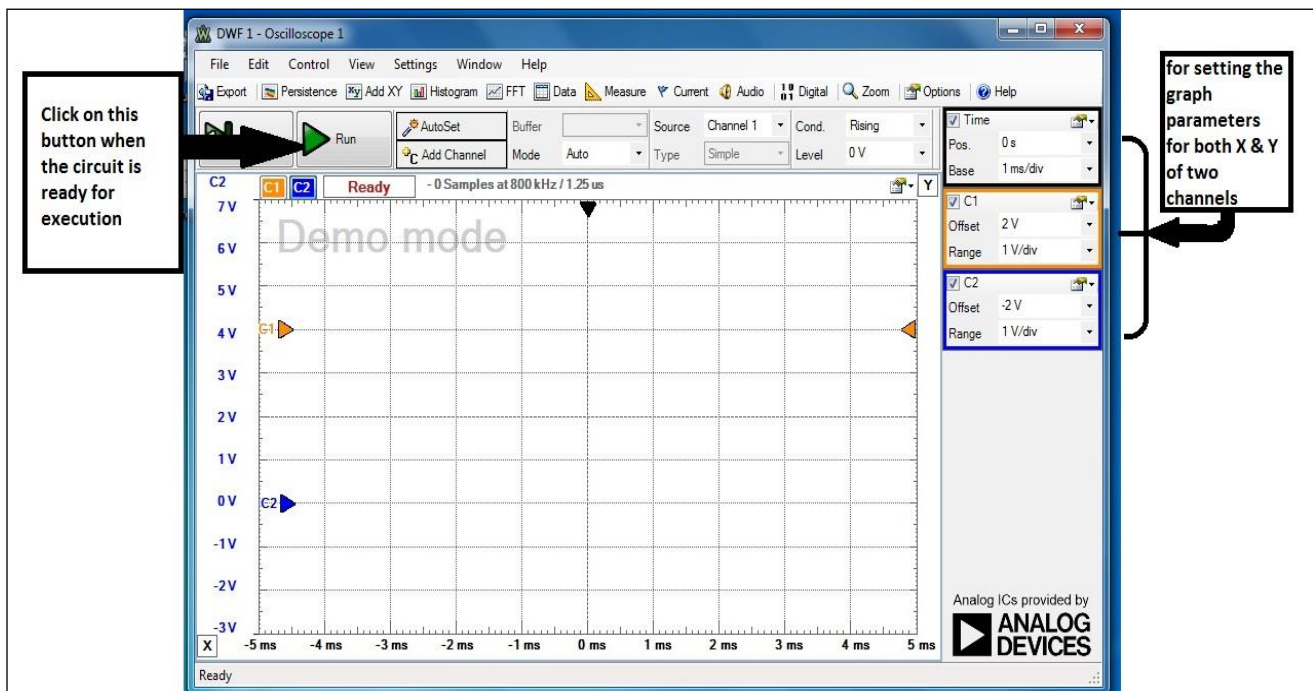
Figure: Shows the "in" window of "Waveform" software

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.
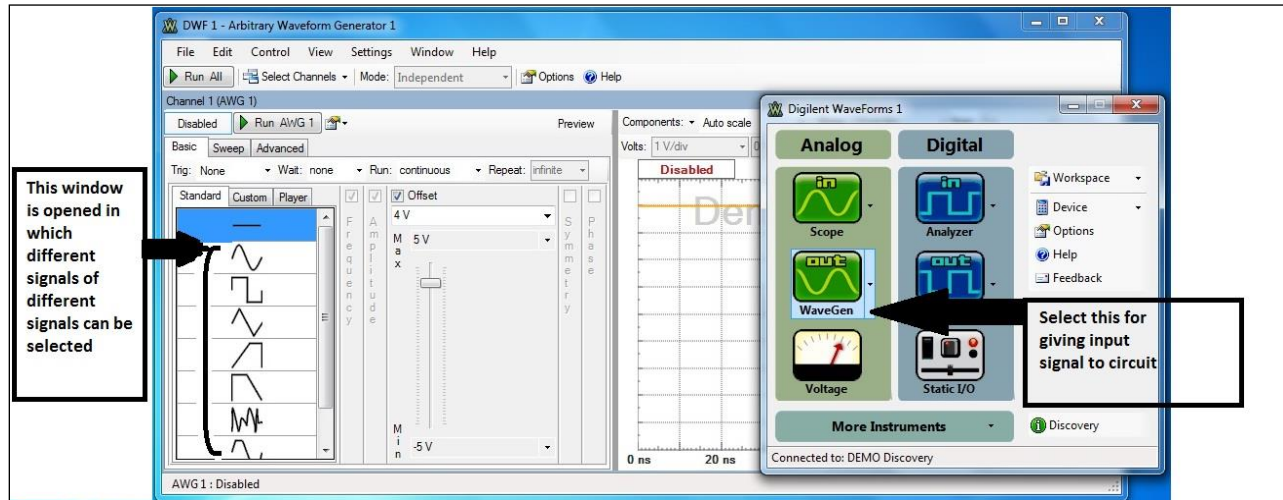

Figure: The "Out" window of Waveform in which different waveforms can be given as input

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.
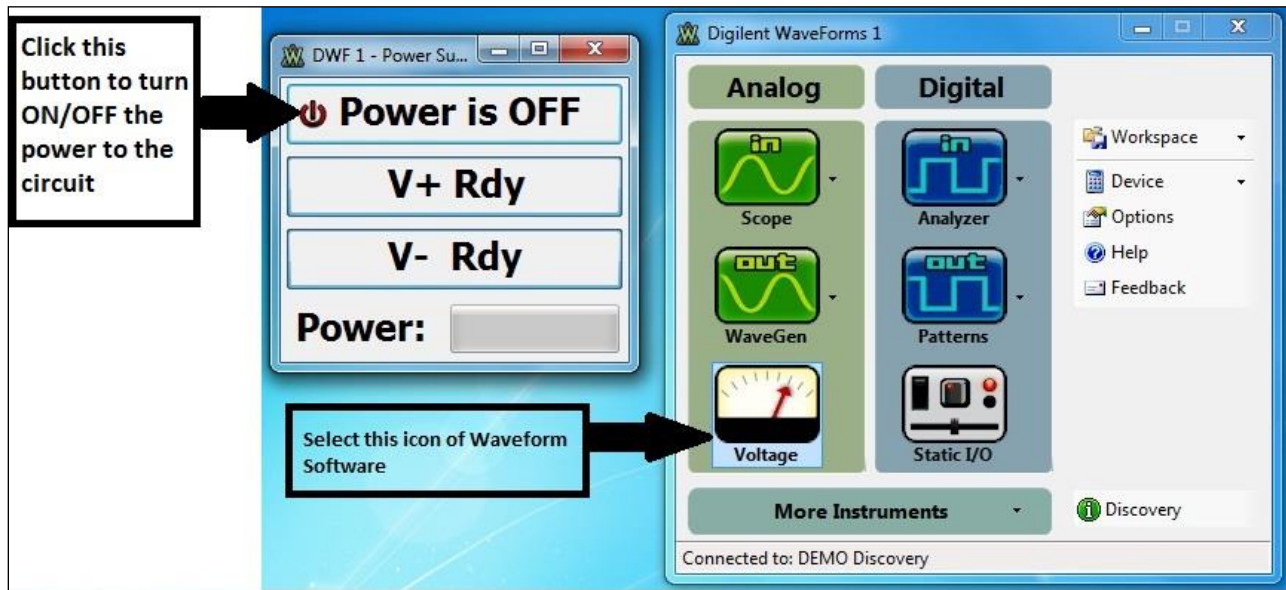

Figure: The "Voltage" window of Waveform helps to run the ADE kit

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:

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

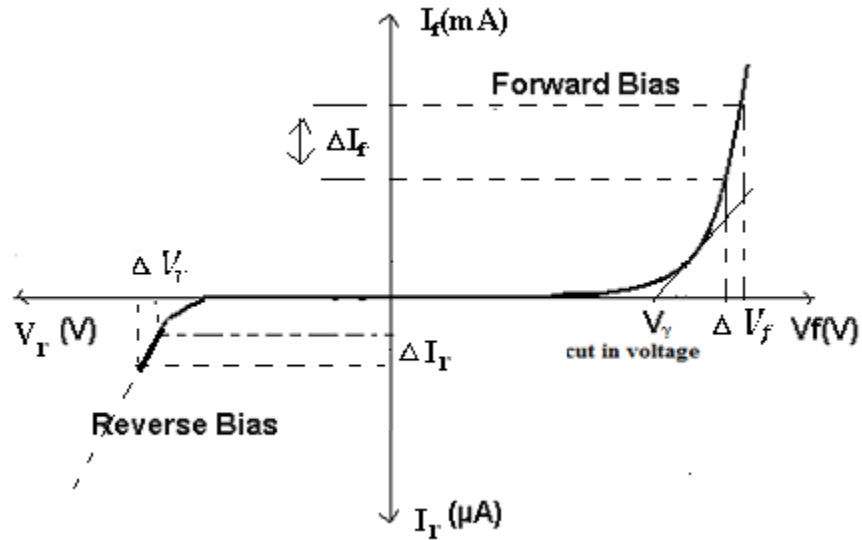Where I = current flowing in the diode,

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:

Calculations from Graph:

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 $r_{ac} = \Delta V_r / \Delta I_r \Omega$
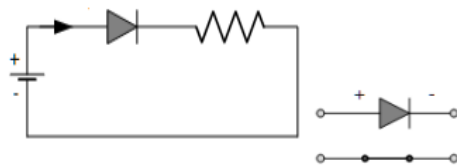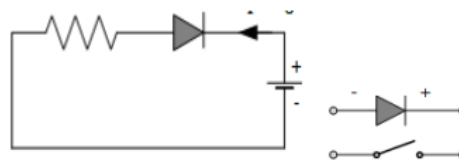
CIRCUIT DIAGRAM:

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
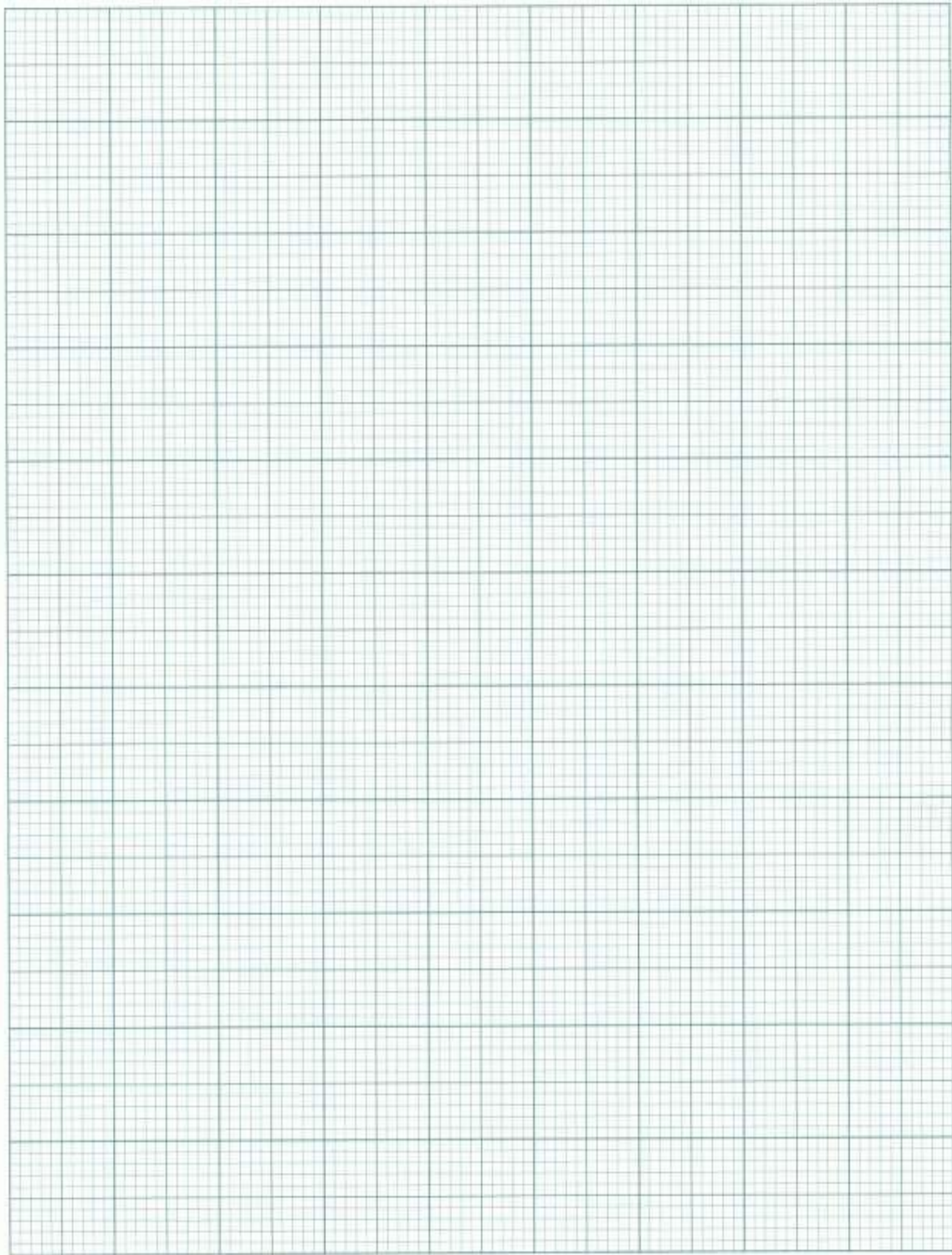5. Compare the theoretical and practical values (cut-in voltage and resistances).

(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:

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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:

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

and

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

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

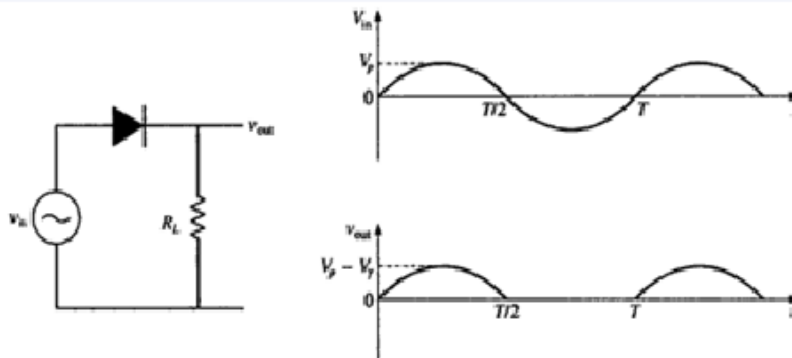where

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

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),
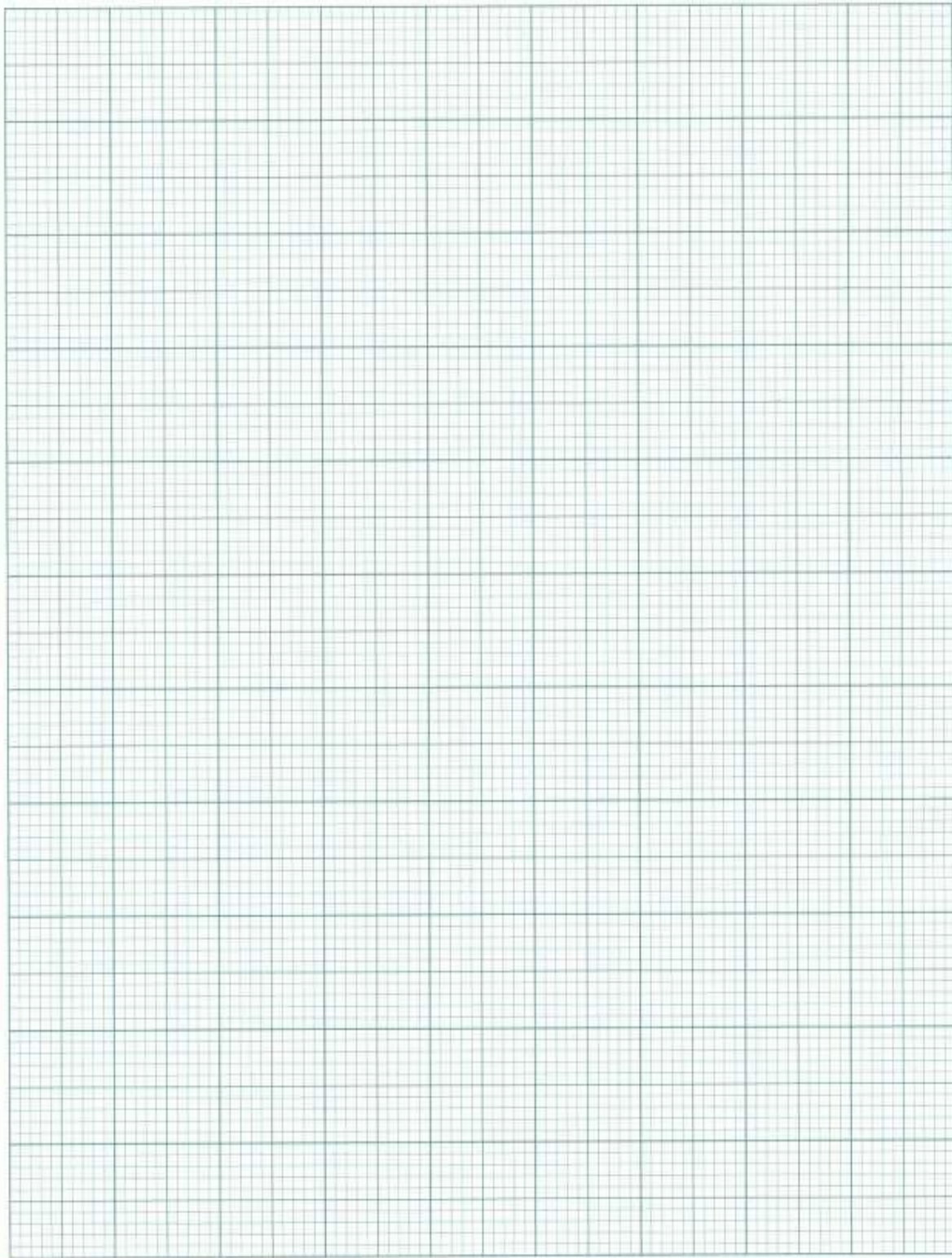
$$r = \sqrt{(FF)^2 - 1}$$

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

GRAPH:

RESULT:

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<h1 style="text-align:center">EXPERIMENT-3a
CLIPPING CIRCUITS</h1>

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.
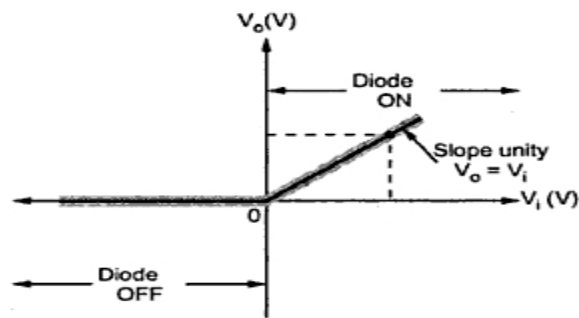
CIRCUIT DIAGRAMS:

Input Signal
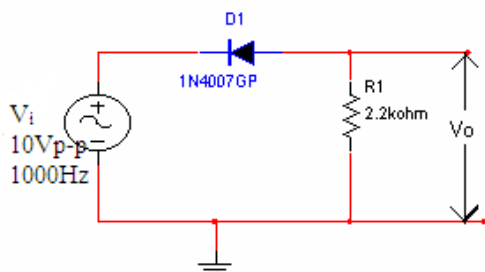

(a)

(b)

output voltage with respect to input voltage
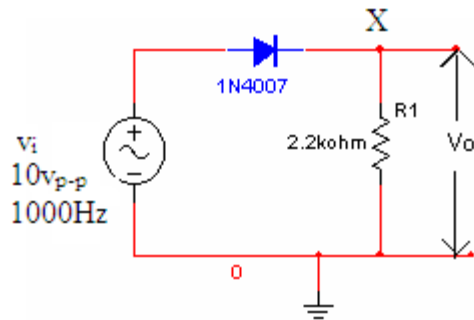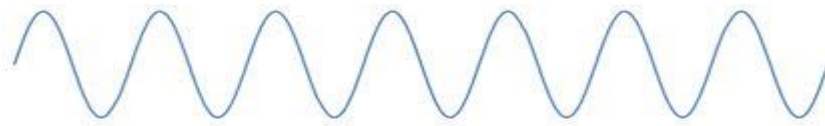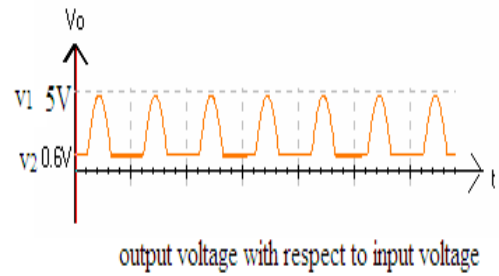
TRANSFER CHARACTERISTICS:

(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)**

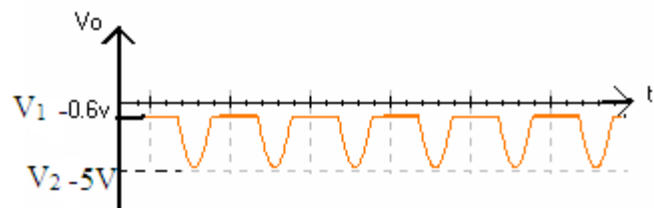**TRANSFER CHARACTERISTICS:**

(c)

Fig 2.3 (a) Negative clipper with zero reference (Shunt clipper), (b) Waveforms and (c) Input Voltage vs Output Voltage graph
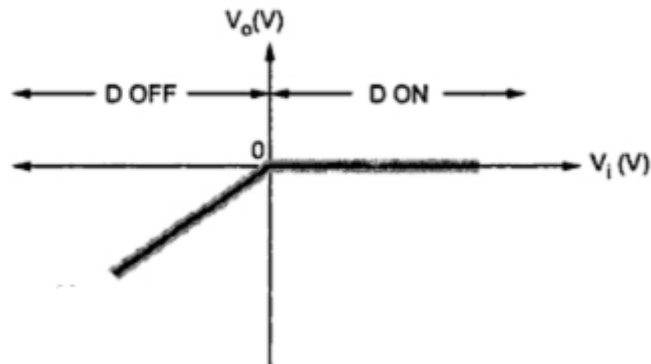
15

(a)   (b)
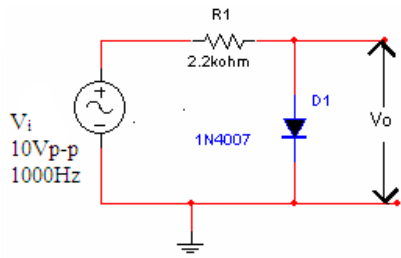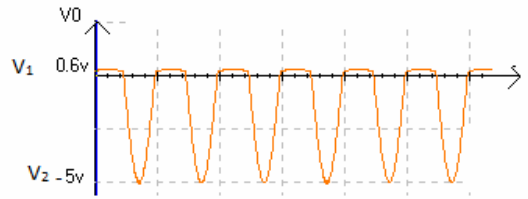
TRANSFER CHARACTERISTICS:
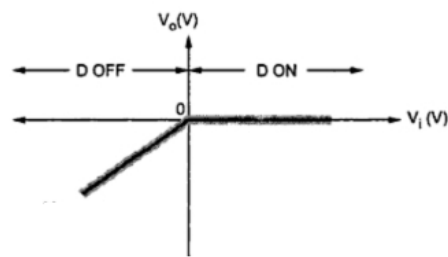
(c)

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

(a)   **(b)**
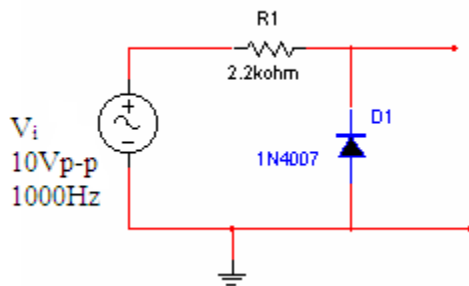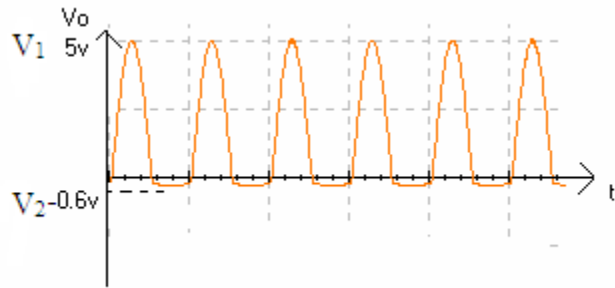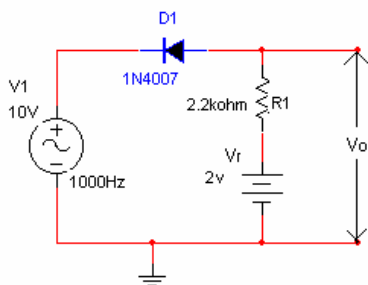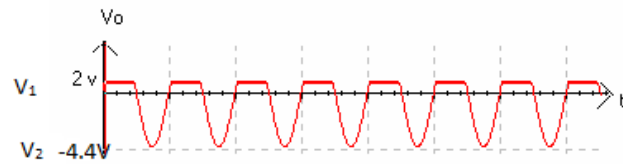
TRANSFER CHARACTERISTICS:
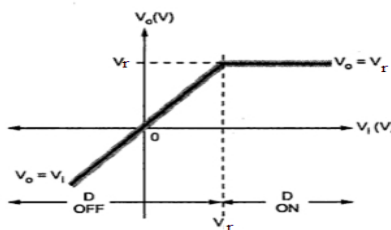
(c)

Fig. 2.5 (a) Positive clipper with positive reference (Series clipper) , (b) Waveforms and (c) Input Voltage vs Output Voltage graph
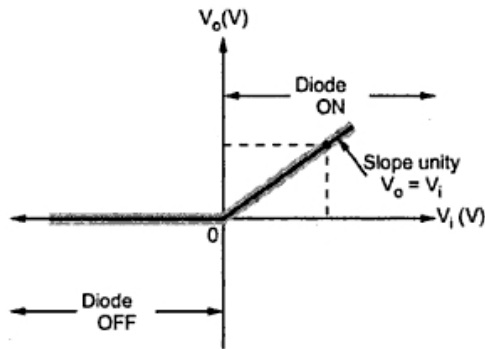
16

(a)

(b)
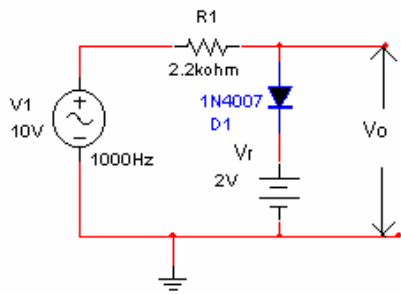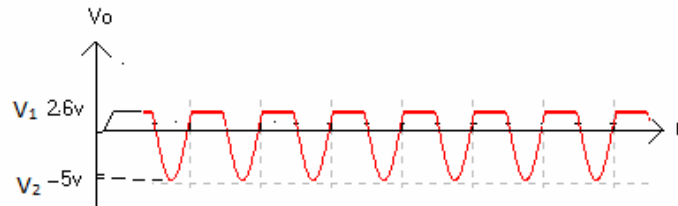
Transfer characteristics:
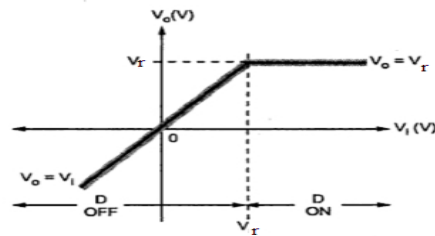
(c)

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

(a)

(b)
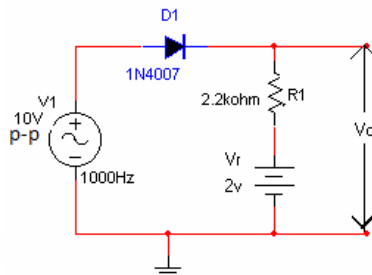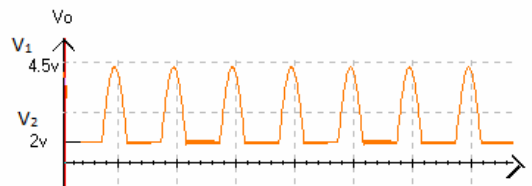
Transfer characteristics:
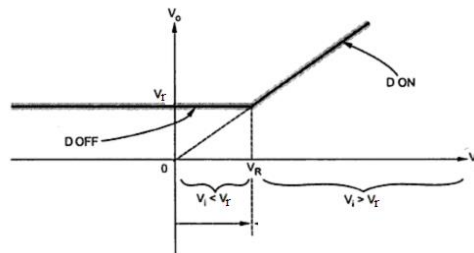
(c)

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


(a)

(b)
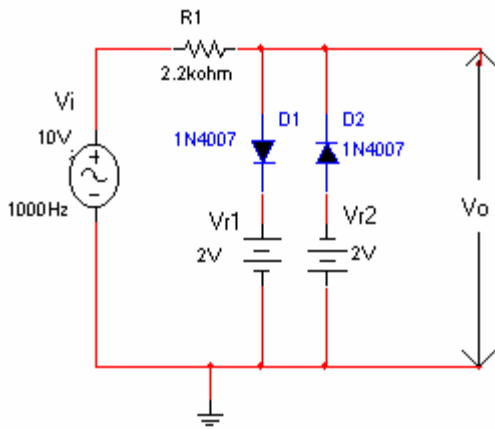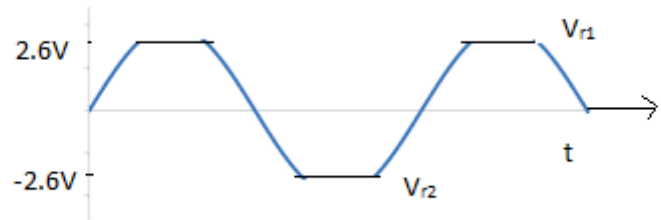
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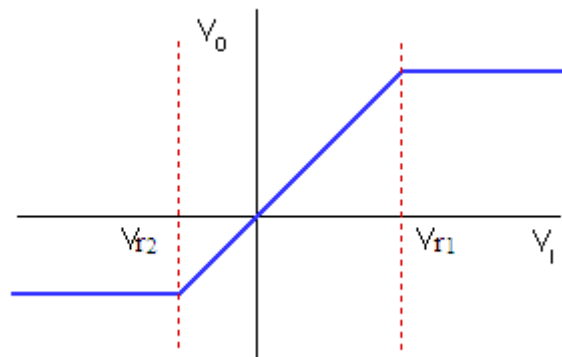

(c)

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	

S.No.	Type of Clipper	Reference Voltage	Practical Clipping Voltage levels

GRAPH:

RESULT:

21
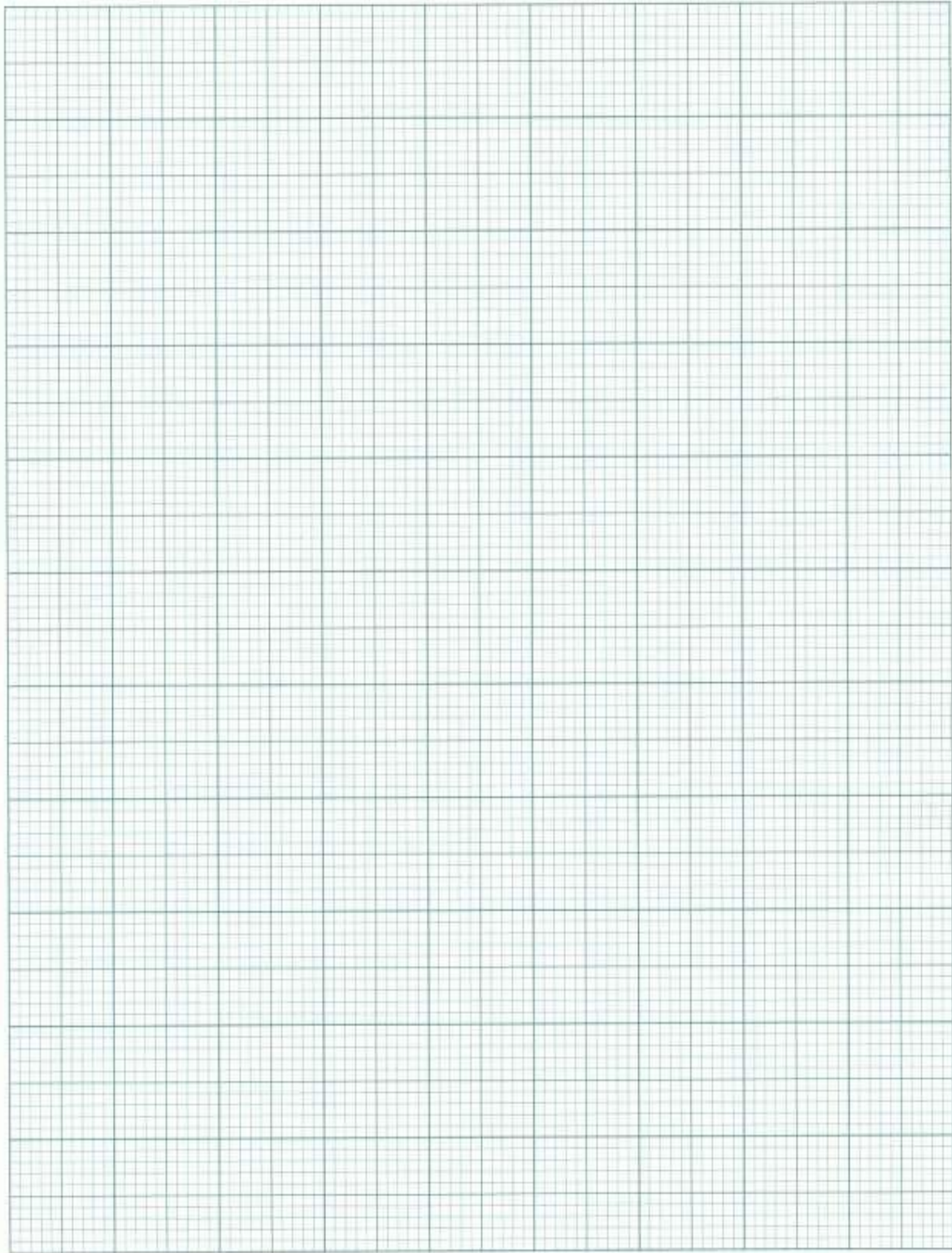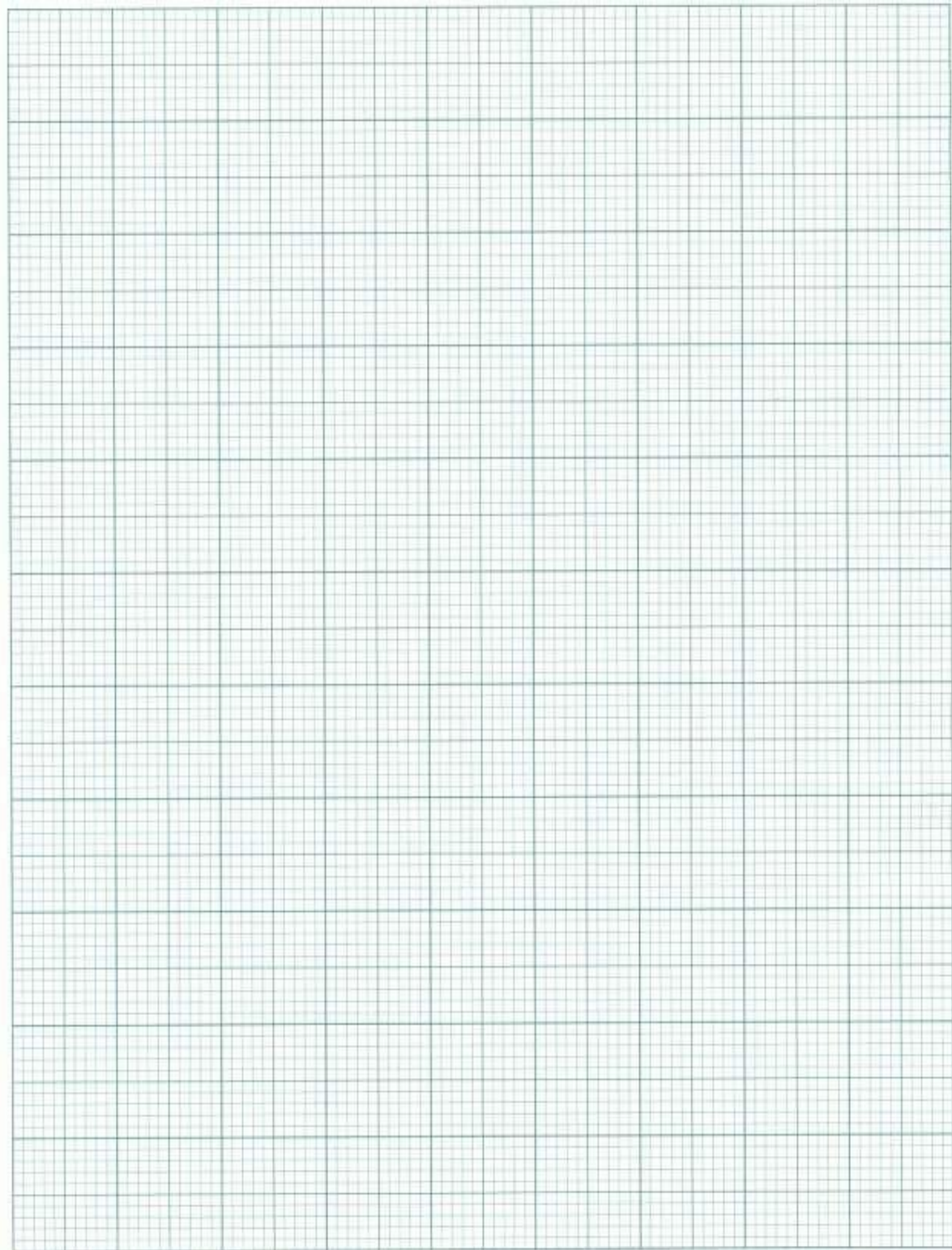
EXPERIMENT-3b
CLAMPING CIRCUITS

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
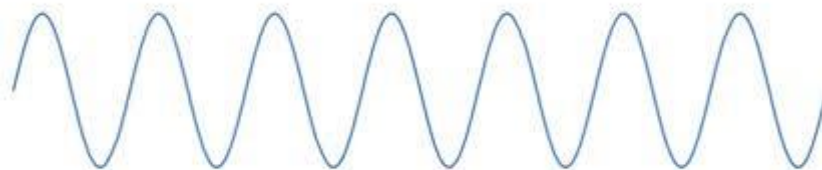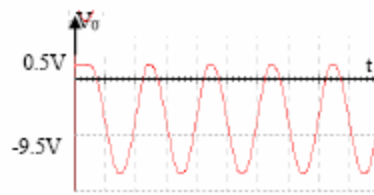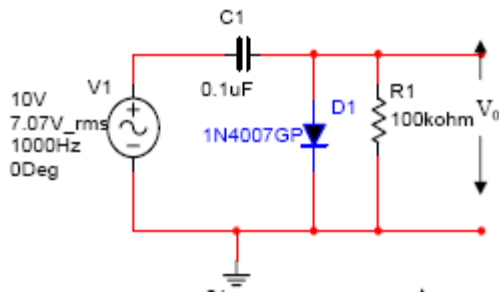
Fig.3.1 Negative clamping with zero reference voltage
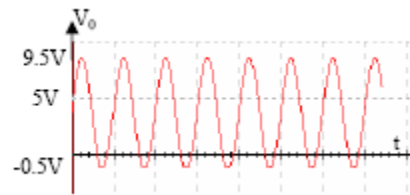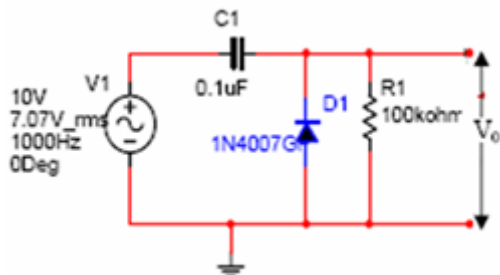
Fig.3.2 positive clamping with zero reference voltage
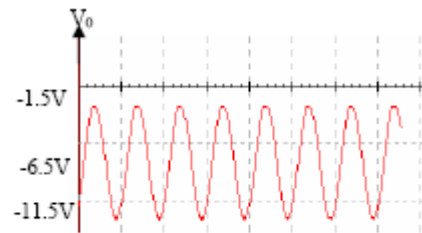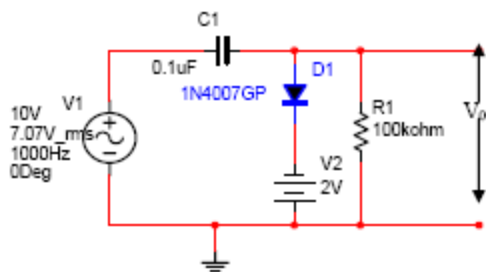
Fig.3.3 Negative clamping with Negative reference voltage
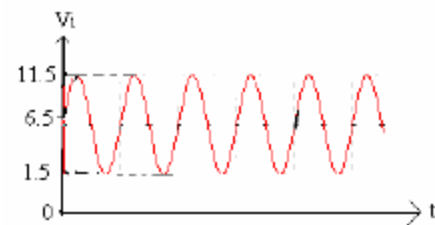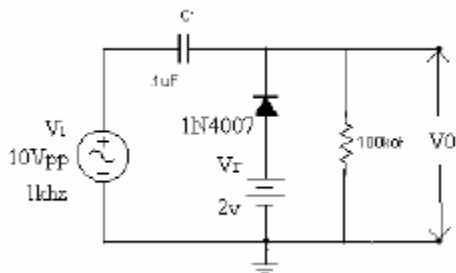
Fig.3.4 positive clamping positive reference voltage
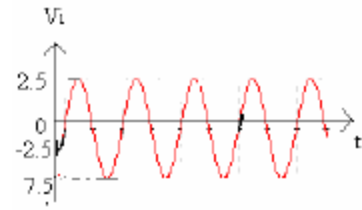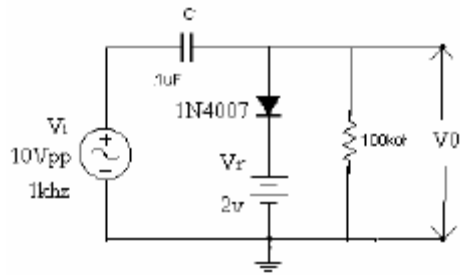
Fig.3.5 Negative clamping with Positive reference voltage
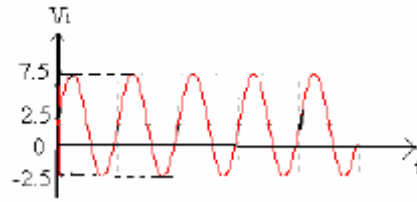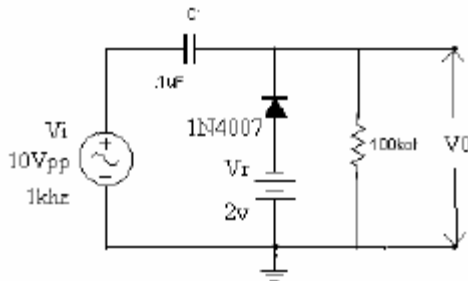
Fig.3.6 Positive clamping with Negative reference voltage

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:

25
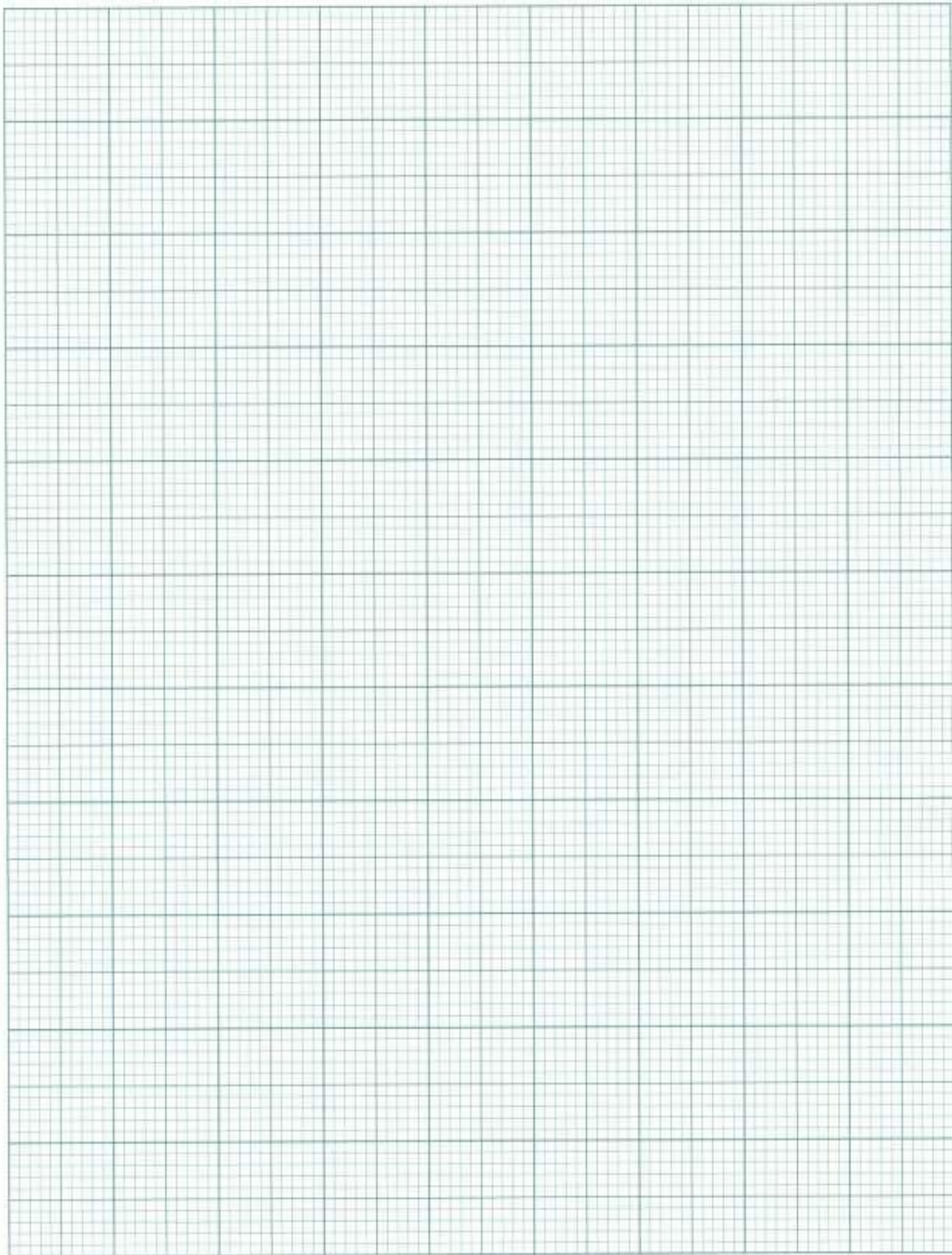
EXPERIMENT-4
BJT STATIC CHARACTERISTICS

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.
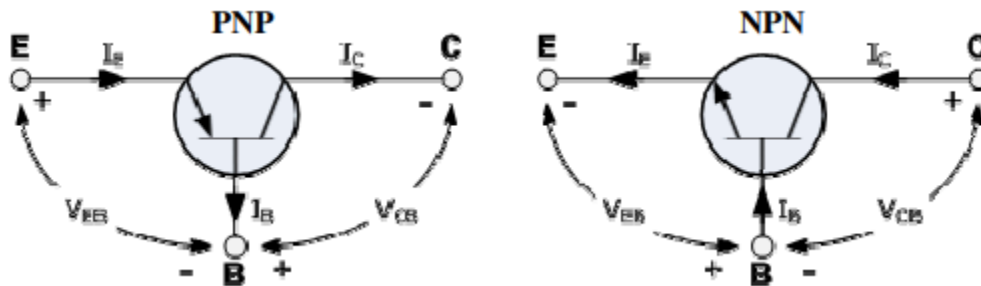
The symbols for both the NPN and PNP bipolar transistor are shown above along with the direction of conventional current flow. The direction of the arrow in the symbol shows current flow between the base and emitter terminal, pointing from the positive P-type region to the negative N-type region, like 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.

$$r_i = \left.\frac{\Delta V_{EB}}{\Delta I_E}\right|_{V_{CB}}$$

(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.

$$r_o = \left.\frac{\Delta V_{CB}}{\Delta I_C}\right|_{I_E}$$

(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.

$$\alpha_{ac} = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{V_{CB}}$$

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,

$$\alpha_{dc} = \left.\frac{I_C}{I_E}\right|_{V_{CB}}$$

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:
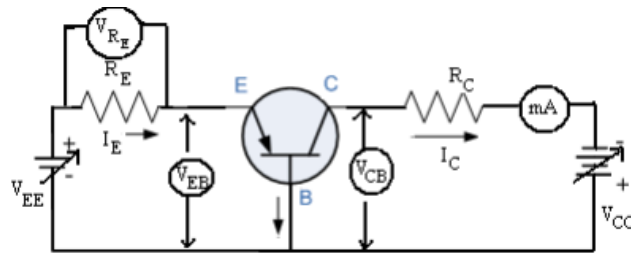
PNP transistor in CB configuration
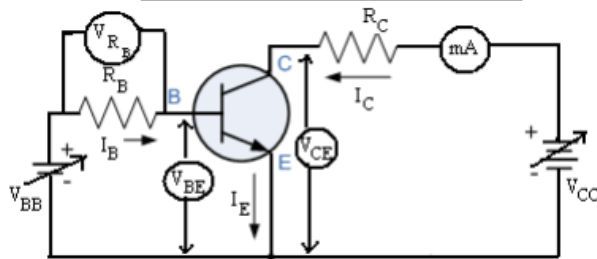
NPN transistor in CE configuration

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 $RE = RC = 150\ \Omega$.

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 $R_C = 1\ k\Omega$. 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$_B$(μA)	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:
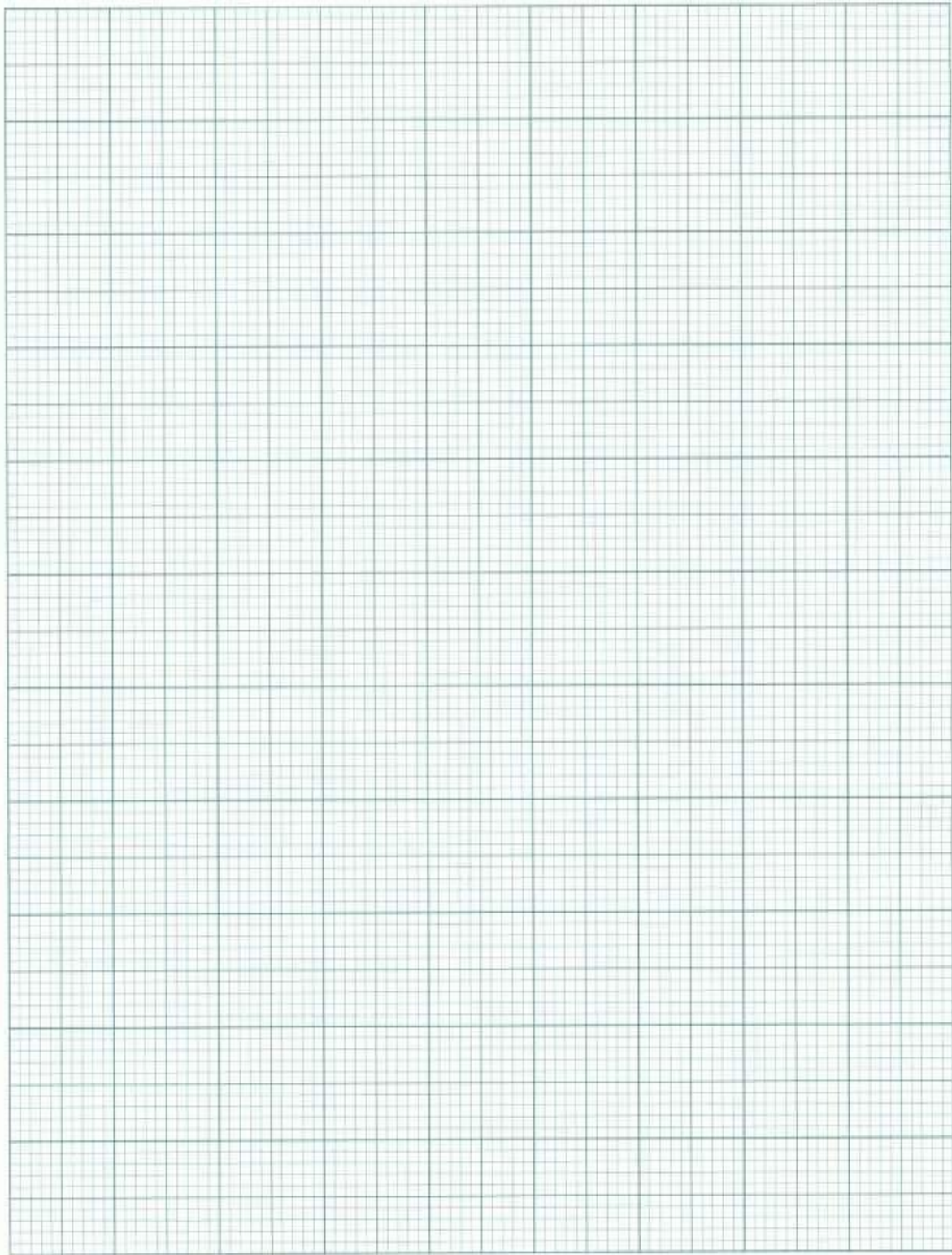
RESULT:

EXPERIMENT-5
# N-CHANNEL MOSFET CHARACTERISTICS

AIM: To study transfer and output characteristics of an n-channel Metal Oxide Semiconductor field effect Transistor (MOSFET) in Common-source configuration.

APPARATUS:

MOSFET (2N7000 or its equivalent) – 1 No.
Resistor (1KΩ, 100KΩ)
Analog Discovery Kit/ESIM Software / EC Studio Software
Connecting wires
Bread board

THEORY:

A metal-oxide-semiconductor field-effect transistor (MOSFET) is a three-terminal device that can be used as a switch (e.g. in digital circuits) or as an amplifier (e.g. in analog circuits). The three terminals are referred to as the Source, Gate, and Drain terminals. The MOSFET also has a Body terminal, which is usually tied to the source terminal (so that $V_{BS} = 0$ volts) in discrete transistors. Current flow between the source and drain terminals is controlled by the voltage V_{GS} applied between the gate and source terminals. If the gate-to-source voltage V_{GS} is less than the threshold voltage value V_T (e.g. ~2 Volts, for the transistors which you will be using in this lab), no current can flow between the source and the drain – i.e. the transistor is OFF; if $V_{GS} > V_T$, then current can flow between the source and the drain – i.e. the transistor is ON. The circuit symbol for an n-channel enhancement-mode ($V_T > 0$ Volts) MOSFET is shown in Figure 1, along with the terminal current reference directions.
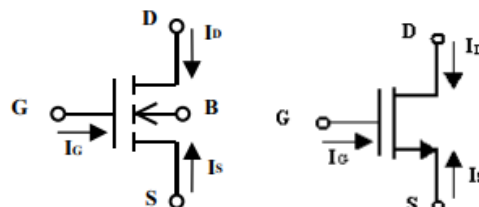
Figure 1 Circuit symbol for n-channel enhancement MOSFET

Note that each terminal current is defined to be positive flowing into the terminal. In the physical structure of the MOSFET, the gate terminal is electrically insulated from the source, body and drain terminals, so that no DC current can flow into the gate terminal: $I_G = 0$ →eq:1

In addition, if the transistor is operated properly, no DC current should flow between the body terminal and the source or drain terminals: $I_B = 0$ →eq:2

From Kirchhoff's Current Law, we know that the sum of all the terminal currents flowing into the MOSFET must be zero: $I_G + I_D + I_B + I_S = 0$→eq:3.
Substituting Eq. 1 and Eq. 2 into Eq. 3, we obtain $I_S = -I_D$ →eq:4
Thus, **all the current that flows into the drain terminal flows out of the source terminal**.

In the ON state, the current I_{DS} flowing from the drain to the source will depend on the potential difference V_{DS} between the drain and the source: I_{DS} increases with increasing drain-to-source voltage V_{DS} as long as the drain voltage is at least V_T below the gate voltage, i.e. as long as $V_{GS}-V_T > V_{DS}$. When V_{DS} increases above $V_{GS}-V_T$, I_{DS} saturates at a constant value (i.e. it no longer increases with increasing V_{DS}.) Figure 2 shows the I-V operating curves for a typical n-channel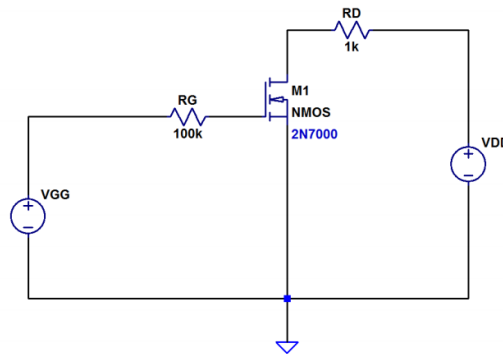 enhancement-mode Field Effect Transistor (FET). As can be seen in the figure, for each value of V_{GS} there is a unique curve of I_{DS} vs. V_{DS}.
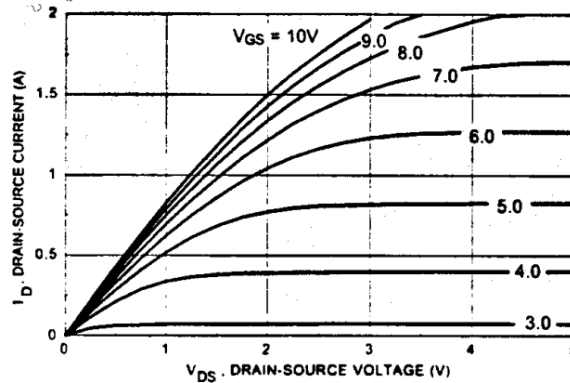
Figure 2 Current I_{DS} flowing through the drain to source of an n-channel MOSFET versus the voltage V_{DS} across drain to source, parameterized by the voltage V_{GS} applied across the gate to source

CIRCUIT DIAGRAM:

PROCEDURE: OUTPUT/DRAIN CHARACTERISTICS:

1. Connect the circuit as per given diagram properly.
2. Keep V_{GS} constant at some value say 1.1 V by varying V_{GG}
3. Vary V_{DS} in step of 1V up to 10 volts and measure the drain current I_D. Tabulate all the readings.
4. Repeat the above procedure for V_{GS} as 1.2V, 1.3V, 1.4V, 1.5V etc

$V_{GS}=1.1V$		$V_{GS}=1.2V$		$V_{GS}=1.3V$		$V_{GS}=1.4V$		$V_{GS}=1.5V$	
$V_{DS}(V)$	$I_D(mA)$	$V_{DS}(V)$	$I_D(mA)$	$V_{DS}(V)$	$I_D(mA)$	$V_{DS}(V)$	$I_D(mA)$	$V_{DS}(V)$	$I_D(mA)$

GRAPH:

RESULT:

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
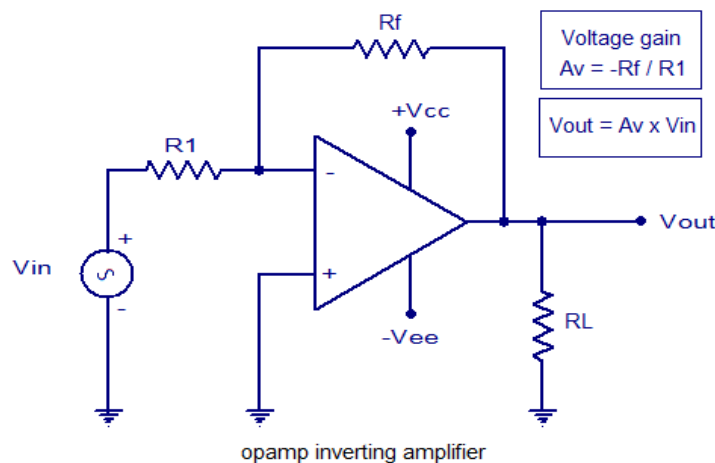
Connecting wires

Breadboard

CIRCUIT DIAGRAM:

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)

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

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:
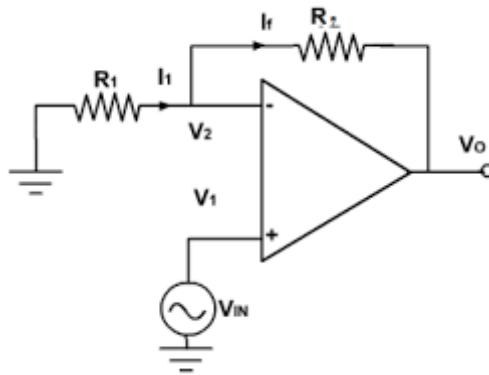
MODEL GRAPH:
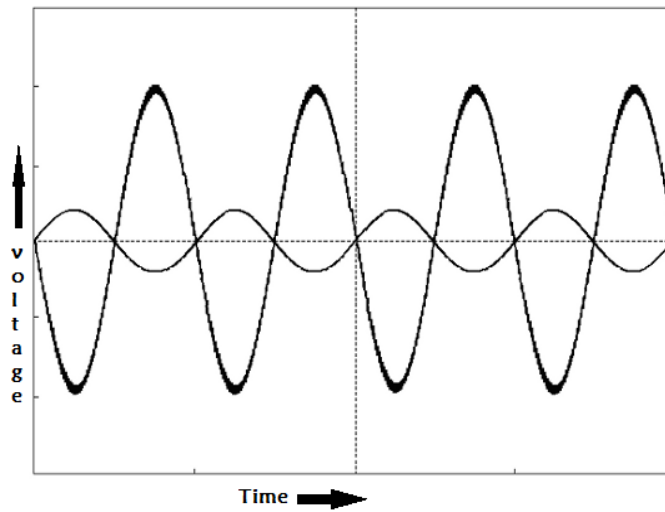
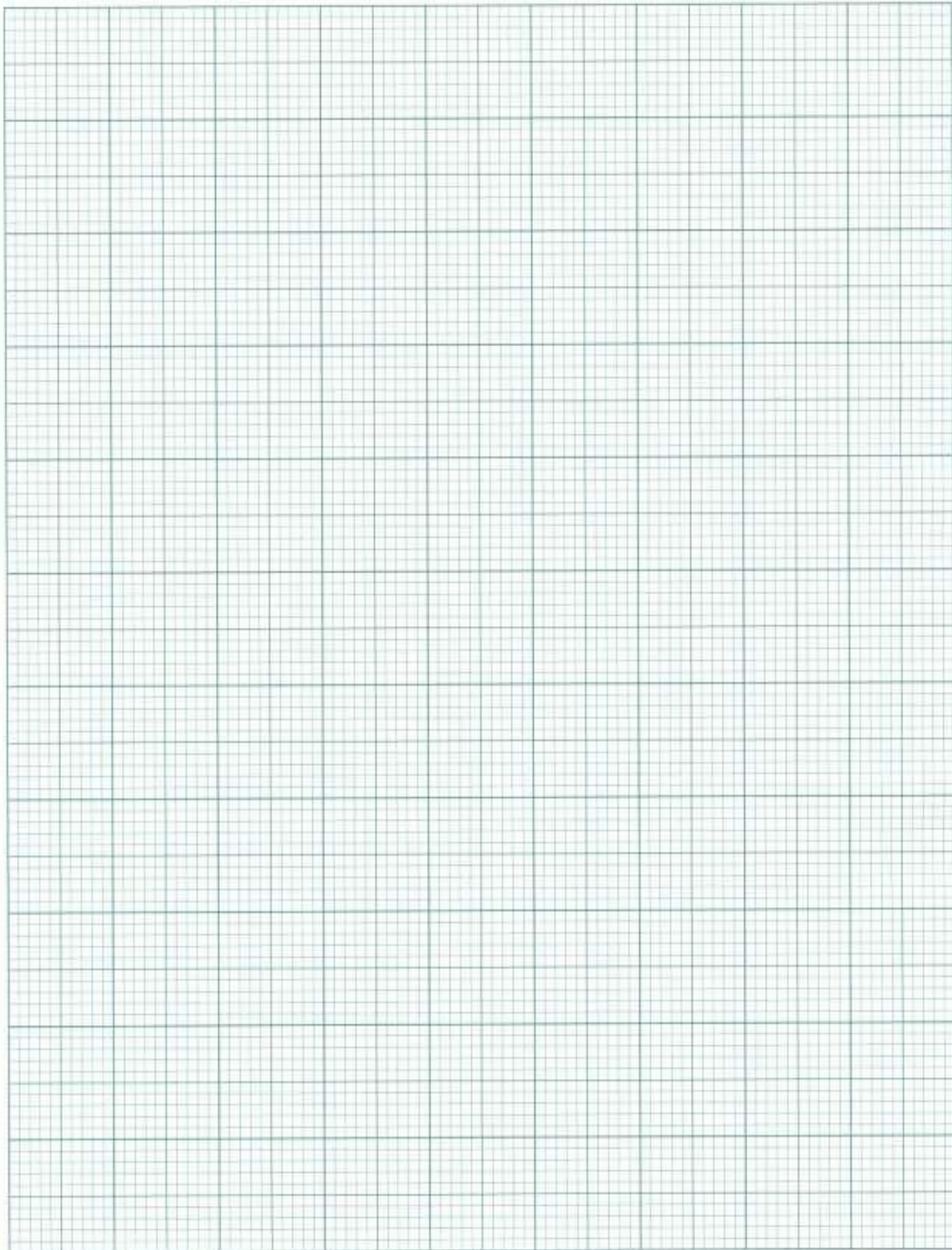**GRAPH SHEET:**
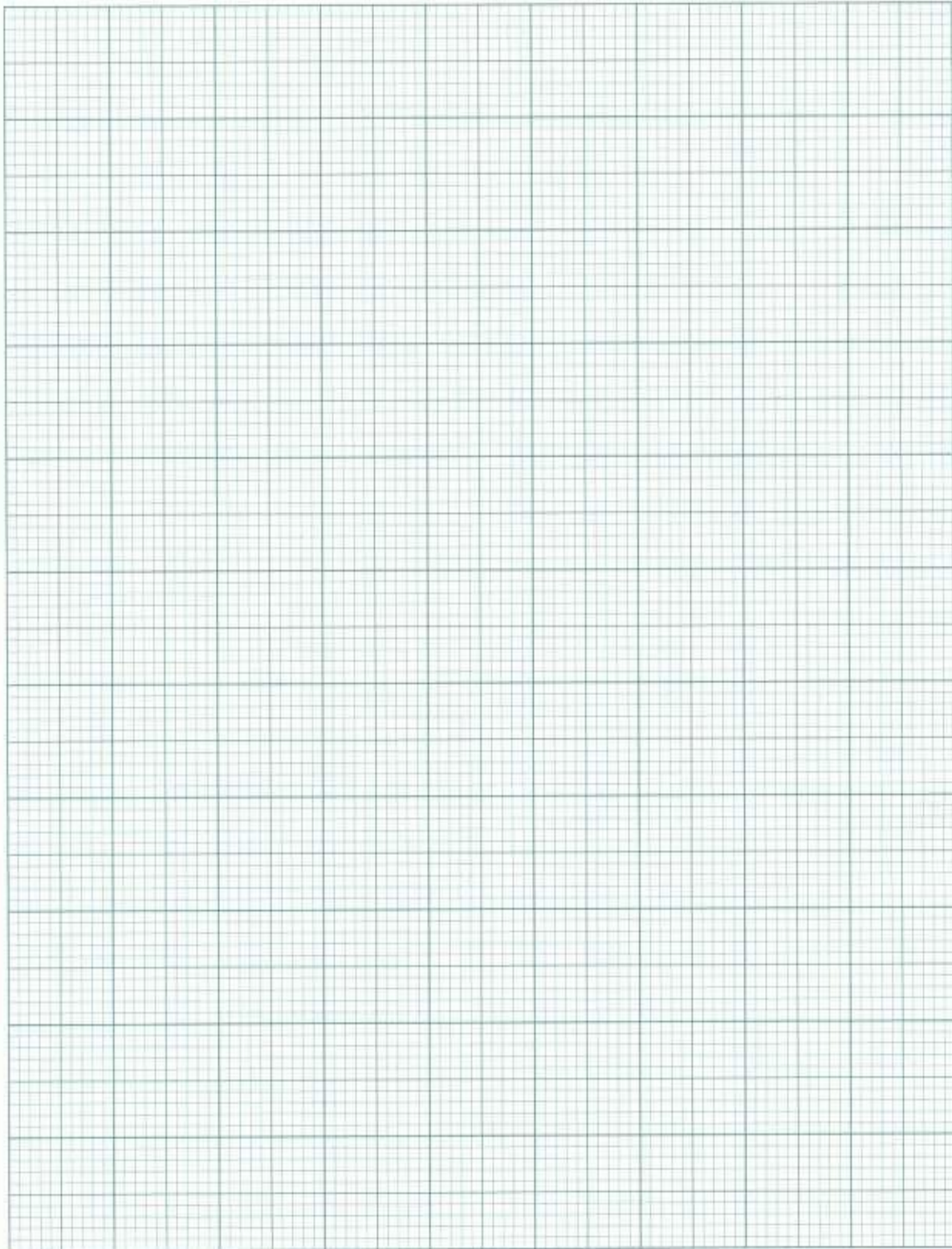
RESULT:

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:

<div align="center">

EXPERIMENT:7
SUBTRACTOR CIRCUIT

</div>

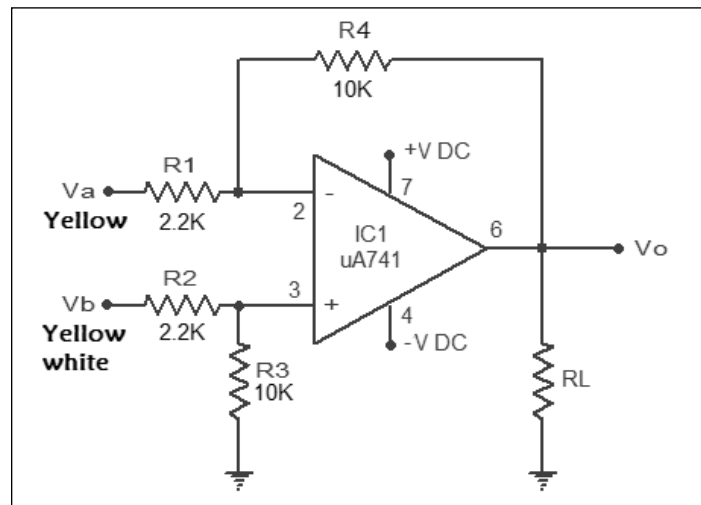**AIM:** To design a Subtractor Circuit using Op-Amp.

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:

<div align="center">

Figure: Subtractor/Difference Circuit

</div>

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:

<div align="center">

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</div>

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

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:
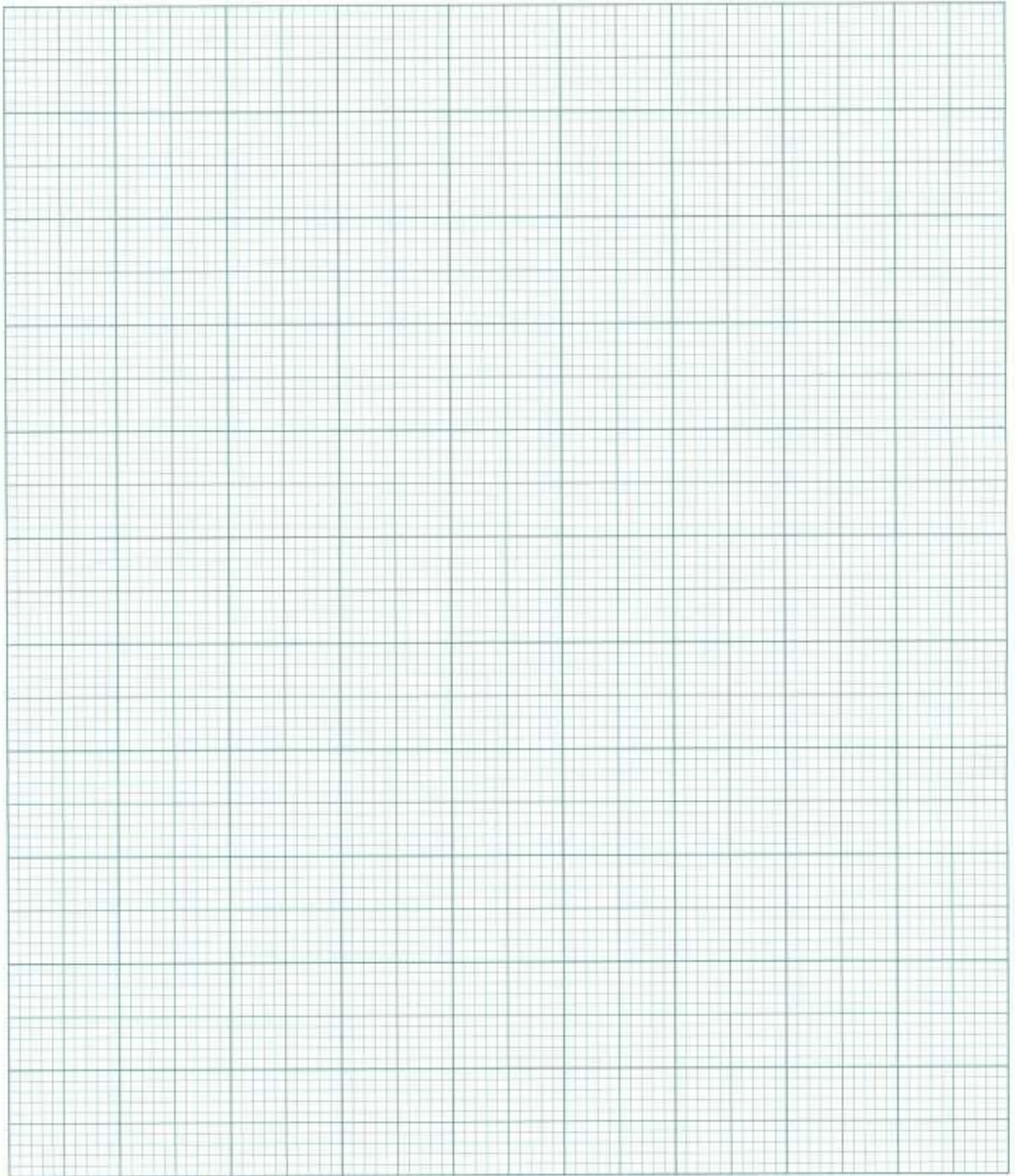
RESULT:

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
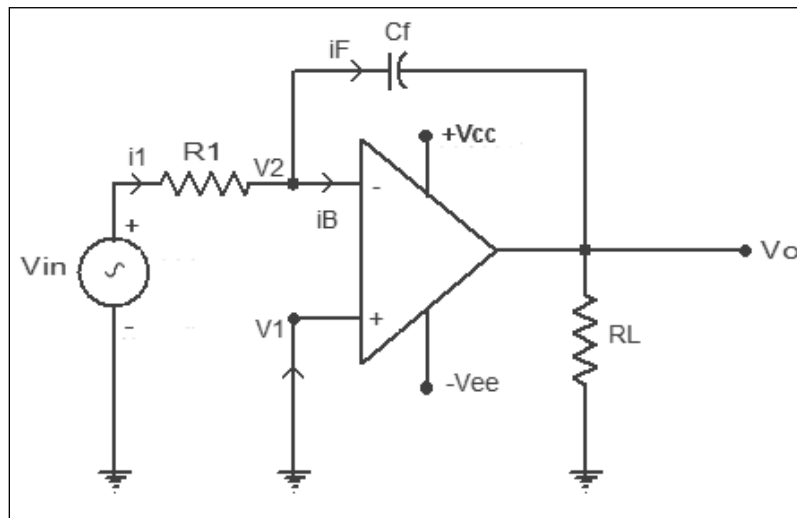
100nF Capacitor

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 $R_f C_1$ 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:
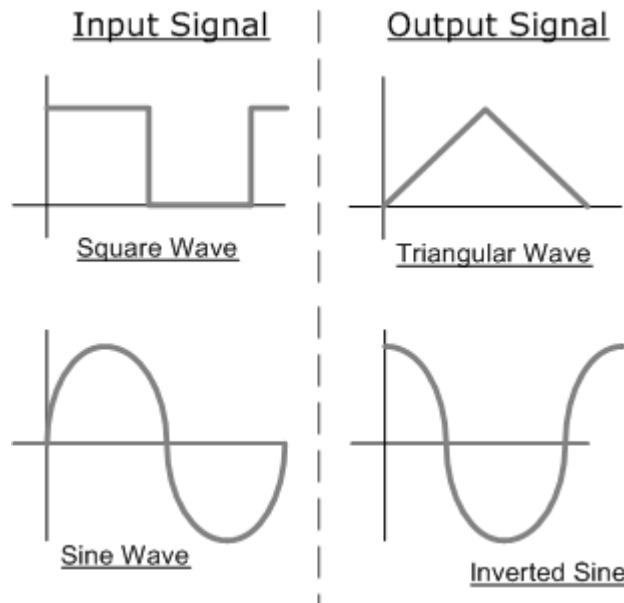
Figure: showing the output waveforms for different input waveforms

THEORETICAL CALCULATIONS:
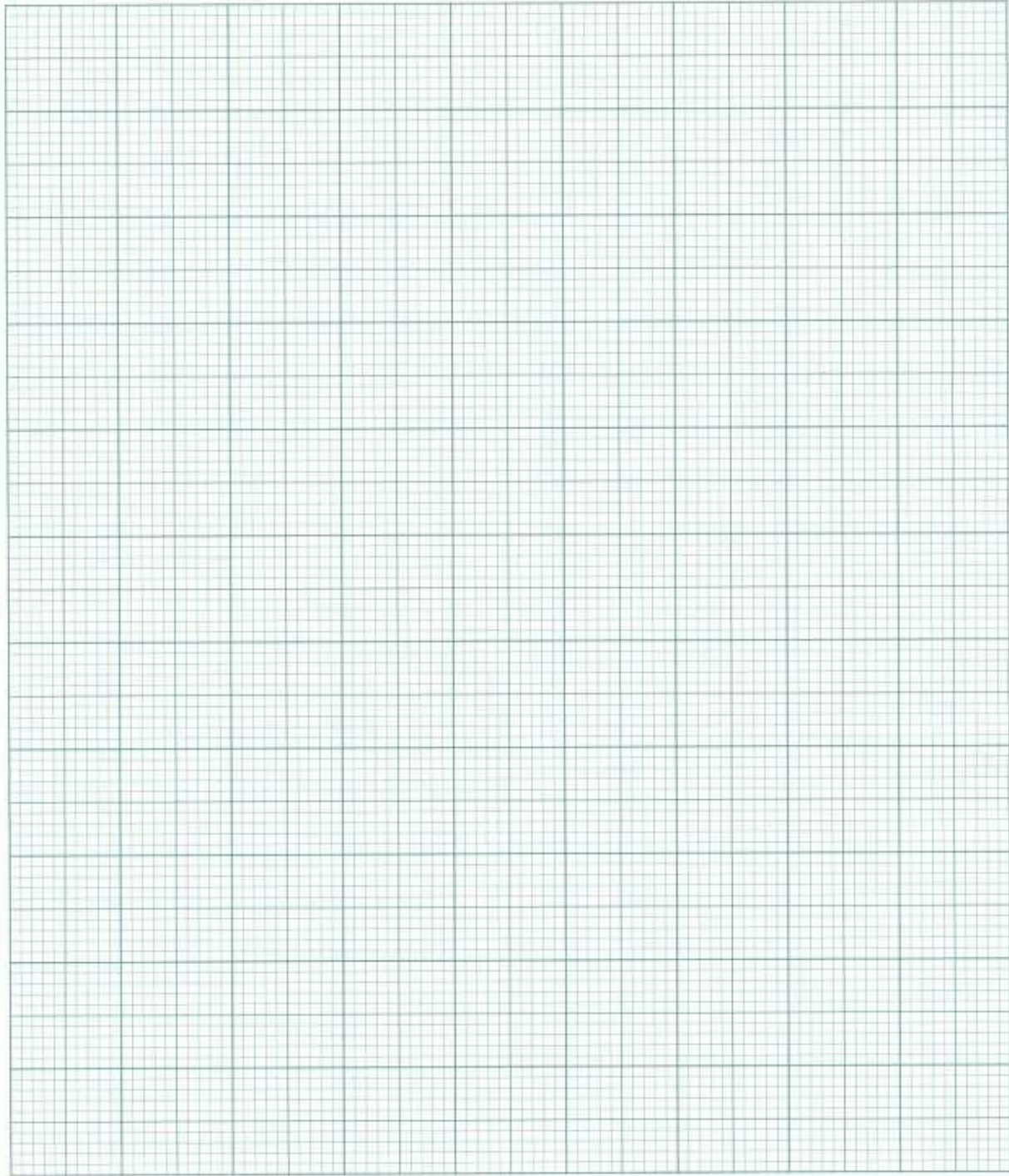
THEORETICAL CALCULATIONS:

GRAPH SHEET:

RESULT:

Exercise: List the applications of integrating amplifier and derive the expression of Integrating Amplifier
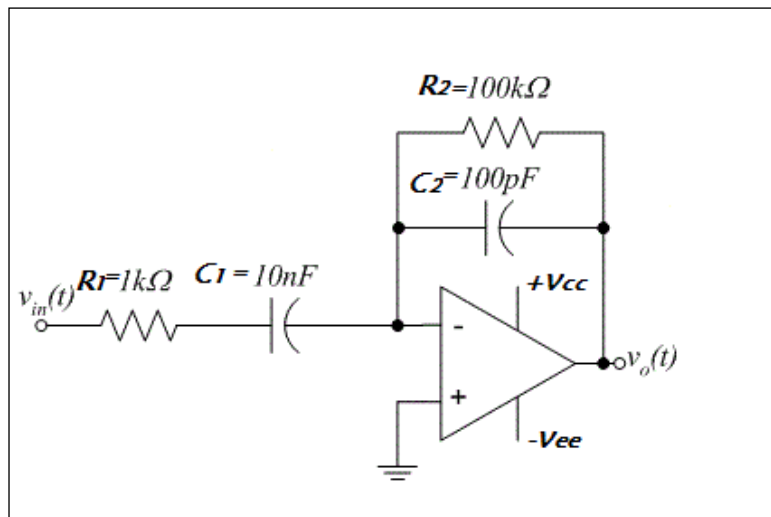
DIFFERENTIATOR CIRCUIT

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:

Figure: Differentiator

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:
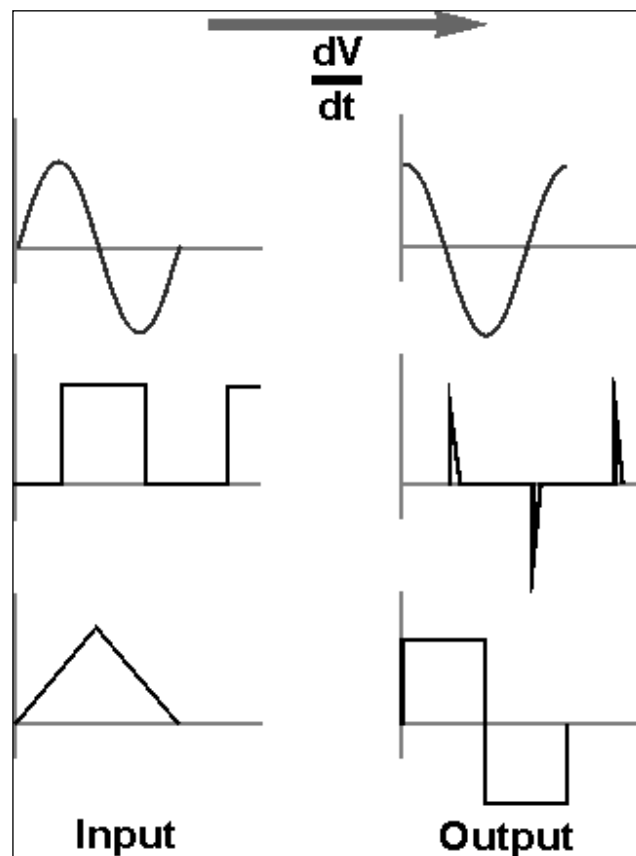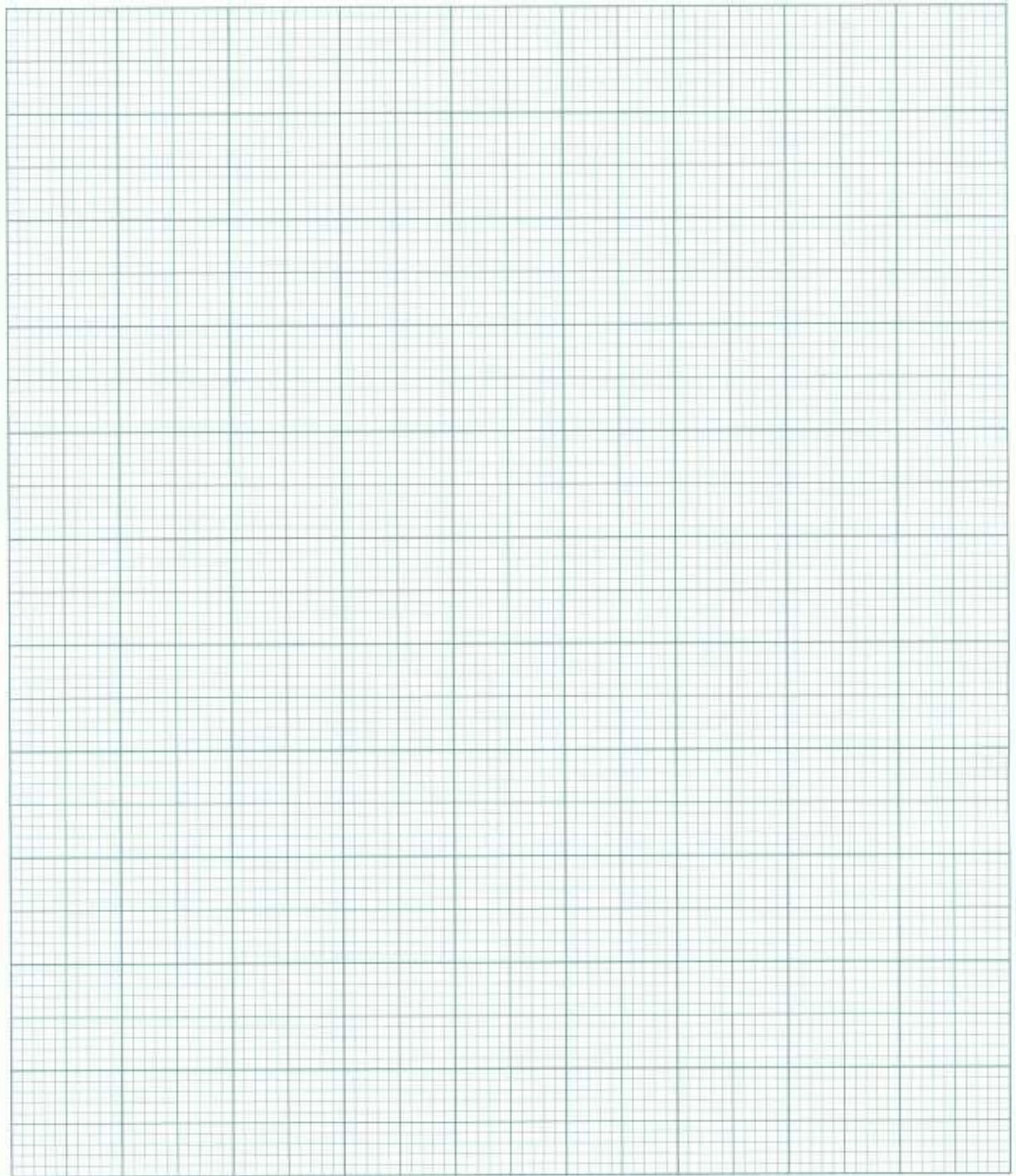

Figure: Model output waveforms for different input signals

THEORETICAL CALCULATIONS:

GRAPH SHEET:

RESULT:

Exercise: List the applications of integrating amplifier and derive the expression of Differentiating Amplifier

EXPERIMENT-10
PRECISION RECTIFIER USING OPAMPS

AIM: To study the half wave rectifier using op-amp or a precision rectifier.
APPARATUS:

      Operation Amplifier (741 or its equivalent) – 1 No.
      Diode (IN4007) – 1 No.
      Resistor (1KΩ, 100KΩ)
      Analog Discovery Kit/ESIM Software / EC Studio Software
      Connecting wires
      Bread board

THEORY:

A half wave rectifier using OP amp is also known as a Precision rectifier or super diode, is a configuration obtained with an operational amplifier in order to have a circuit behaving like an ideal diode and rectifier.

Fig.1 shows the circuit of a Precision rectifier. On positive voltage swings the diode conducts and a voltage is developed across the resistor. On negative swings, the diode turns off and the output voltage is zero (no current through the resistor).

The basic idea behind the super diode is to use the high-gain of an op-amp to mask the finite turn-on voltage (and other nonlinearities) of the diode. This is done by placing it in the negative feedback path as shown in fig 1. Any positive voltage at the op-amp "+" terminal is now sufficient to turn on the diode, and the negative feedback regulates the current through the load resistor to maintain an output voltage equal to the input voltage for these positive input voltages. For positive signals the circuit is a unity-gain buffer (fig 2). For negative signals, the output goes negative, and the diode turns off (fig 3). Because of the high open-loop gain of the op-amp, the circuit operates as a perfect switch for even very small voltages; hence it is called "super diode".
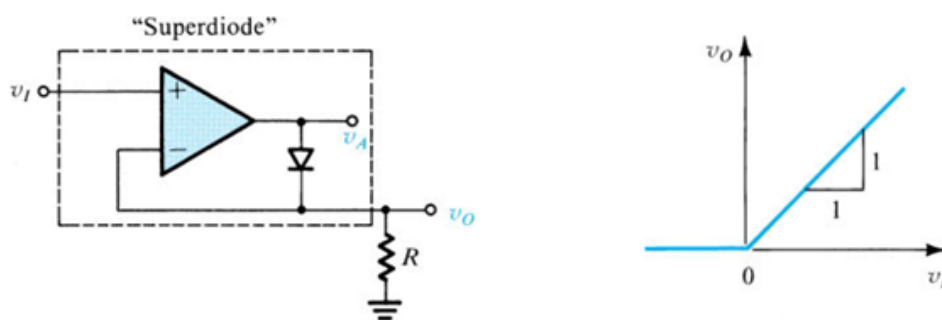

Fig 1. Circuit diagram of a precision rectifier and its input output relation.

When Diode is conducting: The feedback loop is closed, and the circuit looks like the buffer with small drop across diode. And Vo=Vin
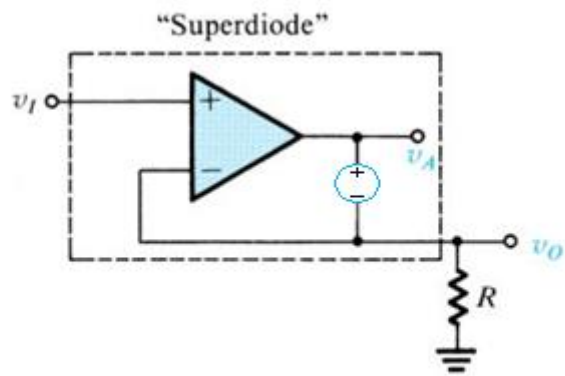
Fig 2. The circuit behaves as a buffer for positive input voltages.

When Diode is not conducting: i.e. $V_i < 0$ And $V_o = 0V$.
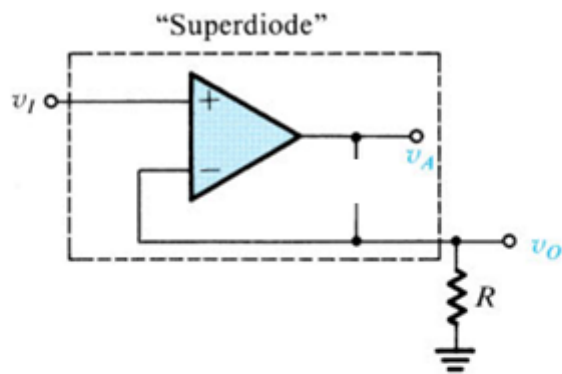
Fig 3. The diode acts as an open circuit for negative value of voltages.
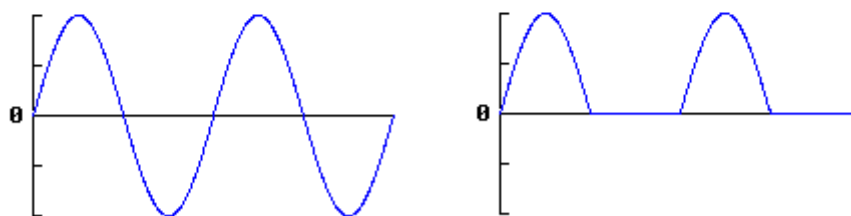
Fig 4. Input(a) and output (b) of a rectifier circuit.

CIRCUIT DIAGRAM:
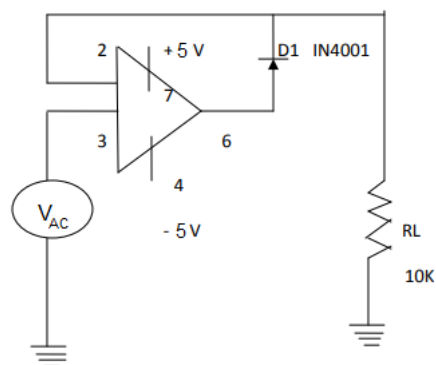
PROCEDURE:

1. Connect the relevant circuit for the precision/half wave rectifier as shown in the circuit diagram.

2. Check the output voltage V_o from AD Kit.

3. Observe the waveforms at input voltage and output voltage

4. The waveforms are to be plotted.

GRAPH:
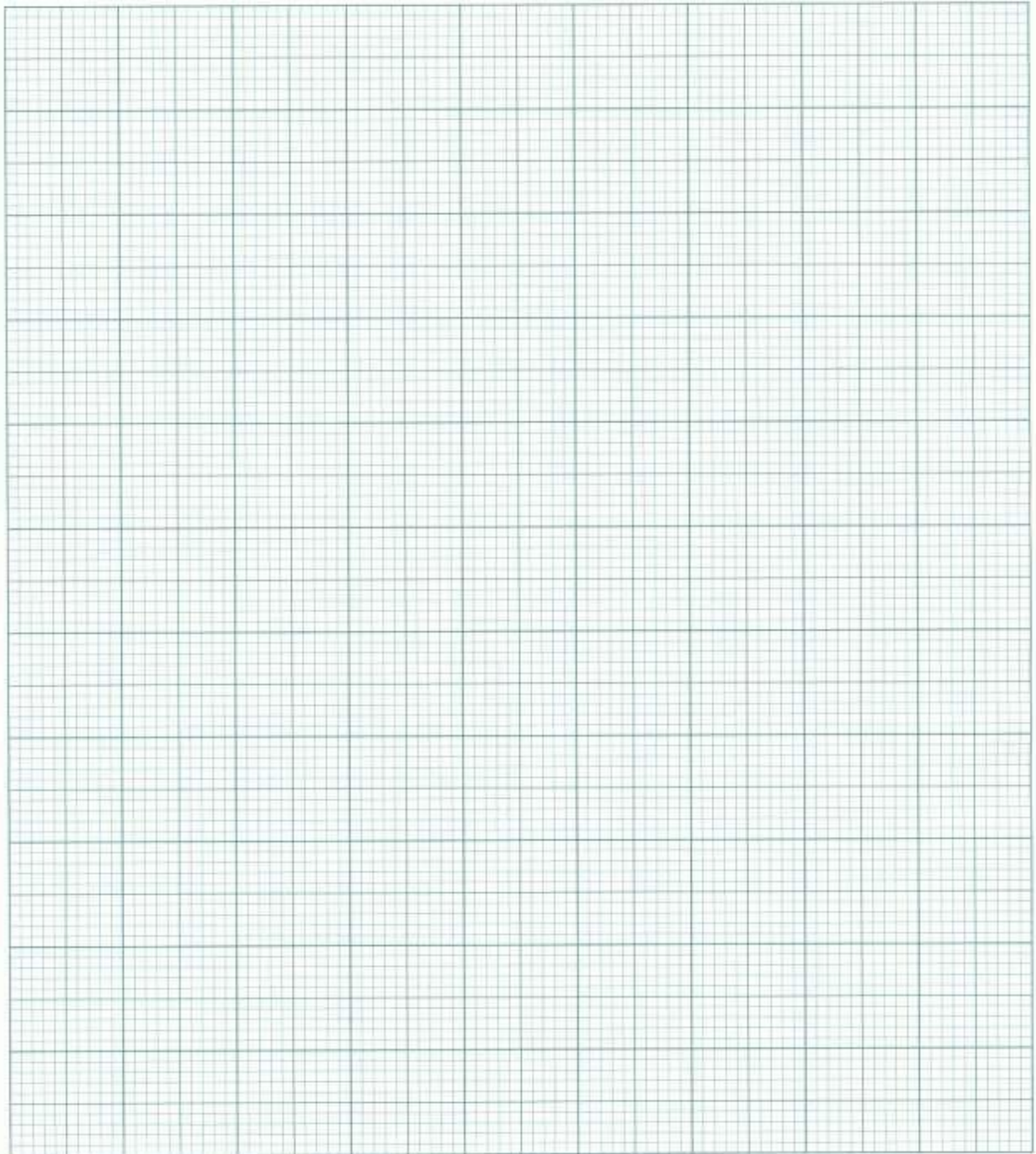
RESULT:

ANALOG TO DIGITAL CONVERTER (ADC)

AIM:

To design and implement a 8-bit Analog to Digital Converter circuit.

APPARATUS:

Analog Discovery Kit

8-Bit ADC Trainer Kit using IC ADC0808

Connecting Wires

Circuit Diagram & ADC 0808 IC Pin Diagram:

Successive Approximation type ADC

Successive Approximation type ADC is the most widely used and popular ADC method. The conversion time is maintained constant in successive approximation type ADC, and is proportional to the number of bits in the digital output, unlike the counter and continuous type A/D converters. The basic principle of this ty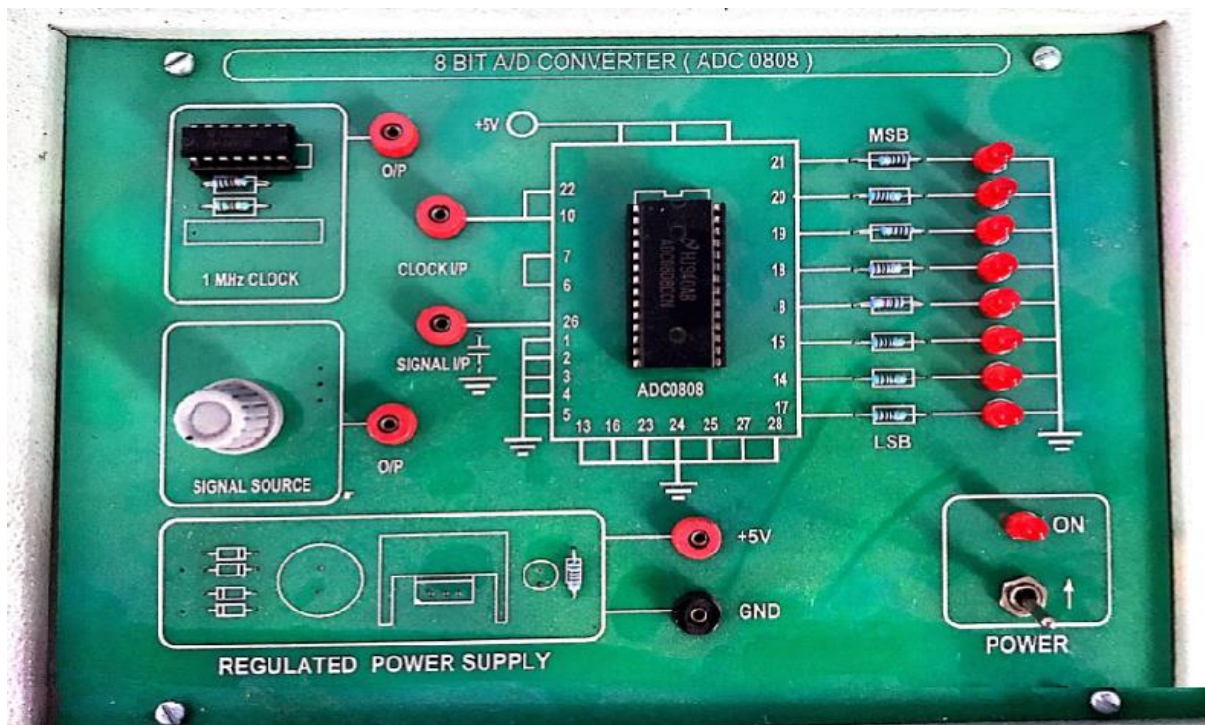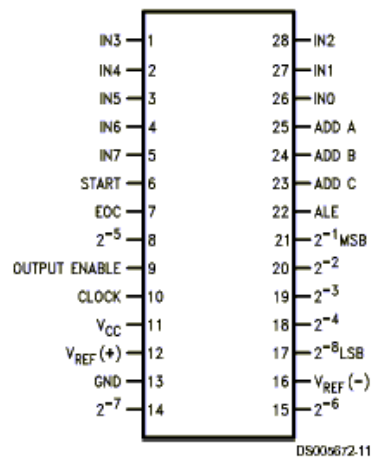pe of A/D converter is that the unknown analog input voltage is approximated against an n-bit digital value by trying one bit at a time, beginning with the MSB. The principle of successive approximation process for a 4-bit conversion is explained here. This type of ADC operates by successively dividing the voltage range by half, as explained in the following steps.

(1) The MSB is initially set to 1 with the remaining three bits set as 000. The digital equivalent voltage is compared with the unknown analog input voltage.

(2) If the analog input voltage is higher than the digital equivalent voltage, the MSB is retained as 1 and the second MSB is set to 1. Otherwise, the MSB is set to 0 and the second MSB is set to 1. Comparison is made as given in step (1) to decide whether to retain or reset the second MSB. The above steps are more accurately illustrated with the help of an example. Let us assume that the 4-bit ADC is used and the analog input voltage is $VA = 11$ V. when the conversion starts, the MSB bit is set to 1. Now $VA = 11V > VD = 8V = [1000]_2$ Since the unknown analog input voltage VA is higher than the equivalent digital voltage VD, as discussed in step (2), the MSB is retained as 1 and the next MSB bit is set to 1 as follows $VD = 12V = [1100]_2$

Now $VA = 11V < VD = 12V = [1100]_2$

Here now, the unknown analog input voltage VA is lower than the equivalent digital voltage VD. As discussed in step (2), the second MSB is set to 0 and next MSB set to 1 as $VD = 10V = [1010]_2$

Now again $VA = 11V > VD = 10V = [1010]_2$

Again, as discussed in step (2) VA>VD, hence the third MSB is retained to 1 and the last bit is set to 1. The new code word is $VD = 11V = [1011]_2$

Now finally $VA = VD$, and the conversion stops.

The functional block diagram of successive approximation type of ADC is shown below.
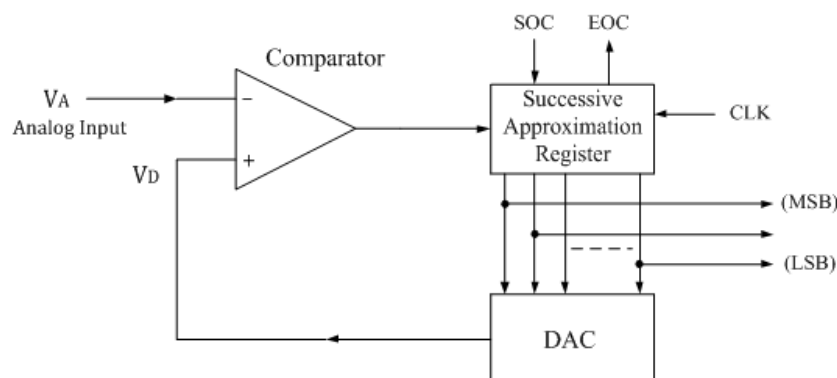
It consists of a successive approximation register (SAR), DAC and comparator. The output of SAR is given to n-bit DAC. The equivalent analog output voltage of DAC, VD is applied to the non-inverting input of the comparator. The second input to the comparator is the unknown analog input voltage VA. The output of the comparator is used to activate the successive approximation logic of SAR.

When the start command is applied, the SAR sets the MSB to logic 1 and other bits are made logic 0, so that the trial code becomes 1000.

PROCEDURE:

1. Complete the connections as per the diagram.
2. Switch ON the trainer kit.
3. Apply specified amount of analog input voltage.
4. Note down the corresponding digital Output value.

OBSERVATIONS:

S. No	Analog input voltage	Digital output Voltage

RESULT:
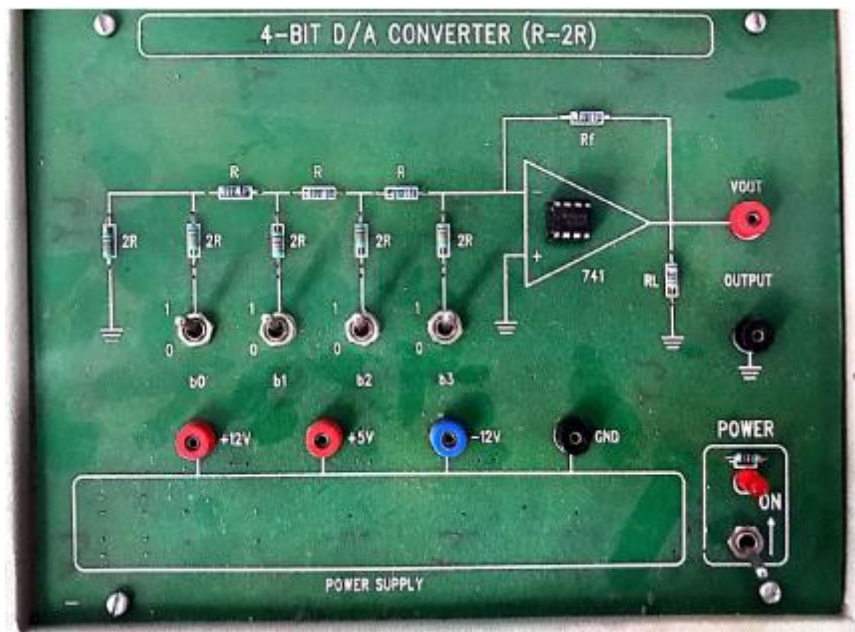
EXPERIMENT NO: 12
DIGITAL TO ANALOG CONVERTER (DAC)

AIM:

To design and implement a 4-bit Digital to Analog Converter circuit.

APPARATUS:

Analog Discovery Kit

4-Bit DAC Trainer Kit

Connecting Wires

LOGIC DIAGRAM:
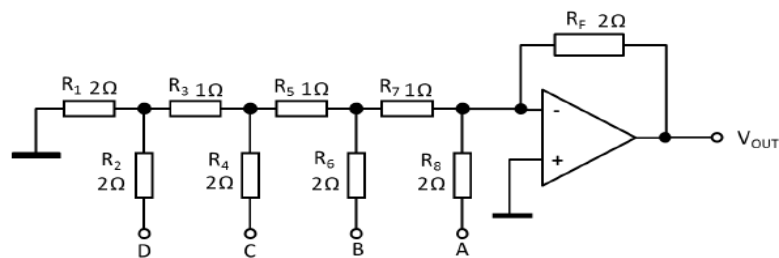
THEORY:

R-2R weighted resistor ladder network uses only 2 set of resistors- R and 2R. This is a 4 bit DAC. Let us consider the digital data $D_3D_2D_1D_0 = 0001$ is applied to the DAC, the analog Output Voltage is given by the following expression.

$$V_{out} = -\frac{R_f}{R_i} V_{ref} \left[\frac{D_0}{16} + \frac{D_1}{8} + \frac{D_2}{4} + \frac{D_3}{2} \right]$$

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PROCEDURE:

1. Connect the trainer kit to the mains and switch on the power supply.
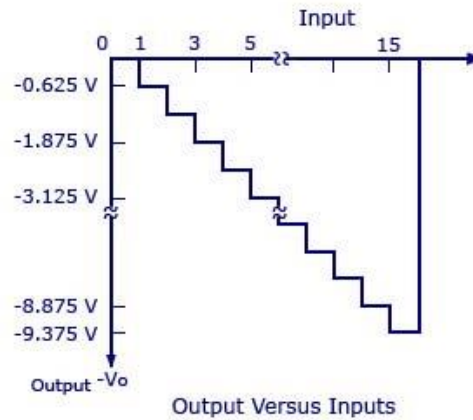2. Measure the supply voltages of the circuit as +12V and - 12V.
3. Calculate theoretically output voltage V_{out} for all digital Input data using the above expression.
4. Note down the Output voltages for different combinations of digital inputs and compare with theoretical values.

MODEL GRAPH:

Output Versus Inputs

TABLE:

Digital Input Data $D_3D_2D_1D_0$	Theoretical V_{out}	Practical V_{out}
0 0 0 0		
0 0 0 1		
0 0 1 0		
0 0 1 1		
0 1 0 0		
0 1 0 1		
0 1 1 0		
0 1 1 1		
1 0 0 0		
1 0 0 1		
1 0 1 0		
1 0 1 1		
1 1 0 0		
1 1 1 0		
1 1 1 1		

RESULT:

Vision of the Department

The Vision of Electrical and Electronics Engineering Department is to become a nationally and internationally leading institution of higher learning, building upon the culture and values of universal science and contemporary education, and a center of research and education generating the knowledge and the technologies which lay the groundwork in shaping the future in Electrical and Electronics Engineering.

Mission of the Department

To become an internationally leading department for higher learning.

To build upon the culture and values of universal science and contemporary education.

To be a center of research and education generating knowledge and technologies which lay groundwork in shaping the future in the fields of electrical and electronics engineering.

To develop partnership with industrial, R&D and government agencies and actively participate in conferences, technical and community activities.

Program Educational Objectives

This education is meant to prepare our students to thrive and to lead. In their careers, our graduates:

1.   Will have successful technical or professional careers, including supportive and leadership roles on multidisciplinary teams.
2.   Will acquire, use and develop skills required for effective professional practices.
3.   Will acquire the holistic education necessary to be a responsible member of society.
4.   Engage in life-long learning to remain current in their profession and be leaders in our technological society.

Programme Learning Outcomes:

Students in the Electrical and Electronics Engineering program should, at the time of their graduation, be in possession of:

A.   Ability to apply knowledge of mathematics, science, and engineering.
b.   Ability to design and conduct experiments, as well as to analyze and interpret data.
c.   Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
d.   Ability to function on multi-disciplinary teams.
e.   Ability to identify, formulate, and solve engineering problems.
f.   Understanding of professional and ethical responsibility.
G.   Ability to communicate effectively.
h.   Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
i.   Recognition of the need for, and an ability to engage in life-long learning.
J.   Knowledge of contemporary issues.
k.   Ability to utilize experimental, statistical and computational methods and tools necessary for engineering practice.
l.   Graduates will demonstrate an ability to design electrical and electronic circuits, power electronics, power systems, electrical machines analyze and interpret data and also an ability to design digital and analog systems and programming them.

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