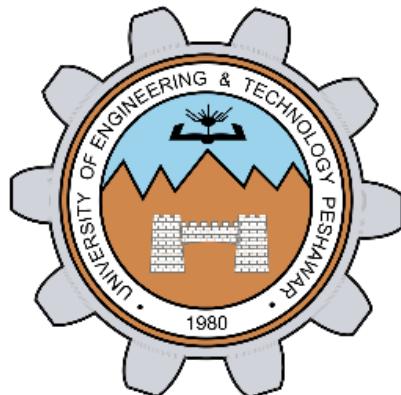


# CSE-206L ELECTRONIC CIRCUITS

## LAB MANUAL 2023



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# Experiment No. 1: Introduction Proteus

## Objectives:

In this lab we will learn the basics of Proteus Software and, we will make and simulate some basic circuits.

## Theory:

### Proteus:

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards.

## Main Window:

Main window when opened.

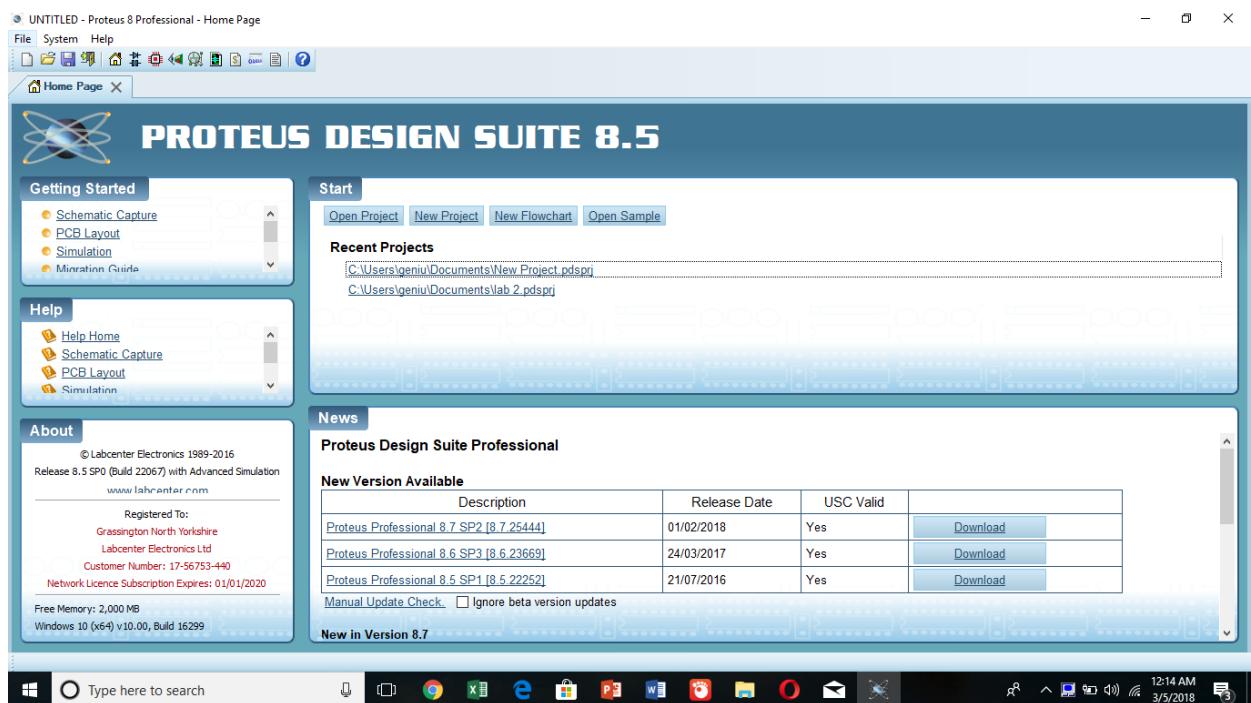


Figure 1 Main Window

## To Open a New Project:

To open a new project, select circled icon in the given image...

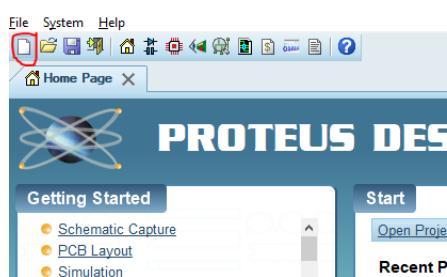


Figure 2 New Project

After that we will get this window...

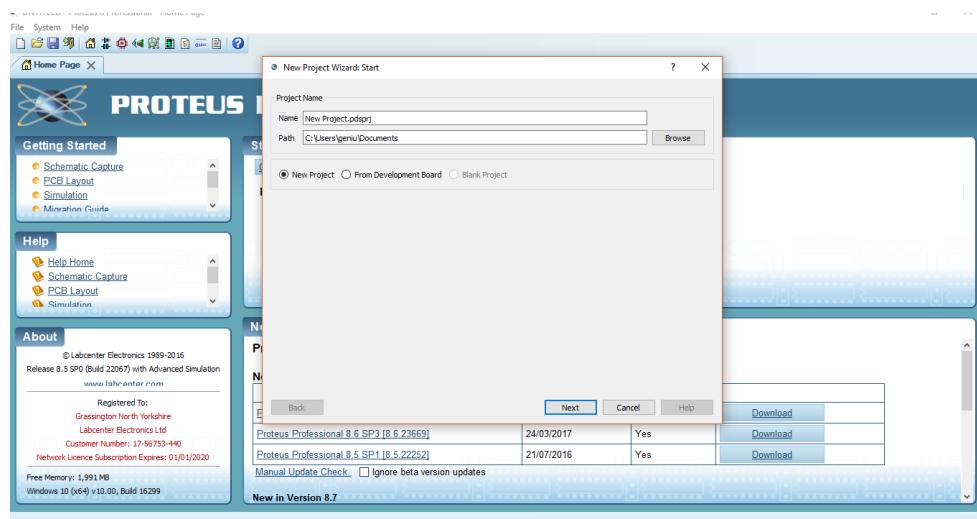


Figure 3 Option

After that select Portrait A4 from the options...

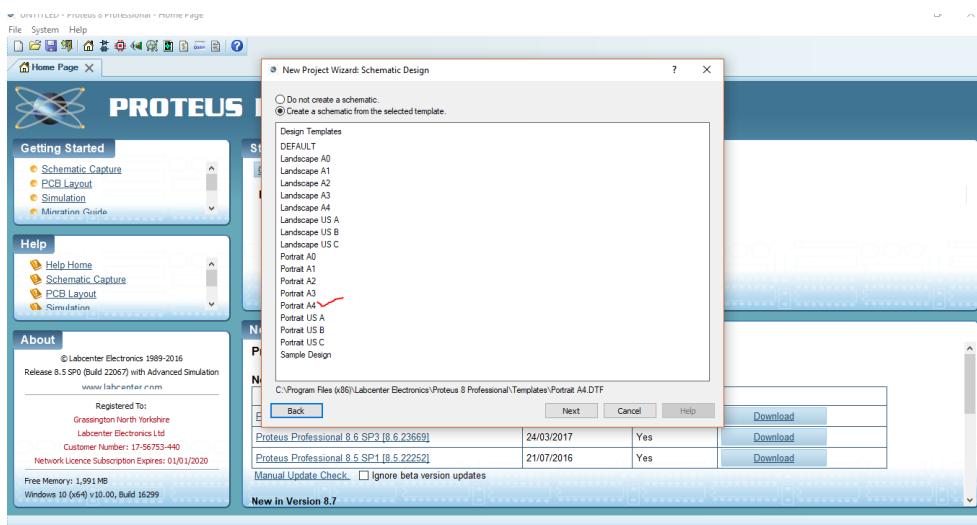


Figure 4 Options

After that select Single Eurocad (2 layer)...

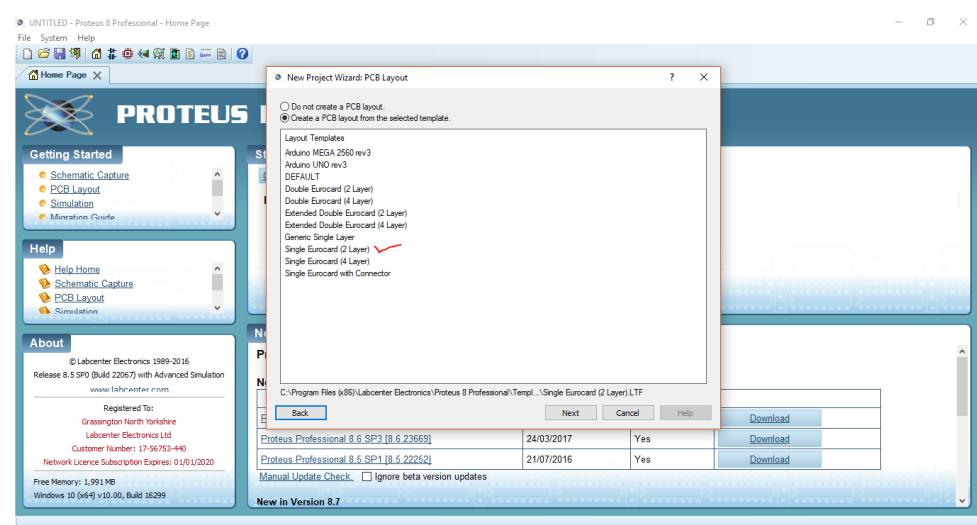


Figure 5 Options

So. after finishing this we will get this screen ...

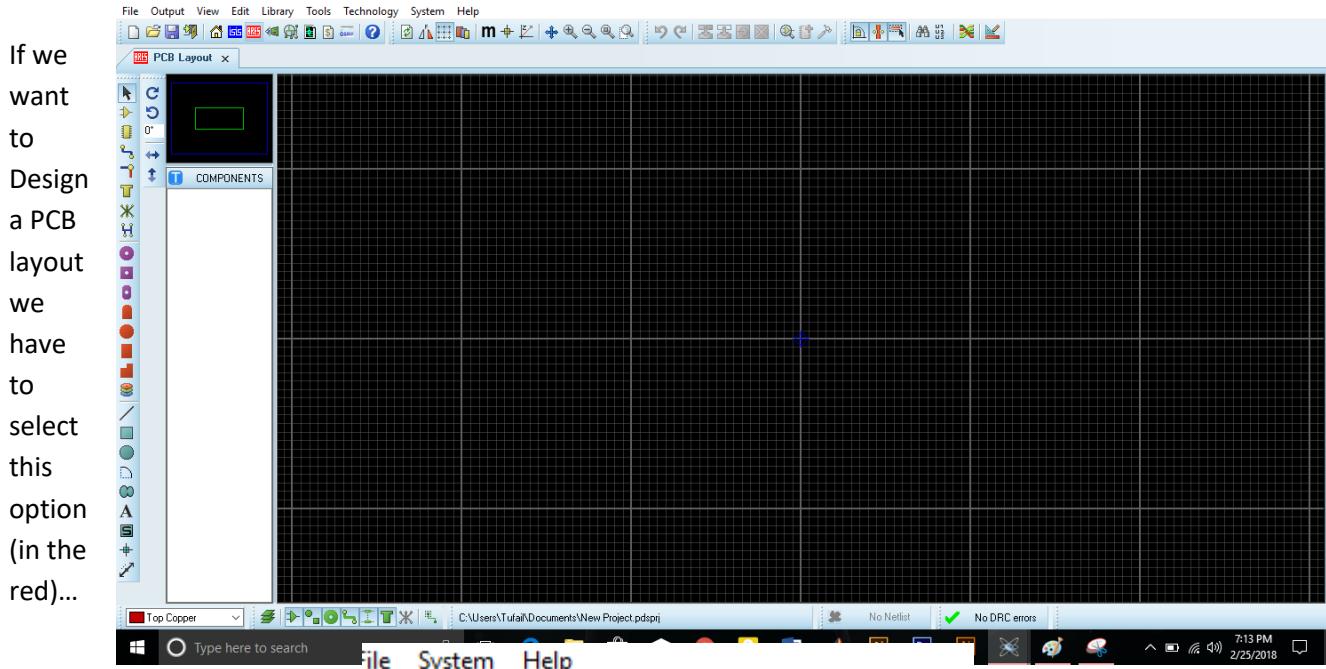


Figure 6 Main Interface

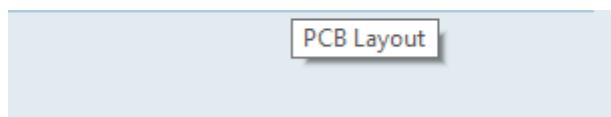


Figure 7 PCB Layout

If we want to Design Schematic we have to select this option (in the blue)...

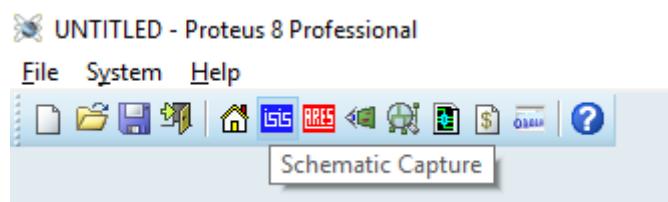


Figure 8 Schematic

### **Component Mode:**

For designing a circuit, we need components which can be selected from here below the arrow.

### New Project - Proteus 8 Profes

File Edit View Tool Design

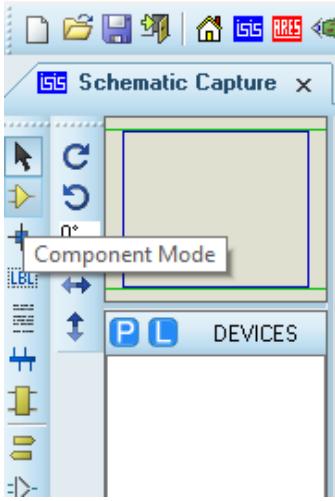


Figure 9 Component Mode

We will get this window to select or search for a specific component type the keyword of that component. We can select it from the category list or can search it directly by typing the keyword of element we want to search. E.g we have

searched for resistor. Keyword is res.

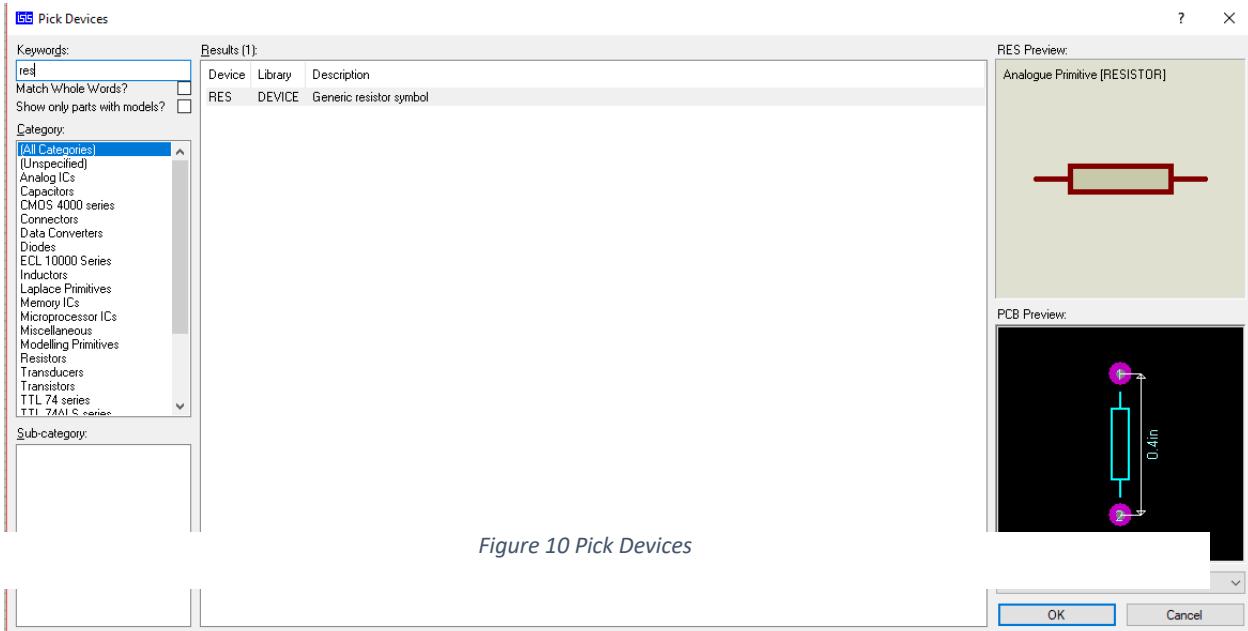
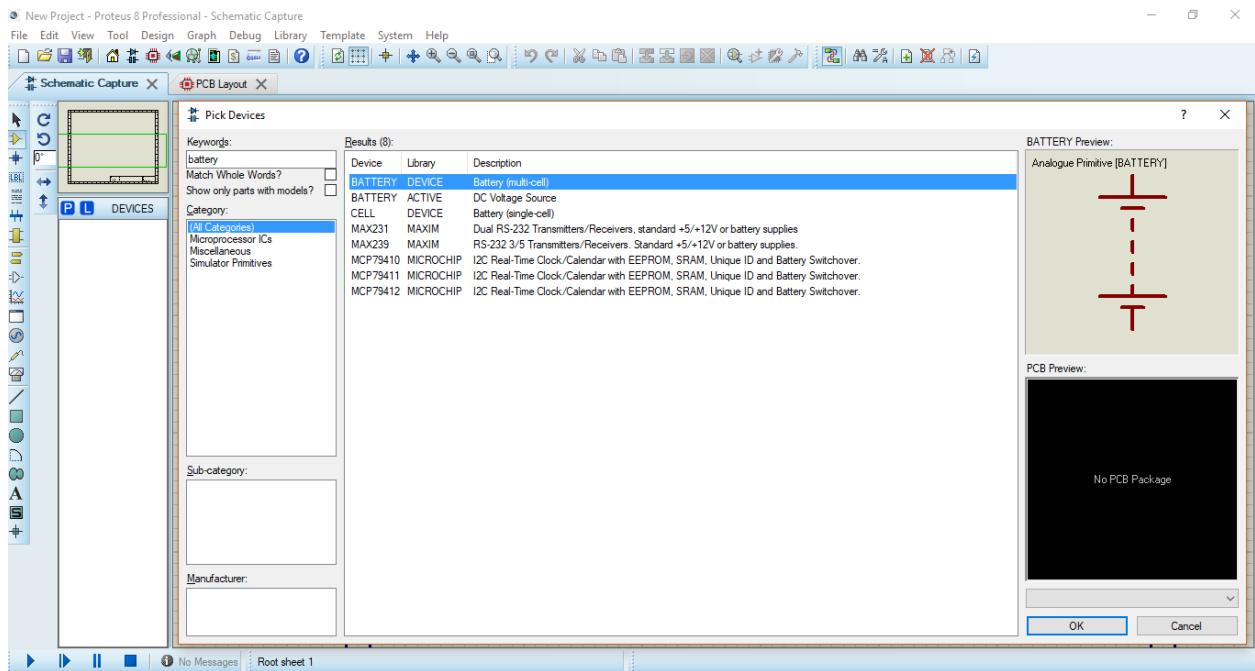
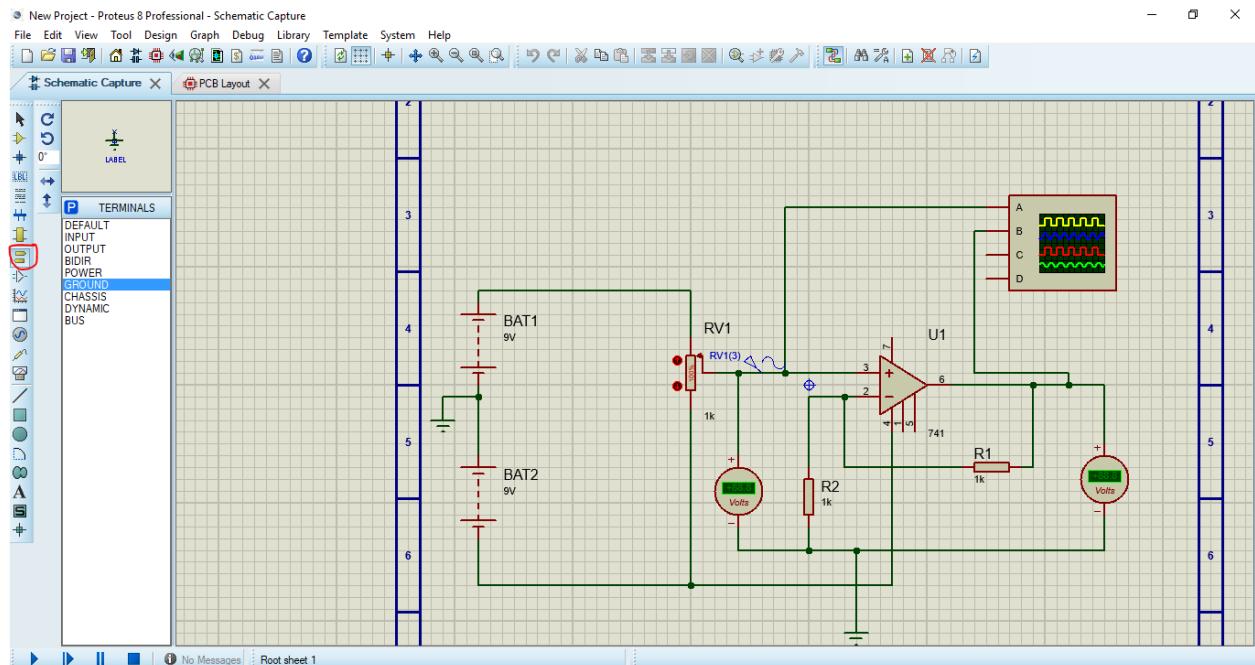


Figure 10 Pick Devices

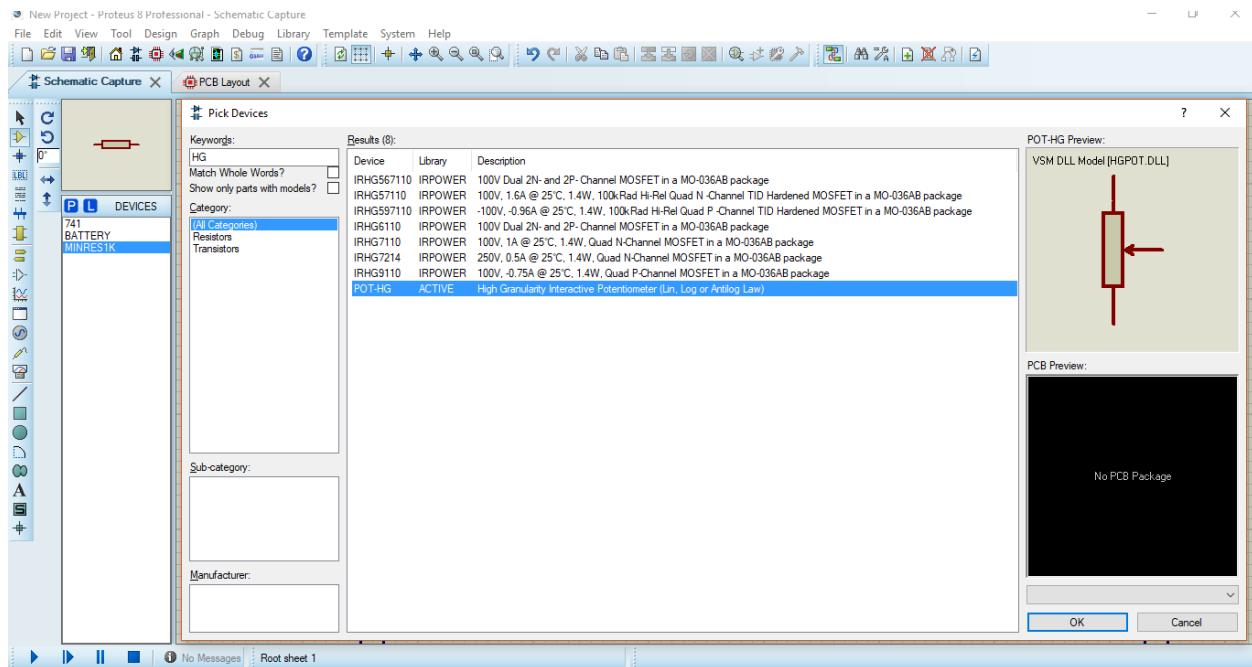
For selecting battery



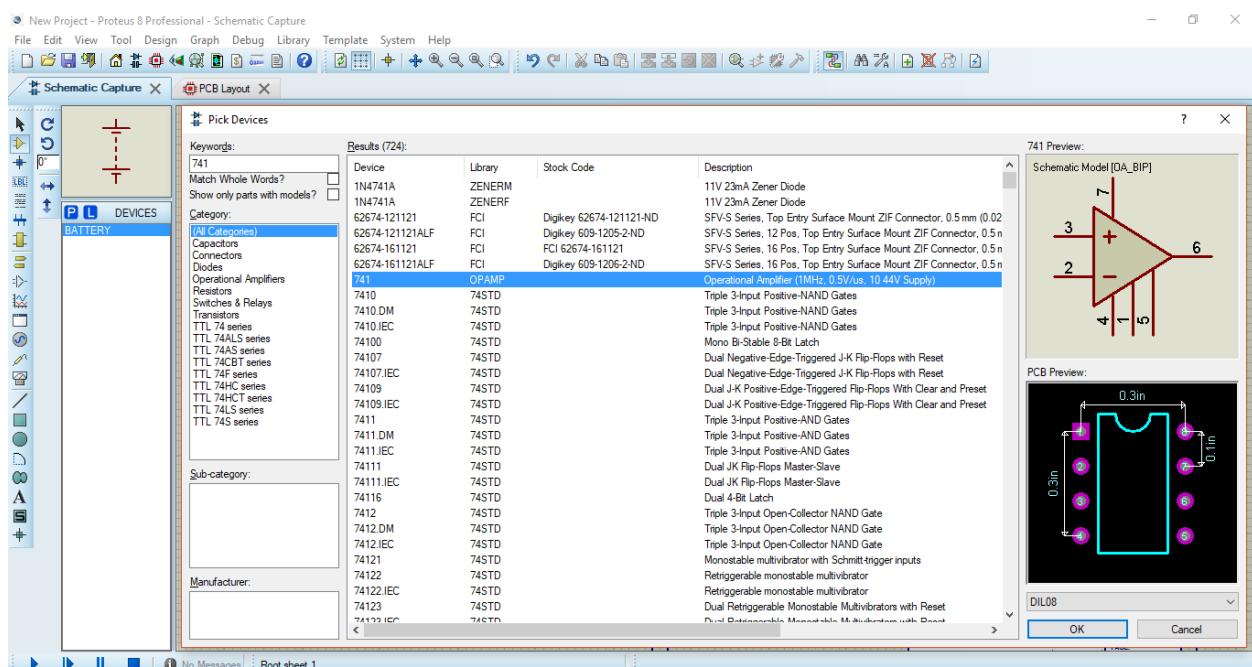
For selecting ground go to the Terminal Mode as shown below and Select GROUND



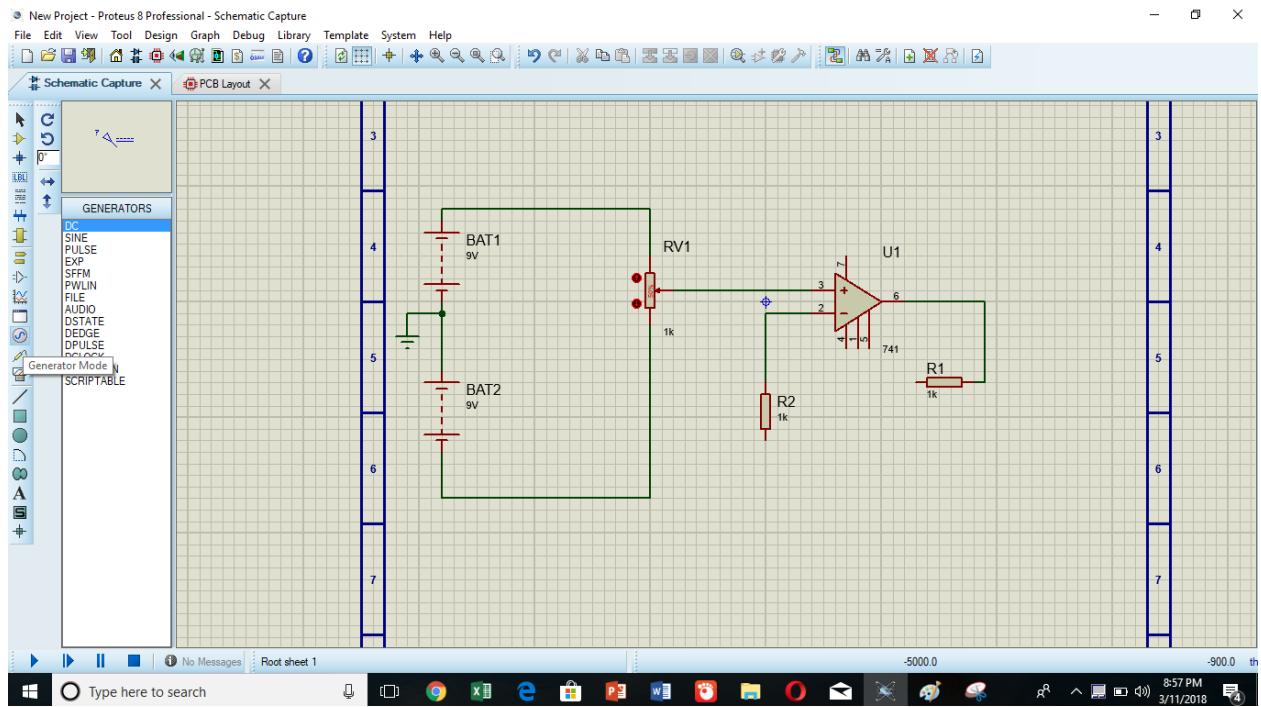
For potentiometer go to component mode and type HG



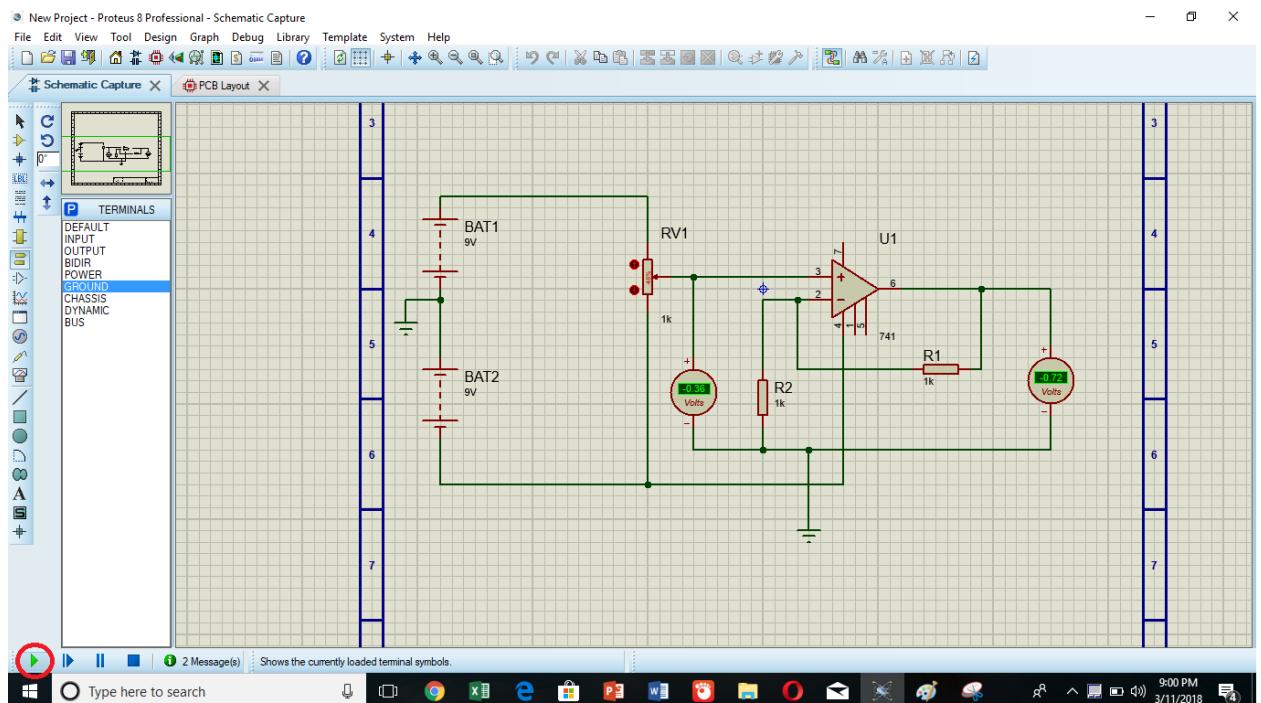
For Op-Amp type 741 or any model number



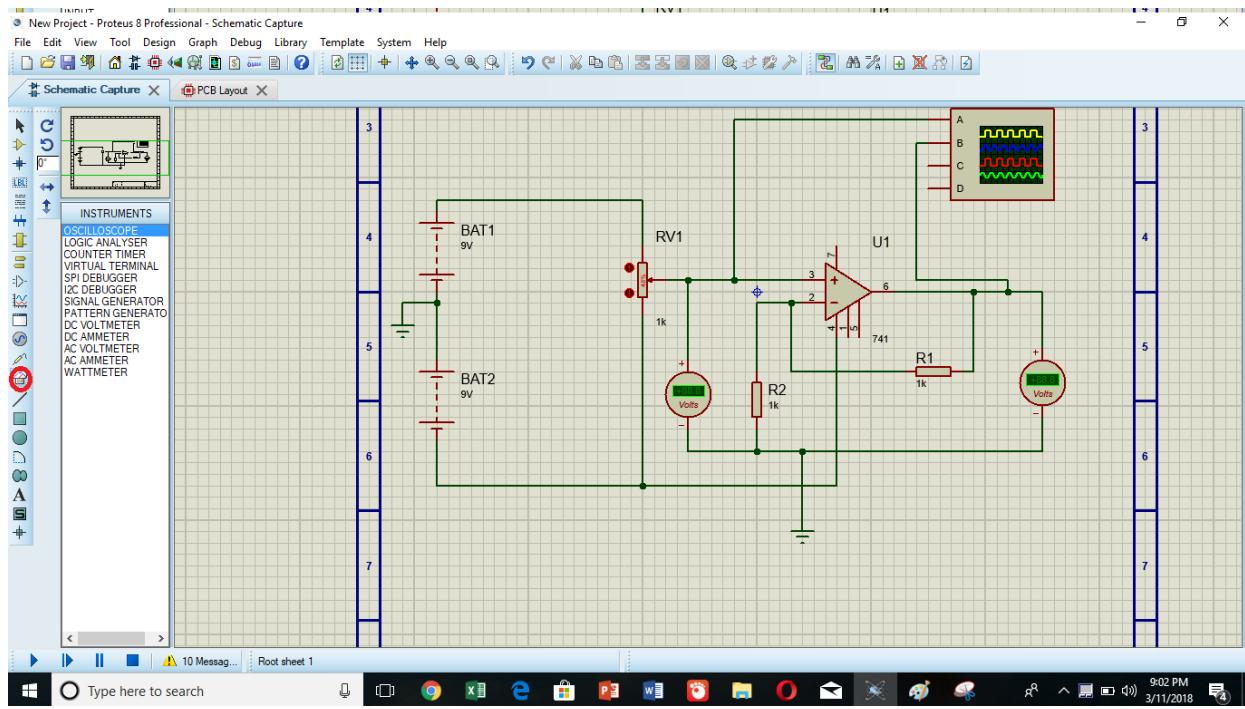
You can select DC or Sine in Generator mode as shown below.



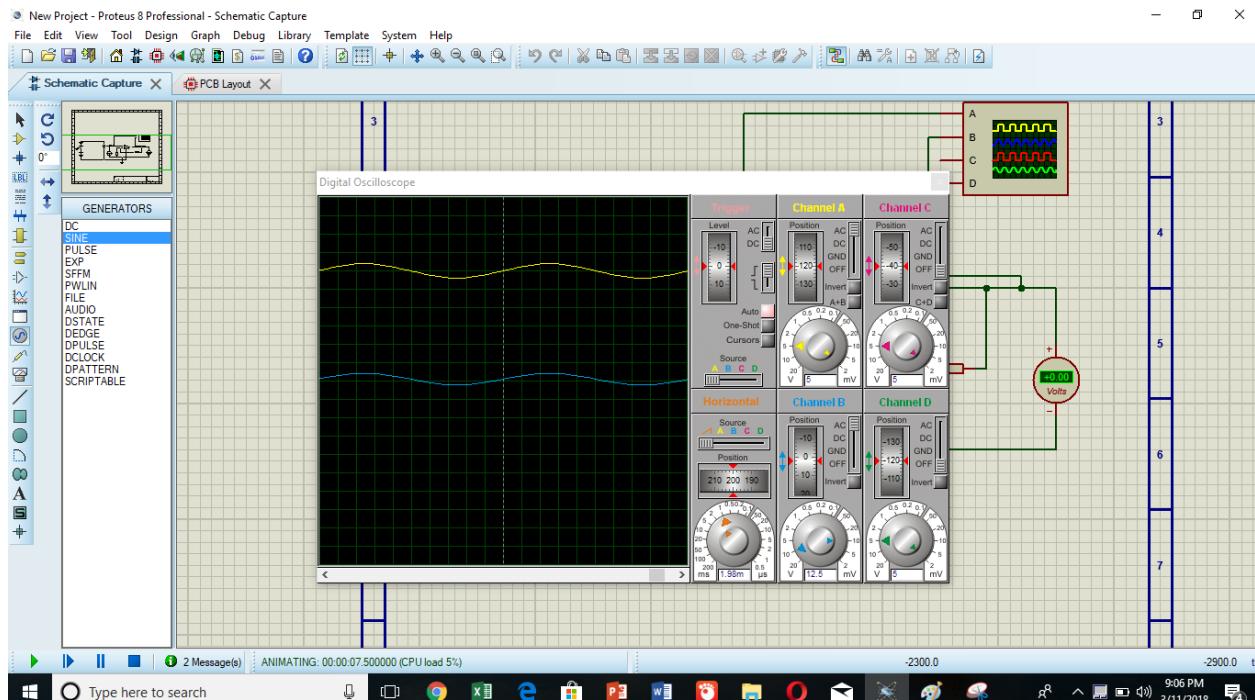
Click on the arrow in the bottom left for simulation.



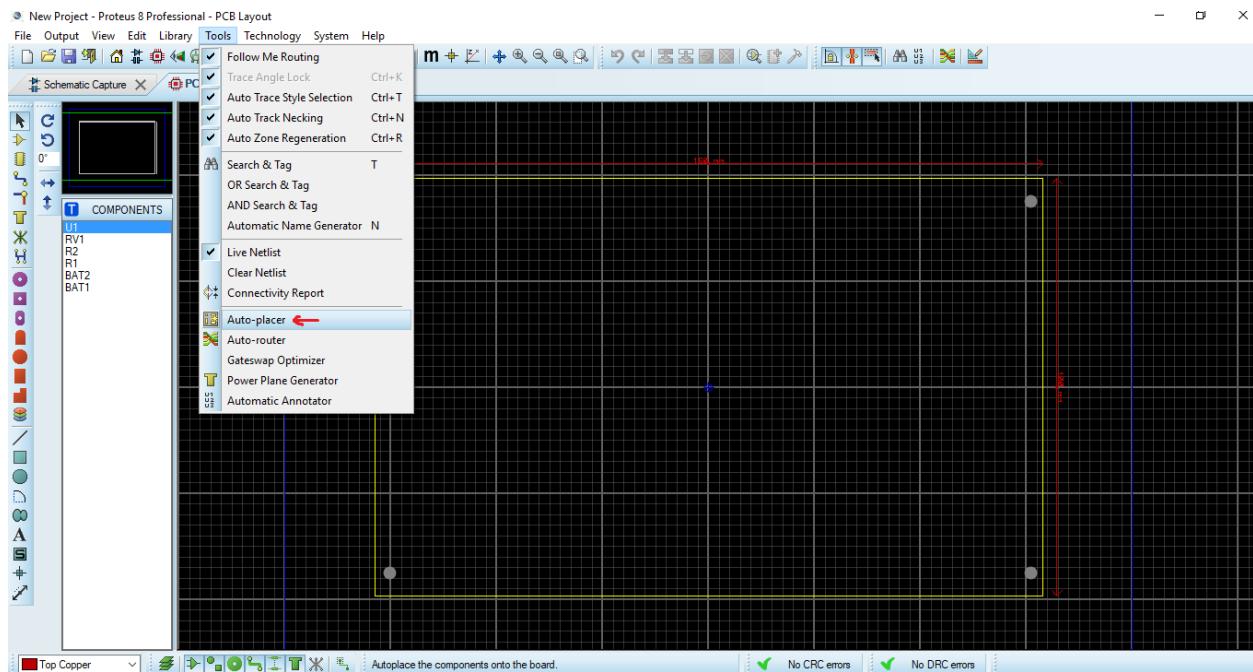
Now if you want to see the waves on oscilloscope you can select it from Instruments where you can also get voltmeter, ammeter etc.



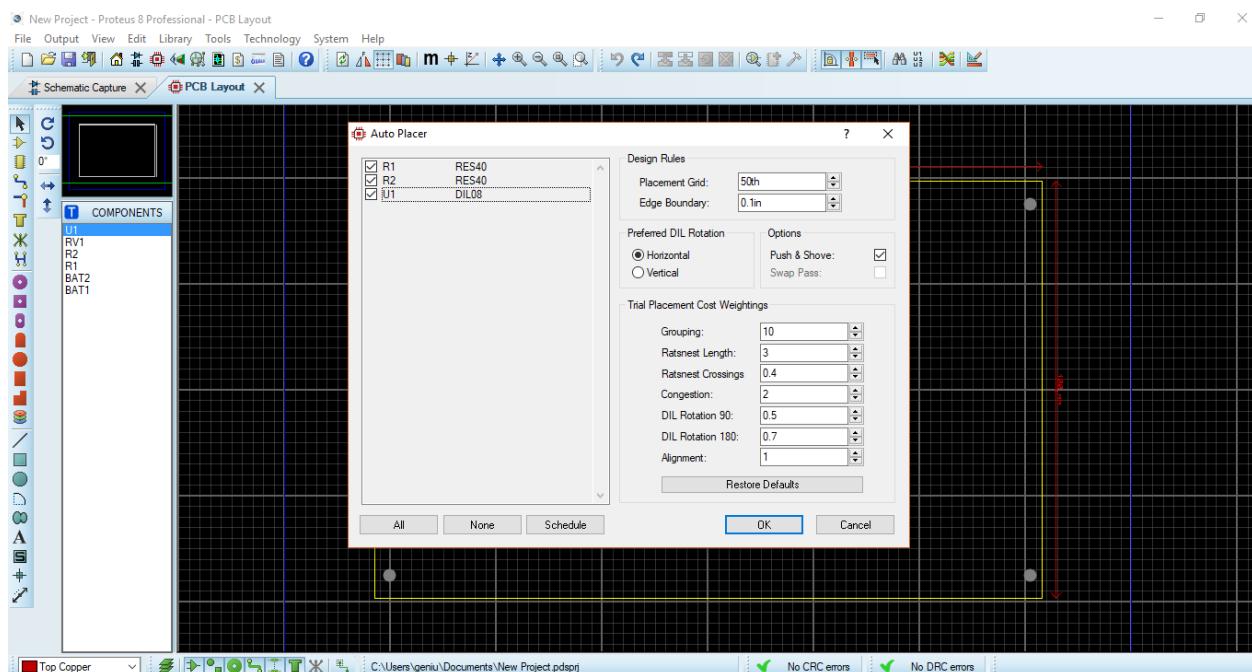
Here is the oscilloscope simulation.



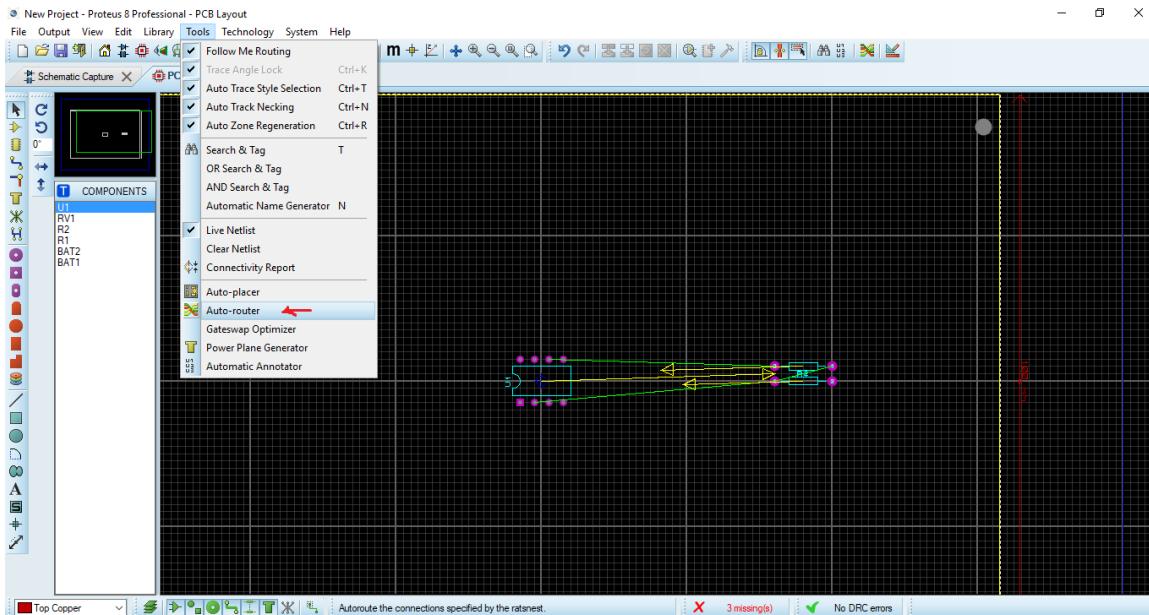
For PCB layout go to tools and click on auto placer



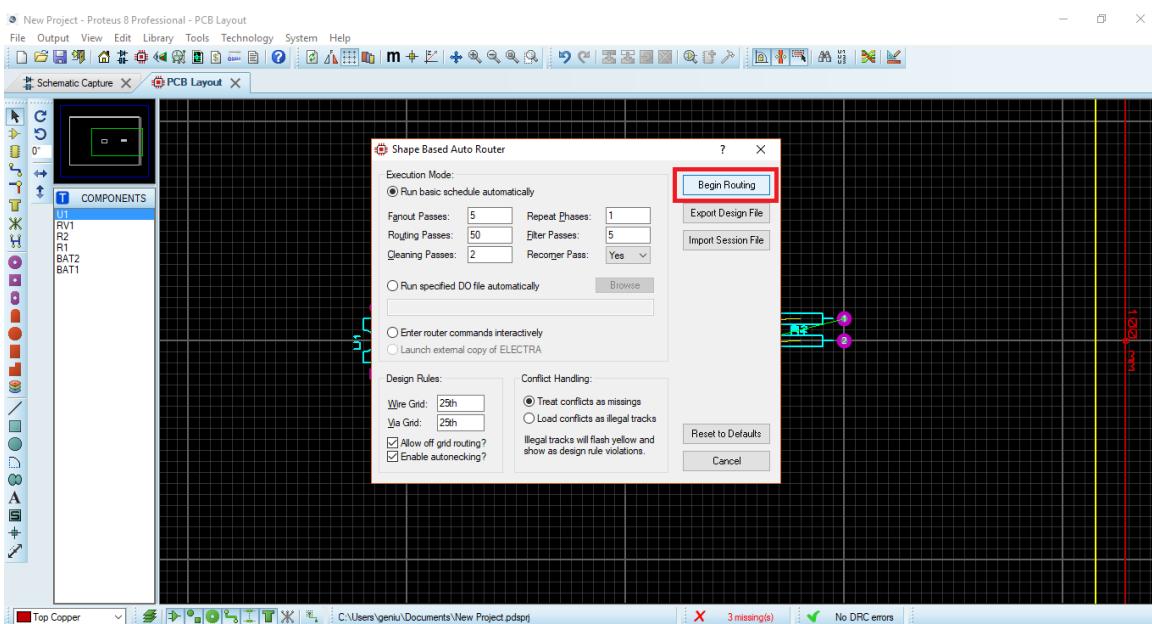
Then you will get this window and select all components then press ok



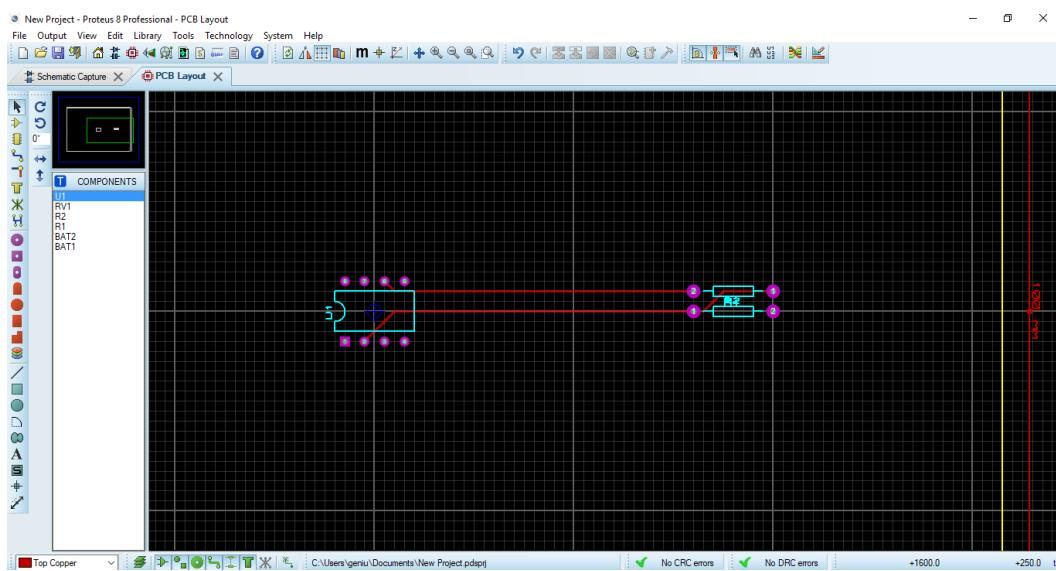
Now for routing purpose go to tools and select auto router.



Click on begin routing.



You will get the output result.



## Experiment No. 2: Diode Characteristics

### Objectives:

To study the characteristics of silicon and germanium diodes.

### Equipment:

DC power supply

Function Generator

Digital Multimeter (DMM)

### Components

Diodes: Silicon (D1N4002), Germanium (D1N4148)

Resistors:  $1\text{k}\Omega$ ,  $1\text{M}\Omega$

### Theory:

#### **Diode:**

A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low resistance in one direction, and high resistance in the other.

#### **Characteristics:**

- Three important characteristics of a diode are,
- first of all, the forward voltage drops. Under a forward bias condition, this should be about 0.7 volts.
- Then there is the reverse voltage drop. In the reverse, when we reverse bias the diode the depletion layer widens and usually, the applied voltages are felt across the diode.
- Then there is the reverse breakdown voltage. Reverse voltage drop that will reverse current flow and, in most cases, destroy the diode.

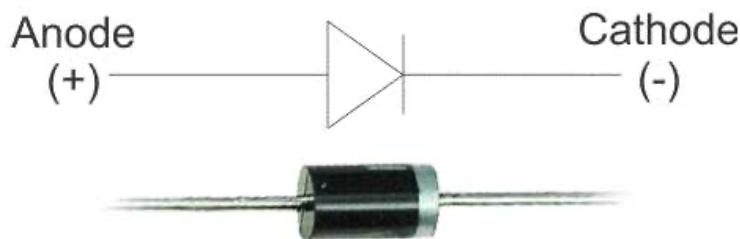


Figure 11 Diode

### Function Generator

A function generator is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine, square, triangular and saw tooth shapes.



Figure 2 Function Generator

## Power Supply

A *power supply* is an electronic device that supplies electric energy to an electrical load. The primary function of a *power supply* is to convert one form of electrical energy to another and, as a result *power supplies* are sometimes referred to as electric *power converters*.



Figure 3 DC Power Supply

## Digital Multimeter

A digital multimeter (DMM) is a test tool used to measure two or more electrical values principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries.



Figure 4 Digital Multimeter

## Procedure

### Part A: Forward-bias Diode Characteristics

1. Construct the circuit of *Fig. 3.1* with the supply (*E*) is set at 0 V. Record the measured value of the resistor.

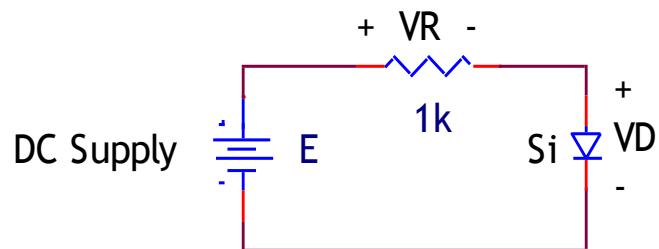


Fig. 3.1

2. Increase the supply voltage until  $V_D$  reads 0.1 V. Then measure current  $I_D$  and record the results in Table 3.1
3. Repeat step 2 for the remaining settings of  $V_D$  shown in the Table 3.1.  
Plot on a graph paper  $I_D$  versus  $V_D$  for the silicon. Complete the curves by extending the lower region of each curve to the intersection of the axis at  $I_D = 0$  mA and  $V_D = 0$  V.

## Part B: Reverse-bias Diode Characteristics

1. Construct the circuit of Fig. 3.2 with E is set at 20V. Record the measured value of the resistor.

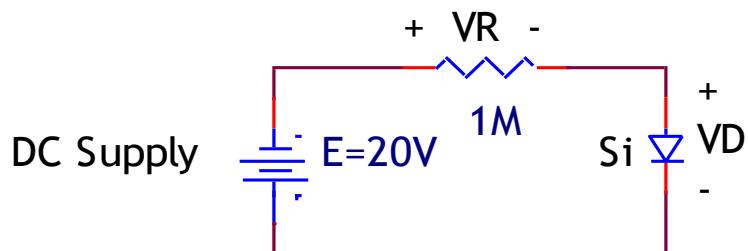
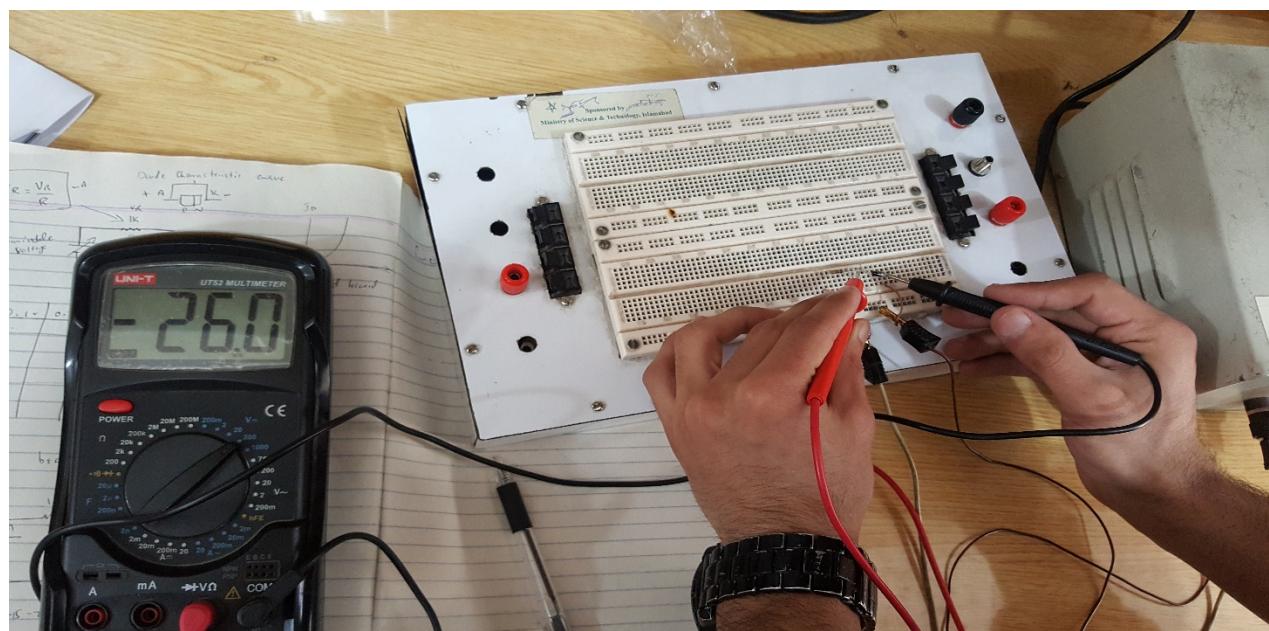


Fig. 3.2

2. Measure the voltage  $V_D$ . Measure the reverse saturation current,  $I_s$ .

## Results and Calculations:



**Part A (Forward Bias):**R (measured) = **1k Ω**I<sub>D</sub> (measured). Fill in Table 3.1

V <sub>D</sub> (V)	0.13	0.21	0.37	0.42	0.51	0.60
V <sub>R</sub> (V)	0.5 mV	0.7 mV	14.5 mV	26.2 mV	2V	12.72V
I <sub>D</sub> (mA)	0.0005mA	0.0007mA	0.0145mA	0.0262mA	2mA	12.72mA

Table 3.1(Silicon Diode)

**Part B (Reverse Bias):**R (measured) = **1M Ω****Silicon Diode**

V <sub>D</sub> (V)	-10.77	-15.21	-20.8	-25.0
V <sub>R</sub> (V)	-4.3 mV	-5.3 mV	-5.6 mV	-5.9 mV
I <sub>D</sub> (nA)	-4.3 nA	-5.3 nA	-5.6 nA	-5.9 nA

Figure 4 Forward Biased

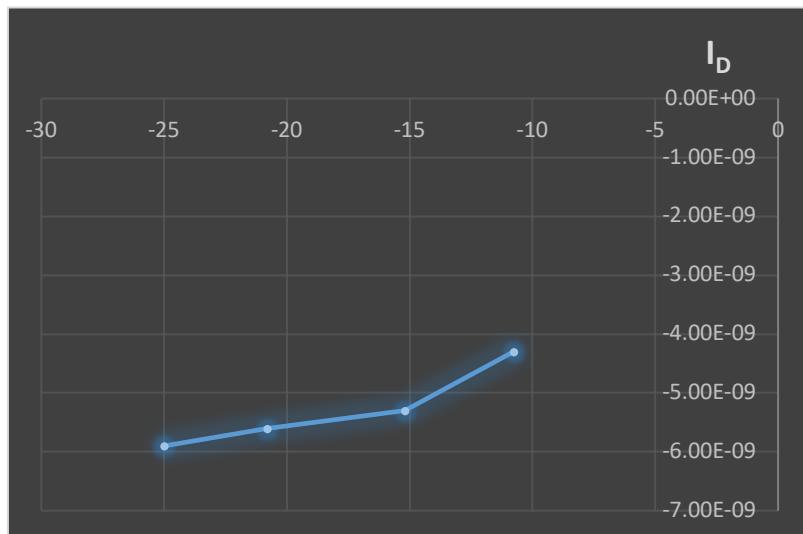
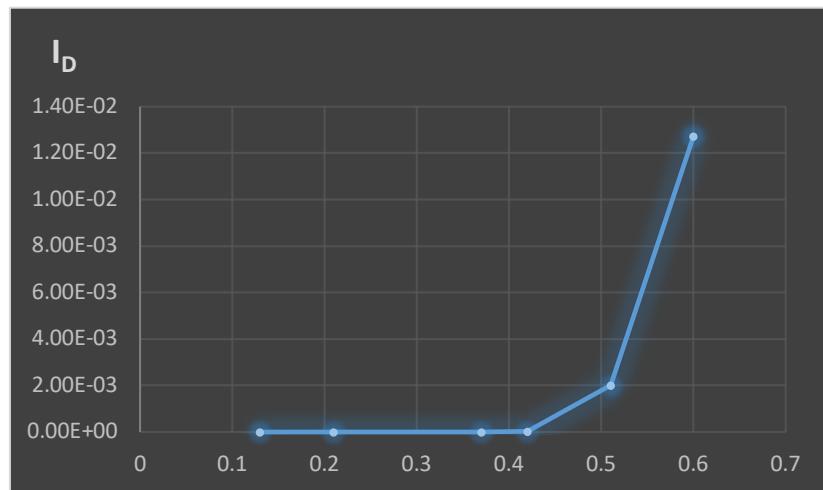


Figure 5 Reverse Biased

### Conclusion:

Hence, we practically observed the characteristics of diode in both forward and reversed biased using digital multimeter. In forward biased we saw the gradual increase in current  $I_D$  with the increase in voltage  $V_D$ . whereas in reverse biased we selected  $V_D$  from  $-10.77V$  to  $-25.0V$  on which we got the values of current  $I_D$  from  $-4.3 \text{ nA}$  to  $-5.9 \text{ nA}$ .

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## **Experiment No. 3: Series and Parallel Diodes**

### **Objectives:**

To study the characteristics of silicon diodes in series and in parallel.

### **Equipment:**

DC power supply

Function Generator

Digital Multimeter (DMM)

### **Components**

Diodes: Silicon (D1N4002)

Resistor:  $1.8\text{ k}\Omega$ ,

### **Theory:**

#### **Diode:**

A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low resistance in one direction, and high resistance in the other.

### **Series Configuration**

Series connection means a side-by-side connection. When two components are connected in series, they have one common junction. The variation of voltage and current in a series connection is as follows:

- Potential difference across every component is different.
- The current across every component connected in series remains the same.

#### **Diode Characteristics in Series Configuration**

When connected in series, we observe the following properties to hold true among the diodes:

- Resultant diode's forward voltage increases.
- Reverse blocking capabilities of diodes are increased in series connection.

### **Parallel configuration**

Parallel connection means the components are connected across each other, having two common points. Current differs across each component while voltage drop is same. When diodes are connected in parallel, this same trend is observed.

#### **Diode Characteristics in Parallel Configuration**

- Current carrying capacity increases.
- No conduction in resultant diode in both sides.

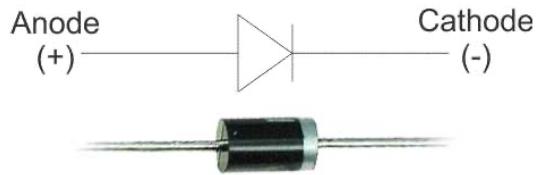


Figure 12 Diode

## Function Generator

A function generator is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine, square, triangular and saw tooth shapes.



Figure 2 Function Generator

## **Power Supply**

A *power supply* is an electronic device that supplies electric energy to an electrical load. The primary function of a *power supply* is to convert one form of electrical energy to another and, as a result *power* supplies are sometimes referred to as electric *power* converters.



Figure 3 DC Power Supply

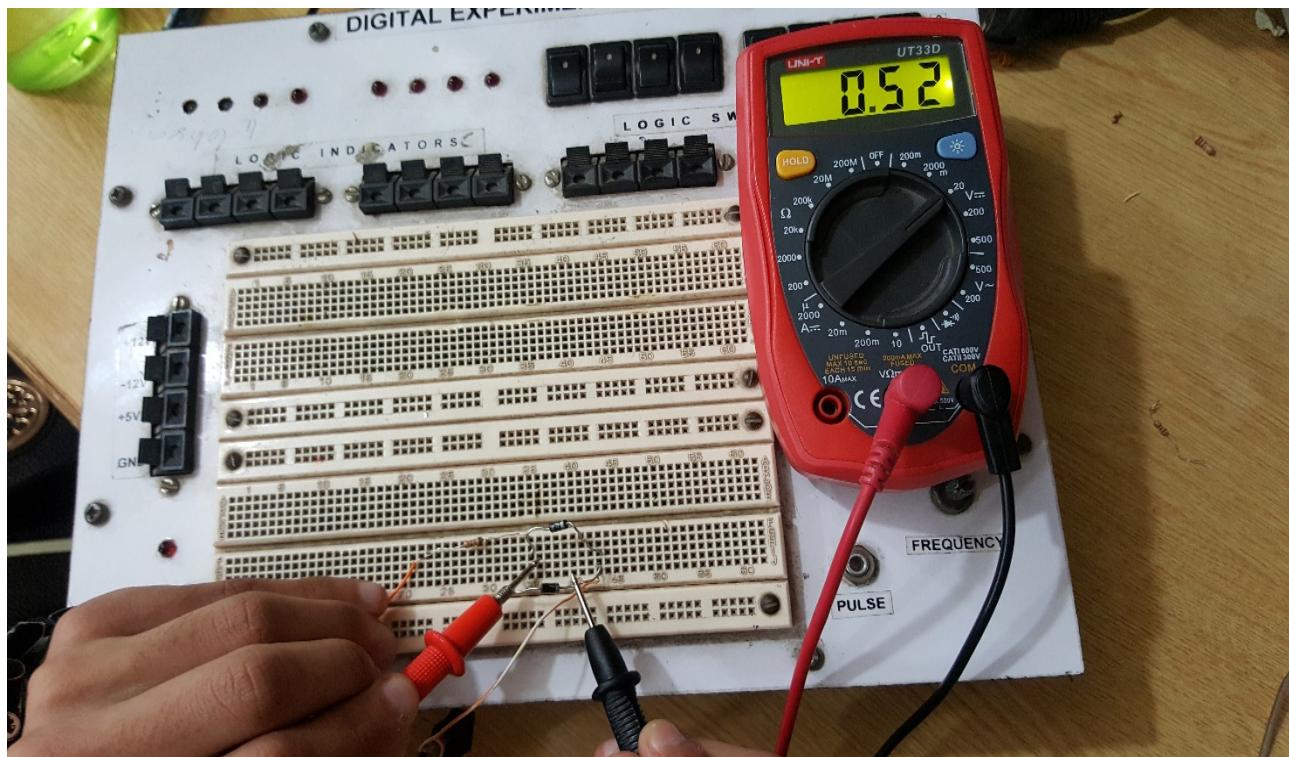
## Digital Multimeter

A digital multimeter (DMM) is a test tool used to measure two or more electrical values principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries.



Figure 4 Digital Multimeter

## Procedure



## Part 1: Diode in Series

4. Construct the circuit of *Fig. 1.0* with the supply (E) is set at 5 V. Record the measured value of the resistor.

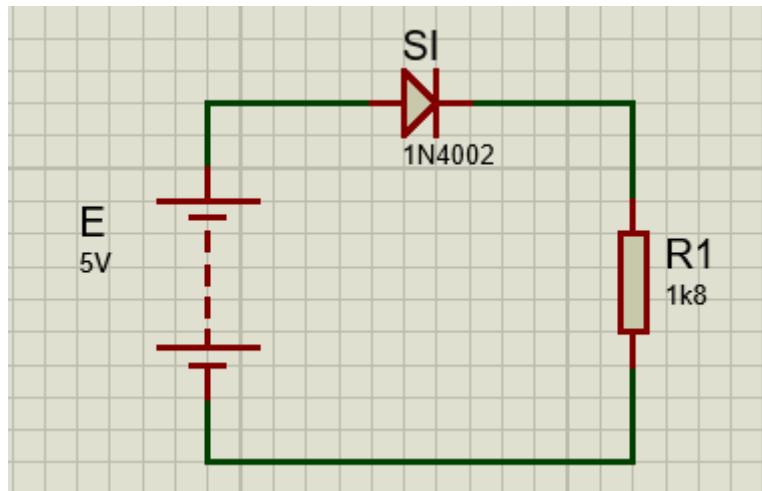


Figure 1.0

5. Measure the value of voltage across diode  $V_D$  and  $V_O$ .  
6. Also calculate the current  $I_D$ .

### Results:

#### Calculated:

Supplied Voltage = **5.22 V**

Voltage  $V_D$  = **0.63 V**

Resistance  $R$  = **1.76 kΩ**

Voltage  $V_O$  = **5.22 – 0.63 = 4.59 V**

Current  $I_D$  = **2.60 mA**

#### Measured:

Supplied Voltage = **5.22 V**

Voltage  $V_D$  = **0.56 V**

Resistance  $R$  = **1.76 kΩ**

Voltage  $V_O$  = **4.67 V**

Current  $I_D$  = **2.65 mA**

## Part 2: 2 Diodes in Series

1. Construct the circuit of *Fig. 1.1* with the supply (E) is set at 5 V. Record the measured value of the resistor.

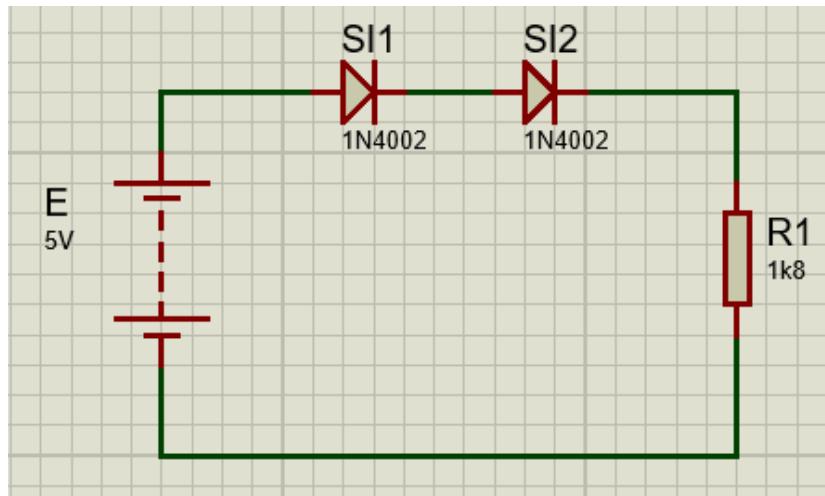


Figure 1.1

2. Measure the value of voltage across diode  $V_D$  and  $V_O$ .
3. Also calculate the current  $I_D$ .

### Results:

#### Calculated:

Supplied Voltage = **5.22 V**

Voltage  $V_{T1}$  = **0.63 V**

Voltage  $V_{T2}$  = **0.60 V**

Voltage  $V_D = V_{T1} + V_{T2} = 1.23 \text{ V}$

Resistance  $R = 1.76 \text{ k}\Omega$

Voltage  $V_O = 5.22 - 1.23 = 3.99 \text{ V}$

Current  $I_D = 2.62 \text{ mA}$

#### Measured:

Supplied Voltage = **5.22 V**

Voltage  $V_D = 1.23 \text{ V}$

Resistance  $R = 1.76 \text{ k}\Omega$

Voltage  $V_O = 4.13 \text{ V}$

Current  $I_D = 2.34 \text{ mA}$

### Part 3: Diodes in Parallel

1. Construct the circuit of *Fig. 1.3* with the supply (E) is set at 5 V. Record the measured value of the resistor.

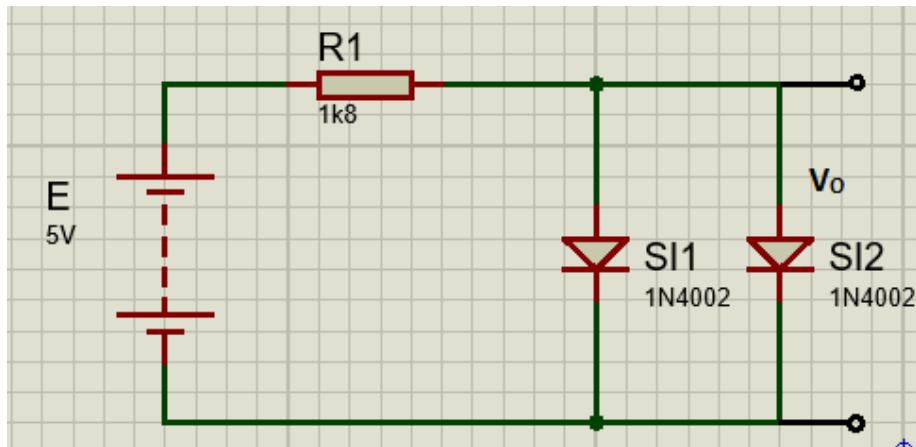


Figure 1.3

2. Measure the value of voltage across diode V<sub>D</sub> and V<sub>O</sub>.
3. Also calculate the current I<sub>D</sub>.

### Results:

#### Calculated:

Supplied Voltage = **5.22 V**

Voltage V<sub>T1</sub> = **0.63 V**

Voltage V<sub>T2</sub> = **0.60 V**

Voltage V = V<sub>T1</sub> + V<sub>T2</sub> = **1.23 V**

Resistance R = **1.76 kΩ**

Voltage V<sub>O</sub> = **0.60 V**

Voltage V<sub>R</sub> = **5.22 – 0.60 = 4.62 V**

#### Measured:

Voltage V<sub>O</sub> = **0.53 V**

Voltage V<sub>R</sub> = **4.70 V**

**Conclusion:**

Hence, we practically observed the behavior of diodes in both series and parallel. We saw that,

- Connecting diodes in series will increase the forward voltage of the resultant diode.
  - Connecting diodes in series will cause an open circuit until peak inverse voltage (smallest diode) is applied on total resultant.
  
  - Connecting diodes in parallel will increase the current carrying capacity of the diode.
  - Connecting diodes in parallel will not get you a resultant diode conduction in both sides.
-

## Experiment No. 4: Diode as Rectifier

### Objectives:

To become familiar with Full wave and Half wave rectification.

### Equipment:

Oscilloscope

Function Generator

Digital Multimeter (DMM)

### Components

Diodes: Silicon (D1N4002)

Resistor:  $2.2\text{ k}\Omega$ ,

### Theory:

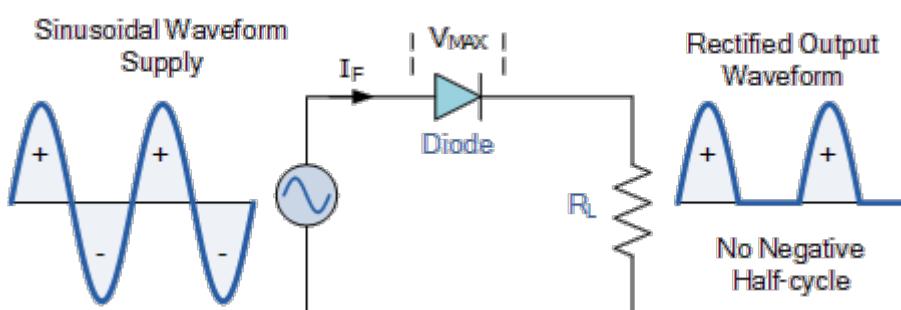
#### Diode:

A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low resistance in one direction, and high resistance in the other.

A widely used application of this feature and diodes in general is in the conversion of an alternating voltage (AC) into a continuous voltage (DC). In other words, *Rectification*.

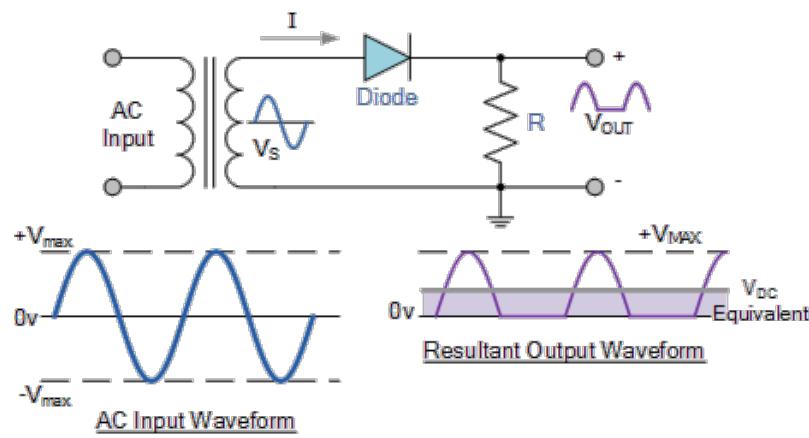
Power diodes can be used individually as above or connected together to produce a variety of rectifier circuits such as “Half-Wave”, “Full-Wave” or as “Bridge Rectifiers”.

### Half Wave Rectification

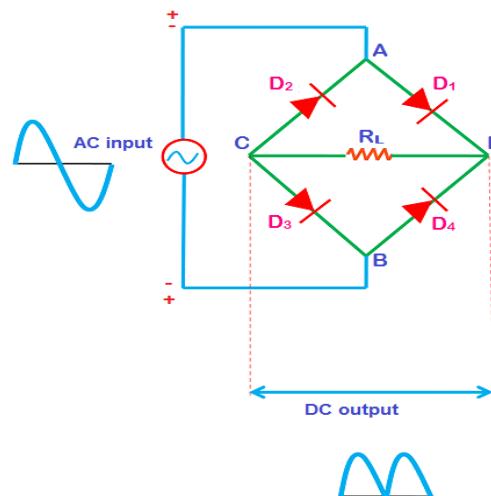


A rectifier is a circuit which converts the *Alternating Current* (AC) input power into a *Direct Current* (DC) output power. The input power supply may be either a single-phase or a multi-phase supply with the simplest of all the rectifier circuits being that of the **Half Wave Rectifier**.

The power diode in a half wave rectifier circuit passes just one half of each complete sine wave of the AC supply in order to convert it into a DC supply. Then this type of circuit is called a “half-wave” rectifier because it passes only half of the incoming AC power supply as shown.

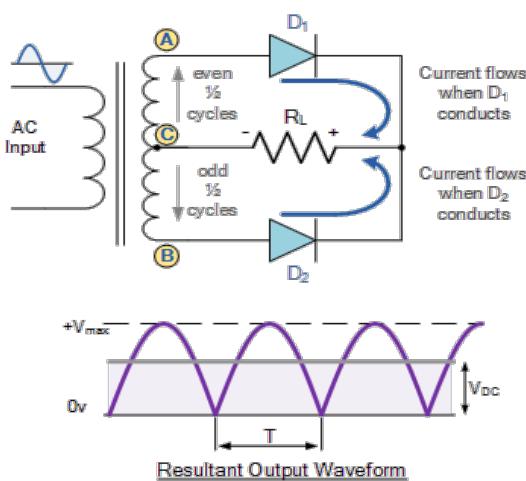


### Full Wave Rectifier Circuit



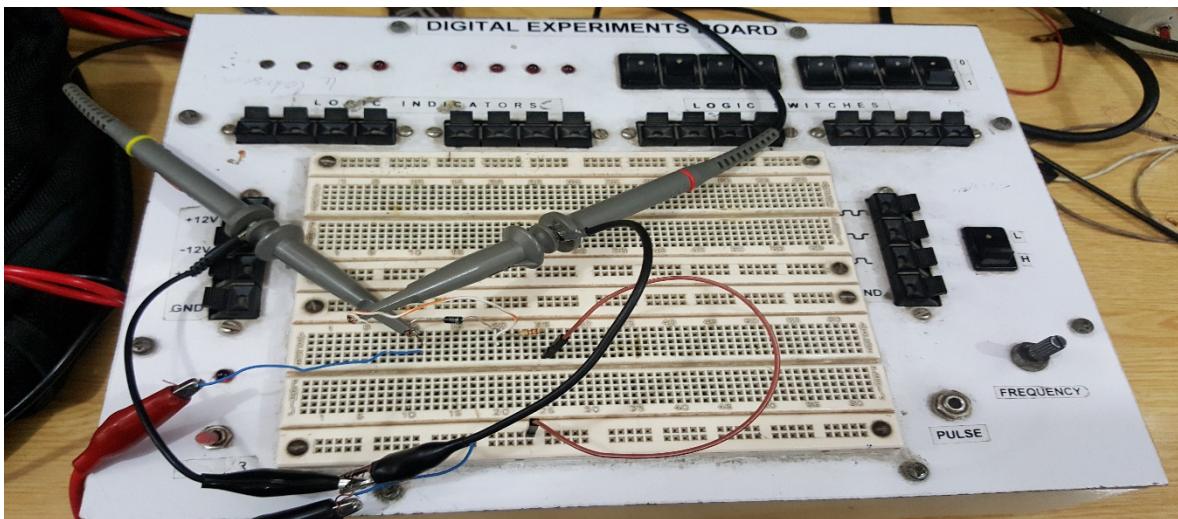
The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance ( $R_L$ ) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D<sub>1</sub> conducts in the forward direction as indicated by the arrows.

When point B is positive (in the negative half of the cycle) with respect to point C, diode D<sub>2</sub> conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a “bi-phase” circuit.

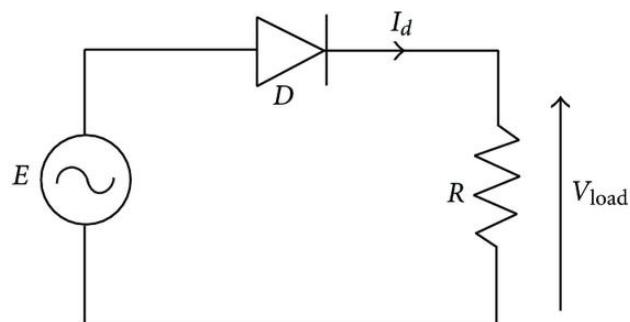


## Procedure

### Part 1



1. Construct the circuit of Fig . Record the measured values as well as calculated values.



## Results:

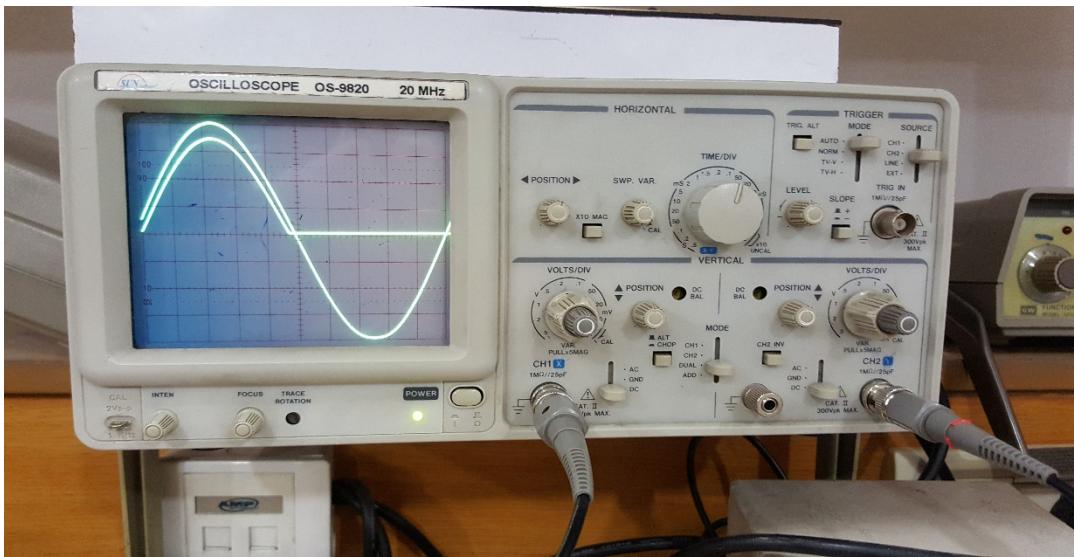
### **Calculated:**

$$V_T = 0.49 \text{ V}$$

$$\text{Voltage } V_D = \frac{V_m - V_T}{\pi} = \frac{4 - 0.49}{\pi} = 1.117 \text{ V}$$

### **Measured:**

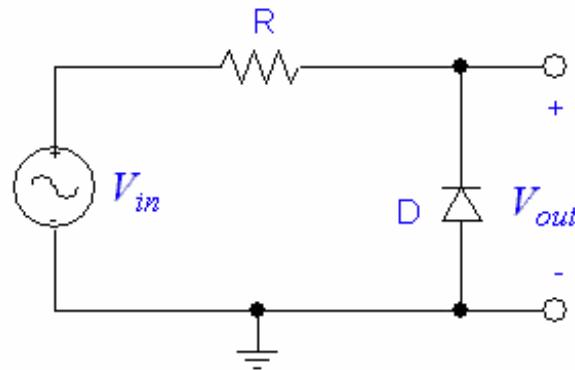
$$\text{Voltage } V_D = 1 \text{ V}$$



## Part 2:

Construct the circuit of Fig . Record the measured values as well as calculated values.

Half-Wave Rectifier



## Results:

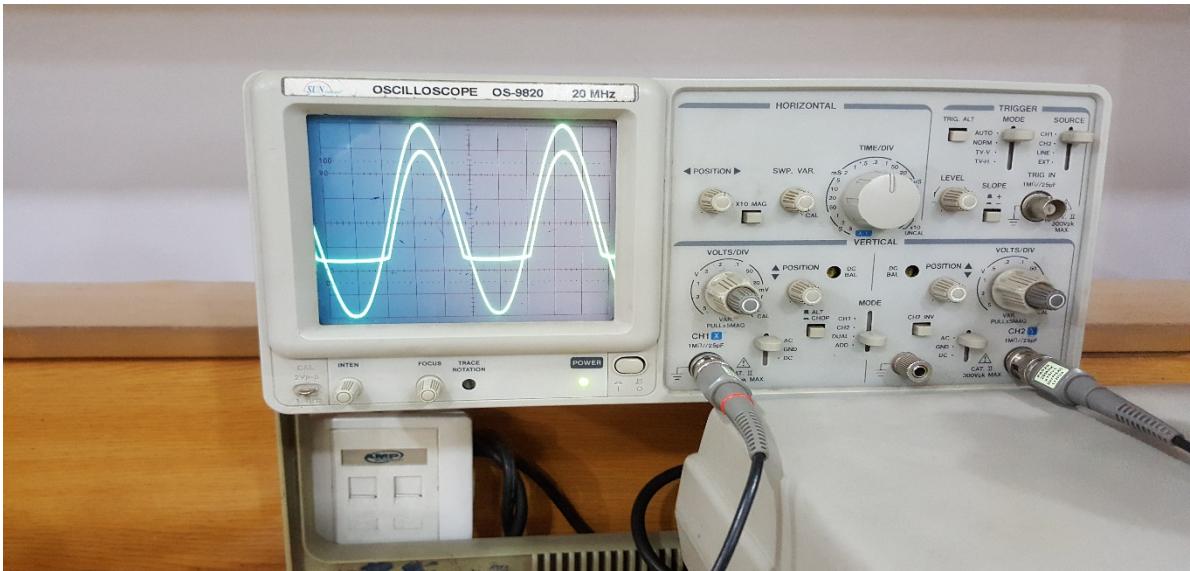
### Calculated:

Voltage  $V_{T1} = 0.51 \text{ V}$

$$\text{Voltage } V_D = \frac{\text{Total Area}}{2\pi} = \frac{Vm}{\pi} - \frac{Vt}{2} = 0.945 \text{ V}$$

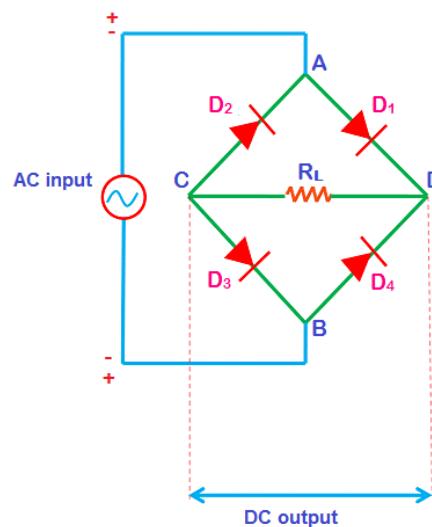
### Measured:

Voltage  $V_D = 0.93 \text{ V}$



### Part 3:

4. Construct the circuit of Fig. Record the measured as well as calculated values.



### Results:

#### Calculated:

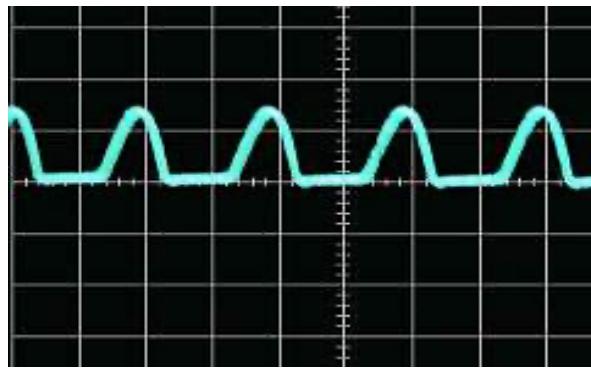
$$\text{Voltage } V_T = \frac{VT_1 + VT_2 + VT_3 + VT_4}{4} = 0.495 \text{ V}$$

Resistance  $R = 2.2 \text{ k}\Omega$

$$\text{Voltage } V_D = \frac{2}{\pi} (Vm - 2Vt) = 0.636 (4 - 2(0.495)) = 1.91 \text{ V}$$

#### Measured:

Voltage  $V_D = 1.58 \text{ V}$



### **Percentage Error:**

$$(V_{DC\ Cal} - V_{DC\ Measured}) / V_{DC\ Cal} \times 100 = 17.7\%$$

---

### **Conclusion:**

Hence, we practically observed the behavior of diodes as rectifiers.

- In half wave rectification we saw that only half of every cycle of an alternating current is made to flow in one direction only.
  - In full wave rectification we saw that it converted both half cycles of the AC signal into pulsating DC signal.
-

## Experiment No. 5: Parallel Clippers

### Objectives:

To calculate and measure the output voltages of Parallel & Series clipper circuits.

### Equipment:

Oscilloscope

Function Generator

Digital Multimeter (DMM)

DC power supply

### Components

Diode: Silicon (D1N4002)

Resistors:  $2.2\text{k}\Omega$ ,  $3.3\text{k}\Omega$

### Theory:

#### Diode:

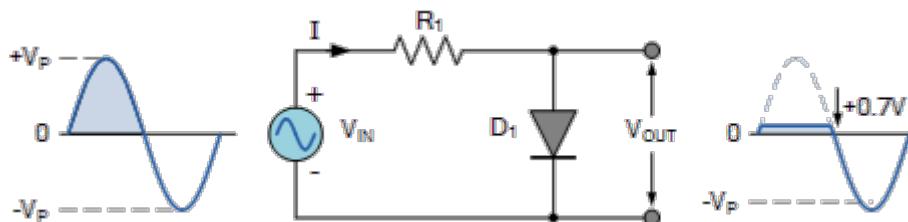
A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low resistance in one direction, and high resistance in the other.

#### Clipper:

a **clipper** is a device designed to prevent the output of a circuit from exceeding a predetermined voltage level without distorting the remaining part of the applied waveform.

A clipping circuit consists of linear elements like resistors and non-linear elements like junction diodes or transistors, but it does not contain energy-storage elements like capacitors. Clipping circuits are used to select for purposes of transmission, that part of a signal wave form which lies above or below a certain reference voltage level.

Thus a clipper circuit can remove certain portions of an arbitrary waveform near the positive or negative peaks. Clipping may be achieved either at one level or two levels. Usually under the section of clipping, there is a change brought about in the wave shape of the signal.



### **Procedure:**

#### Part A: Parallel Clippers

Construct the circuit in Fig. 1. The input signal is an 16 V p-p square wave at frequency of 1000 Hz. Record the measured resistance value.

Set the oscilloscope in DC mode.

Put the oscilloscope probes at function generator and sketch the input waveform obtained.

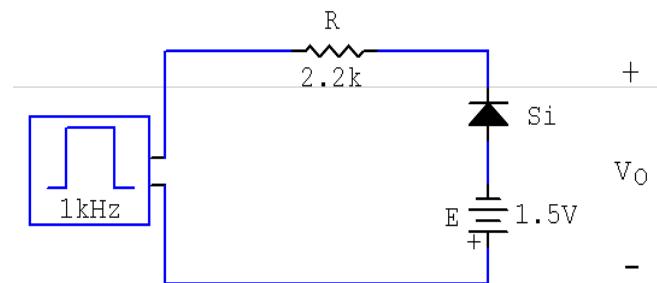
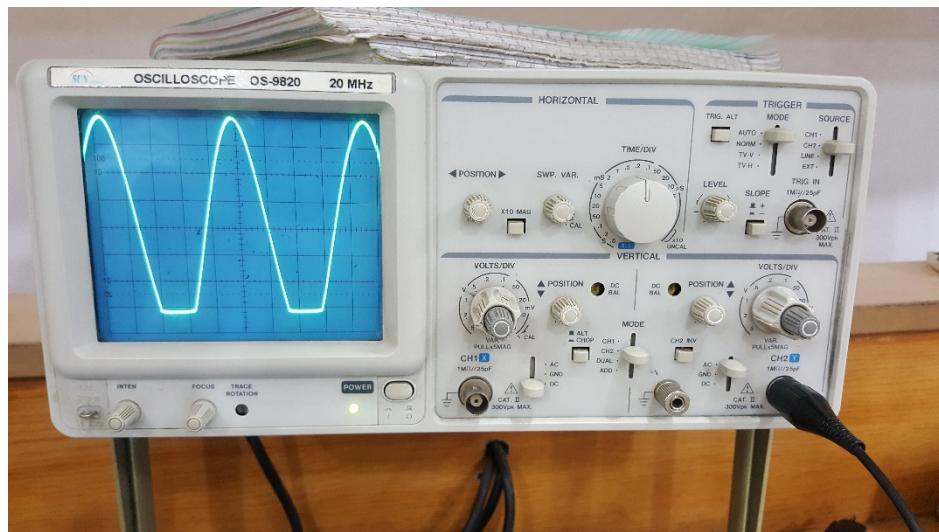


Figure 13



## Results:

### Calculated

$$\text{Resistor } R = 2.14\text{ k}\Omega$$

$$V_T = 0.49 \text{ V}$$

$$E = -5.21 \text{ V}$$

$$V_0 = -5.21 - 0.49 = -5.7 \text{ V}$$

### Measured

$$V_0 = -6.1 \text{ V}$$

$$\% \text{error} = 1.93\%$$

## Part B: Series Clippers:-

Construct the circuit in Fig.2. The input signal is an 8 V p-p square wave at frequency of 1000 Hz. Record the measured resistance value.

Set the oscilloscope in DC mode.

Put the oscilloscope probes at function generator and sketch the input waveform obtained.

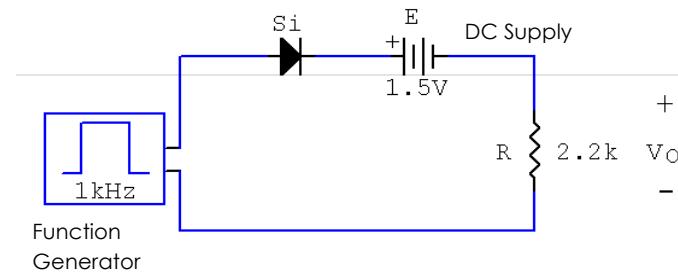
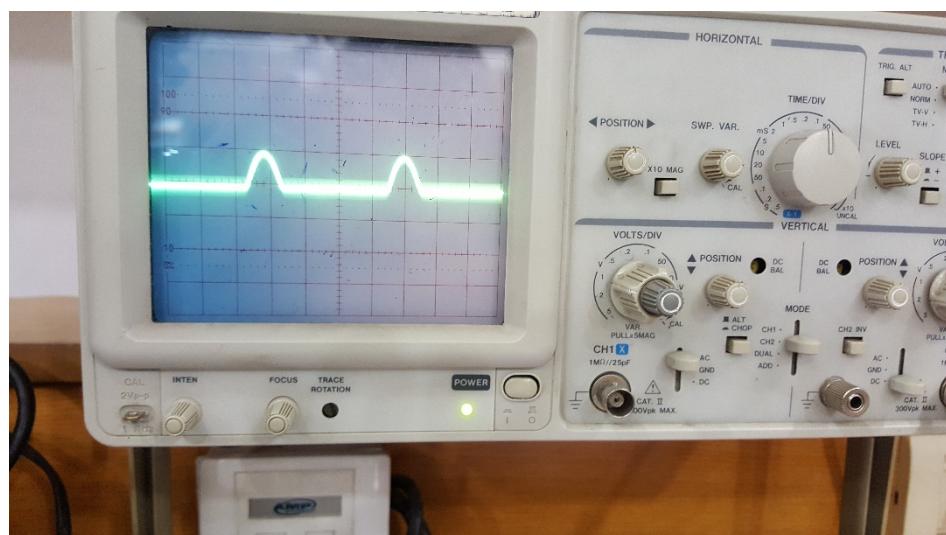


Figure 14



## Results:

### Calculated

$$\text{Resistor } R = 1.01 \text{ k}\Omega$$

$$V_T = 0.49 \text{ V}$$

$$\text{DC Supply} = 5.22 \text{ V}$$

### KVL

$$V_i + 0.7 + 5 + V_o = 0$$

$$V_o = V_i - 5.7$$

$$V_o = V_M - 5.7$$

$$V_o = 8 - 5.7 = 2.3 \text{ V}$$

$$8 - (5.22 + 0.49) = 2.29 \text{ V or } 2.3 \text{ V}$$

## Measured

$$V_O = 2.3 \text{ V}$$

Conclusion:

- **Positive series clipper:** During positive half of cycle input voltage is positive therefore diode is reversed biased and act as open circuit hence output is zero. During negative half input voltage is negative, diode is forward biased and act as a closed switch and hence all the input voltage drop appear across the resistor.
- **Negative series clipper:** During positive half cycle of input voltage is positive therefore diode is forward biased and act as closed switch hence all the input voltage drop appear across the resistor. During negative half input voltage is negative therefore diode is reversed biased and act as open circuit hence output is zero .
- **Positive shunt clipper:** During positive half cycle of input voltage is positive therefore diode is forward biased and act as closed switch hence all the current flows through the diode and no voltage drop across the output and output is zero. During negative half cycle input voltage is negative hence diode is reverse biased and act as open switch hence there is direct connection between input and output
- **Negative shunt clipper:** During positive half cycle of input voltage is positive therefore diode is reverse biased and act as open switch hence there is direct connection between input and output hence during positive half, we get output waveform. During negative half cycle input voltage is negative therefore diode is forward biased and act as closed switch hence all the current flows through the diode and no voltage drop across the output and output is zero.

## Experiment No. 6: Clampers

### Objectives:

To become familiar with the function and operation of clampers

### Equipment:

Oscilloscope

Function Generator

Digital Multimeter (DMM)

### Components

Diode: Silicon (D1N4002)

Resistors:  $100\text{k}\Omega$

Capacitor:  $1 \mu\text{F}$

### Theory:

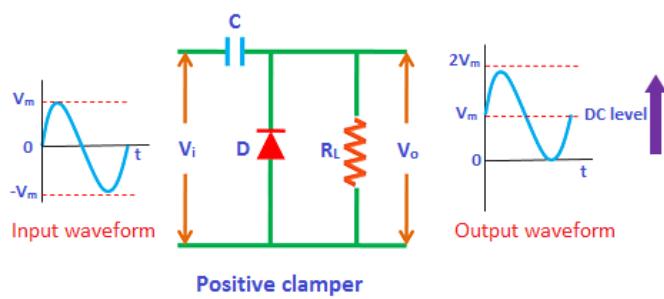
#### Diode:

A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low resistance in one direction, and high resistance in the other.

#### Clammer

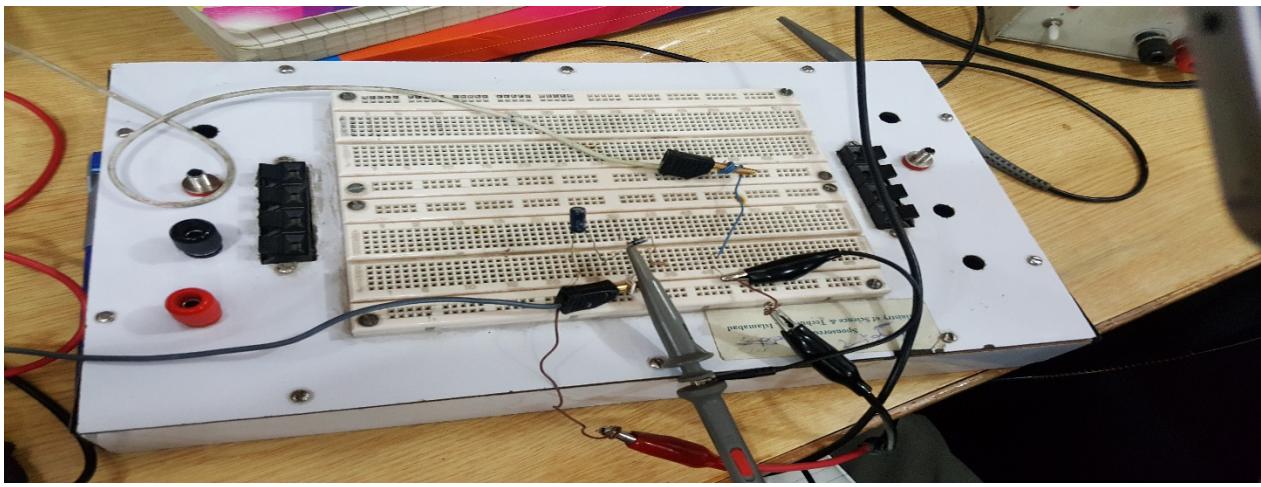
A clamper is an electronic circuit that changes the DC level of a signal to the desired level without changing the shape of the applied signal. In other words, the clamper circuit moves the whole signal up or down to set either the positive peak or negative peak of the signal at the desired level.

The dc component is simply added to the input signal or subtracted from the input signal. A clamper circuit adds the positive dc component to the input signal to push it to the positive side. Similarly, a clamper circuit adds the negative dc component to the input signal to push it to the negative side.



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### **Procedure:**

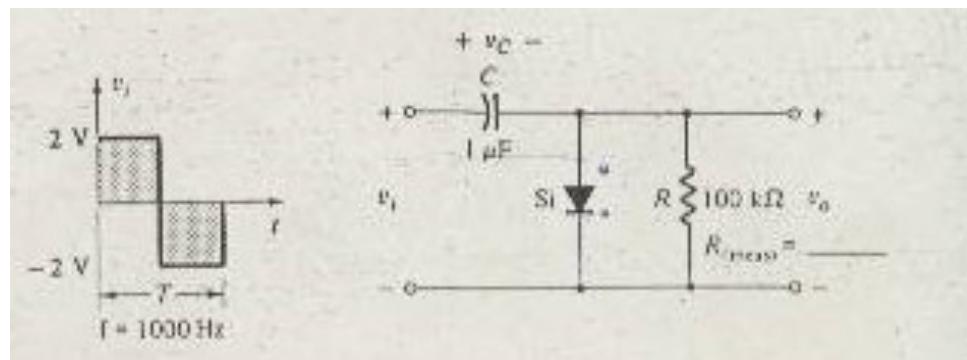


### Part A: Clampers (R,C, Diode Combination)

Construct the circuit in *Fig. 1*. The input signal is an 16 V p-p square wave at frequency of 1000 Hz. Record the measured resistance value.

Set the oscilloscope in DC mode.

Put the oscilloscope probes at function generator and sketch the input waveform obtained.



### Results:

#### Calculated

$$\text{Resistor } R = 57.8 \text{ k}\Omega$$

$$V_T = 0.49 \text{ V}$$

$$8V + V_C + V_O = 0$$

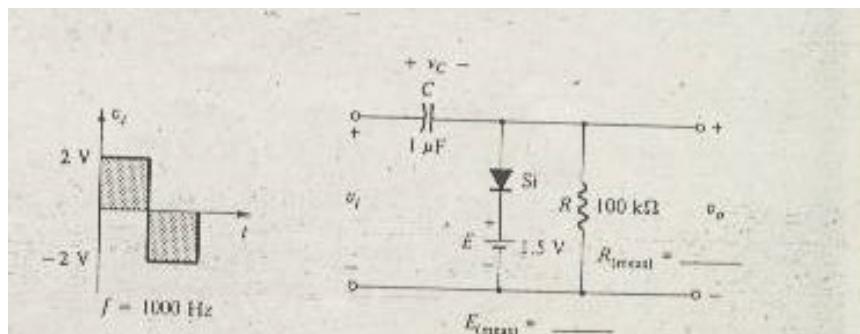
$$V_O = -8 - 2.29 = -10.29 \text{ V}$$

#### Measured

$$V_O = -10.19 \text{ V}$$

### Part B Clampers with DC

Construct the network and record the measured values.



## Results:

### Calculated

$$\text{Resistor } R = 57.8 \text{ k}\Omega$$

$$V_T = 0.49 \text{ V}$$

$$\text{DC Supply} = 5.22 \text{ V}$$

### KVL

$$-8\text{V} + V_c + V_T = 0$$

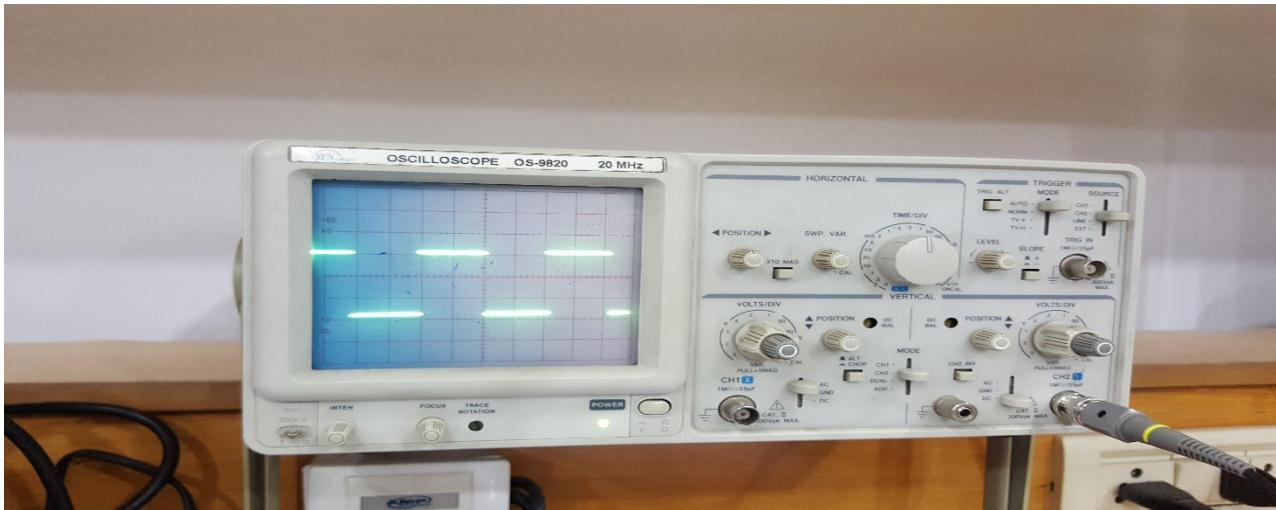
$$V_c = 8 - 5.22 - V_T$$

$$V_c = 8 - 5.22 - 0.49 = 2.29 \text{ V}$$

$$V_o = 5.22 + V_T = 5.71 \text{ V}$$

### Measured

$$V_o = 5.56 \text{ V}$$



### Conclusion:

1. Clampers can be used to increase the dc-value of the signal.5.
  2. We connect a high value resistance in parallel with the diode to eliminate the distortion inthe output signal.6.
  3. A dc source can be connected in the clamper network to change the dc-level.
-

## **Experiment No. 7: Zener Diode Characteristics**

### **Objectives:**

To study the characteristics of Zener diode.

To study the voltage regulation in Zener diode regulation circuit.

### **Equipment:**

Oscilloscope

Function Generator

Digital Multimeter (DMM)

### **Components**

Diode: Silicon (D1N4002)

Resistors:  $100\Omega$

Potentiometer

Variable Voltage Source

### **Theory:**

#### **Diode:**

A diode is a two-terminal electronic component that conducts current primarily in one direction; it has low resistance in one direction, and high resistance in the other.

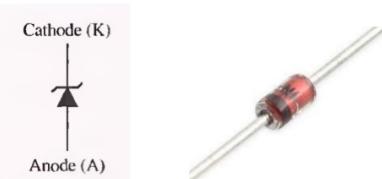
#### **Zener diode**

Zener diode is a P-N junction diode specially designed to operate in the reverse biased mode. It is acting as normal diode while forward biasing. It has a particular voltage known as break down voltage, at which the diode break downs while reverse biased. In the case of normal diodes, the diode damages at the break down voltage. But Zener diode is specially designed to operate in the reverse breakdown region.

The basic principle of Zener diode is the Zener breakdown. When a diode is heavily doped, its depletion region will be narrow. When a high reverse voltage is applied across the junction, there will be very strong electric field at the junction. And the electron hole pair generation takes place. Thus, heavy current flows. This is known as Zener break down.

So, a Zener diode, in a forward biased condition acts as a normal diode. In reverse biased mode, after the break down of junction current through diode increases sharply. But the voltage across it remains constant.

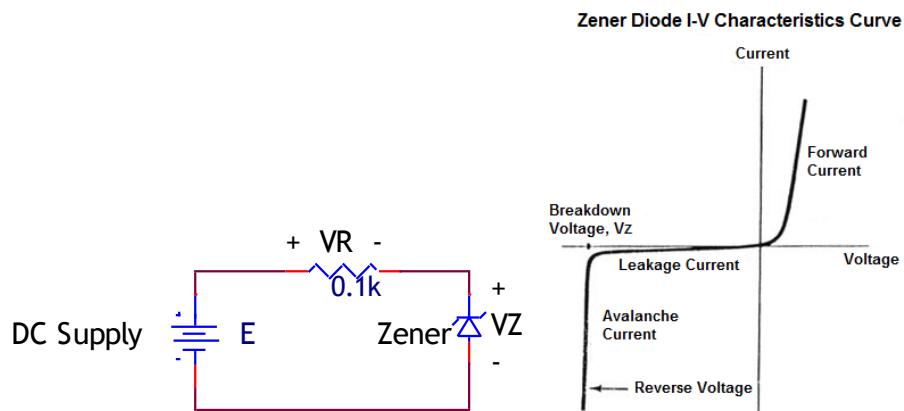
## Zener Diode



### **Procedure:**

#### **Part A: Zener Diode Characteristics**

Construct the circuit of *Fig. 1*. Set the DC supply to 0 V and record the measured value of R.



*Fig. 1*

Set the DC supply (E) to the values appearing in Table 4.1 and measure both  $V_z$  and  $V_R$ . Calculate the Zener current,  $I_z$  using the Ohm's law given in the table and complete the table.

### **Results:**

$E(V)$	2.10 V	4.01 V	6.07 V	8.01 V	10.22 V	12.17 V	13.01 V	14.15 V	15.53 V
$V_z$	2.10 V	3.96 V	6.06 V	7.88 V	10.20 V	12.10 V	12.23 V	13.40 V	13.41 V
$V_R$	0	0	0	0	0	0	0.06 V	0.71 V	1.56 V
$I_z = V_R/R$	0	0	0	0	0	0	0.6 mA	7.1 mA	15.6 mA

$$R_z = V_{z2} - V_{z1} / I_{z2} - I_{z1}$$

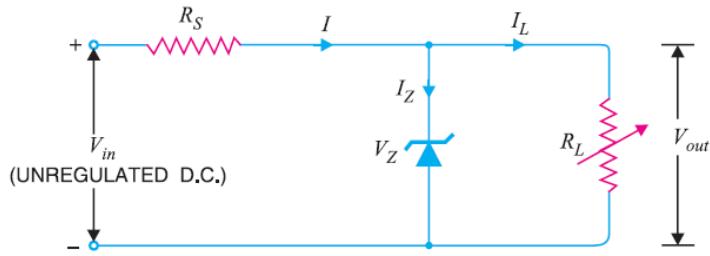
$$R_z = 13.41 - 12.10 / 0.0156 - 0.0006$$

$$R_Z = 87.33\Omega$$

## Curve on graph paper

## Part B As A Regulator

Construct the circuit of Fig. 4.2. Record the measured value of each resistor.



Measure the value of  $V_L$  and  $V_R$ . Using the measured values, calculate the

Value for current across  $R$ ,  $I_R$ , current across  $R_L$ ,  $I_L$ , and current across the Zener

Diode,  $I_Z$ .

## Results:

### Calculated

$$RL_{min} = \frac{1k \times 12.33}{15 - 12.33} = 4.41 \text{ k}\Omega$$

**Measured**  $R_{Lmin} = 4.64 \text{ k}\Omega$

## Experiment No. 8: Characteristics of Transistors

### Objectives:

1. To determine transistor type (npn, pnp), terminals and material using Digital multimeter.
2. To determine the values of the alpha and beta ratios of transistors.

### Equipment:

Digital Multimeter (DMM)

DC Power Supply

### Components

Resistors: 1 k $\Omega$ , 330 k $\Omega$ , 10 k $\Omega$  potentiometer, 1M $\Omega$  potentiometer

Transistors: 2N3904

### Theory:

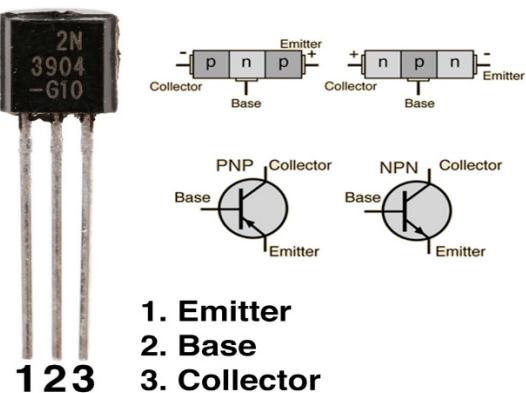
#### Transistor

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit.

#### Bipolar Junction Transistor (BJT)

Bipolar Junction Transistor (BJT) is a Semiconductor device constructed with three doped Semiconductor Regions (Base, Collector and Emitter) separated by two p-n Junctions, Figure 1. The p-n Junction between the Base and the Emitter has a Barrier Voltage ( $V_0$ ) of about 0.6 V, which is an important parameter of a BJT.

The relationships between the voltages and the currents associated with a BJT under various operating conditions determine its performance. These relationships are collectively known as characteristics of the transistor.



### Procedure:

Construct the circuit of Fig.1. Vary the 1M $\Omega$  potentiometer to set  $I_B = 10 \mu A$  as in Table.

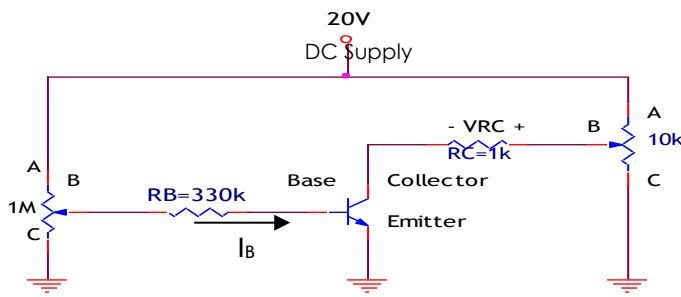


Fig. 1

1. Set the  $V_{CE}$  to 2V by varying the  $10\text{k}\Omega$  potentiometer as required by the first line of Table.
2. Record the  $V_{RC}$  and  $V_{BE}$  values in Table.
3. Vary the  $10\text{k}\Omega$  potentiometer to increase  $V_{CE}$  from 2V to the values appearing in Table .  
(Note:  $I_B$  should be maintained at  $10\text{ }\mu\text{A}$  for the range of  $V_{CE}$  levels.)
4. Record  $V_{RC}$  and  $V_{BE}$  values for each of the measured  $V_{CE}$  values. Use the mV range for  $V_{BE}$ .
5. Repeat step 2 through 5 for all values of  $I_B$  indicated in Table.
6. Compute the values of  $I_C$  (from  $I_C = V_{RC}/R_C$ ) and  $I_E$  (from  $I_E = I_B + I_C$ ). Use measured resistor value for  $R_C$ .
7. Compute the values of  $\alpha$  (from  $\alpha = I_C/I_E$ ) and  $\beta$  (from  $\beta = I_C/I_B$ ).

### Results:

$V_{RB}(\text{V})$	$I_B(\mu\text{A})$	$V_{CE}(\text{V})$	$V_{RC}(\text{V})$	$I_C(\text{mA})$	$V_{BE}(\text{V})$	$I_E(\text{mA})$	$\alpha$	$\beta$
0.19	9.7	1.87	0.73	0.48	0.57	0.489	1	50
0.22	10	2.10	3.98	2.8	0.71	2.81	1	280
0.45	20	4.04	8.30	5.9	0.75	6.1	1.03	295

Characteristic Curve on graph paper.

## **Experiment No. 9: BJT BIASING CIRCUITS FIXED BIASED CONFIGURATION**

### **Objectives:**

To determine the quiescent operating conditions of the fixed-bias BJT configuration.

### **Equipment:**

Digital Multimeter (DMM)

DC Power Supply

### **Components**

Resistors: 2.7 kΩ, 1 MΩ

Transistors: 2N3904, 2N4401

### **Theory:**

**Biassing of the bipolar junction transistor (BJT)** is the process of applying external voltages to it. In order to use the BJT for any application like amplification, the two junctions of the transistor CB and BE should be properly biased according to the required application. Depending on whether the two junctions of the transistor are forward or reverse biased, a transistor is capable of operating in three different modes.

#### **Cutoff Mode of BJT**

The BJT is fully off in this state. In the cut-off mode both the base emitter as well as collector base junction is reverse biased. The BJT is equivalent to an open switch in this mode.

#### **Saturation Mode of BJT**

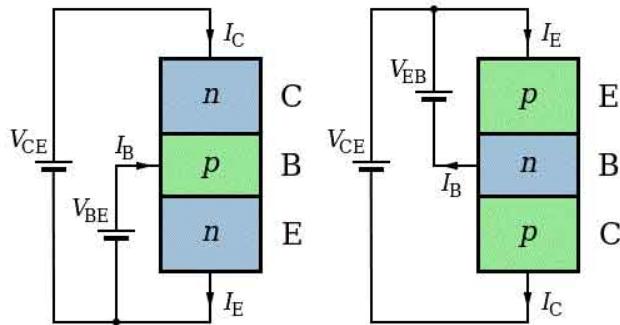
The transistor is fully on in this state. The CB as well as BE junctions are forward biased. The BJT operates like a closed switch in the saturation mode. If a BJT is in saturation mode than it should satisfy the following condition,

$$| I_B | \geq \left( \frac{| I_C |}{\beta_{DC}} \right)$$

Where,  $\beta_{DC}$  is common emitter current amplification factor or current gain.

#### **Active Mode of BJT**

In order to use the transistor as an amplifier, it must be operated in the active mode. The BE junction is forward biased whereas the CB junction is reverse biased. Figure below shows both n-p-n and p-n-p transistors biased in the active mode of operation.

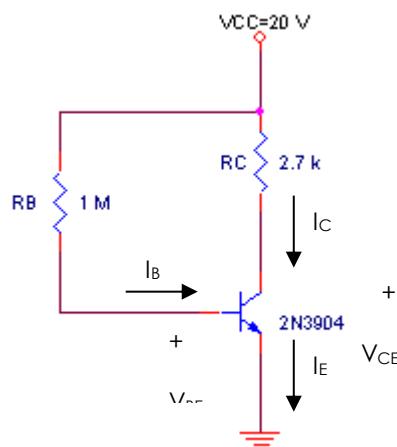


## Biasing Circuits of BJT

To make the Q point stable different biasing circuits are tried. The Q point is also called as operating bias point, is the point on the DC load line (a load line is the graph of output current vs. output voltage in any of the transistor configurations) which represents the DC current through the transistor and voltage across it when no ac signal is applied. The Q point represents the DC biasing condition. When the BJT is biased such that the Q point is halfway between cutoff and saturation than the BJT operates as a CLASS-A amplifier. The three circuits or biasing arrangements which are practically used are explained below.

## Procedure:

1. Measure all resistor values ( $R_B$  and  $R_C$ ) from circuit in *Fig. 1* using DMM. Record them.
2. Construct circuit as of *Fig. 1* using 2N3904 transistor and set  $V_{CC} = 20$  V.
3. Measure the voltages  $V_{BE}$  and  $V_{RC}$ . Record them.
4. Calculate the resulting base current,  $I_B$  and collector current,  $I_C$ . Using the values obtained, find  $\beta$ .
5. Using the values obtained in Step 4, calculate the values of  $V_B$ ,  $V_C$ ,  $V_E$  and  $V_{CE}$ .
6. Energize the network in *Fig. 1*, measure  $V_B$ ,  $V_C$ ,  $V_E$  and  $V_{CE}$ .
7. How do the measured values (Step 6) compare to the calculated values (Step 5)?
8. Simply remove the 2N3904 transistor and replace with 2N4401 transistor.
9. Then, measure the voltages  $V_{BE}$  and  $V_{RC}$ . Using the same equations, calculate the values of  $I_B$  and  $I_C$ . From the values obtained, determine the  $\beta$  value for 2N4401 transistor.
10. Compile all the data needed for both transistors in Table.
11. Calculate the magnitude (ignore the sign) of the percent change in each quantity due to a change in transistors.



*Fig. 1*

## Results:

## Formulas

$$I_B = \frac{V_{RB}}{R_B} = \frac{V_{CC} - V_{BE}}{R_B} =$$

$$I_C = \frac{V_{RC}}{R_C} = \beta = \frac{I_C}{I_B} =$$

$$\% \Delta \beta = \frac{|\beta_{(4401)} - \beta_{(3904)}|}{|\beta_{(3904)}|} \times 100\% =$$

$$\% \Delta I_C = \frac{|I_{C(4401)} - I_{C(3904)}|}{|I_{C(3904)}|} \times 100\% =$$

$$\% \Delta V_{CE} = \frac{|V_{CE(4401)} - V_{CE(3904)}|}{|V_{CE(3904)}|} \times 100\% =$$

$$\% \Delta I_B = \frac{|I_{B(4401)} - I_{B(3904)}|}{|I_{B(3904)}|} \times 100\% =$$

### **Calculated: Transistor 1**

$I_B = 14.34 \mu A$ ,  $I_C = 3.9 \text{ mA}$ ,  $\beta_{DC} = 271.96$ ,  $V_B = 0.64 \text{ V}$ ,  $V_C = 6.37 \text{ V}$ ,

$V_{CE} = 6.37 \text{ V}$

### **Measured:**

$V_{CE} = 6.39 \text{ V}$

### **Calculated: Transistor 2**

$I_B = 14.46 \mu A$ ,  $I_C = 5.51 \text{ mA}$ ,  $\beta_{DC} = 380$ ,  $V_B = 0.52 \text{ V}$ ,  $V_C = 2.81 \text{ V}$ ,

$V_{CE} = 2.81 \text{ V}$

### **Measured:**

$V_{CE} = 2.77 \text{ V}$

**Table**

Trans. Type	V <sub>CE</sub> (V)	I <sub>C</sub> (mA)	I <sub>B</sub> ( $\mu$ A)	$\beta$
2N3904	6.39	3.9	14.34	271.96
2N4401	2.77	5.51	14.46	380

**%AGE ERROR:**

%error  $\beta$  = **39.72%**

%error I<sub>B</sub> = **0.83%**

%error I<sub>C</sub> = **41%**

%error V<sub>CE</sub> = **55.88%**

## **Experiment No. 10: BJT BIASING CIRCUITS Voltage-Divider-Bias Configuration**

### **Objectives:**

To determine the quiescent operating conditions of the fixed-bias BJT configuration.

### **Equipment:**

Digital Multimeter (DMM)

DC Power Supply

### **Components**

Resistors:  $680\Omega$ ,  $10\text{ k}\Omega$ ,  $2.2\text{ k}\Omega$ ,  $33\text{ k}\Omega$

Transistors: 2N3904, 2N4401

### **Theory:**

**Biassing of the bipolar junction transistor (BJT)** is the process of applying external voltages to it. In order to use the BJT for any application like amplification, the two junctions of the transistor CB and BE should be properly biased according to the required application. Depending on whether the two junctions of the transistor are forward or reverse biased, a transistor is capable of operating in three different modes.

#### **Cutoff Mode of BJT**

The BJT is fully off in this state. In the cutoff mode both the base emitter as well as collector base junction is reverse biased. The BJT is equivalent to an open switch in this mode.

#### **Saturation Mode of BJT**

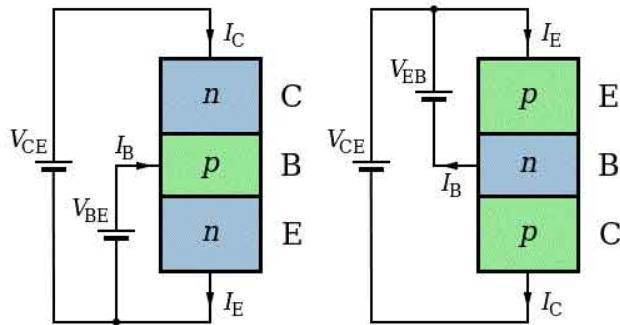
The transistor is fully on in this state. The CB as well as BE junctions are forward biased. The BJT operates like a closed switch in the saturation mode. If a BJT is in saturation mode than it should satisfy the following condition,

$$| I_B | \geq \left( \frac{| I_C |}{\beta_{DC}} \right)$$

Where,  $\beta_{DC}$  is common emitter current amplification factor or current gain.

#### **Active Mode of BJT**

In order to use the transistor as an amplifier, it must be operated in the active mode. The BE junction is forward biased whereas the CB junction is reverse biased. Figure below shows both n-p-n and p-n-p transistors biased in the active mode of operation.



## Biasing Circuits of BJT

To make the Q point stable different biasing circuits are tried. The Q point is also called as operating bias point, is the point on the DC load line (a load line is the graph of output current vs. output voltage in any of the transistor configurations) which represents the DC current through the transistor and voltage across it when no ac signal is applied. The Q point represents the DC biasing condition. When the BJT is biased such that the Q point is halfway between cutoff and saturation than the BJT operates as a CLASS-A amplifier.

## Procedure:

1. Measure all resistor values ( $R_1$ ,  $R_2$ ,  $R_B$  and  $R_C$ ) from circuit in Fig. 1 using DMM. Record them.
2. Using the  $\beta$  determined for 2N3904 transistor in Part B, calculate the theoretical values of  $V_B$ ,  $V_E$ ,  $I_E$ ,  $I_C$ ,  $V_C$ ,  $V_{CE}$  and  $I_B$  for the network shown in Fig. 1. Record them in Table
3. Construct the network of Fig. 1 and measure  $V_B$ ,  $V_E$ ,  $V_C$  and  $V_{CE}$ . Record them in Table

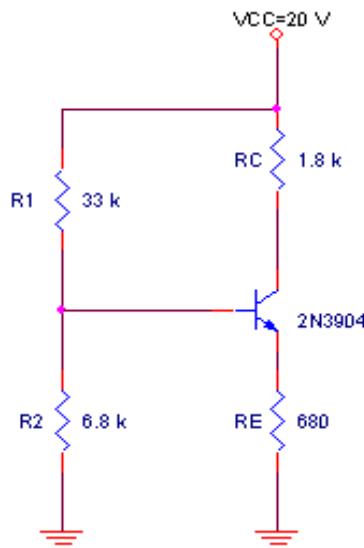


Figure 15

## Results:

### Formulas

$$I_1 = \frac{V_{R1}}{R_1} = \quad I_2 = \frac{V_{R2}}{R_2} = \quad I_B = I_1 - I_2 \quad V_C = V_{CC} - I_C R_C \quad V_{CE} = V_{CC} - I_C (R_C + R_E)$$

$$I_C = \frac{V_{RC}}{R_C} = \quad \beta = \frac{I_C}{I_B} =$$

$$\% \Delta \beta = \frac{|\beta_{(4401)} - \beta_{(3904)}|}{|\beta_{(3904)}|} \times 100\% =$$

$$\% \Delta I_C = \frac{|I_{C(4401)} - I_{C(3904)}|}{|I_{C(3904)}|} \times 100\% =$$

$$\% \Delta V_{CE} = \frac{|V_{CE(4401)} - V_{CE(3904)}|}{|V_{CE(3904)}|} \times 100\% =$$

$$\% \Delta I_B = \frac{|I_{B(4401)} - I_{B(3904)}|}{|I_{B(3904)}|} \times 100\% =$$

### Calculated: Transistor 1

$$I_1 = 0.000359 \text{ A}, \quad I_2 = 0.000343 \text{ A}, \quad I_B = 1.6 \times 10^{-5} \text{ A}, \quad I_C = 4.0 \text{ mA}, \quad \beta_{DC} = 250,$$

$$V_B = 3.35 \text{ V}, \quad V_E = 2.6 \text{ V}, \quad V_C = 6.16 \text{ V}$$

$$V_{CE} = 3.56 \text{ V}$$

### Measured:

$$V_{CE} = 3.49 \text{ V}$$

### Calculated: Transistor 2

$$I_1 = 0.00035 \text{ A}, \quad I_2 = 0.00034 \text{ A}, \quad I_B = 0.1 \times 10^{-6} \text{ A}, \quad I_C = 0.00408 \text{ A}, \quad \beta_{DC} = 370.90,$$

$$V_B = 3.39 \text{ V}, \quad V_E = 2.6 \text{ V}, \quad V_C = 6.16 \text{ V}$$

$$V_{CE} = 3.56 \text{ V}$$

**Measured:** $V_{CE} = 3.25 \text{ V}$ **Table**

Trans. Type	$V_{CE}$ (V)	$I_C$ (mA)	$I_B$ ( $\mu\text{A}$ )	$\beta$
2N3904	3.49	4.00	0.16	250
2N4401	3.25	4.08	0.1	370.90

**%AGE ERROR:** $\% \text{error } \beta = \mathbf{48.36\%}$  $\% \text{error } I_B = \mathbf{0.6\%}$  $\% \text{error } I_C = \mathbf{1.74\%}$  $\% \text{error } V_{CE} = \mathbf{7.38\%}$ 

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