ENP251: Electronic Devices and Circuits Laboratory

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Semester: IIIrd-B

Session:2022-23

Department of Electronics Engineering

Shri Ramdeobaba College of Engineering and Management

(An Autonomous institution affiliated to RTMNU)

Nagpur – 440013

Shri Ramdeobaba College of Engineering and Management, Nagpur-13.

Department of Electronics Engineering

ENP 251 - Electronic Devices & Circuits Lab

ODD Semester – 2022-23

Lab 01-a

Analyze and verify Volt-Ampere characteristics of PN junction diode.

Name:					
Roll No.					
Semester/Section:					
Date of Performance:					
Date of Submission:					
Particulars	**Experiment Performance**	**Observation & Calculations**	**Result & Conclusion**	**Report writing**	**Total**
Max. Marks	**03**	**02**	**03**	**02**	**10**
Marks Obtained					
Name & Signature of Faculty	Prof.R.S.Ochawar				

Lab-01-a

Aim:To Analyze and verify Volt-Ampere characteristics of PN junction diode.

Objectives:

1. To verify and plot Volt-Ampere characteristics of Si PN-Junction Diode.
2. To measure the cut-in voltage of Si PN-Junction Diode
3. To determine static and dynamic resistances of forward and reverse biased diode.

Apparatus:

S. No.	Components/ Equipment	Specification	Quantity
1	PN-Junction Diode (Si)	1N4007	1
2	Resistor	100 Ω, 10% tolerance, 0.5-watt rating	1
3	Resistor	1 kΩ, 10% tolerance, 0.5-watt rating	1
4	Regulated power supply	(0 - 30V), 2A Ratting	1
5	Ammeter	(0 – 30 mA) / (0 – 10 mA)	1
6	Ammeter	(0 – 100 μA) / (0 – 50 μA)	1
7	Voltmeter	(0 – 1V) / (0 – 30V)	1
8	Breadboard& single strand wires		

Theory:

The PN junction diode in the simplest sense is a device that conducts current in one direction and block current in the opposite direction. Donor impurities (pentavalent) are introduced into one-side and acceptor impurities into the other side of a single crystal of an intrinsic semiconductor to form a p-n diode with a junction called depletion region (this region is depleted off the charge carriers). This region gives rise to a potential barrier $V_\gamma$called **Cut- in Voltage**. This is the voltage across the diode at which it starts conducting. The P-N junction canconduct beyond this Potential.

The P-N junction supports unidirectional current flow. If +ve terminal of the input supply is connected to anode (P-side) and –ve terminal of the input supply is connected to cathode (N- side), then diode is said to be forward biased. 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 and constitute a forward current (**injectedminority current** – due to holes crossing the junction and entering N- side of the diode, due to electrons crossingthe junction and entering P-side of the diode). Assuming current flowing through thediode to be very large, the diode can be approximated as short-circuited switch. If –ve
terminal of the input supply is connected to anode (p-side) and +ve terminal of the input supply is connected to cathode (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 thereby increasing the depleted region. However, the process cannotcontinue indefinitely, thus a small current called **reverse saturation current** continues toflow
in the diode. This small current is due to thermally generated carriers. Assuming current flowing through the diode to be negligible, the diode can be approximatedas
an open circuited switch.

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

$$I = I_O (\exp(V / \eta V_T) - 1)$$

Where, I is the forward current flowing through diode.

I_O is the reverse saturation current.

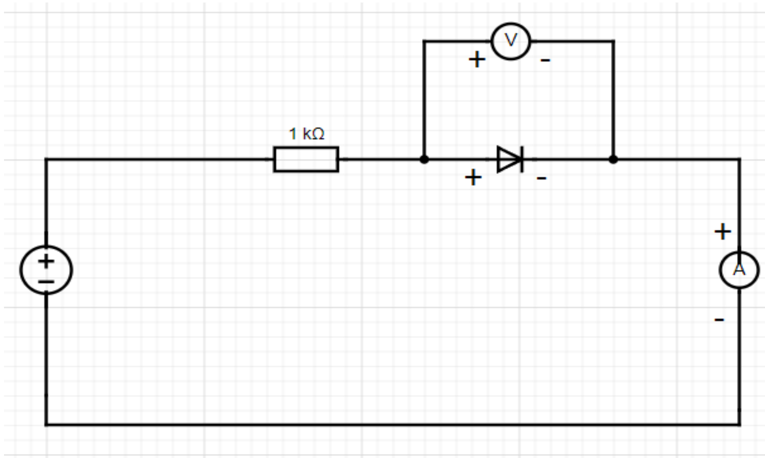
V is the forward voltage applied across the diode.

V_T is the volt equivalent of the temperature = kT/q = T/11600 = 26mV @ roomTemperature.

η = 1 for Germanium and η = 2 for silicon.

Circuit Diagram:

Diode in Forward Bias:



Procedure:

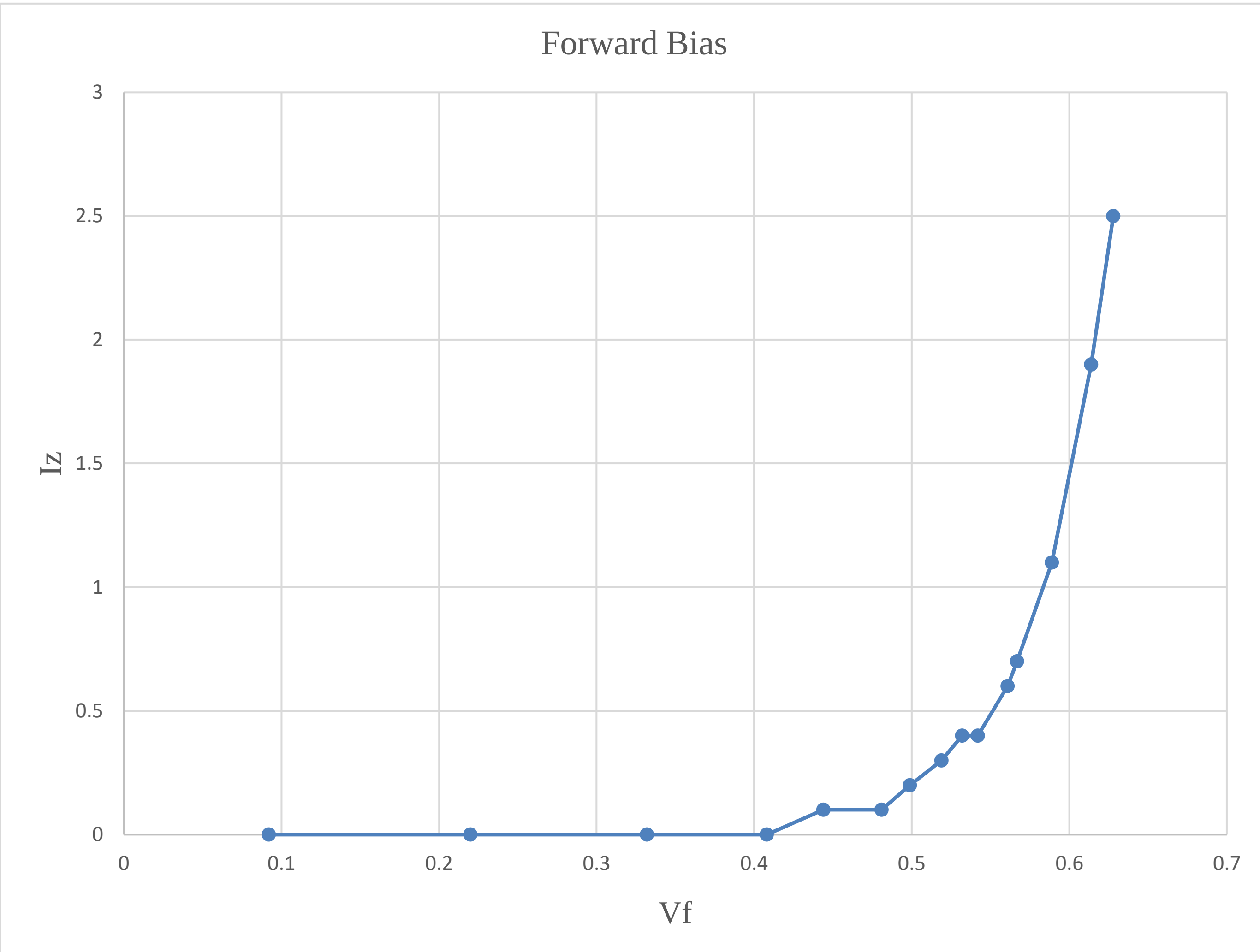
1. Connect the circuit as shown in the Figure-1.
2. Vary the applied voltage V in steps of 0.1V.
3. Note down the corresponding Ammeter and Voltmeter readings.
4. Plot a graph between V_f and I_f

Observation Table 1:

S. No.	Silicon Diode	
	Current (IF) in mA	**Voltage (VF) in V**
1.	0	0.092
2.	0	0.220
3.	0	0.332
4.	0	0.408
5.	0.1	0.444
6.	0.1	0.481
7.	0.2	0.499
8.	0.3	0.519

9.	0.4	0.532
10	0.4	0.542
11.	0.6	0.561
12.	0.7	0.567
13	1.1	0.589
14.	1.9	0.614
15.	2.5	0.628

Graph –



Diode in Reversed Bias:

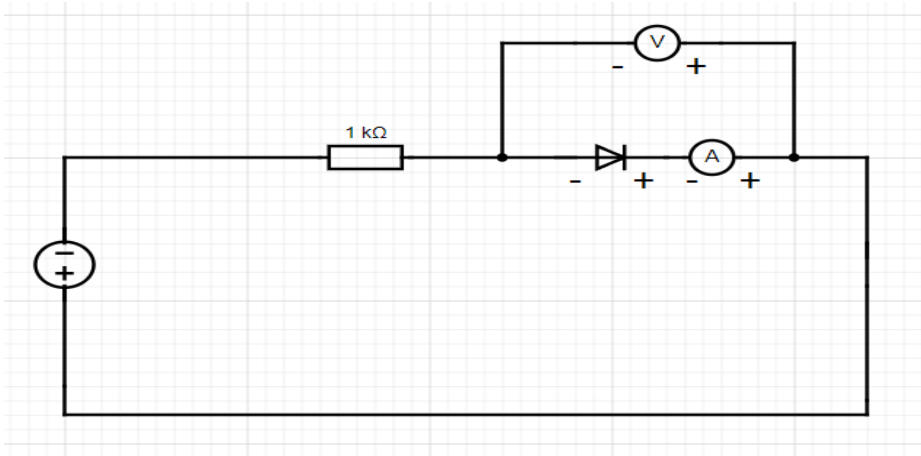


Figure-2: Diode in Reverse Bias

Procedure:

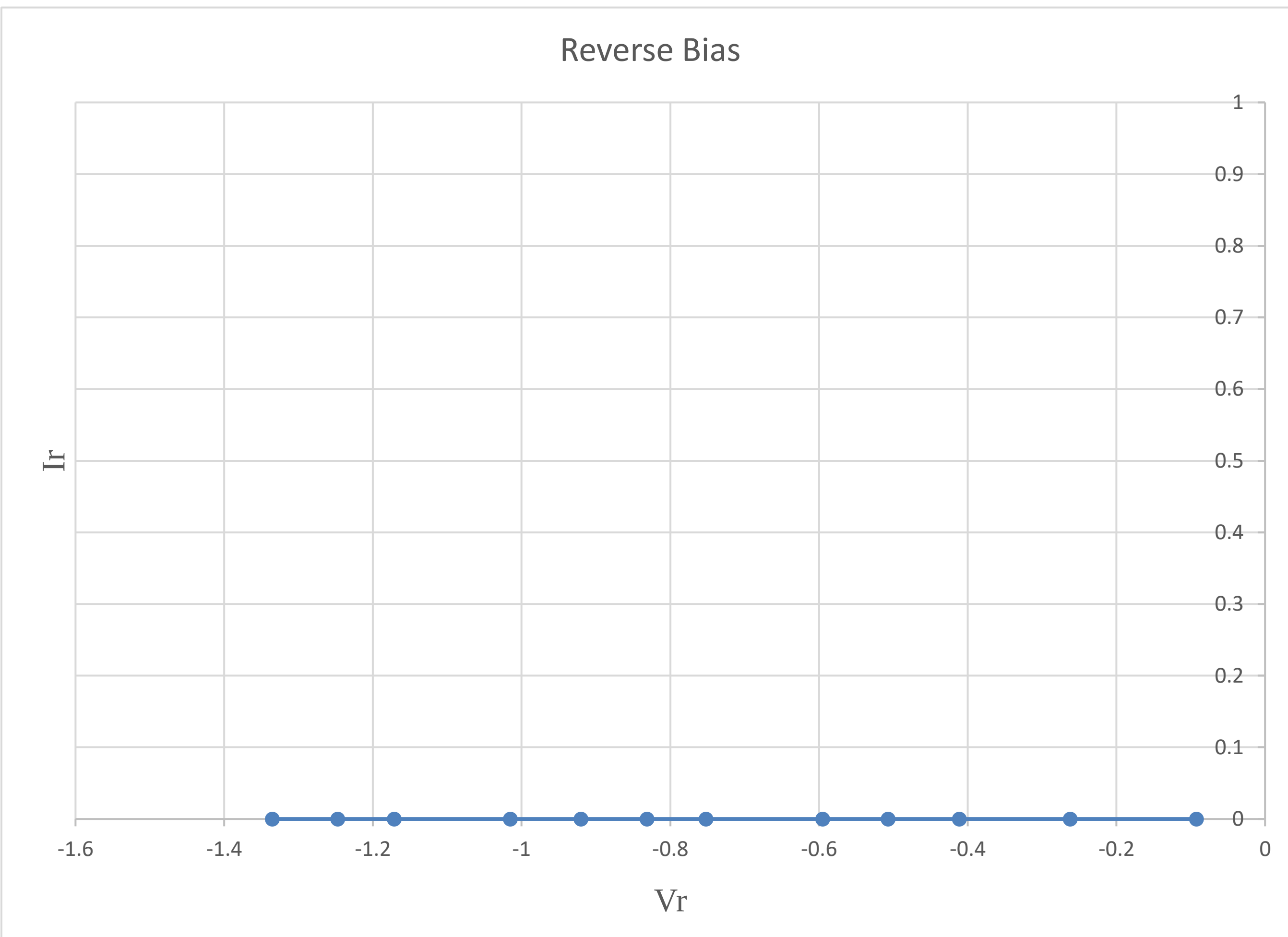
1. Connect the circuit as shown in the Figure-2.
2. Vary the applied voltage V in steps of 0.2 V.
3. Note down the corresponding Ammeter and Voltmeter readings.
4. Plot a graph between V_R and I_R

Observation Table 2:

S.No.	Silicon Diode	
	Reverse Current **I_R (μA)**	Reverse Voltage **V_R (V)**
1.	0	-0.092
2.	0	-0.262
3.	0	-0.411

4.	0	-0.507
5.	0	-0.595
6.	0	-0.752
7.	0	-0.831
8.	0	-0.920
9.	0	-1.015
10.	0	-1.171
11.	0	-1.247
12.	0	-1.335

Graph:



Calculations:

We know,

V=IR

In forward bias,

Static Resistance F_{SR} = V/I = 0.628/2.5*10^{-3} = 251.2ohm

In Reverse bias,

Dynamic Resistance = F_{DR} = ΔV/ΔI = $V_2 - V_1/I_2-I_1$

= 0.602 - 0.628

1.5*10^{-3}- 2.5*10^{-3}

F_{DR} = 26ohm

Result: Thus, the V-I characteristics of the PN junction diode is verified and it is plotted onthe graph paper. From the V-I characteristics plot, following parameters of the diode are determined:

For Silicon Diode:

1) Cut in voltage = 0.628 v
2) Forward static resistance of the diode = 251.2 ohm
3) Forward Dynamic resistance of the diode = 26 ohm
4) Reverse static resistance of the diode = Infinite
5) Reverse Dynamic resistance of the diode = Infinite

Conclusion:

In forward bias diode, the current grows slowly at the begining exponentially when we increase the voltage more than cut-in voltage i.e. 0.62V ,the potential barrier is eliminated and current start flowing in the circuit .

In reverse bias , the current remains zero as we increase the voltage

Discussion Questions:

1) Comment on diode operation under zero biasing condition.

- In this type of bias, there is no external supply as there is the presence of barrier potential in this condition no carrier are in the movement because the condition of equilibrium is attained then the current flowing through the circuit is zero. Because the external voltage applied is zero.

- The condition of the p-n junction diode where the device does not have any external supply is known as zero bias or unbiased.

2) How depletion region is formed in the PN junction?

- When p-n junction has formed the electron in n portion of PN junction moving in. any direction and Colliding with other atom and electrons.
- The electrons close to the junction and high energy they move to the P portion and merge With the hole
- As above we discuss when there is no pn junction created then there are the same number of electrons. and protons in N-type substance and have total charge zero.
- This Condition is also the same in p-type materials
- After the creation OF Junction, the free electron in a portion cross junction positive ion created and in P side negative ion created due to the Combination of electrons and holes.
- In the 'n" side due to electrons movement positive ion Layer is produced and in ´p side negative ion layer is generated due to these 2 layer of the ion depletion region is created.
- As the area of the depletion region is less than as compared to the N and P region
- After a Certain time interval movement of electron from 'N' to 'P' side stops and equilibrium is created.
- further movement of electrons holes repelled by the depletion region as its area also increased and positive ion in 'N' region repel holes. and negative ions in P region repals and it behaves. like a barrier.

3) What is break down voltage?

- The voltage across reverse biased PN junction increase to a certain value called breakdown voltage of diode, the high reverse current is caused which may damage the junction diode.
- 2)This can be caused by a number of factors including the presence of defects or impurities in the material or the application of too much current.

4) What is cut-in or knee voltage? Specify its value in case of Ge or Si?

- The forward voltage at which the flow of the current during the pn junction of the diode begins increasing very quickly is commonly known as knee voltage. This voltage is known as cut in voltage.
- Knee voltage value of Ge and Si diode are 0.3 and 0.7 respectively

5) What is the relationship between depletion width and the concentration of impurities?

- Depletion width is depends upon the concentration of impurities, if the concentration of impurities is more than width of depletion region will decrease they are inversely proportional to each other.

Shri Ramdeobaba College of Engineering and Management, Nagpur-13.

Department of Electronics Engineering

ENP 251 - Electronic Devices & Circuits

LabODD Semester – 2022-23

Lab 02-

To analyze and verify Volt-Ampere characteristics of Zener diode and Construct voltage regulator circuit using Zener diode and evaluate its performance parameters

Name:					
Roll No.					
Semester/Section :					
Date of Performance:					
Date of Submission:					
Particulars	**Experiment Performance**	**Observation & Calculations**	**Result & Conclusion**	**Report writing**	**Total**
Max. Marks	**03**	**02**	**03**	**02**	**10**
Marks Obtained					
Name & Signature of Faculty	Prof.R.S.Ochawar				

Lab-02

Aim: To analyze and verify Volt-Ampere characteristics of Zener diode and Construct voltage regulator circuit using Zener diode and evaluate its performance parameters.

Objectives:

1. To verify and plot Volt-Ampere characteristics of Zener Diode.
2. To determine the cut-in voltage and breakdown voltage of Zener Diode.
3. To determine the Zener resistance of a Zener diode.
4. To understand the concept of Zener diode as voltage regulator.
5. To determine load and line regulation of Zener shunt regulator.

Apparatus:

Sr. No.	Components/Equipment	Specification	Quantity
1.	Zener Diode	IZ6.2 or 5.6 v	1
2.	Resistance	1k ohm, 10% tolerance, 1/4 watt rating	1
3.	Regulated power supply	(0 – 30V), 2A rating	1
4.	Ammeter	(0-50) mA	1
5.	Voltmeter	(0 – 1.4) V, (0 – 30) V	1
6.	Breadboard & Single Strand wires		

<u>Part-A- To Analyze and verify Volt-Ampere characteristics of Zener diode</u>

Theory:

1. An ideal P-N Junction diode does not conduct in reverse biased condition. A **Zener diode** conducts excellently even in reverse biased condition. These diodes operate at a precise value of voltage called break down voltage. A **Zener diode** when forward biased behaves like an ordinary P-N junction diode. A **Zener diode** when reverse biased can either undergo **avalanche breakdown** or **Zenerbreakdown**.
2. **Avalanche breakdown**: If both p-side and n-side of the diode are lightly doped, depletion region at the junction widens. Application of a very large electric field

at the junction may rupture covalent bonding between electrons. Such rupture leads to the generation of a large number of charge carriers resulting in **avalanche multiplication**.

3. **Zener breakdown**: If both p-side and n-side of the diode are heavily doped, depletion region at the junction reduces. Application of even a small voltage at the junction ruptures covalent bonding and generates large number of charge carriers. Such sudden increase in the number of charge carriers results in **Zenermechanism.**

Circuit Diagram:

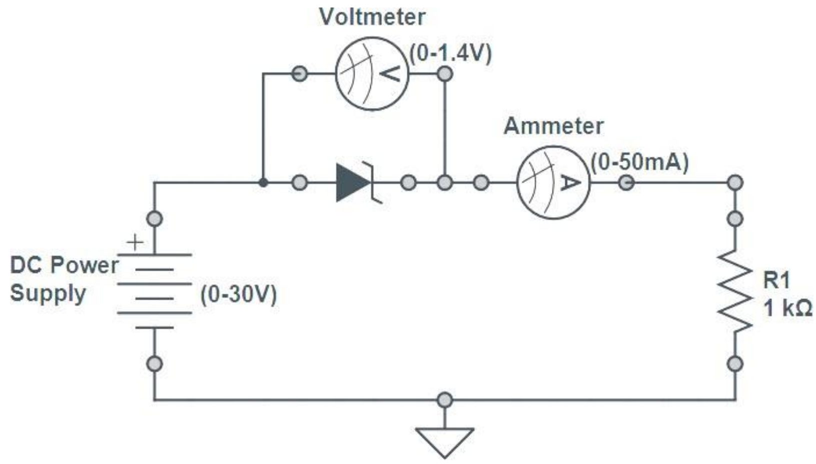


Figure 1: Forward Bias

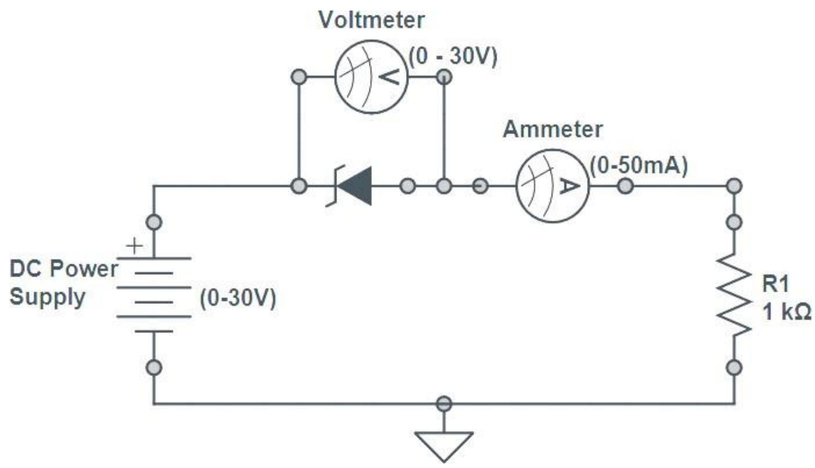


Figure 2: Reverse Bias

PRECAUTIONS:

1. While doing the experiment do not exceed the ratings of the diode. This may lead to damage of the diode.
2. Connect voltmeter and Ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch **ON** the power supply unless you have checked the circuit connections as per the circuit diagram.

Procedure:

Forward Biased Condition:

1. Connect the Zener diode in forward bias i.e. anode is connected to positive terminal of the power supply and cathode is connected to negative terminal of the power supply as in shown in Figure-1.
2. Use a Regulated power supply of range (0-30) V and a series resistance of 1kΩ.
3. For various values of forward voltage (V_D) (Readings of the Voltmeter), note down the corresponding values forward Current (I_f) (Readings of the Ammeter).

Reverse biased condition:

1. Connect the Zener diode in Reverse bias i.e'. anode is connected to negative terminal of the power supply and cathode is connected to positive terminalof the power supply as show in Figure-2.
2. For various values of reverse voltage (V_r) note down the corresponding values of reverse current (Iz).

Observation Table

Table No. 1: Forward Bias

S. No.	V_D(Volt)	If (mA)
1.	0.1	0
2.	0.4	0
3.	0.5	0.1
4.	0.56	0.2
5.	0.6	0.3
6.	0.61	0.4
7.	0.64	0.6
8.	0.65	0.7
9.	0.67	0.8
10.	0.677	0.9
11.	0.68	1.0
12.	0.69	1.1
13.	0.699	1.3
14.	0.7	1.5
15.	0.709	1.7
16.	0.712	1.9
17.	0.716	2.1
18.	0.719	2.3
19.	0.72	2.5

GRAPH -

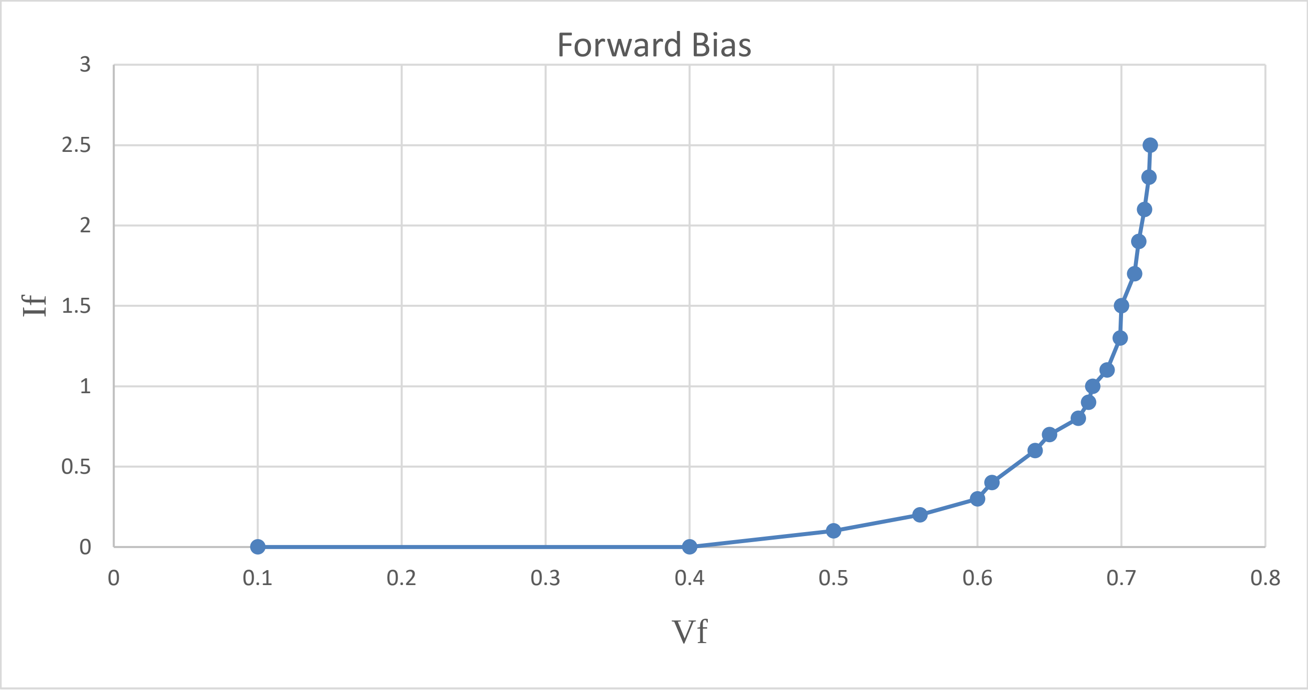
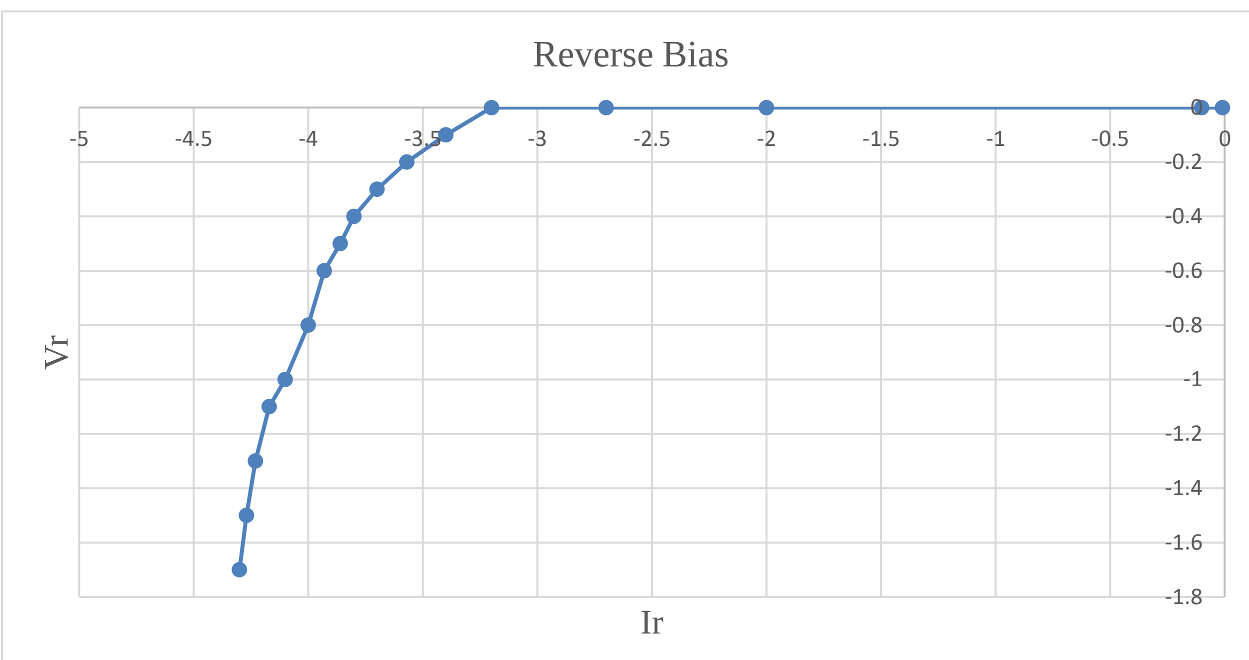


Table No. 2: Reverse Bias

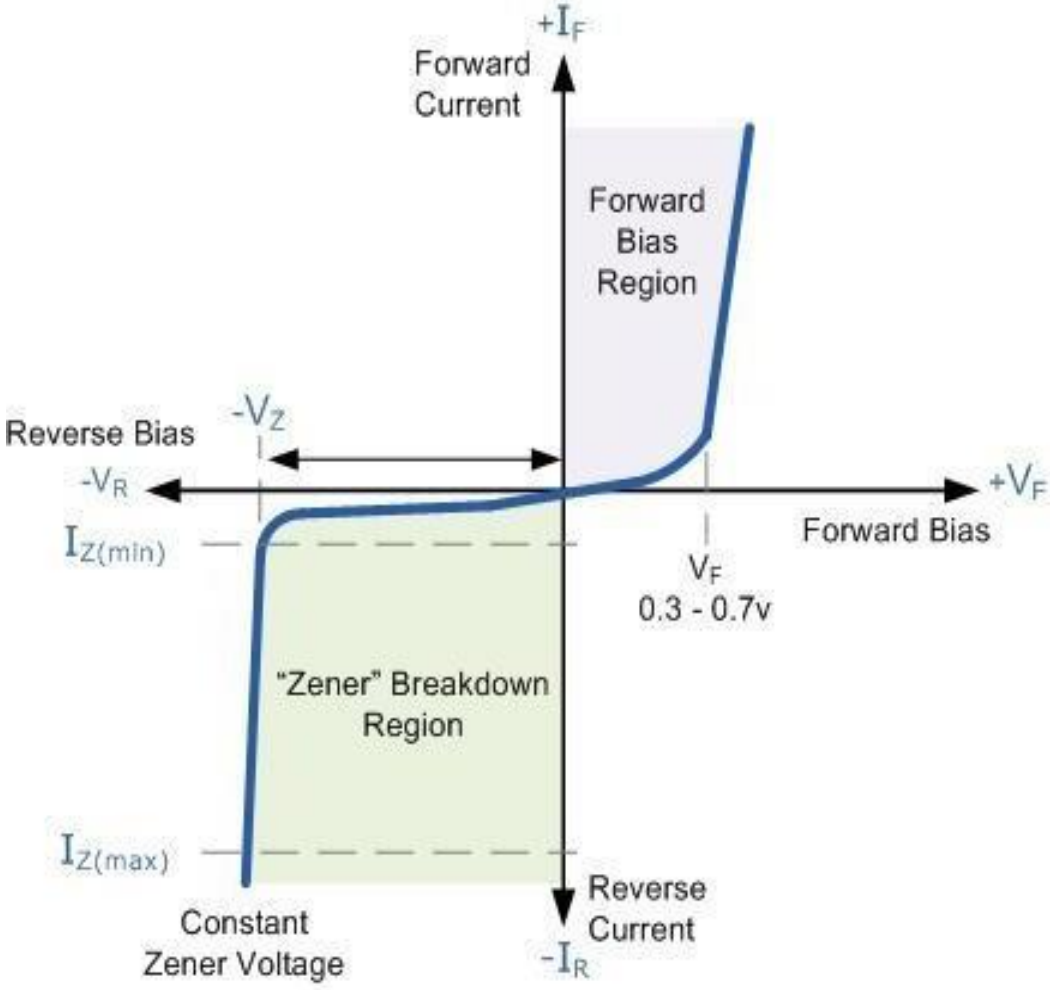
S.No	V_r(volts)	I_z(mA)
1.	-0.01	0
2.	-0.1	0
3.	-2.0	0
4.	-2.7	0
5.	-3.2	0
6.	-3.4	0.1
7.	-3.57	0.2
8.	-3.7	0.3
9.	-3.8	0.4
10.	-3.86	0.5
11.	-3.93	0.6
12.	-4.0	0.8
13.	-4.1	1.0
14.	-4.17	1.1
15.	-4.23	1.3
16.	-4.27	1.5
17.	-4.3	1.7
18.	4.35	1.9
19.	4.38	2.1
20.	4.4	2.3
21.	4.44	2.5

GRAPH-



MODEL GRAPH:

Figure-3: V-I characteristics of Zener Diode



Part-B - Construct voltage regulator circuit using Zener diode and evaluate its performance parameters.

PROBLEM STATEMENT:

Design a Zener Shunt Regulator to meet the following specification:

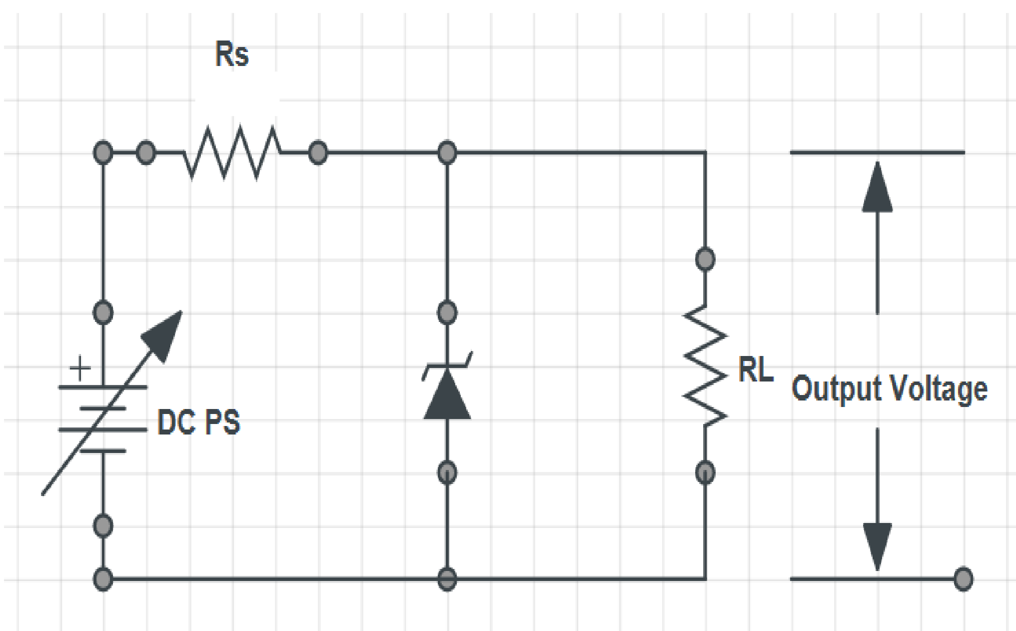
V_0 = 5.6 V, I_{Lmax}= 55mA, Vin = 12 V ± 10%.

APPARATUS:

Sr. No.	Components/Equipment	Specification	Quantity
1.	Zener Diode	Vz = 5.6 V	1
2.	Resistors		1
3	Unregulated power supply	(0 – 30V), 2A rating	1
4	Ammeter	(0 - 30) mA	1
5	Voltmeter	(0 – 10) V	1
6	Breadboard & Single strand cable		

CIRCUIT DIAGRAM

Figure-3: Zener Shunt Voltage Regulator



Procedure:

[a] CALCULATION OF NO LOAD VOLTAGE

i. Make the connections as shown in circuit diagram of Figure-3.
ii. Remove the load resistor from the output terminal and connect a voltmeter across the Zener diode.
iii. Change the input supply voltage gradually from 0 to 30 V and observe the voltage across the Zener diode in the voltmeter.
iv. Once diode enters into breakdown region, voltage across it remains constant. Note this constants voltage shown by voltmeter as the No load voltage.

[b] LOAD REGULATION

i. Keep the i/p supply voltage fixed at a value greater than the breakdown voltage of the Zener diode (say around 10 V).
ii. Do the circuit connection as shown in the Figure-3.
iii. Vary load from minimum to maximum and note down corresponding voltmeters and ammeter reading.
iv. Plot graph of V_L vs I_L for load regulation.
v. Calculate % load regulation.

[c] LINE REGULATION

i. Do the circuit connection as shown in the Figure-3.
ii. Keep the load resistance constant.
iii. Vary supply voltage from 0 to 15 V in steps of 1V and note down corresponding voltmeter readings (across the load resistor).
iv. Calculate % line regulation.

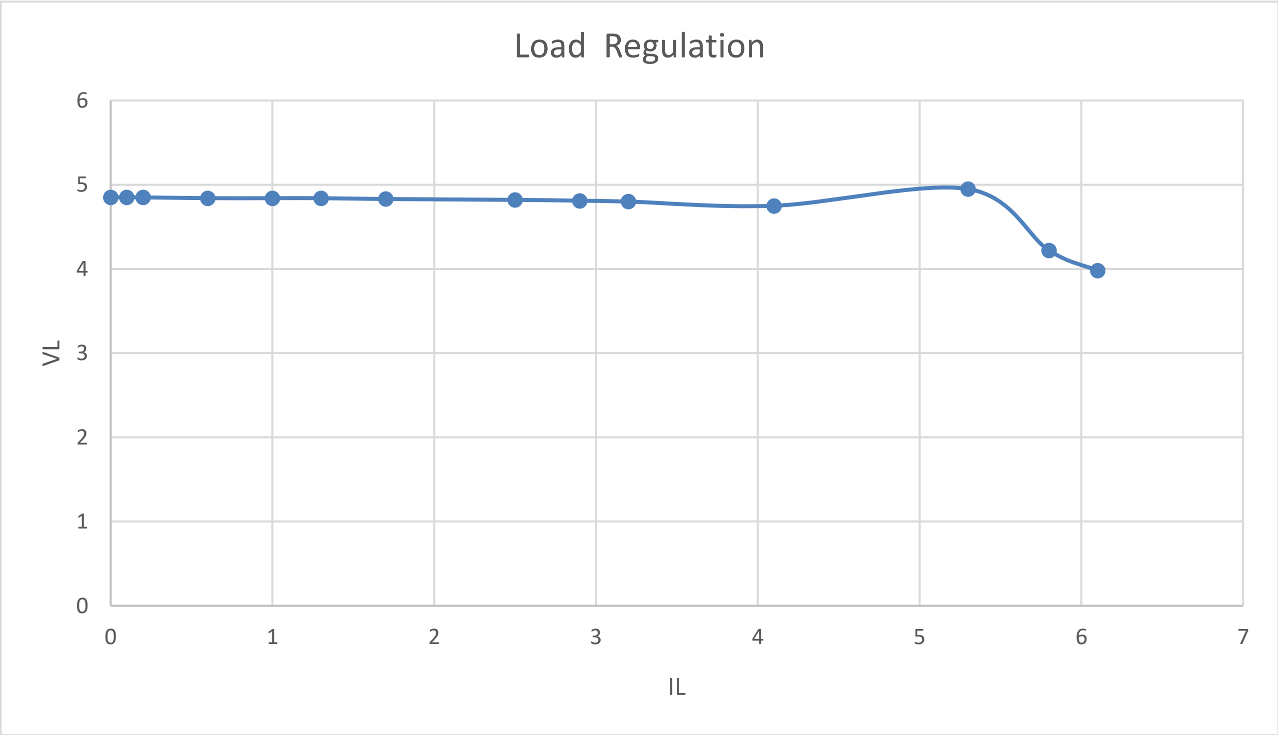
Observation Table:

No load voltage = 4.94 Volts

For Load Regulation :

Sr. No	I_L (Ω)	Vo (Volts)
1	6.1	3.98
2	5.8	4.22
3	5.3	4.949
4	4.1	4.75
5	3.2	4.80
6	2.9	4.81
7	2.5	4.82
8	1.7	4.83
9	1.3	4.84
10	1.0	4.84
11	0.6	4.84
12	0.2	4.85
13	0.1	4.85
14	0	4.85

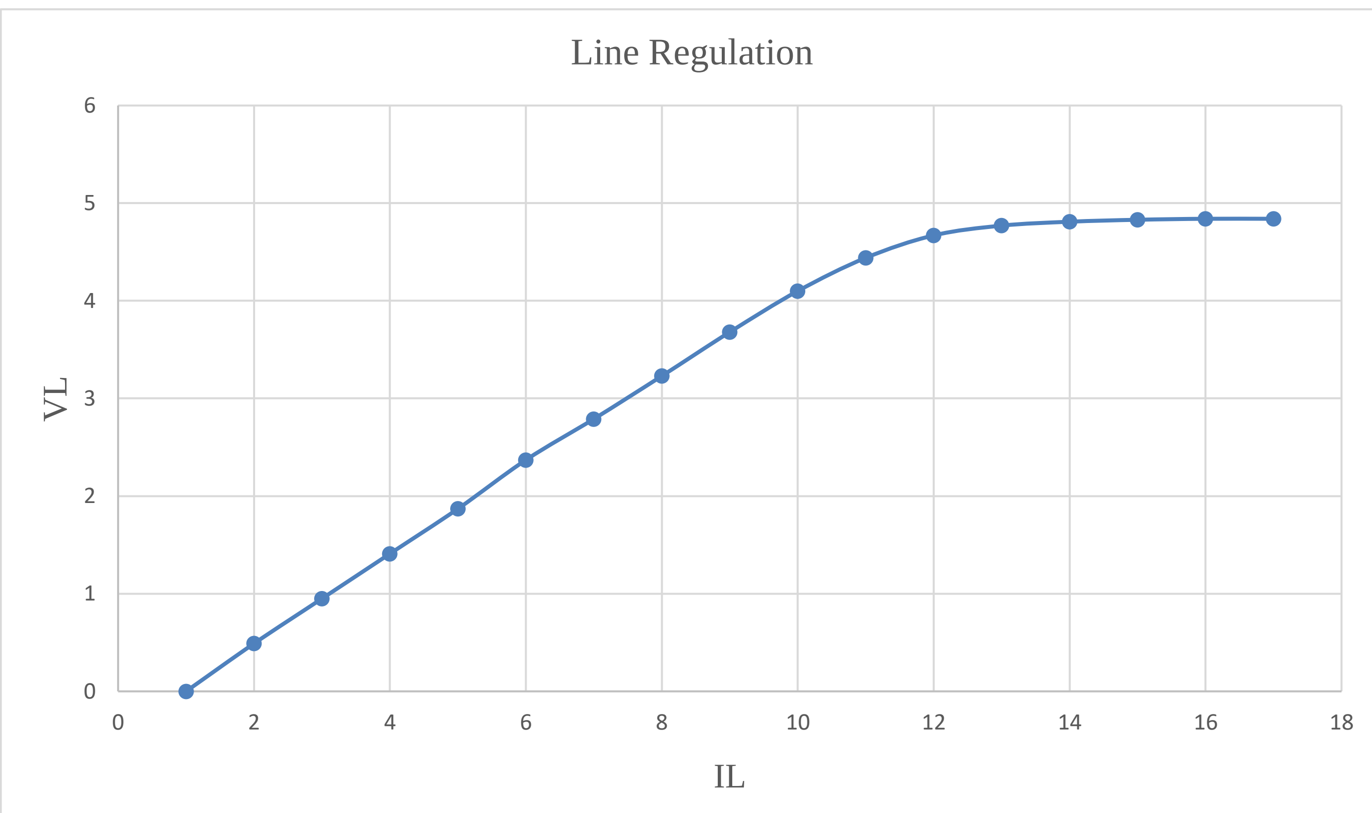
GRAPH –



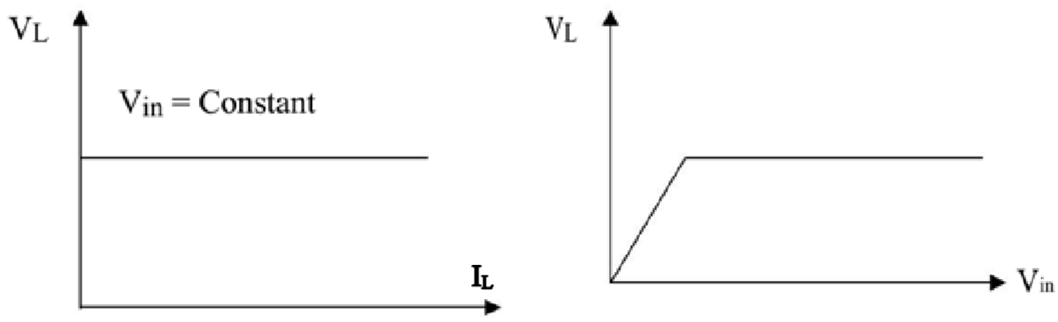
For Line Regulation -

Sr. No.	V_S	$I_{L(mA)}$	V_L
1	1	0.5	0.49
2	2	1.1	0.95
3	3	1.6	1.41
4	4	2.1	1.87
5	5	2.7	2.37
6	6	3.3	2.79
7	7	3.8	3.23
8	8	4.4	3.68
9	9	4.9	4.10
10	10	5.4	4.44
11	11	5.7	4.67
12	12	5.9	4.77
13	13	5.9	4.81
14	14	6	4.83
15	15	6	4.84
16	16	6	4.84

GRAPH-



Model Graph:



LOAD REGULATION LINE REGULATION

Calculation:

For Line Regulation,

V_s = 16V , V_{NL} = 4.94V , V_{FL} = 4.22V

R = 4.94 – 4.22 *100
4.94
<u>R = 14.57%</u>

For Load Regulation,

V_{NL} = 4.99V, V_{FL} = 4.81V

R = 4.94 – 4.81 * 100
4.94
R = <u>2.631%</u>

Result:

Thus, the V-I characteristics of the Zener diode is verified and the circuit of Zener shunt regulator is analyzed practically. From the V-I characteristics plot, following parameters of the Zener diode are determined:

1) Cut in voltage = 0.69V
2) Break down voltage = 3.57V
3) Forward Dynamic resistance of the diode = 50ohm
4) Reverse Dynamic resistance of the diode = 1.7kohm

From the practical analysis of Zener shunt regulator following parameters are determined

5) % Line Regulation = 14.57%
6) % Load Regulation = 2.631%

Conclusion:

Hence we successfully get the output of Zener diode and also studied the V-I characteristics of Zener diode.

Discussion Questions:

1. Explain the concept of Zener breakdown?

- The PN junction is formed by the combination of the p-type and the n-type semiconductor material. The combination of the P-type and N-type regions creates the depletion region.
- The width of the depletion region depends on the doping of the P and N-type semiconductor material. If the material is heavily doped, the width of the depletion region becomes very thin.
- The phenomenon of the Zener breakdown occurs in the very thin depletion region. The thin depletion region has more numbers of free electrons. The reverse bias applies across the PN junction develops the electric field intensity across the depletion region. The strength of the electric field intensity becomes very high.
- The electric field intensity increases the kinetic energy of the free charge carriers. Thereby the carriers start jumping from one region to another. These energetic charge carriers collide with the atoms of the p-type and n-type material and produce the electron-hole pairs.
- The reverse current starts flowing in the junction because of which depletion region entirely vanishes. This process is known as the Zener breakdown.

2. How depletion region gets thin by increasing doping level in Zener diode?

- In Zener diode the Holes and electrons will combine and thus the electrons will get deficient as they move towards the holes. The process, in general, is termed as depletion while this region is termed as depletion region.
- The process of moving of electrons towards the holes makes the region much thinner. In a battery, the electrons move towards the holes making the junction more thin.

3. State the reason why an ordinary diode suffers avalanche breakdown rather than Zener breakdown?

- In Ordinary diode dopping concentration less i.e. 1 impurity atom for 10^8 ,so depletion region is more minority carrier accelerated, moved and collides and lose energy and multiplied ,that's called avalanche breakdown
- Ordinary diodes are lightly doped as compare to the Zener diode.
- Avalanche break down occurs due to thermal collision caused by the increased reverse bias voltage, while the Zener breakdown occurs due to the strong electric field caused by the high doping (narrow depletion region).

4. Give the reasons why Zener diode acts as a reference element in the voltage regulator circuits.

- The Zener diode is broadly used as a voltage reference in which its reverse breakdown factor contributes to a stable voltage across the diode over an expanse of currents which flows through it. The Zener diode or voltage reference diode is an electronic element that contributes to a stable and defined voltage. Hence, Zener diode circuits are often used in voltage regulator circuits which designs where regulated outputs are required.
- The Zener diode is a kind of semiconductor diode which are broadly used in circuit designs of electronics as a voltage reference.

5. What type of biasing must be used when a Zener diode is used as a regulator?

- A Zener diode is designed to operate in a breakdown region. As the reverse voltage is increased, after the reverse breakdown voltage, a large change in reverse current is possible by almost an insignificant change in reverse voltage. In other words, the Zener voltage remains constant even though the current through the Zener diode varies over a wide range. Hence, a Zener diode is always used in reverse bias for regulating supply voltages.

Shri Ramdeobaba College of Engineering and Management, Nagpur-13.

Department of Electronics Engineering

ENP 251 - Electronic Devices & Circuits LabODD

Semester – 2022-23

Lab 01-b-

To design full wave rectifier with and without filter and compute its ripple factor.

Name:					
Roll No.					
Semester/Section :					
Date of Performance:					
Date of Submission:					
Particulars	**Experiment Performance**	**Observation & Calculations**	**Result & Conclusion**	**Report writing**	**Total**
Max. Marks	**03**	**02**	**03**	**02**	**10**
Marks Obtained					
Name & Signature of Faculty	Prof.R.S.Ochawar				

Lab-01-b

Aim: To design full wave rectifier with and without filter and compute its ripple factor.

Objectives:

1. To analyze and plot the input and output waveform of full wave rectifier with and without filter.
2. To find ripple factor for full wave rectifier with and without filter.
3. To find peak inverse voltage of diodes employed as full wave rectifier.

Apparatus:

S. No.	Components/ Equipment	Specification	Quantity
1	PN-Junction Diode (Si)	1N4007	04
2	Resistor	470 Ω, 10% tolerance, 0.5-watt rating	1
3	Transformer	(12V – 0 - 12V)	1
4	Capacitor	470 µF	1
5	Capacitor	100 µF	1
6	Transformer	12-0-12	1
7	DSO/CRO	Dual Channel	1
8	CRO probes		2
9	Breadboard		1
10	Single strand wires		8

Part-2: Full Wave Rectifier:

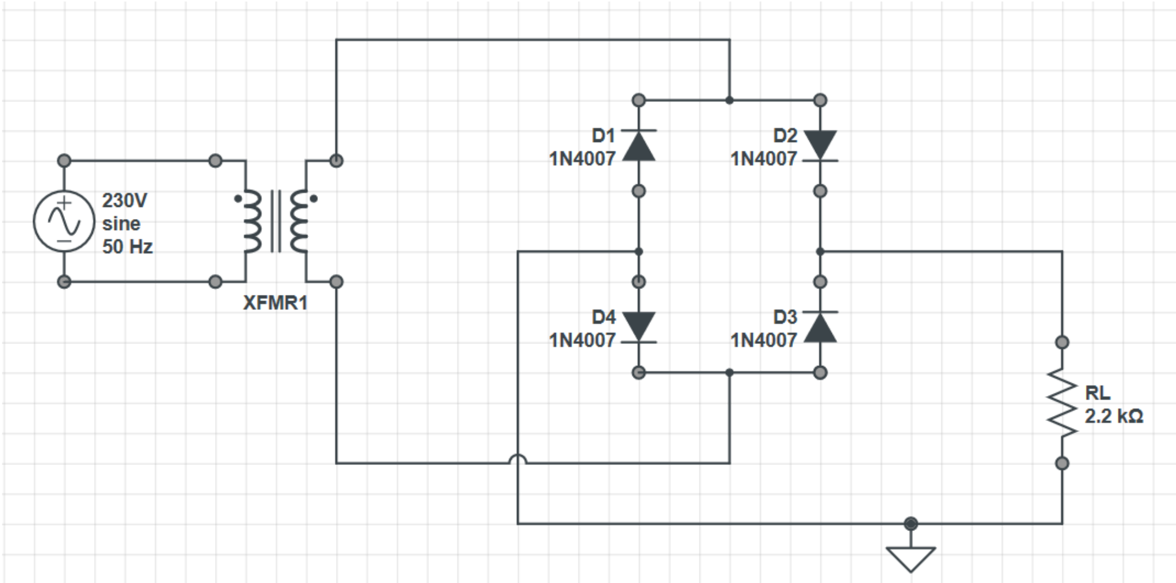


Figure-3: Full wave Rectifier without Filter

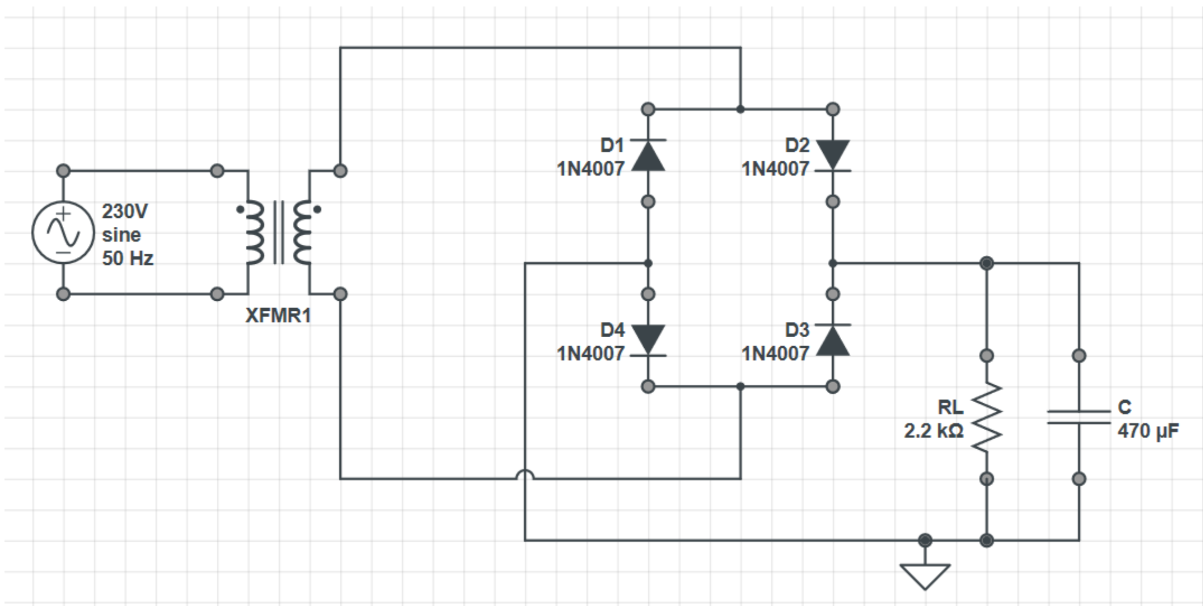


Figure-4: Full wave Rectifier with Filter

PROCEDURE:

Full wave Rectifier Without filter:

1. Connect the circuit as per the Figure-3.
2. Connect CRO across the load.
3. Note down the peak value V_M of the signal observed on the CRO
4. Switch the CRO into DC mode and observe the waveform. Note down the DC shift

5. Calculate V_{rms} and V_{dc} values by using the formulae

$$V_{rms} = \frac{V_m}{\sqrt{2}}, \qquad V_{dc} = \frac{2V_m}{\pi},$$

6. Calculate the ripple factor by using the formulae

$$Ripple\ factor = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$$

Full wave Rectifier With filter:

1. Connect the capacitor filter across the load as shown in Figure-4.
2. Proceed with the same procedure mentioned above to measure $\mathbf{V_{ac}}$ value from the CRO/DSO and dc shift from CRO/DSO.
3. Calculate $\mathbf{V_{rms}}$ and $\mathbf{V_{dc}}$ values by using the following formulae

$$V_{rms} = \frac{V_m}{\sqrt{2}}, \quad V_{dc} = \frac{2V_m}{\pi}$$

4. Calculate the ripple factor by using the formula

$$Ripple\ factor = \frac{rms\ \text{value of alternating component of output wave}}{\text{average value of output wave}} \quad \text{(Practical Value)}$$

$$Ripple\ factor = \frac{1}{4\sqrt{3}} \quad \text{(Theoretical Value)}$$

OBSERVATIONS:

Full wave Rectifier without Filter:

R_L 2.2kΩ	V_m (Volts)	Vrms (Volts)	V_{dc} (Volts)	Ripple factor
Theoretical	16.1	11.31	10.24	0.4689
Practical	16.1	11.35	10.05	0.5248

Full wave Rectifier with Filter:

Capacitor	Rms value of ac component of output signal $V'_{r\,ms}$ (Volts)	Average value of the output signal V_{dc} (Volts)	Ripple factor (Practical Value)	Ripple factor (Theoretical Value)
100 µF	509.11mv	458.36mv	70.588	0.00656
470 µF	123.6mV	107.72mV	111.3999	1.395x10-3

Calculation –

For Full wave rectifier without filter :-

For Theoretical –

V_m = 16.1V

V_{rms} = $V_m/2$ = 16/2 = 11.31 V

V_{dc} = $2V_m/\pi$ = 2*16.1/ π = 10.24V

Ripple Factor –

RF = $\sqrt{(V_{rms}/V_{dc})^2-1} = \sqrt{(11.35/10.05)^2-1}$

RF = 0.5248

For Full wave rectifier with filter :-

Practical for 470uf –

V_{rms} = 123.6mV , V_{dc} = 107.72mV

V_m = $290\text{x}10^{-3}$V , F = 100Hz

Ripple Factor = V_{AC}/V_{DC} = 12/107.72

Ripple Factor = 111.3999

Theoretical for 470uf –

V_m= $290\text{x}10^{-3}$

V_{rms} = $V_m/\sqrt{2}$ = $290\text{x}10^{-3}\text{x}\sqrt{2}$

V_{rms} = 205.06 mV

Ripple Factor = $\dfrac{1}{4\sqrt{3}FR_LC}$

$= \dfrac{1}{4\sqrt{3}\text{x}100\text{x}2200\text{x}470\text{x}10^{-6}}$

Ripple Factor = $1.395\text{x}10^{-3}$

Theoretical for 100uf –
V_m = 720mv ,

$V_{rms} = V_m/\sqrt{2} = 720\text{x}10^{-3}/\sqrt{2} = 0.509V$

$V_{dc} = 2V_m/\pi = 2\text{x}720\text{x}10^{-3}/\pi = 0.458V$

$$\text{Ripple Factor} = \frac{1}{4\sqrt{3}FR_LC}$$

$$= \frac{1}{4\sqrt{3}\text{x}100\text{x}2200\text{x}100\text{x}10^{-6}}$$

Ripple Factor = 0.00656

<u>Practical for 100uf –</u>

V_m = 720mv , V_{dc} = 114.20mv

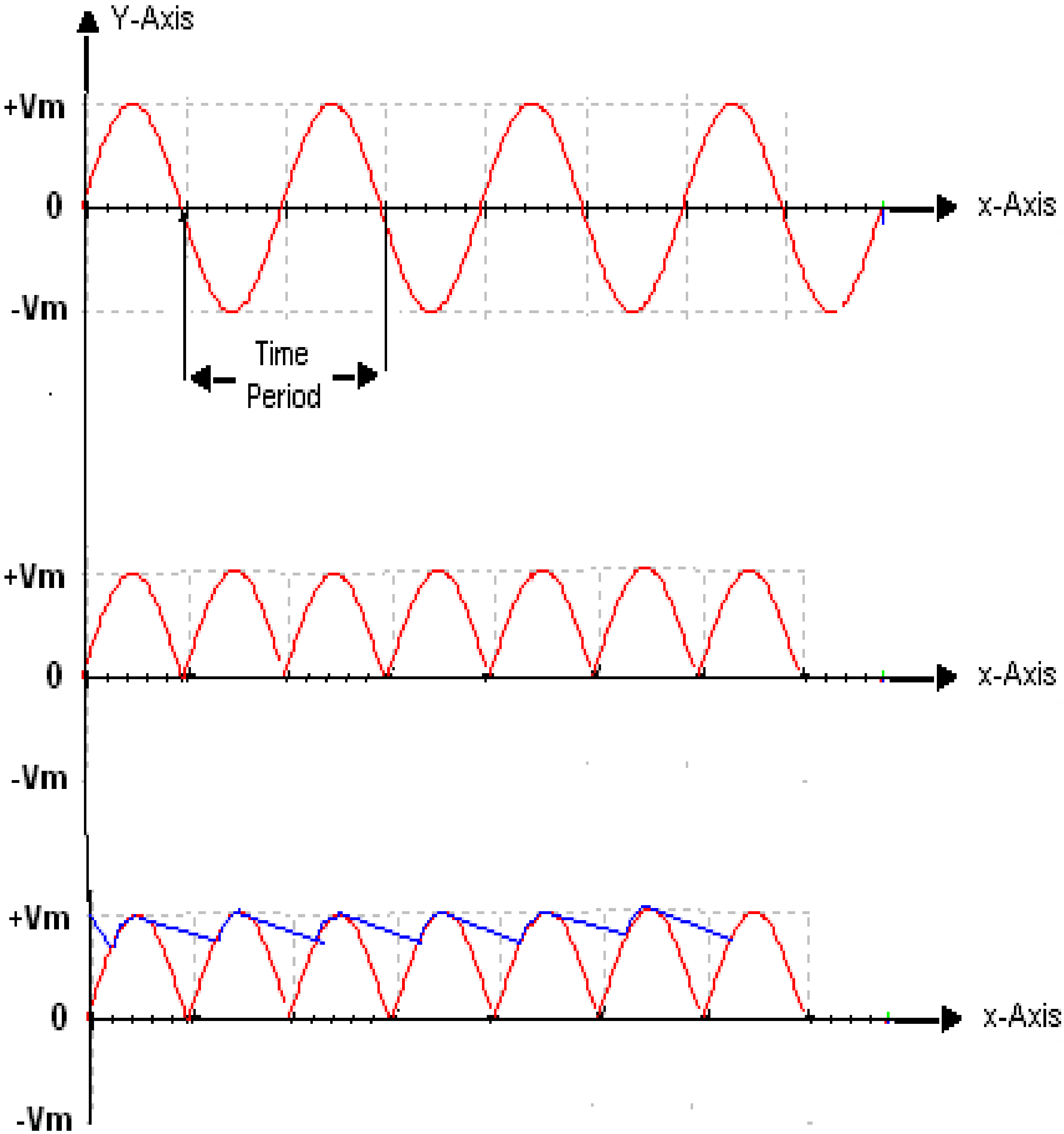
V_{rms} = 170mv , F = 100Hz

$$\text{Ripple Factor} = V_{AC}/V_{DC} = \frac{12}{170\text{x}10^{-3}}$$

Ripple Factor = 70.588

MODEL GRAPHS:

Full wave Rectifier (With & Without Filter):



Result: Thus, we have analyzed the input and output waveform of the Half Wave and Full Wave Rectifier. From the input and output waveforms following parameters of the rectifier are determined:

For Full Wave Rectifier:

1) Ripple Factor (without filter) = 0.4689 (Theoretical Value)
2) Ripple Factor (without filter) = 0.5248 (Practical Value)
3) Ripple Factor (with filter) = 1.395x10-3 (Theoretical Value)
4) Ripple Factor (with filter) =111.3999 (Practical Value)
5) Peak Inverse Voltage =

Conclusion:

Hence , we studied how to build full wave rectifier and also studied the output waveform on DSO.

Discussion Questions:

1) Define a rectifier.

- A rectifier is an electrical component that converts alternating current (AC) to direct current (DC). A rectifier is analogous to a one-way valve that allows an electrical current to flow in only one direction.

2) What is peak inverse voltage (PIV)?

- The maximum value of the reverse voltage that a PN junction or diode can withstand without damaging itself is known as its Peak Inverse Voltage.

3) In a center tapped full-wave rectifier circuit, the peak inverse voltage across each diode is twice the maximum transformer secondary voltage measured from midpoint to either end" justify the statement.

- The peak inverse voltage (PIV) of the diode in the center tapped full wave rectifier is twice the transformer secondary terminal voltage. PIV of the diode is equal to transformer secondary terminal voltage, Thus this type of rectifier used for high voltage application.

4) Describe the necessity of filters in rectifier.

- We know that rectifiers are used to convert AC to DC, but not a pure DC. There would be considerable AC component in their output, called 'ripple', in addition to the desired dc. component.

- Most sophisticated electronic systems need pure DC supply to drive, or power them. To construct a good power supply which gives pure DC output, we need to remove or filter out the AC component from the output of rectifiers.

- The output from these rectifiers with Ripple components, is fed to filter circuits so that the output from the filter is pure DC.

5) What are the limitations of capacitor filter?

- It is bulky due to use of inductance
- Costly due to more number of component
- Current rating of choke need to be high
- Power loss takes place in the inductor
- High peak diode current

Shri Ramdeobaba College of Engineering and Management, Nagpur-13.

Department of Electronics Engineering

ENP 251 - Electronic Devices & Circuits

LabODD Semester – 2022-23

Lab 03-

Examine and verify input, output, and transfer characteristics of BJT in Common Emitter configuration..

Name:					
Roll No.					
Semester/Section :					
Date of Performance:					
Date of Submission:					
Particulars	Experiment Performance	Observation & Calculations	Result & Conclusion	Report writing	Total
Max. Marks	03	02	03	02	10
Marks Obtained					
Name & Signature of Faculty	Prof.R.S.Ochawar				

Lab-03

Aim: Examine and verify input, output, and transfer characteristics of BJT in Common Emitter configuration.

Objectives:

1. To verify and plot the input and output characteristics of BJT.
2. To verify and plot the Transfer characteristics of BJT
3. To determine the input resistance from the input characteristics.
4. To determine the output resistance from the output characteristics.
5. To determine the current gain from the transfer characteristics.

Apparatus:

Sr.No.	Components/Equipment	Specification	Quantity
1.	Transistor (BC 547)	I_{cmax}=100mA P_D=500mw V_{ceo}=45V V_{beo}=6V	1
2.	Resistance	1KΩ	2
3.	Regulated power supply	(0 – 30V), 2A rating	2
4.	Ammeter	(0-50) mA, (0-50) μA	1
5.	Voltmeter	(0 – 1.4) V, (0 – 30) V	1
6.	Breadboard & Single Strand wires		

Theory:

In common emitter configuration the emitter is common to both input and output. For normal operation the Base-Emitter junction is forward biased and base- collector junction is reverse biased. The input characteristics are plotted between I_B and V_{BE} keeping the voltage V_{CE} constant. This characteristic is similar to that of a forward biased diode. The input dynamic resistance is calculated using the formula

$$R_i = (\Delta V_{BE} / \Delta I_B) \text{ at constant } V_{CE}$$

The output characteristics are plotted between I_C and V_{CE} keeping I_B constant. These curves are almost horizontal. The output dynamic resistance is given by,

$$R_o = (\Delta V_{CE} / \Delta I_C) \text{ at constant } I_B$$

At a given operating point, current gains (β) is defined as ratio of output current to input current at constant output voltage as follows

$$\beta = (\Delta I_C / \Delta I_B) \text{ at constant } V_{CE}$$

Circuit Diagram:

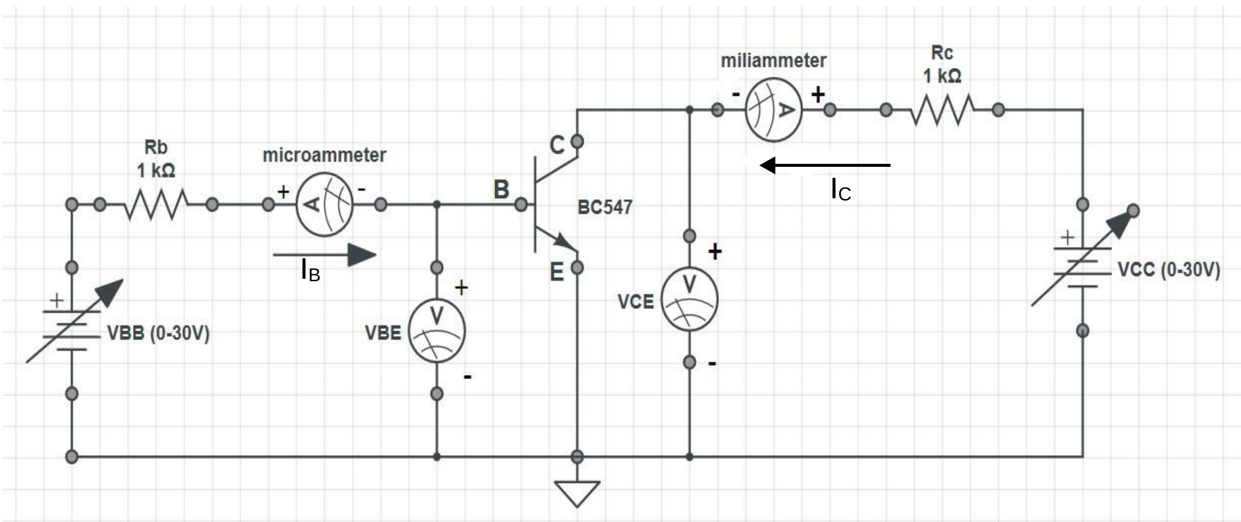


Figure 1: BJT in Common Emitter configuration

PRECAUTIONS:

1. While doing the experiment do not exceed the ratings of the Transistor. This may lead to damage of the Transistor.
2. Connect voltmeter and Ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch **ON** the power supply unless you have checked the circuit connections as per the circuit diagram.

Procedure:

A) Input Characteristics:

1. Connect the circuit as in shown in Figure-1.
2. Keep the voltage V_{CE} constant at 0.5V by varying V_{CC}.
3. By varying V_{BB}, note down the value of I_B (Readings of the Ammeter) for various values of Base to Emitter voltage (V_{BE}) (Readings of the Voltmeter).
4. Repeat the step 1 to 3 for different values of V_{CE}
5. Draw input characteristics for tabulated values.
6. Calculate input resistance.

B) Output Characteristics:

1. Keep the current I_B constant at 20µA by varying V_{BB}.
2. By varying V_{CC}, note down the value of I_C (Readings of the Ammeter) for various values of Collector to Emitter voltage (V_{CE}) (Readings of the Voltmeter).
3. Repeat the step 1 to 3 for different values of V_{CE}
4. Draw input characteristics for tabulated values.
5. Calculate input resistance.

C) Transfer Characteristics:

1. Keep the voltage V_{CE} constant at 5V by varying V_{CC}.
2. By varying V_{BB}, note down the value of Collector current, I_C (Readings of the milli-Ammeter) for various values of V_{BE} (Readings of the voltmeter across base and emitter terminal).
3. Draw Transfer characteristics for tabulated values.

Observation Table

Table No. 1: Input Characteristics

Sr. No.	V_{CE} = 5 (V)		V_{CE} = 7 (V)	
	V_{BE} (V)	I_B (μA)	V_{BE} (V)	I_B (μA)
1.	0.091	1	0.031	1
2.	0.202	1	0.278	2
3.	0.286	2	0.473	4
4.	0.341	2	0.524	7
5.	0.414	3	0.541	16
6.	0.484	4	0.561	28
7.	0.494	5	0.570	32
8.	0.508	6	0.580	42
9.	0.515	7	0.608	95
10.	0.521	10	0.628	170
11.	0.530	12	0.637	221
12.	0.541	16	0.644	273
13.	0.564	30	0.648	306
14.	0.583	48		
15.	0.6	78		
16.	0.611	105		
17.	0.624	152		
18.	0.635	207		
19.	0.649	313		

Table No. 2: Output Characteristics

Sr. No.	I_B = 20 (μA)		I_B = 40 (μA)	
	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)
1.	0.09	0.9	0.06	0.9
2.	0.13	2	0.9	1.9
3.	0.15	2.9	0.1	2.9
4.	0.22	3.9	0.12	3.9
5.	0.56	4.5	0.13	4.9
6.	1.39	4.6	0.15	5.9
7.	2.17	4.9	0.17	6.9
8.	3	5.1	0.19	8
9.	3.9	5.2	0.23	9
10.	4.8	5.3	0.84	9.4
11.	5.65	5.4	2.17	8.9
12.	6.5	5.5	2.7	9.4
13.	7.49	5.6	3.3	9.9
14.	9.5	5.7	3.9	10.2
15.	10.2	5.8	4.6	10.6
16.	11.4	5.9	5.5	10.9
17.	12.2	5.9	6.1	11.1
18.	13.1	6	6.9	11.3
19.	14.1	6	7.7	11.6

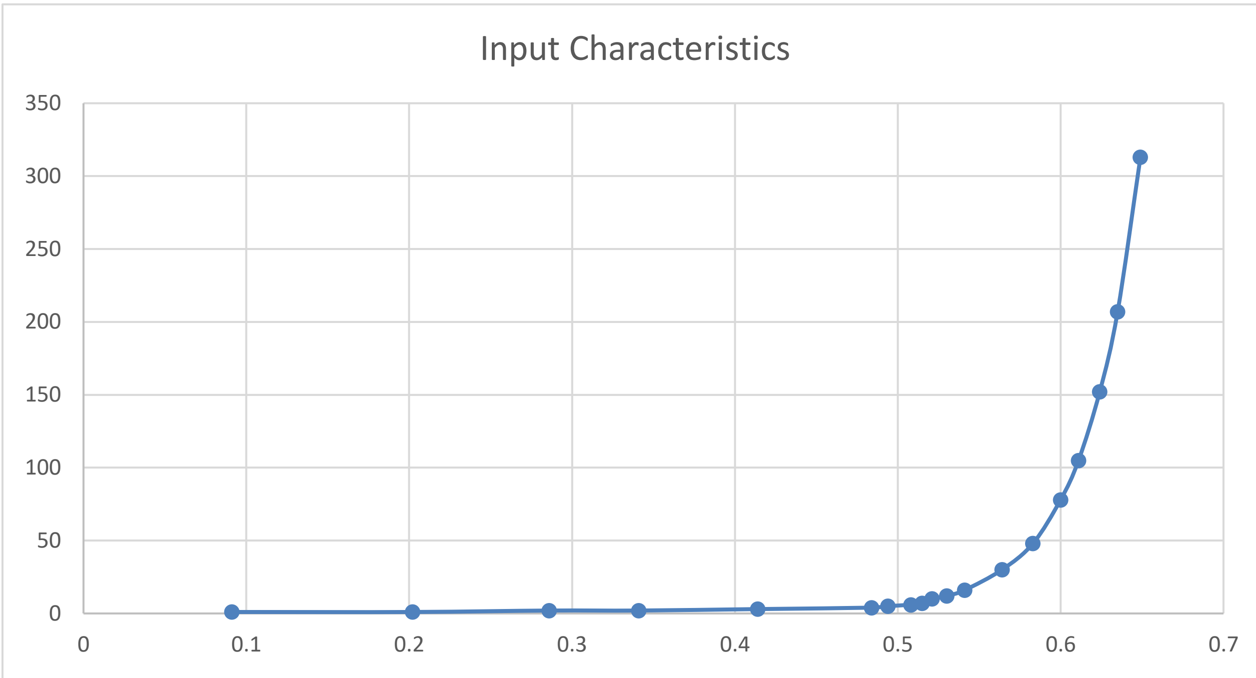
Table No. 3: Transfer Characteristics

Sr. No.	V_{BE} (V)	I_C (mA)	I_B(uA)
1.	0.58	1.3	5
2.	0.61	3.9	15
3.	0.69	4.9	23
4.	0.696	4.9	30
5.	0.67	4.9	52
6.	0.7	4.9	65
7.	0.701	4.9	85
8.	0.704	5	120
9.	0.707	5	155
10.	0.708	5	180
11.	0.710	5	200
12.	0.711	5	225
13.	0.713	5	250
14.	0.714	5	275
15.	0.716	5	300
16.	0.717	5	325
17.	0.719	5	350

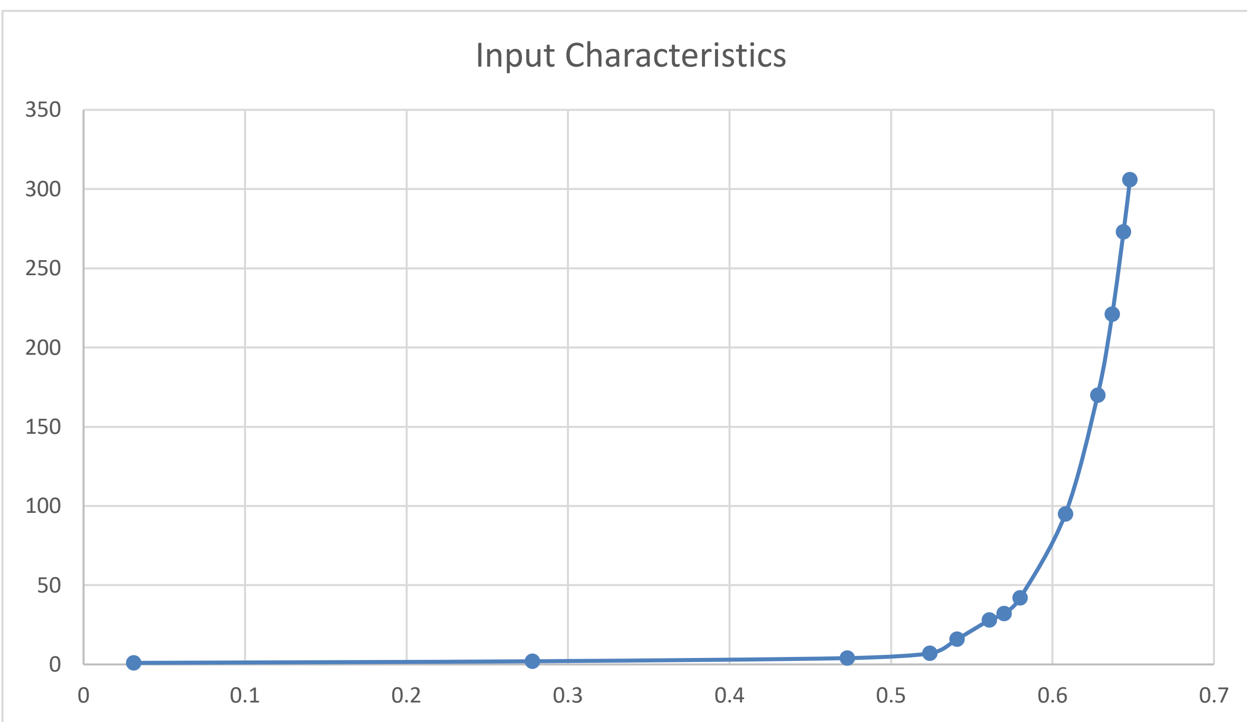
GRAPH:

Input Characteristics –

For V_{CE} =__5____V

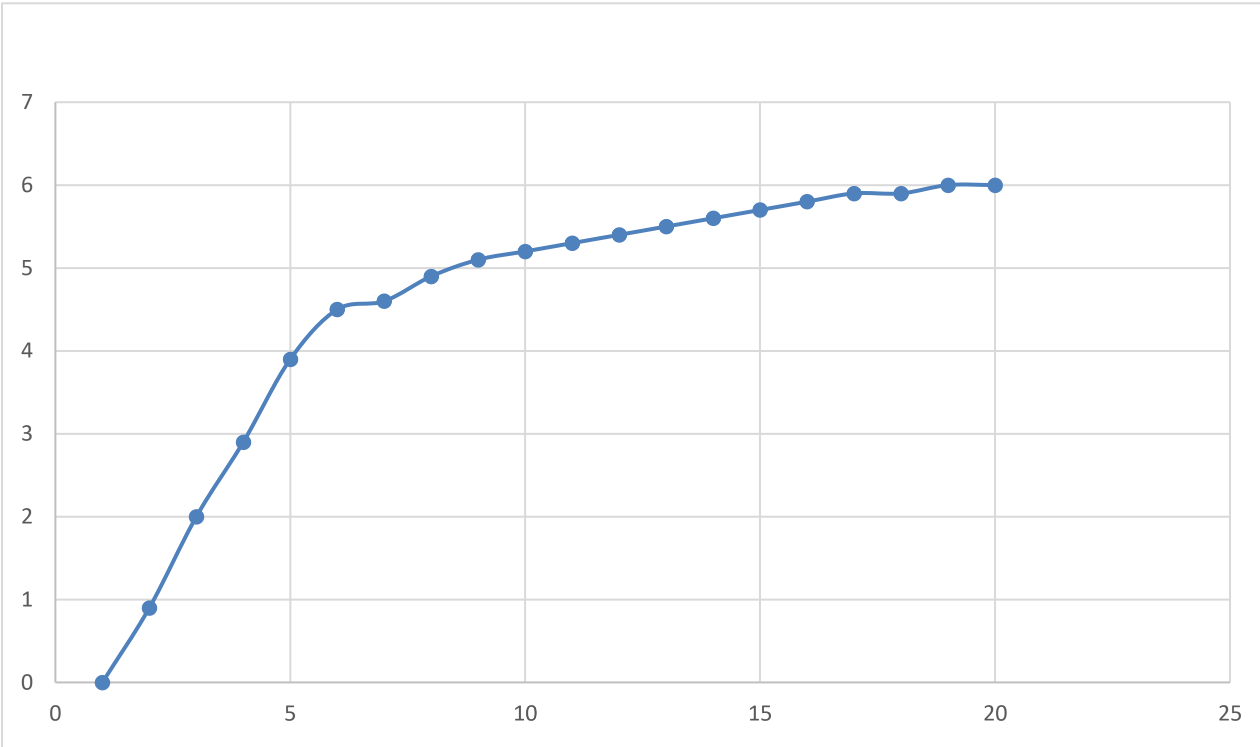


For V_{CE} =__7__(V)

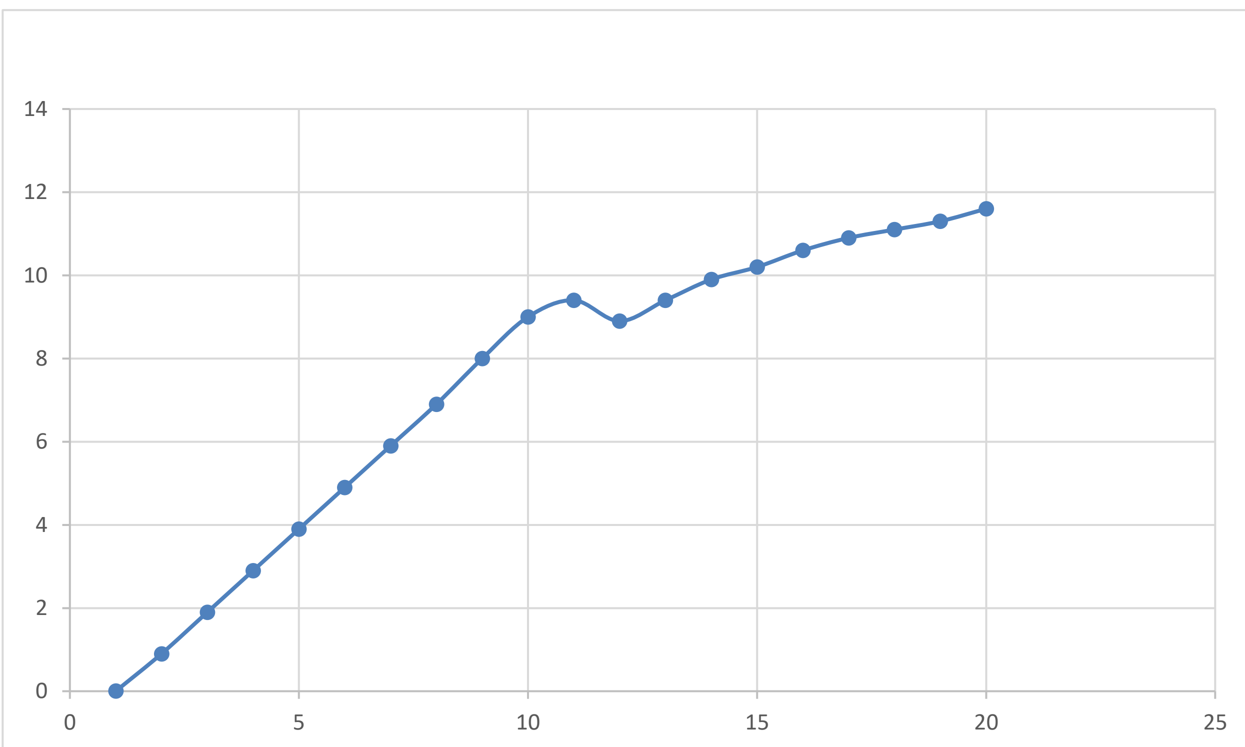


Output Characteristics –

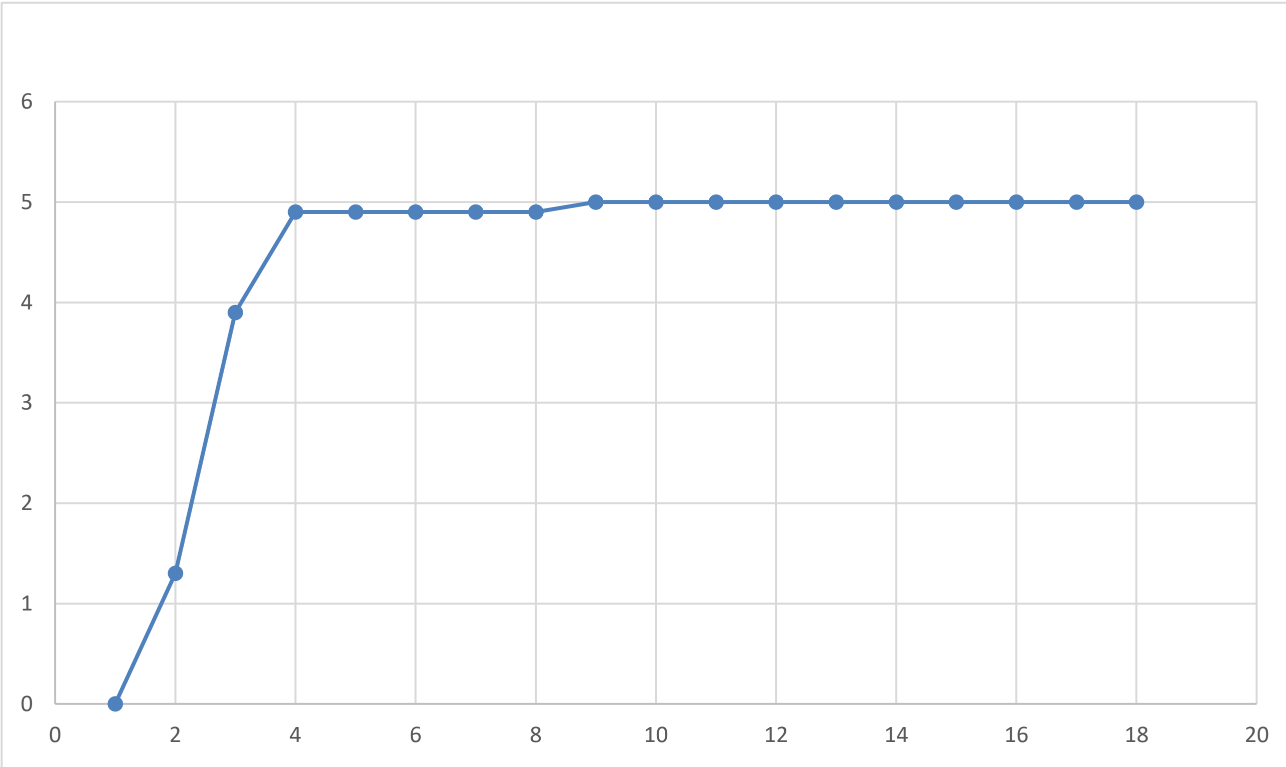
For I_B = __20_ (μA)



For I_B = __40_ (μA)



Transfer Characteristics –



Calculation:

Input resistance -

Ri = (Δ VBE / Δ IB) at constant VCE

R_i = (0.6/78x10^{-6})x5

Ri = 3861Ω

Output resistance-

$R_o = (\Delta V_{CE} / \Delta I_C)$ at constant I_B

Ro = (13.1/6x10^{-3})x20x10^{-6}

Ro = 0.04366

Current Gain

$\beta = (\Delta I_C / \Delta I_B)$ at constant V_{CE}

$\beta = (5\times10^{-3}/120\times10^{-6})$

β = 208.33

Result: Thus, the input, output and transfer characteristics of BJT in Common Emitter configuration are verified. From the characteristics plot, following parameters are determined:

1) Input resistance, R_i = _38461Ω
2) Output resistance, R_o = 0.04366Ω
3) Current Gain, β = _ 208.33

Conclusion:

Hence we successfully studied and verified input, output, and transfer characteristics of BJT in Common Emitter configuration.

Discussion Questions:

1. What are the different configurations of BJT?

There are three basic BJT amplifier configurations that are generally identified as:

- common- emitter
- common-base,
- common-collector (sometimes called the emitter-follower).

2. Which configuration of BJT is mostly preferred and why?

Common emitter transistors are used most widely, because a common emitter transistor amplifier provides high current gain, high voltage gain and high power gain. This type of transistor gives for a small change in input there is small change in output. The output voltage is 180 degree out of phase with the input voltage.

3. What is the application of BJT in Common Emitter configuration?

Most amplifiers use common emitter circuit configuration because it offer both current and voltage gain resulting in higher power gain than in common base emitter configuration. The other consideration is that its input resistance is higher and of the order of load resistance.

4. Can we exchange the collector and emitter terminal of BJT? Justify your answer.

No. Transistors are designed to provide the optimum performance when they are correctly connected. Interchanging the collector and emitter terminals not only degrades the transistor performance but also might cause permanent damage to the device.

5. Can we use Transistor as a rectifier?

A transistor can be used as a low current rectifier. When we connect the base-emitter or base-collector region and use it as a diode, then transistor can be used as a low current rectifier.

6. Simulate the Input-Output characteristics of Common Base configuration in Multisim.

Shri Ramdeobaba College of Engineering and Management, Nagpur-13.

Department of Electronics Engineering

ENP 251 - Electronic Devices & Circuits

LabODD Semester – 2022-23

Lab 05-

To examine the stability of the Quiescent point in Fixed bias and Self Bias circuit.

Name:					
Roll No.					
Semester/Section :					
Date of Performance:					
Date of Submission:					
Particulars	**Experiment Performance**	**Observation & Calculations**	**Result & Conclusion**	**Report writing**	**Total**
Max. Marks	**03**	**02**	**03**	**02**	**10**
Marks Obtained					
Name & Signature of Faculty	Prof.R.S.Ochawar				

Lab-05

Aim: To examine the stability of the Quiescent point in Fixed bias and Self Bias circuit.

Objectives:

1. To determine the *Q-point* of the Fixed bias and Self bias circuit.
2. To examine the *stabilization of the Q-point* against the variation in β in the Fixed bias and Self-bias circuit.
3. To determine the *Stability factor* of the Fixed bias and Self-bias circuit.
4. To examine the stabilization of the Q-point against the variation in β of the Self bias circuit.

Apparatus:

Sr. No.	Components/Equipment	Specification	Quantity
1.	Transistor (BC 547)	I_{cmax}=100mA P_D=500mw V_{ceo}=45V V_{beo}=6V	3
2.	Resistance	470Ω, 1kΩ, 2.2 kΩ, 10 kΩ, 4.7 kΩ, 100 kΩ	1 of each type
3.	Regulated power supply	(0 – 30V), 2A rating	1
4.	Ammeter	(0-50) mA,	1
5.	Voltmeter	(0 – 30) V	1
6.	Breadboard & Single Strand wires		

Theory:

In the experiment no. 4 (Lab-04), we have verified that the transistor functions most linearly when it is constrained to operate in its active region. To establish an operating point in this region it is necessary to provide appropriate direct potentials and currents, using external sources. Once an operating point Q is established time varying excursions of the input signal (base current, for example) should cause an output signal (Collector current or collector voltage) of the same waveform. If the output signal is not a faithful reproduction of the input signal, for example, if it is clipped on one side, the operating point is unsatisfactory and should be relocated on the collector characteristics.

There are various techniques to bias the transistor in the active region. In this experiment (Lab-05) , we will examine the stability of the Quiescent point in Fixed bias and Self Bias circuit. The fixed bias circuit is shown in the Figure-1(a) and the Self Bias circuit is shown in the Figure-1(b).

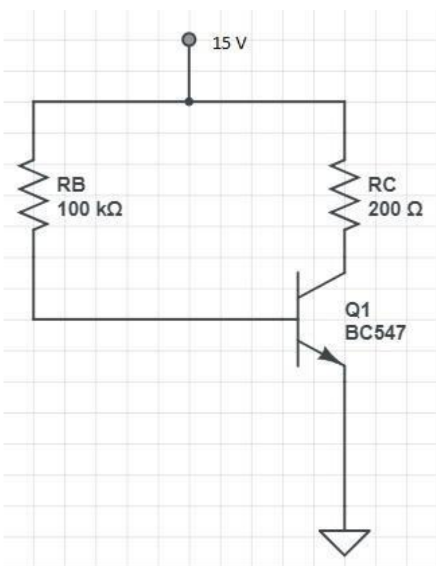
The stability factor for the Fixed bias circuit is given by:

$$S = 1 + \beta \qquad (1)$$

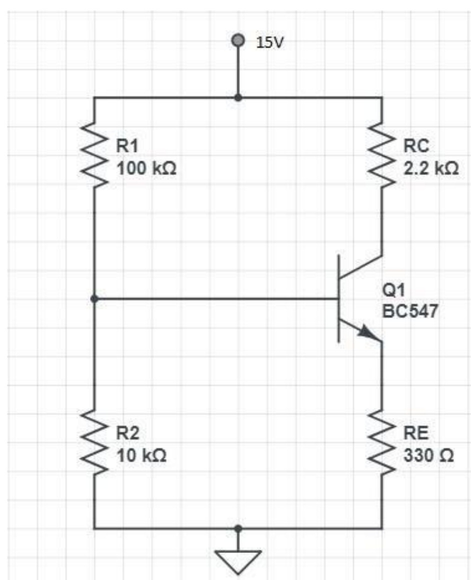
The stability factor for the Self bias circuit is given by:

$$S = \frac{(1+\beta)\left(1+\frac{R_b}{R_e}\right)}{1+\beta+\frac{R_b}{R_e}} \qquad (2)$$

Circuit Diagram:



(a)



(b)

Figure 1: (a) Fixed bias circuit (b) Self-bias circuit

Procedure:

A) For Fixed Bias Circuit

1. Construct the circuit as shown in Figure-1(a).
2. Measure the base current I_B, collector current I_C and collector to emitter voltage V_{CE} using digital multimeter and note it down in observation Table-1.
3. Calculate the stability factor using the formula given in equation-1 and note it down in observation Table-1.
4. Now, replace the transistor by a new transistor of same type.
5. Repeat the step 2 and 3.

B) For Self-Bias Circuit:

1. Construct the circuit as shown in Figure-1(b).
2. Measure the base current I_B, collector current I_C and collector to emitter voltage V_{CE} using digital multimeter and note it down in observation Table-1.
3. Calculate the stability factor using the formula given in equation-1 and note it down in observation Table-1.
4. Now, replace the transistor by a new transistor of same type.
5. Repeat the step 2 and 3.

Observation Table
Table No. 1: For Fixed Bias Circuit

Sr. No.	I_B (µA)	I_C (mA)	V_{CE} (V)	β
Transistor-1	143	24.5	9.89	171.328
Transistor-2	140	23.9	7.33	170.714
Transistor-3	143	24.7	9.45	172.727
Transistor-4	143	9.55	9.55	171.3286
Transistor-5	142	8.67	8.67	174.647
Transistor-6	142	8.79	8.79	168.309

Table No. 2: For Self Bias Circuit

Sr. No.	I_B (µA)	I_C (mA)	V_{CE} (V)	β
Transistor-1	8.99	1.245	11.50	138.48
Transistor-2	7.77	1.447	11.54	186.22
Transistor-3	7.76	1.457	11.53	187.51
Transistor-4	7.86	1.460	11.57	185.7
Transistor-5	8.95	1.270	11.49	141.89
Transistor-6	8.98	1.299	11.44	144.05

Calculation:

For Fixed Bias circuit.

$$I_{CQ} = \beta \times I_B$$
$$= 171.328 \times 143 \times 10^{-6}$$
$$= 0.0244$$
$$V_{CEQ} = V_{CC} - I_C R_C$$
$$= 15 - 24 \times 10^{-3} \times 200$$
$$= 10.2V$$
$$S = \frac{(1+171.328)\left(1+\frac{100\times10^3}{330}\right)}{1+171.328+\frac{100\times10^3}{330}}$$
$$S = 110.21$$

For Self Bias circuit-

$$I_{CQ} = \beta I_B$$
$$= 138.48 \times 8.99 \times 10^{-6}$$
$$= 1.244 \text{ mA}$$
$$V_{CEQ} = V_{CC} - (I_C R_C + I_E R_E)$$
$$= \cancel{1.24}$$
$$= 15 - (1.245\times10^{-3} \times 2200 + 1.245\times10^{-3} \times 330)$$
$$= 11.85V$$
$$S = \frac{1+\beta\left(1+\frac{R_b}{R_e}\right)}{1+\beta+\frac{R_b}{R_e}}$$
$$= \frac{1+138.48\times\left(1+\frac{100\times10^3}{330}\right)}{1+138.48+\frac{100\times10^3}{330}}$$
$$S = 95.14$$

Result: Thus, we have examined the stability of the Quiescent point in Fixed bias and Self Bias circuit. From the circuit analysis, following parameters are determined:

For Fixed Bias Circuit:

1) I_{CQ} = 0.0244A
2) V_{CEQ} = 10.2V
3) Stability factor, S = 110.21

For Self-Bias Circuit:

1) I_{CQ} =1.244mA
2) V_{CEQ} = 11.85V
3) Stability factor, S = 95.14

Conclusion:

Hence we successfully performed the stability of the Quiescent point in Fixed bias and Self Biascircuit and noted down the readings.

Discussion Questions:

1. What are the different techniques to bias the BJT in the active region?

The types of transistor biasing include: Fixed Base Bias or Fixed Resistance Bias. Collector Feedback Bias. Dual Feedback Bias.

2. List all the factors which influences the selection of the Quiescent point?

- Changes in temperature
- Changes in the value of β
- Variations of parameters from one transistor to the other.
- However the Q point instability due to any reason is not desirable because it will introduce distortion in the amplified signal.

3. Consider the circuit shown in Figure-1(b), if the emitter resistor (470 Ω) is replaced by 1kΩ resistor, then what effect it would create in the Operating point of the transistor?

4. What are the limitations of Fixed bias circuit?
    - The collector current does not remain constant with variation in temperature or power supply voltage.
    - Therefore the operating point is unstable.Changes in Vbe will change IB and thus cause RE to change. This in turn will alter the gain of the stage.

5. What are the merits of Self Bias circuit over Fixed bias circuit?

    - Stability factor s for voltage divider or self bias is less as compared to other biasing circuits . So this circuit is more stable and hence it is most commonly used.
    - This circuit is used where only moderate changes in ambient temperature are expected
    - The bias automatically adjusts to any variations in the circuit.

Roll No:63,64,66,67

Shri Ramdeobaba College of Engineering and Management, Nagpur-13.

Department of Electronics Engineering

ENP 251 - Electronic Devices & Circuits

LabODD Semester – 2022-23

Lab 06-

Examine and verify the working of BJT as an amplifier and inverter.

Name:					
Roll No.					
Semester/Section :					
Date of Performance:					
Date of Submission:					
Particulars	**Experiment Performance**	**Observation & Calculations**	**Result & Conclusion**	**Report writing**	**Total**
Max. Marks	**03**	**02**	**03**	**02**	**10**
Marks Obtained					
Name & Signature of Faculty	Prof.R.S.Ochawar				

Lab-06

Aim: Examine and verify the working of BJT as an amplifier and inverter.

Objectives:

1. To identify the region of operation of BJT.
2. To determine the voltage gain of the amplifier.
3. To verify the phase shift of 180^0 in between input and output of Common emitter configuration of BJT as an amplifier.

Apparatus:

Sr.No.	Components/Equipment	Specification	Quantity
1.	Transistor (BC 547)	I_{cmax}=100mA P_D=500mw V_{ceo}=45V V_{beo}=6V	1
2.	Resistance	100KΩ , 10KΩ, 4.7KΩ, 470Ω	1
		1KΩ	2
3.	Regulated power supply	(0 – 30V), 2A rating	2
5.	Voltmeter	(0 – 1.4)V, (0 – 30)V	1
6.	Breadboard &Single Strand wires		

Theory:

The areas of operation for a Transistor switch are known as the Active, Saturation and the Cut-off Region. Depending on the mode of operation of BJT, the applications of BJT's are as an amplifier and switch. When transistor is operated in active region then it can be used as an amplifier. The common-emitter (CE) transistor amplifier configuration is most widely used since it provides large voltage gain and current gain along with the moderate input and output impedance. When transistor is operated in saturation & cutoff region then it can be used as ON switch & OFF switch respectively. Solid state switches are one of the main applications for the use of transistors, and transistor switches can be used for controlling high power devices such as motors, solenoids or lamps, but they can also used in digital electronics and logic gate circuits.

Circuit Diagram -

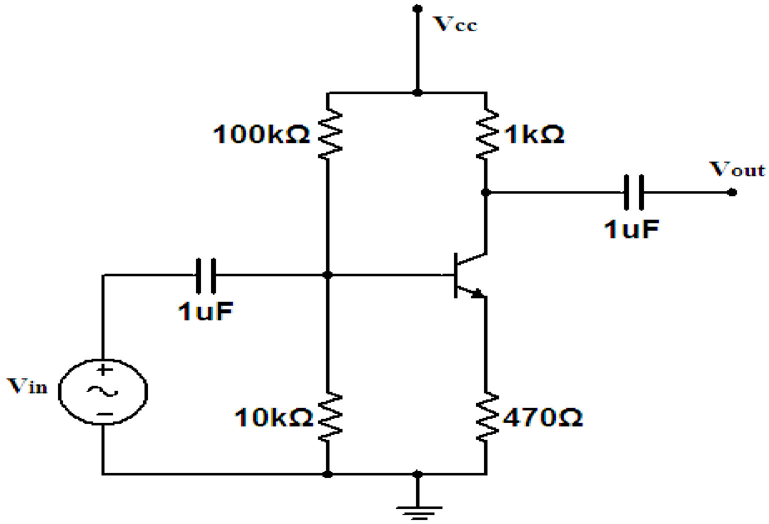


Figure 1: BJT as an Amplifier

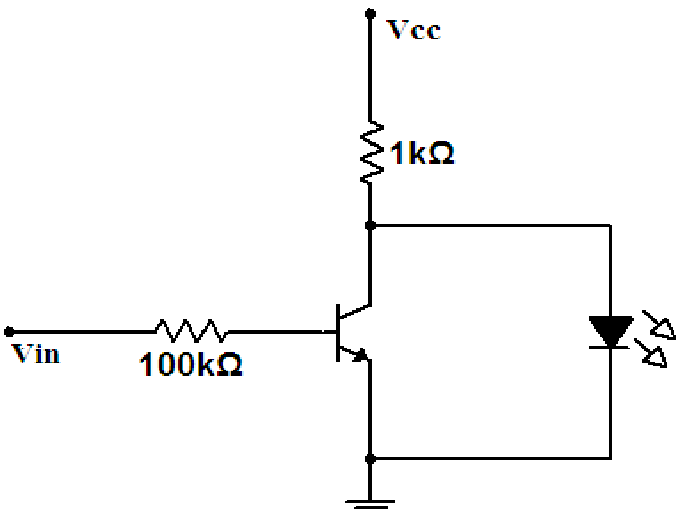


Figure 2: BJT as an inverter

PRECAUTIONS:

1. While doing the experiment do not exceed the ratings of the Transistor. This may lead to damage of the Transistor.
2. Connect voltmeter and Ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch **ON** the power supply unless you have checked the circuit connections as per the circuit diagram.

Procedure:

A) BJT as an Amplifier:

1. Connect the circuit as in shown in Figure-1.
2. Keep the value of voltage V_{CC} = 15V.
3. Set the input to the amplifier at 50 mV pea-to-peak with frequency of 10 kHz.
4. Observe the output signal and note the peak to peak voltage of the output signal.
5. Draw input and output waveforms.
6. Calculate the voltage gain of the amplifier.

B) BJT as an Inverter:

1. Connect the circuit as in shown in Figure-2..
2. Keep the value of voltage V_{CC} = +5V
3. Set V_{in} to 5V
4. Measure the value of voltages at base, collector and emitter terminal with the help of multimeter.
5. Note down the status (ON or OFF) of LED.
6. Identify the region of operation of BJT.
7. Repeat the steps from 3 to 6 after setting V_{in} to 0V.

Observation Table

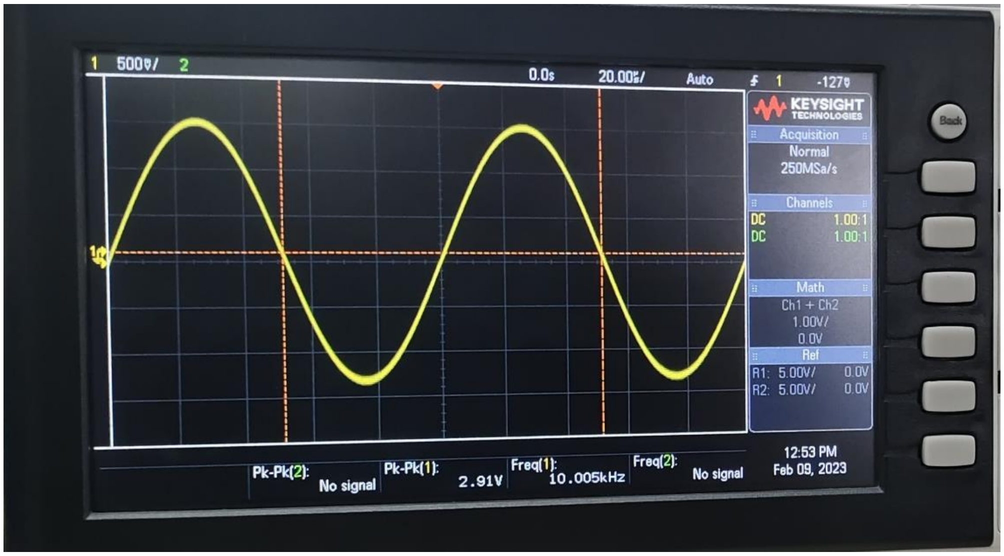
Table No. 1: BJT as an Amplifier

V_{in}	f_{in}	V_{out}	f_{out}
15V	10kHz 1V pk-pk	2.91V	10kHz

Table No. 2: BJT as an inverter

V_{in}	V_b	V_c	V_e	Region of operation of BJT	LED position
5V	0.691V	0.13V	0	Saturation Region	Off
0	04V	1.9V	0	Cutt-off Region	On

GRAPH:



Calculation:

Voltage Gain = V_{out}/V_{in} = 2.91V/15V

Voltage Gain = 0.194

Result: Thus, the working of BJT as an amplifier and inverter is verified. From the inputoutput waveforms of amplifier, following parameters are determined:

1) Voltage Gain = 0.194_

Conclusion:

Hence we successfully studied the circuit of bjt as amplifier and inverter

Discussion Questions:

1. What are the applications of BJT?
   - The bipolar junction transistor (BJT) is used in logic circuits.
   - The BJT is used as an oscillator.
   - It is used as an amplifier.
   - It is used as a multivibrator.
   - For wave shaping it is used in clipping circuits.
   - Used as a detector or demodulator.
   - It is also used as modulator.
   - Used in timer and time delay circuits.
   - It is used in electronics switch.
   - It is used in switching circuits.

2. What is the phase relationship between input and output waveforms of BJT in common emitter configuration?

In a common emitter amplifier, the input and output voltages are `180^(@)` out of opposite phases

3. What is the biasing rule for the BJT to be used as a switch?

If the transistor is biased into the linear region, it will operate as an amplifier or other linear circuit, if biased alternately in the saturation and cut-off regions, then it is being used as a switch, allowing current to flow or not to flow in other parts of the circuit.