Experiment No:1

P - N Junction Diode Characteristics

Aim:

1. To plot Volt-Ampere Characteristics of Silicon and Germanium P-N Diode.
2. To find cut-in voltage for Silicon and Germanium P-N Junction diode.
3. To find static and dynamic resistances in both forward and reverse biased conditions.

Components:

Name	Quantity
Diodes 1N4007(Si)	1
Diodes DR-25(Ge)	1
Resistor 1KΩ	1
Resistor 3.3KΩ	1

Equipment:

Name	Range	Quantity
Bread board		1
Regulated power supply	0-30V	1
Digital Ammeter	0-200µA/200mA	1
Digital Voltmeter	0-20V	1
Connecting Wires		

Specifications:

Silicon Diode 1N4007:

Max Forward Current = 1A

Max Reverse Current = 5.0µA

Max Forward Voltage = 0.8V

Max Reverse Voltage = 1000V

Max Power Dissipation = 30mW

Temperature = -65 to 200° C

Germanium Diode DR-25:

Max Forward Current = 250mA

Max Reverse Current = 200µA

Max Forward Voltage = 1V

Max Reverse Voltage = 25V

Max Power Dissipation = 250mW

Temperature = -55 to 75° C

Theory:

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 called Cut-in Voltage. This is the voltage across the diode at which it starts conducting. The P-N junction can conduct beyond this potential.

The P-N junction supports uni-directional current flow. If positive terminal of the input supply is connected to anode (P-side) and negative terminal of the input supply is connected the cathode. 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 from n-side (injected minority current – due to holes crossing the junction and entering P- side of the diode). Assuming current flowing through the diode to be very large, the diode can be approximated as short- circuited switch.

If negative terminal of the input supply is connected to anode (p-side) and positive 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 there by increasing the depleted region. However the process cannot continue indefinitely, thus a small current called reverse saturation current continues to flow in the diode. This current is due to be negligible; the diode can be approximated as an open circuited switch.

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

$$I = I_O \left(e^{\frac{V_D}{\eta V_T}} - 1 \right)$$

Where, I = current flowing in the diode, I_0 = reverse saturation current

V_D = Voltage applied to the diode

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

η = 1(for Ge) and 2 (for Si)

It is observed that **Ge** diodes has smaller cut-in-voltage when compared to **Si** diode. The reverse saturation current in **Ge** diode is larger in magnitude when compared to silicon diode.

Theoretically the dynamic resistance of a diode is determined using the following equation: Dynamic Resistance:

$$R_D = \frac{\eta\ V_T}{\mathrm{I}}$$

Circuit Diagrams:

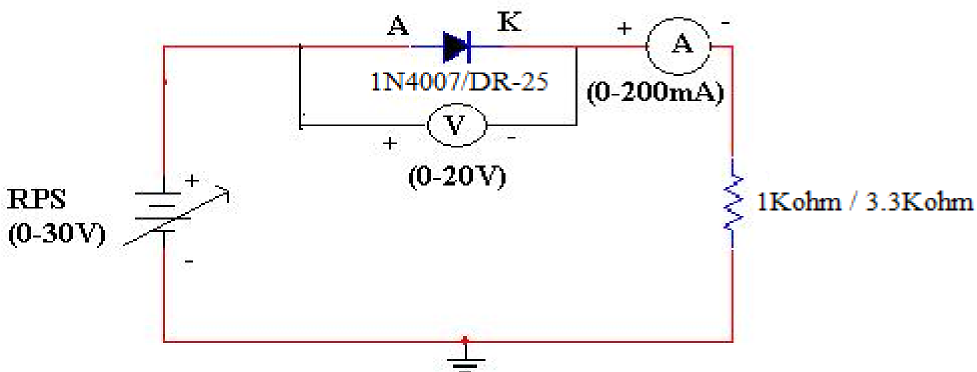


Fig. (1) - Forward Bias Condition

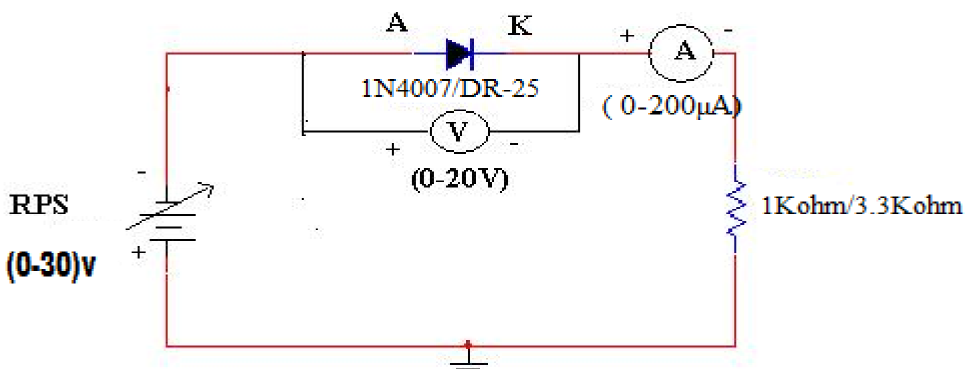


Fig. (2) - Reverse Bias Condition

Procedure:

Forward Bias Condition:

1. Connect the components as shown in the circuit diagram (1).
2. Vary the supply voltage such that the voltage across the Silicon diode varies from 0 to 0.6 V in steps of 0.1 V and in steps of 0.02 V from 0.6 to 0.76 V. In each step record the current flowing through the diode as I.
3. Repeat the above steps for Germanium diode too but with the exception that the voltage across the diode should be varied in steps of 0.01 V from 0.1 to 0.3 V in step-2.

Reverse Bias Condition:

1. Connect the diode in the reverse bias as shown in the circuit diagram (2)
2. Vary the supply voltage such that the voltage across the diode varies from 0 to 10V in steps of 1 V. Record the current flowing through the diode in each step.
3. Repeat the above steps for Germanium diode too and record the current in each step.
4. Now plot a graph between the voltage across the diode and the current flowing through the diode in forward and reverse bias, for Silicon and Germanium diodes on separate graph sheets. This graph is called the V-I characteristics of the diode.
5. Calculate the static and dynamic resistance of each diode in forward and reverse bias using the following formulae.

$$\text{Static resistance, } R = V/I$$

$$\text{Dynamic resistance, } r = \Delta V/\Delta I$$

Observations:

(a) Forward and Reverse bias characteristics of Silicon diode

Forward Bias Condition:

S. No.	Forward Voltage across the diode (volts) V_d (Volt)	Forward Current through the diode I_d (mA)

Reverse Bias Condition:

S. No.	Reverse Voltage across the diode (volts) V_r (Volt)	Reverse Current through the diode I_d (µA)

(b) Forward and Reverse bias characteristics of Germanium diode

Forward Bias Condition:

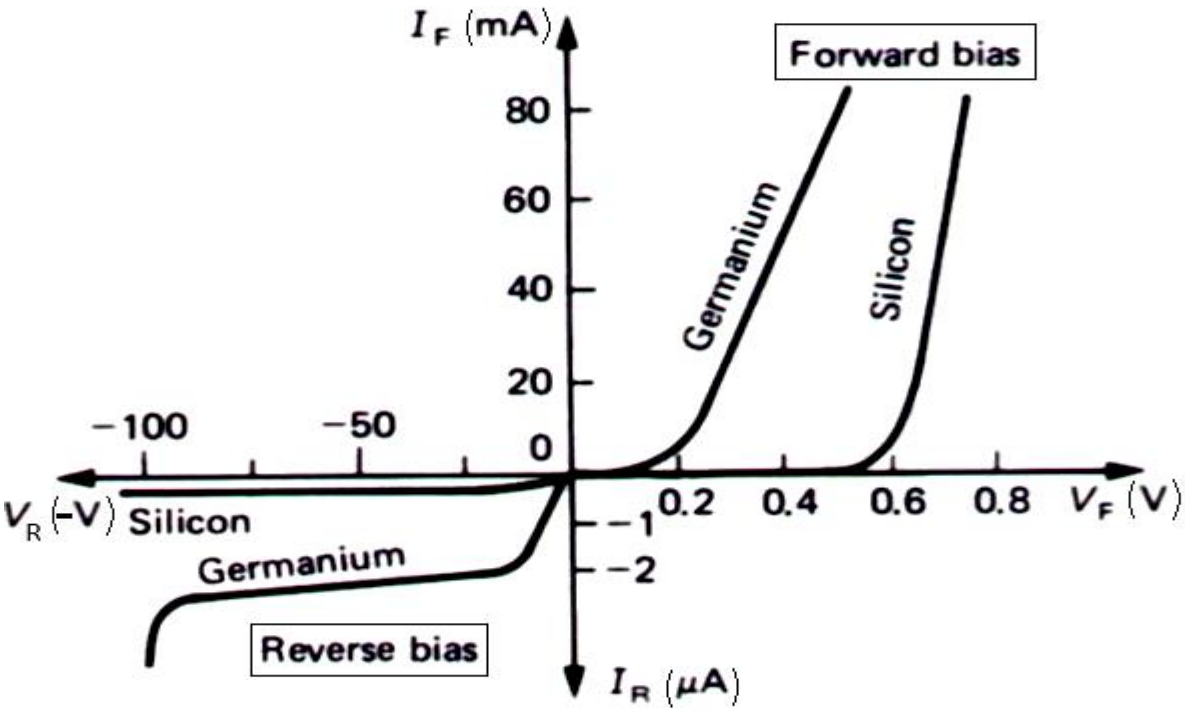
S. No.	Forward Voltage across the diode (volts) V_d (Volt)	Forward Current through the diode I_d (mA)

Reverse Bias Condition:

S. No.	Reverse Voltage across the diode (volts) V_r (Volt)	Reverse Current through the diode I_d (µA)

Graph:

1. Take a graph sheet and divide it into 4 equal parts. Mark origin at the center of the graph sheet.
2. Now mark +ve X-axis as , -ve X-axis as , +ve Y-axis as and –ve Y-axis as .
3. Mark the readings tabulated for Si forward biased condition in first Quadrant and Si reverse biased condition in third Quadrant.
4. Repeat the same procedure for plotting the Germanium characteristics.



Calculations from Graph:

Static forward Resistance

$R_{dc} = V_f / I_f \Omega$

Dynamic Forward Resistance

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

Static Reverse Resistance

$R_{dc} = V_r / I_r \Omega$

Dynamic Reverse Resistance

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

Precautions:

1. While doing the experiment do not exceed the readings of the diode. This may lead to damaging 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.

Result:

Cut in voltage = ________________ V

Static Forward Resistance = ________________ Ω

Dynamic Forward Resistance = ________________ Ω

Static Reverse Resistance = ________________ Ω

Dynamic Reverse Resistance = ________________ Ω

Volt-Ampere Characteristics of Silicon P-N Diode are studied.

Viva Questions:

1. What are trivalent and pentavalent impurities?

Ans: Doping is the process of adding impurity atoms to intrinsic silicon or germanium to improve the conductivity of the semiconductor.

Commonly Used Doping Elements

Trivalent Impurities to make p-Type: Aluminum (Al), Gallium (Ga), Boron(B) and Indium (In).

Pentavalent Impurities to make n-type: Phosphorus (P), Arsenic (As), Antimony (Sb) and Bismuth (Bi).

2. How PN junction diode does acts as a switch?

Ans: Apply voltage in one direction; it acts like an open circuit. Reverse the polarity of the voltage and it acts like a short circuit.

3. Diode current equation?

Ans: $I = I_S(e^{V_D/(\eta V_T)} - 1)$

4. What is the value of V_t at room temperature?

Ans: 26mV

5. Dynamic resistance expression?

Ans: $r_d = \Delta V / \Delta I$