Study of Diode Characteristics

Objectives:

i) To study and plot the forward and reverse bias characteristics of a normal diode and to determine the threshold voltage, static and dynamic resistance.

ii) To study and plot forward and reverse bias characteristics of a zener diode and to determine the threshold and zener break-down voltage.

Overview:

A diode is a nonlinear circuit element. The symbol of a diode and a real commercial diode is shown in Fig. 1. Generally there is a band marked at its cathode for its identification. There exists another type of diode known as zener diode, which has a heavily doped PN junction.

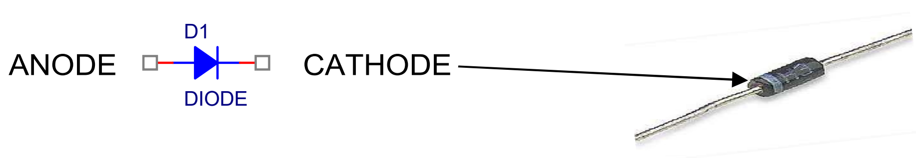


Fig. 1

The theoretical equation for the diode current I_D is

$$I_D = I_S\left[\exp\left(\frac{V_D}{nV_T}\right) - 1\right]$$

where V_D is the diode voltage drop, I_S is the saturation current, n is the emission coefficient, and V_T = kT/q (≈ 0.026V at T=300K) is the thermal voltage. The emission coefficient accounts for recombination of electrons and holes in the depletion region, which tend to decrease the current. For discrete diodes, the value of n is 2.

The I~V characteristic of an ideal diode is shown in Fig. 2-a. Under forward biased condition of a real PN junction diode, the P-side is connected to the positive and N-side is connected to the negative terminal of the power supply. This reduces the potential barrier. As a result current flows from P to N-type in forward direction. When the applied voltage is more than the barrier potential, the resistance is small (ideally 0) and the current increases rapidly. This point is called the *Knee-point* or *turn-on voltage* or *threshold voltage* (Fig. 2-b). This voltage is about 0.3 volts for Ge diodes and 0.7 volts for Si diodes.

Under reverse biased condition, the P-side of the junction diode is connected to the negative and N-side is connected to the positive terminal of the power supply. This increases the potential barrier due to which no current should flow ideally. But in practice, the minority carriers can travel down the potential barrier to give very small current. This is called as the *reverse saturation current*. This current is about 2-20 μA for Ge diodes and 2-20 nA for Si diodes (the values might differ for diodes of different makes).

However, if the reverse bias is made too high, the current through the PN junction increases abruptly. The voltage at which this phenomenon occurs is known as the *break-down or reverse voltage* and the mechanism involved depends on the construction of the diode. In conventional diodes with a lightly doped junction, application of higher reverse voltage leads to large number of carriers produced by collision of thermally generated electrons and the phenomenon is called *avalanche breakdown*. When the reverse bias exceeds this breakdown voltage, a conventional diode is subject to high current. Unless this current is limited by external circuitry, the diode will be permanently damaged. If the junction is heavily doped with narrow depletion layers, break-down occurs when the reverse voltage is strong enough to rupture the covalent bonds generating large number of electron-hole pairs. This phenomenon is called *zener breakdown*.

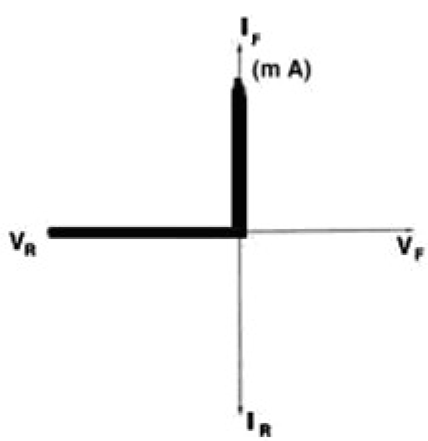


Fig. 2 (a)

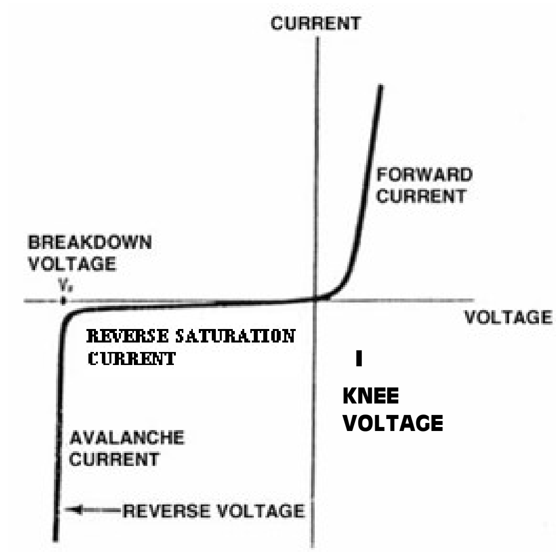


Fig. 2 (b)

Zener diode:

It is a heavily doped PN junction diode generally operated in zener breakdown region with reverse bias. Zener voltage is the reverse voltage above which there is a controlled *breakdown* which does not damage the diode. The voltage drop across the diode remains constant at zener voltage no matter how high the reverse bias voltage is. The forward characteristic of a zener diode is similar to a normal diode. The symbol of a zener diode is shown in Fig. 3.

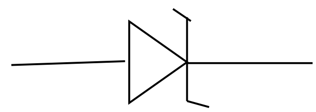


Fig. 3

Static and Dynamic Resistance:

At a given operating point Q, the static and dynamic resistance of a diode can be determined from its characteristics as shown in Fig. 4. The *static or dc resistance*, R_D, is simply the quotient of the corresponding levels of V_D and I_D at Q.

$$R_D = V_D/I_D$$

The dc resistance measured below the threshold level will be greater than the dc resistance measured above the threshold level.

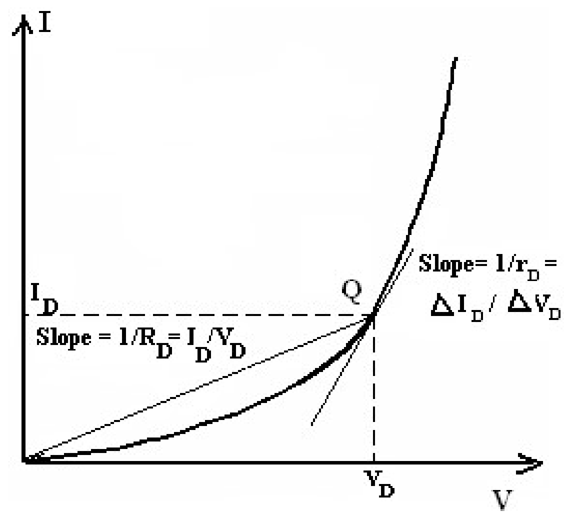


Fig. 4

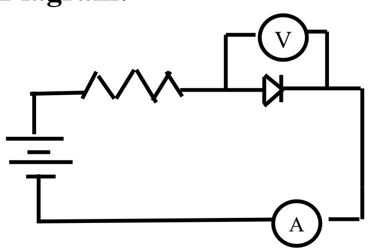
The diode circuits generally operate with varying (ac) inputs, which will move the operating point up and down a region along the I-V characteristics. This means a very small change in the input voltage will lead to change in current through the diode. *Dynamic or ac Resistance*, r_d, is defined as the quotient of this change in voltage and change in current around the operating point.

$$r_d = \Delta V_D / \Delta I_D$$

Components/Instruments:

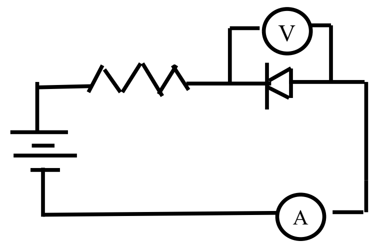
(i) Junction diodes (Si), (ii) Zener diode, (iii) A current limiting Resistor (1kΩ), (iv) D.C. Power supply, (iv) 2 multimeters and (vi) PCB board, (vii) Connecting wires

Circuit Diagram:



Forward Biasing

Fig. 5 (a)



Reverse Biasing

Fig. 5 (b)

Procedure:

Before you proceed, identify the p and n-side of the diode in order to connect them properly in a circuit in forward and reverse bias mode as shown in Fig. 5. A photograph of the complete experimental set up is shown in Fig. 6.

(i) Forward and reverse bias characteristics of a normal diode:

Forward Bias characteristics:

1. Connect the PCB board (with diode and resistor in series) with the power supply (0-30V) and multimeters as shown in Fig. 5(a).
2. Switch on the power supply. Slowly increase the supply voltage in steps of 0.1 Volt using the fine adjustment knob. Using multimeters in appropriate modes, measure voltage drop across the diode and the current in the circuit. When you find the change in current is larger (which means you have already crossed the threshold point!), increase the supply voltage in steps of 0.5 to note down current.

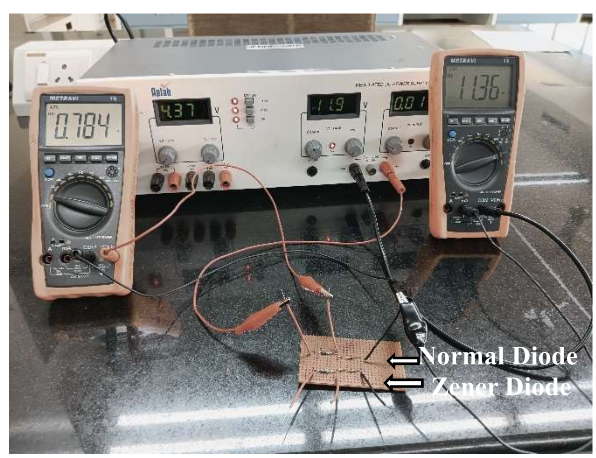


Fig. 6: Complete experimental set up

3. Switch off the supply after taking sufficient readings.
4. Plot the I~V characteristics and estimate the threshold voltage.
5. Choose two points on the plot, below and above the threshold point, and determine the static and dynamic resistance at each of the points.

Reverse Bias characteristics:

1. Connect again the PCB board (with diode and resistor in series) with the power supply (0-30V) and multimeters as shown Fig 5(b).
2. Switch on the supply. Increase the supply voltage in steps of 0.5 Volt. Using multimeters in appropriate modes, measure voltage drop across the diode and the current in the circuit. Keep in mind that magnitude of current flowing in the circuit will be very small, so choose current range properly.
3. Switch off the supply after taking sufficient readings.
4. Plot the I~V characteristics on the same graph sheet and estimate the reverse saturation current.

(ii) Forward and reverse bias characteristics of a zener diode:

Forward Bias characteristics:

1. Connect the PCB board (with Zener diode and resistor in series) with the power supply (0-30V) and multimeters as shown in Fig. 5(a). Repeat steps 2-4 of forward bias characteristics of normal diode described earlier.

Reverse Bias characteristics:

1. Connect again the PCB board (with Zener diode and resistor in series) with the power supply (0-30V) and multimeters as shown Fig 5(b).
2. Keep in mind that initially the magnitude of current flowing in the circuit will be very small. So choose current range in the multimeter accordingly.
3. Switch on the power supply. Increase the supply voltage in steps of 0.5 Volt and note down the corresponding readings of diode current. When you find the change in current is larger (which means you have already crossed the break-down point!), using the fine adjustment knob increase the supply voltage in steps of 0.1 to note down diode current.
4. Switch off the supply after taking sufficient readings.

5. Plot the I~V characteristics on the same graph sheet and estimate the threshold and break-down voltages.

Observation:

Table (i) For normal Diode (Si)

Obs. No.	Forward Biasing			Reverse biasing		
	Voltage Applied (V)	Voltage, V_D (V)	Current, I_D (mA)	Voltage Applied (V)	Voltage, V_D (V)	Current, I_D (μA)
1						

Table (ii) For zener Diode:

Obs. No.	Forward Biasing			Reverse biasing		
	Voltage Applied (V)	Voltage, V_D (V)	Current, I_D (mA)	Voltage Applied (V)	Voltage, V_D (V)	Current, I_D (μA/mA)
1						

Graphs:

Plot I~V characteristics for both the diodes and estimate the required parameters.

Discussions/Results:

i) Describe the behavior of the I~V curve for each diode.

ii) Threshold voltage for normal diode is ______V

iii) Static resistance = ------, Dynamic resistance = ------ at operating point Q.

iv) Threshold voltage for Zener diode = --------

Zener Break-down voltage = -------

Precautions: