Experimental Study of PN Junction Diode & Its Applications in Regulated Power Supply

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Abstract— A p-n junction diode is two terminal or two electrode semiconductor device, which allows the electric current in only one direction while blocks the electric current in opposite or reverse direction. If the diode is forward biased, it allows the electric current flow. On the other hand, if the diode is reverse biased, it blocks the electric current flow. PN junction is a significant building block and it is one among the indispensable structures offered by the semiconductor technology in electronics. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage relationship.

Keywords: Diode, Rectifier

I. Introduction

PN junction diode is formed by joining P type semiconductor and N type semiconductor. A junction is formed between P type and N type semiconductor on joining them. An electrode is taken from P region called anode and another electrode is taken from N region called cathode. When no voltage is applied to the diode it is called unbiased diode.

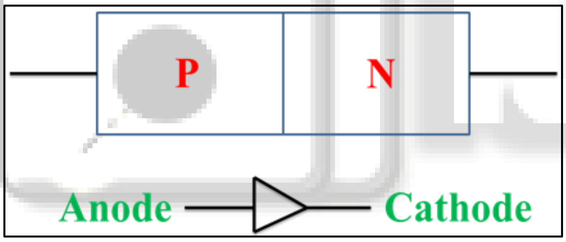

Fig. 1: PN Junction Diode

There is none uniform distribution of charge carriers on n side and p side due to which diffusion occurs. The movement of charge carriers from higher concentration area towards lower concentration area is called diffusion. Electrons diffuse from N to P region. Holes diffuse from P to N region. Electrons and holes recombine with each other. Positive ions accumulate near the junction in N side

- Negative ions accumulate near the junction in P side.
- These accumulation of charge carriers near the junction on N side and P side foms depletion layer.
- Depletion layer is also called space charge region or depletion region.

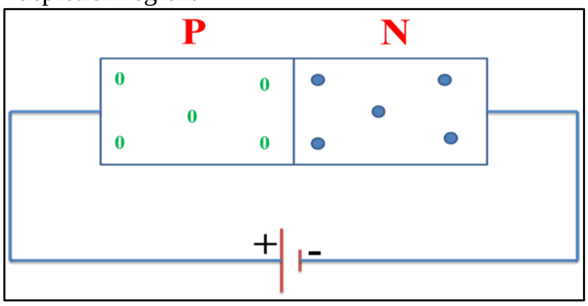

Fig. 2: Forward Biased Diode

Due to accumulation of positive and negative ions near the junction on the side of N region and P region there exists a potential difference across the junction. This potential difference is called barrier potential. Cut in voltage of silicon Si = 0.6 volt. Cut in voltage of Germanium Ge = 0.2 volt.

Applying voltage to the PN junction diode is called biasing. When Positive terminal of battery is connected to P type region and negative terminal of battery is connected to N type region then it is called forward bias operation. Electrons repel from the negative terminal of battery and holes repel from positive terminal of battery. Electrons move from n to p region. Holes move from p to n region. They cross the junction and current flows due to majority carriers. This is called forward current. Width of depletion region reduces.

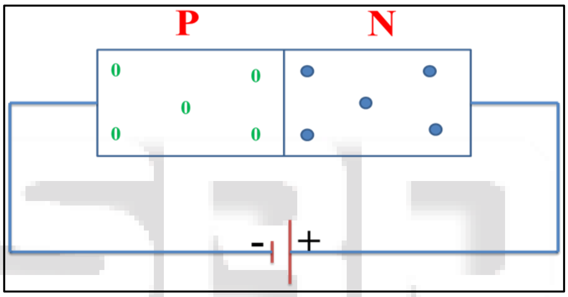

Fig. 3: Reverse Biased Diode

When positive terminal of voltage is connected to N type region and negative terminal of voltage is connected to P type region then it is called reverse bias operation. Electrons in n region are attracted towards the positive terminal. Holes in P region are attracted toward the negative terminal. Current does not flow due to majority carriers because they do not cross the junction. Small current flows due to minority carriers. This is called reverse saturation current. Width of depletion region increases.

Forward characteristics is plotted between forward voltage Vf and forward current If. When forward voltage Vf is less than cut in voltage Vj then diode does not conduct. Current does not flow. When forward voltage Vf becomes greater than the cut in voltage Vj of diode the current starts flowing. When forward voltage is increased further the current increases exponentially.

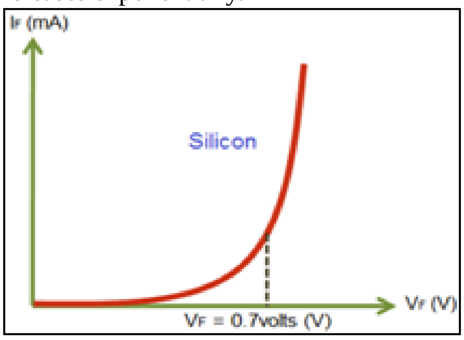

Fig. 4: Forward Bias Characteristics

Reverse characteristics is plotted between reverse voltage Vr and reverse current Ir. When reverse voltage Vr is increased reverse current Ir increases initially. When reverse voltage is increased further the reverse current becomes constant and does not increases. This is called reverse saturation current Io. When reverse voltage is increased further then breakdown of diode takes place and reverse current increases sharply damaging the diode.

Ideal diode conducts in forward biased condition and its forward resistance is zero. Hence its circuit model in ON state is closed switch. Ideal diode does not conducts in reverse biased condition and its reverse resistance is infinite. Hence its circuit model in OFF state is open switch.

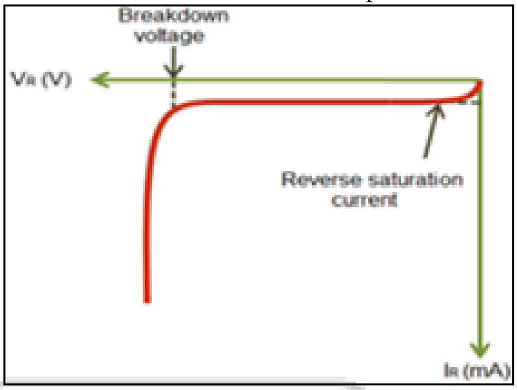

Fig. 5: Reverse Bias Characteristics

II. Rectifier

A rectifier is a device which converts an a.c. Voltage to pulsating d.c. Voltage.

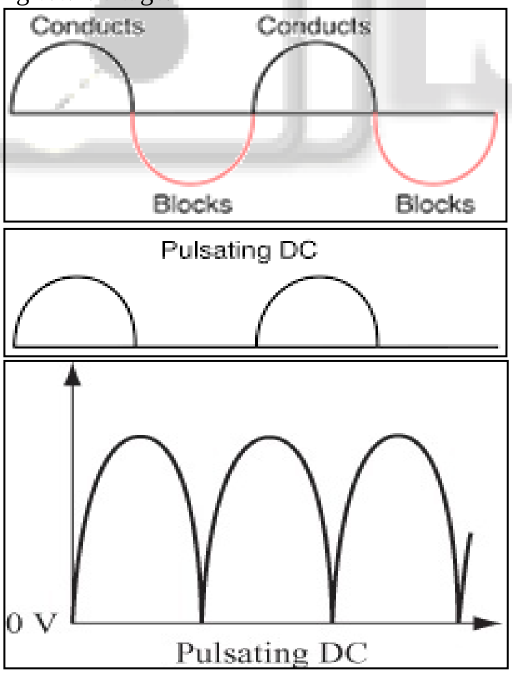

Fig. 6:

A. Regulated Power Supply

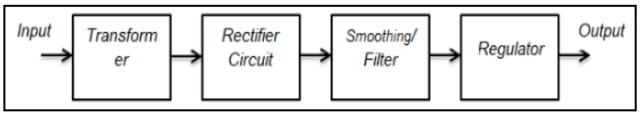

Fig. 7: Regulated Power Supply Block Diagram

The basic building blocks of a regulated DC power supply are as follows:

1) A Step down Transformer

A step down transformer will step down the voltage from the ac mains to the required voltage level. The turn's ratio of the transformer is so adjusted such as to obtain the required voltage value. The output of the transformer is given as an input to the rectifier circuit.

2) A Rectifier

Rectifier is an electronic circuit consisting of diodes which carries out the rectification process.

Rectification is the process of converting an alternating voltage or current into corresponding direct (DC) quantity. The input to a rectifier is ac whereas its output is unidirectional pulsating DC. Usually a full wave rectifier or a bridge rectifier is used.

3) A DC Filter

The rectified voltage from the rectifier is a pulsating DC voltage having very high ripple content. It gives a ripple free DC. A capacitor filter is used.

4) A Regulator

This is the last block in a regulated DC power supply. The output voltage or current will change or fluctuate when there is change in the input from ac mains or due to change in load current at the output of the regulated power supply or due to other factors like temperature changes. This problem can be eliminated by using a regulator. A regulator will maintain the output constant even when changes at the input or any other changes occur. IC regulators are used.

B. Half Wave Rectifier

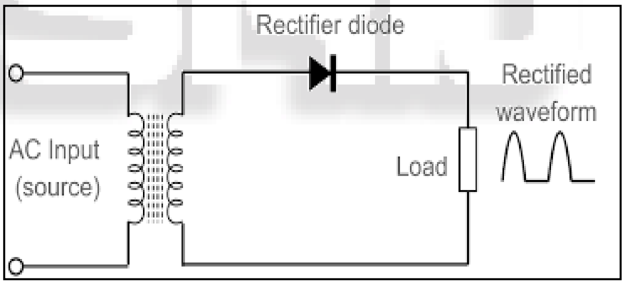

Fig. 8: Circuit Diagram of HWR

It consists of a single PN junction diode connected to a load resistance RL. Input ac voltage is applied to the primary winding of transformer. Secondary winding of transformer is connected to the diode. During positive half cycle of input signal the diode is forward biased. Therefore diode acts as short circuit. Current flows through the circuit and load resistance. Thus the output is same as input signal i.e. Vo = Vin. During negative half cycle of input signal the diode is reverse biased. Therefore diode acts as open circuit. No current flows through the circuit and load resistance. Thus the output is zero i.e. Vo = 0.

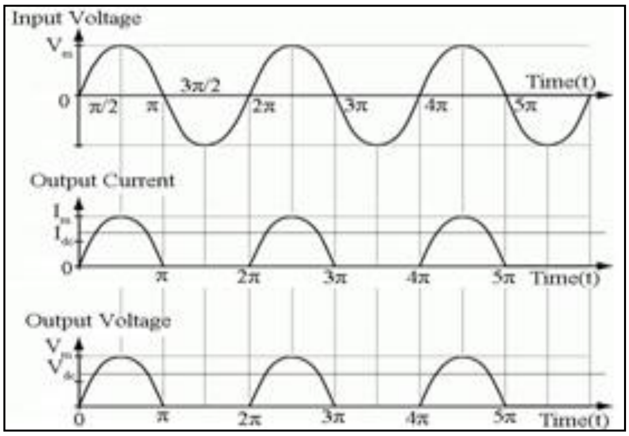

Fig. 9:

C. Centre Tapped Full Wave Rectifier

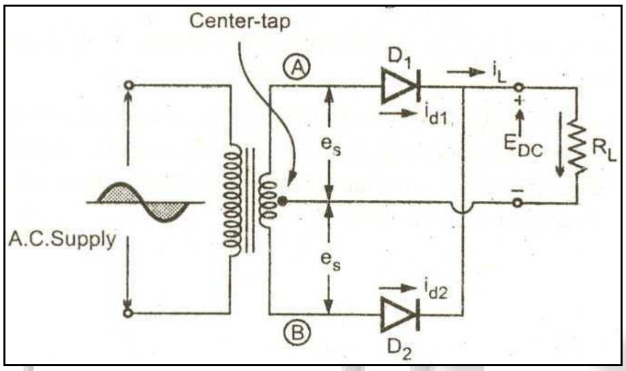

Fig. 10: Circuit Diagram of Centre Tapped FWR

A tap is taken from the center of secondary winding of transformer. Two diodes are connected at the two ends of secondary winding. A load resistance is connected. During positive half cycle diode D1 is forward biased and diode D2 is reverse biased. Diode D1 acts as short circuit and diode D2 acts as open circuit. Thus current flows through the load resistance. Output voltage follows the input voltage. During negative half cycle diode D1 is reverse biased and diode D2 is forward biased. Diode D1 acts as open circuit and diode D2 acts as short circuit. Thus current flows through the load resistance. Output voltage follows the input voltage.

D. Full Wave Bridge Rectifier

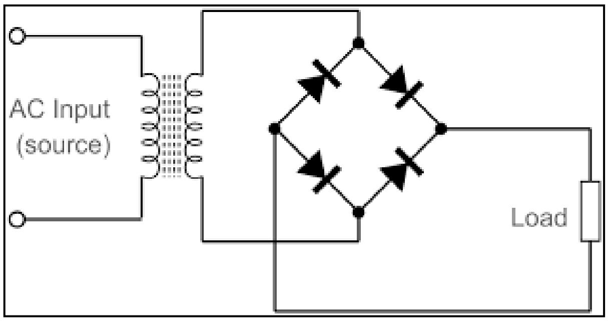

Fig. 11: 2 Circuit Diagram of Bridge FWR

During positive half cycle diodes D1 and D2 are forward biased and acts as short circuit. Diodes D3 and D4 are reverse biased and acts as open circuit. During negative half cycle diodes D3 and D4 are forward biased and acts as short circuit. Diodes D1 and D2 are reverse biased and acts as open circuit.

III. Results

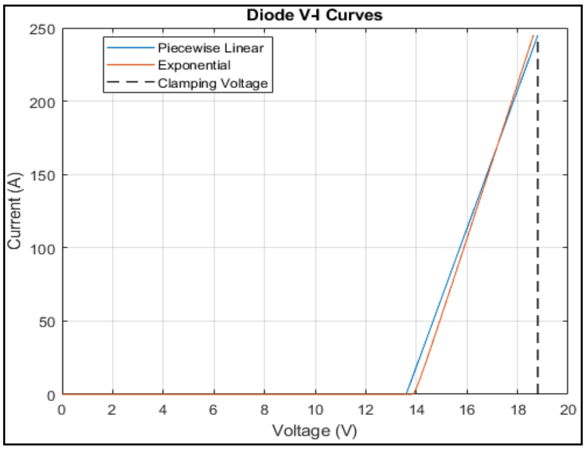

Fig. 12: Forward Bias Characteristics

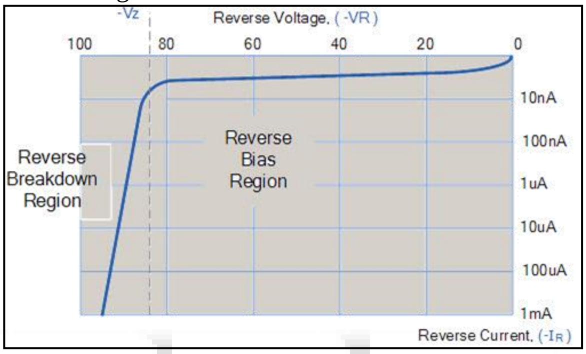

Fig. 13: Reverse Bias Characteristics

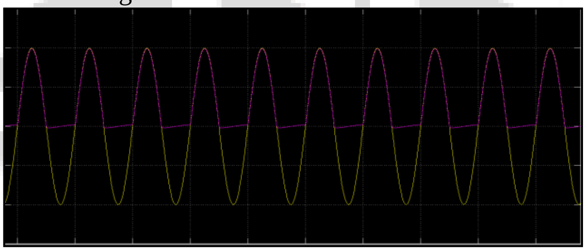

Fig. 14: Rectifier Characteristics

IV. Conclusion

Thus PN Junction diode can be used for the designing of Rectifiers which will be further used for regulated power supply. Forward biased and reverse biased characteristics can be obtained.

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