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Electrical Characteristics of PN Junction Diode (IN4148) With Mono and Bipolarity Voltage at Anode and Cathode Using MATLABand Experimental Setup

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Abstract:
The diode is one of the important semiconductor devices used in many commercial electronic equipments. It is a unidirectional device, in which forward current rises with an increase in forward voltage. Earlier studies on diode were done with anode at positive and cathode at negative polarity voltage in order to make the diode act as a closed switch [1]. In this paper, both anode and cathode are connected to positive voltages to act as a closed switch and the corresponding forward V-I characteristics are obtained. In addition to it, reverse characteristics also obtained for different voltage magnitudes. Here, MATLAB Simulink is used to obtain theoretical values. Also, experimental setup with IN4148 and 460 Ohms are used and practical V-I characteristics are obtained.

***Key Word**: Semiconductor device; PN junction diode; V-I characteristics; IN4148; MATLAB.*

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I. Introduction

Most of the mobile phone chargers and other portable electronic equipments are using diode rectifiers, because of its cheap and reliable operation. So it is necessary to know the V-I characteristics of a diode to enhance the knowledge in order to develop more applications. The diode is a semiconductor device that can conduct only in forward voltage and operate as an open switch in the reverse voltage. Here, forward voltage represents anode at higher potential, and reverse voltage represents cathode at lower potential. Lower potential represents positive or negative voltage. In forward bias condition, the depletion region of the PN junction diode becomes narrow and the barrier potential gets formed in the depletion region. Usually, barrier potential varies from 0.6 to 0.8V for silicon materials and 0.2 to 0.4V for germanium. In reverse bias condition, the width of the depletion region becomes wider as a result reverse breakdown value will be higher than the forward barrier potential. Reverse breakdown voltage is decided by the manufacturer. Germanium made diodes is not commonly used, because of its loosely bounded valence electrons compared to silicon material. In this paper, silicon made PN junction diode (IN4148) with 0.76V barrier potential, and reverse breakdown voltage with 100V is selected for analysis. One of the major difference in this paper is both anode and cathode are connected with positive voltage magnitudes in different values and performance characteristics of the diode is obtained. MATLAB Simulink is used in this paper to obtain the V-I characteristics and also experimental setup is used to verify the simulated results practically.

II. Material And Methods

The anode is made positive and the cathode is connected to negative voltage is a conventional method to make the diode to conduct in forward bias condition. Also to reverse bias, the anode is made negative with respect to the cathode. In the conventional method, different polarities of voltage should be applied at anode and cathode in order to forward or reverse bias the diode. In this paper, both the anode and cathode are connected to the same polarities of voltage with different voltage magnitudes are applied to forward or reverse bias the diode. MATLAB Simulink software is used to analyze the forward and reverse characteristics of the diode. Also, IN4148 silicon diode and 460 Ohms resistor is used for experimental setup to verify the simulation results.

III. Electrical Characteristics Of PN Junction Diode

In the conventional method, the anode should be made positive with respect to the cathode to turn on the diode. As a result, a narrow depletion region is formed with a barrier potential of 0.76V. The arrangement of the circuit diagram using MATLAB is shown in fig 1.a. Variable DC input varies from 0 to 2V is used as shown in the fig.1.b. A snubber resistance is connected parallel with the diode to discharge the stored charges in the depletion region. Here, positive of the supply is connected to the anode and cathode is connected to negative through 460 Ohms as shown in the fig 1.a.

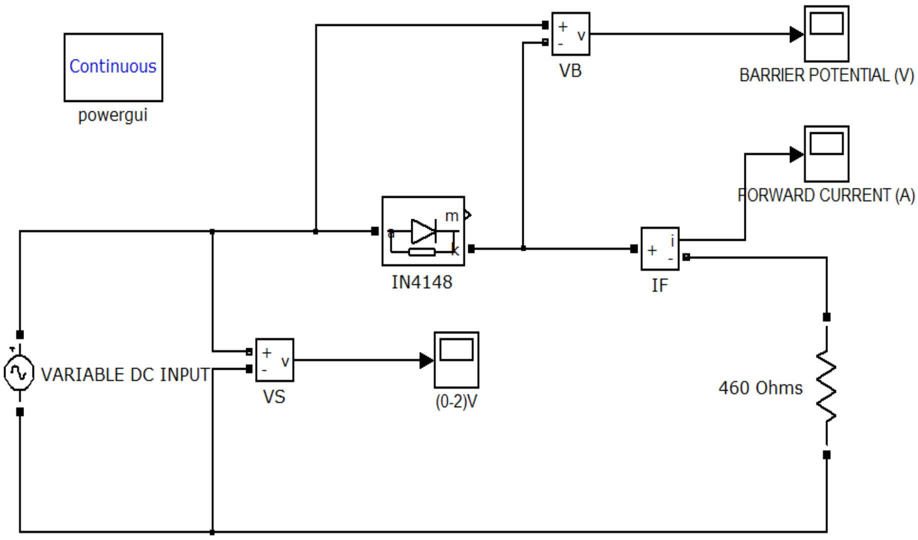

Fig 1.a. Forward bias circuit arrangement

When forward voltage is lesser than 0.76V, the diode does not conduct any electrons due to the barrier potential. However, small leakage current will flow when the supply voltage is lesser than barrier potential as shown in fig 1.c. At 1.35 ms, the supply voltage becomes equal to barrier potential. As a result, forward current starts to increase with increase in the supply voltage. From 0 to 1.35 ms, it is observed that charge in the depletion region increases gradually, as a result, barrier potential also increases with increase in charge (charge=capacitance*voltage) as shown in the fig. 1.d.

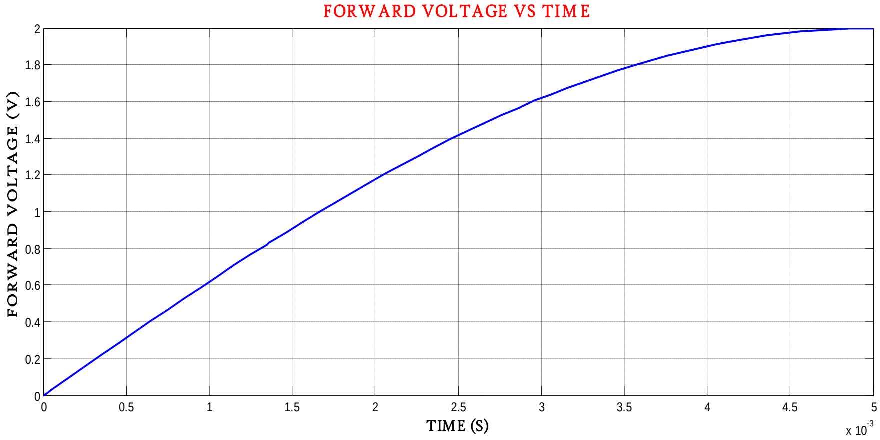

Fig 1.b. Forward voltage vs time graph

At the time, t = 1.35 ms, charges in the depletion region attains equilibrium state and barrier potential reaches its higher value. The presence of barrier potential is due to the escape of electron from n-region and recombines with the holes in the p-region. This barrier potential prevents the further diffusion of the electron from n-region to p-region. It is due to the energy of the electron is lesser to diffuse through the barrier potential. At the time, t=1.4 ms, the supply voltage starts increasing than the barrier potential. When the supply voltage is greater than the barrier potential, free electrons in the n-region attain energy and diffuse through the depletion region and move towards the positive terminal due to the force of attraction. This shows that electrons get attracted towards the higher potential (positive voltage). As a result, conventional forward current flows from higher potential to lower potential (negative voltage) from time t= 1.4 to 5 ms as shown in the fig.1.c.

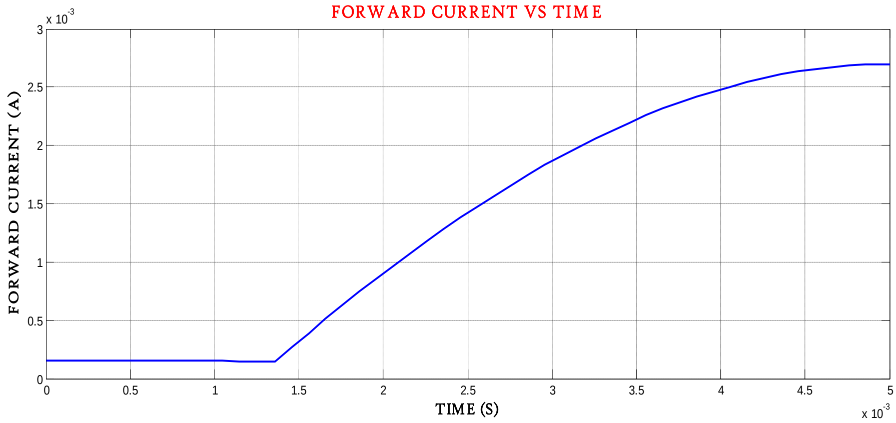

Fig 1.c. Forward current vs time graph

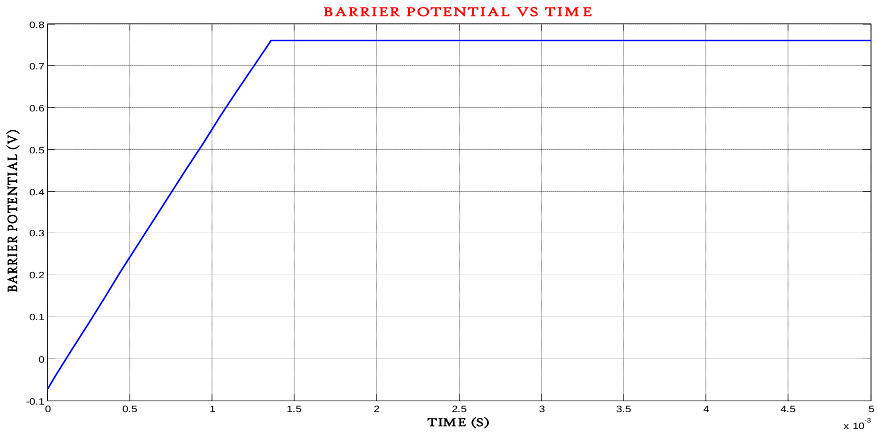

Fig 1.d. Barrier potential vs time graph

From the forward characteristics of the diode as shown in the fig.1.e, it is observed that from 0V to 0.82V, there is only forward leakage current around 0.2 mA. The magnitude of 0.82V is the addition of barrier potential and initially stored charges due to PN junction capacitance in the depletion region.

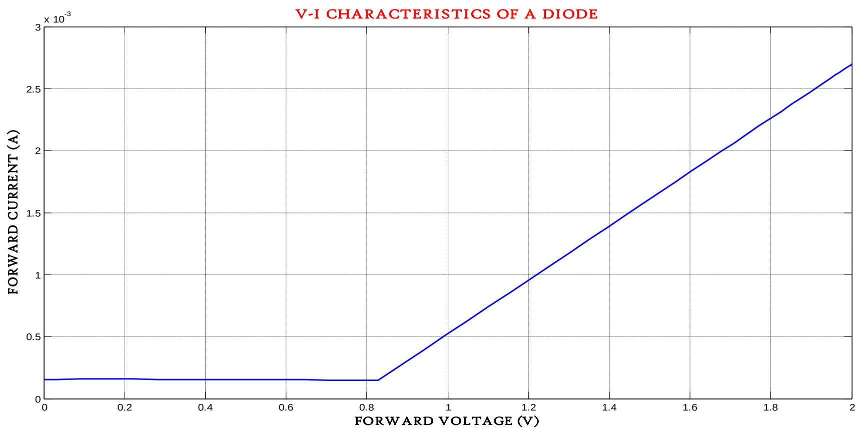

Fig 1.e. Forward voltage and current characteristics of diode

If the forward voltage gets higher than the barrier potential, forward current starts increasing linearly with increase in forward voltage. From forward characteristics of the diode, it is evident that diode will act as a closed switch when forward voltage is higher than the barrier potential and becomes open switch when forward voltage is lower than the barrier potential.

During reverse bias, the anode is made negative with respect to cathode increases the width of the depletion region. Only reverse leakage current flow. When reverse voltage is increased beyond the reverse breakdown voltage, reverse current increases rapidly due to avalanche breakdown and damages the diode. This reverse current can be controlled by external resistance.

The V-I characteristics obtained for variable dc input supply is shown in the fig.1.e. The same analysis is done with fixed dc voltage using MATLAB Simulink as shown in the fig.2.a. In this circuit arrangement, fixed +12.04 dc voltage is applied at the anode with the load resistance of 460 ohms. As a result, 0.0245 Ampere current flow through the circuit. The same simulation circuit is verified with the practical experiment as shown in the fig.2.b.

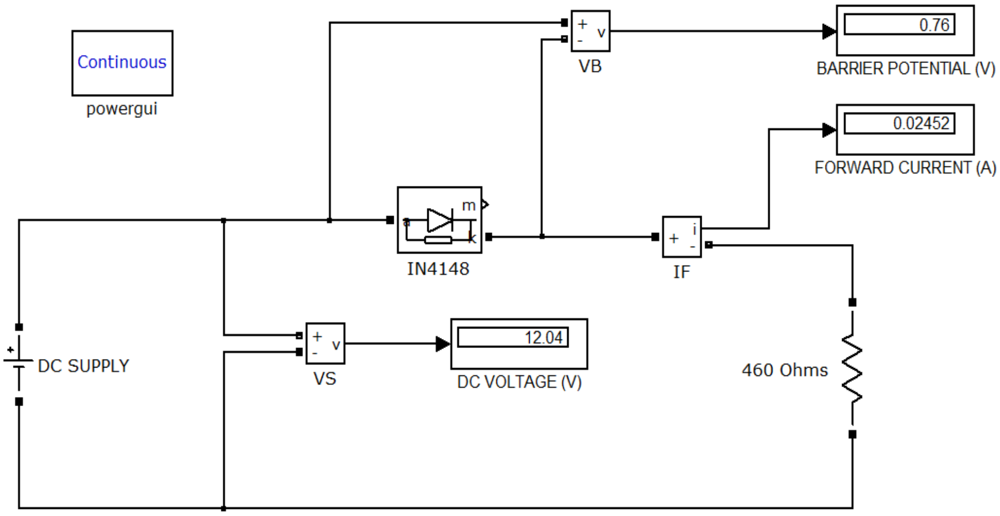

Fig 2.a Forward bias with fixed dc input voltage

For the experiment, diode IN4148, 460 Ohms, breadboard, connecting wires, millimeters and DC supply are used as shown in the fig.2.b. Here, forward voltage represents the +12.04 voltage at the anode terminal. Since input voltage is higher than the barrier potential, forward current of 0.03A flows through the circuit.

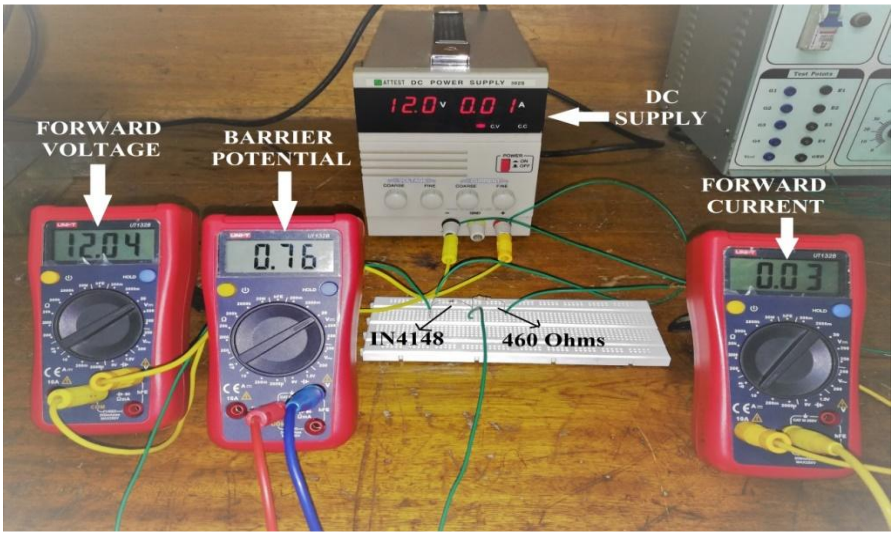

Fig 2.b. Forward biasexperimental setup with fixed dc input voltage

The above experiment is conducted with one dc supply to make the diode to conduct in the forward bias. The reverse bias of diode with one fixed dc voltage is shown in the fig.2.c. From the fig. 2.c, it is observed that anode is made negative with respect to the cathode. Also, the current through the circuit becomes zero. It represents diode acts as an open switch during reverse bias.

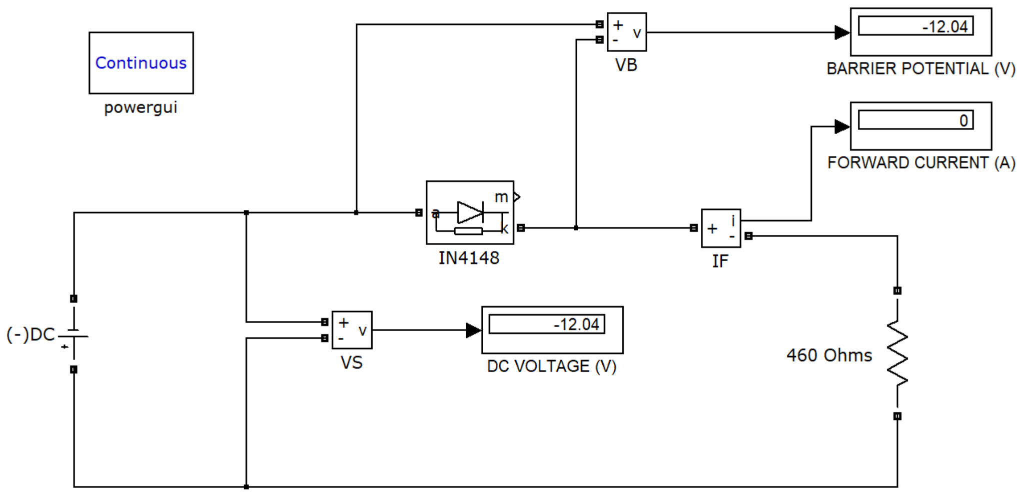

Fig 2.c. Circuit arrangement of reverse bias

In the fig.3.a, two dc power supplies are used to forward bias the diode. It is clearly depicted that, +12V is connected at the anode and +5V is connected to the cathode through the load resistance 460 Ohms. These two power supplies create a potential difference of +7V across the two power supply positive terminals, which is higher than the barrier potential. As a result, free electrons in the n-region attain energy and attracted to the higher potential +12V dc supply. This makes the diode to conduct forward current of 0.01357A. In this circuit, forward voltage and reverse voltage represents the voltages at the anode and cathode respectively.

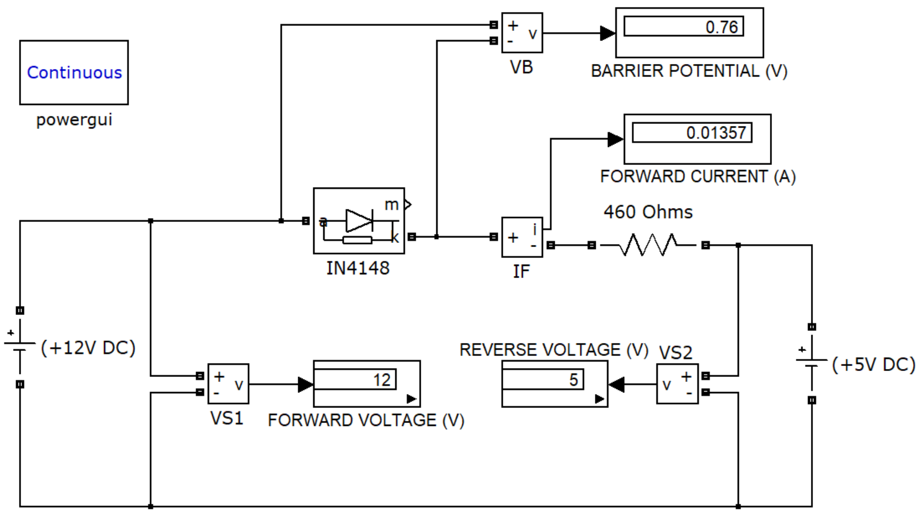

Fig 3.a Forward bias circuit arrangement with two dc supply

The same analysis is done with practical experiment as shown in fig.3.b. Here, DC supply with two sources is selected to make the circuit arrangement. +12.07V is applied at the anode and +5.07V applied to the cathode. This creates a potential difference higher than barrier potential which makes the diode to conduct with the forward current of 0.02A. From this experiment, it is clearly depicted that, conduction of diode is independent of the polarity of the voltage and it depends only on input voltage higher than the barrier potential. Also, the direction of the movement of electrons depends on the higher potential. As per conventional statements [1], when the input voltage is higher than the barrier potential makes the free electrons in the n-region are repelled by negative cathode voltage and get attracted to the positive anode voltage. From fig.3.b, it is clearly depicted that the movement of free electrons in the n-region to p-region does not require negative cathode voltage. The mandatory condition is the potential difference should be higher than the barrier potential and the direction of free electrons in the n-region move towards the higher potential.

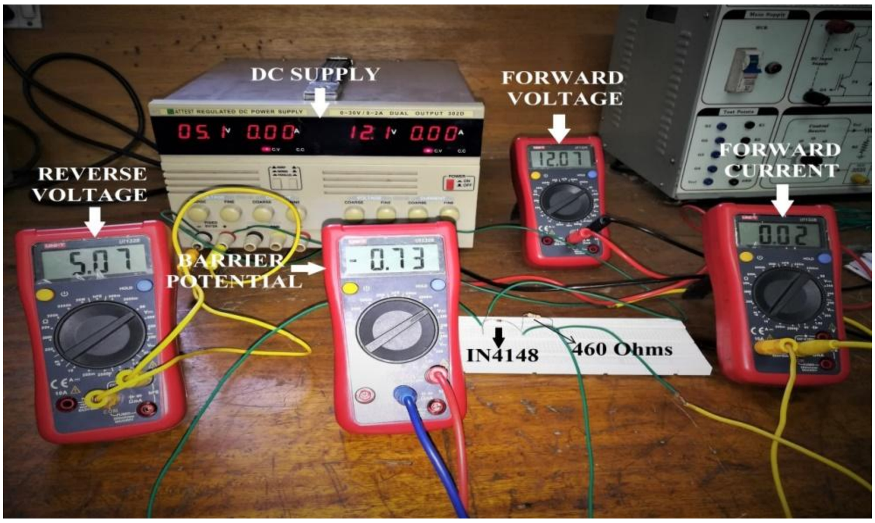

Fig 3.b. Forward bias experiment with two dc supply

Even diode can be reverse biased with two dc supply as shown in the fig.4.a. Here, the anode is connected to +4V and cathode is connected to +5V through load resistance 460 Ohms. This makes the free electrons attract towards the higher potential (+5V) as a result width of the depletion region increases which blocks the forward current through the diode. Only a small reverse leakage current will flow, which is practically considered as zero.

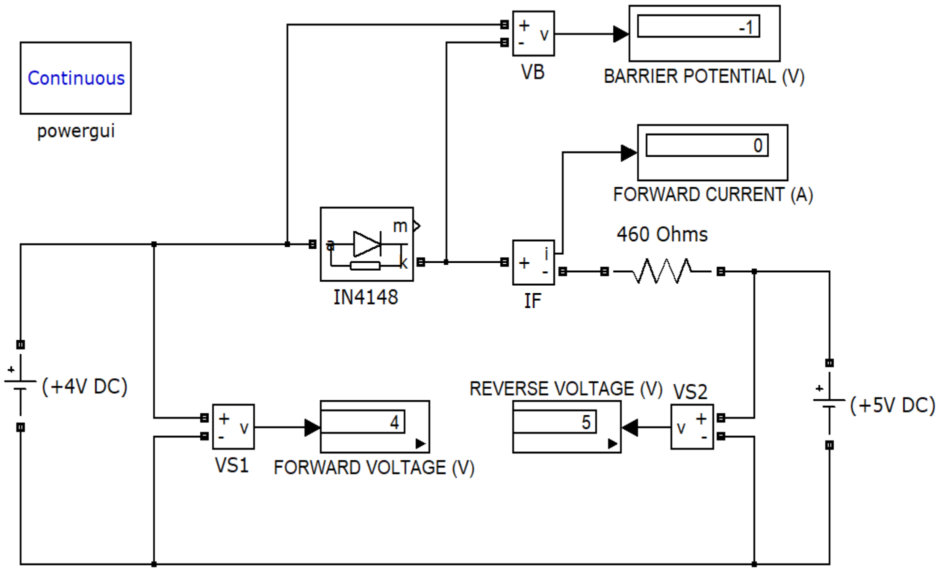

Fig 4.a. Reverse bias circuit arrangement with two dc supply

The above simulation is carried out as an experiment as shown in the fig.4.b. Even the practical results show that the difference of potential with the same polarity applied across anode and cathode (ie anode with lower potential (+4.05V) and cathode with lower potential (+5.03V)) make the diode to be reverse biased and forward current becomes zero. Therefore diode can be reverse biased with low anode voltage and high cathode voltage. It is independent on the polarity of the voltage across the diode.

Fig 4.b. Reverse bias experiment with two dc supply

IV. Result

Figures 2.b and 3.b show the forward bias of PN junction diode. In fig.2.b, the anode is connected with +12V with respect to the cathode and forward current of 0.03A flows through the circuit. In fig.3.b, the anode is connected with +12.07V and cathode with +5.07V, as a result, 0.02A of forward current flows through the circuit. Fig.4.b shows that the diode is reverse biased with +5.03V at cathode and +4.05V at the anode. As a result forward current becomes zero.

V. Conclusion

From the simulation and experimental results, it is clearly observed that diode can be forward biased with the same polarity of voltages, but there should be higher potential at the anode and lower potential at the cathode. Similarly, the diode can be reverse biased with lower potential at the anode and higher potential at cathode of the same polarity. It is not mandatory to have the different polarity of the voltage at the anode and cathode for both forward and reverse bias condition of the diode.

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