Experiment No. 3

I-V Diode Characteristics

1. OBJECTIVES

** To plot I-V Characteristics curve of Silicon P-N Junction Diode.

** To find the forward working voltage of Silicon P-N Junction Diode (potential barrier).

** To find static and dynamic resistances in forward biased.

2. COMPONENTS REQUIRED

**Diode 1N4007.

**Decade box resistor or variable resistance.

**Bread board.

**DC Power supply (0 -15 V variable).

** DSO1052B Digital Oscilloscope and Probes.

** Signal Generator.

** Resistors 10Ω, 1kΩ.
** Connecting wires.
**Digital Ammeter (0 - 400 mA).

**Digital Voltmeter (0 - 20V).

3. THEORY

P-N Junction Diode

The diode is a semiconductor device formed from a junction of n-type and p-type semiconductor material. The Junction called depletion region (this region is depleted off the charge carriers). This Region gives rise to a potential barrier called working voltage of the diode. This is the voltage across the diode at which it starts conducting. The lead connected to the p-type material is called the **anode** and the lead connected to the n-type material is the **cathode.** In general, the cathode of a diode is marked by a solid line on the diode.

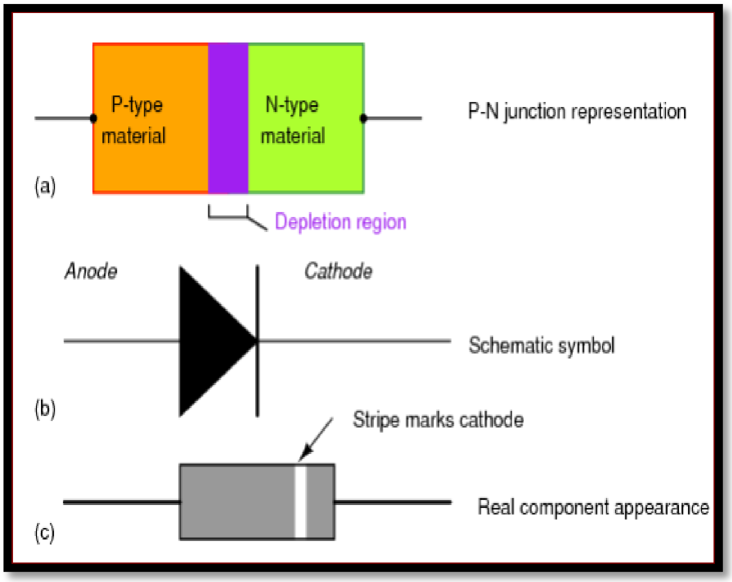


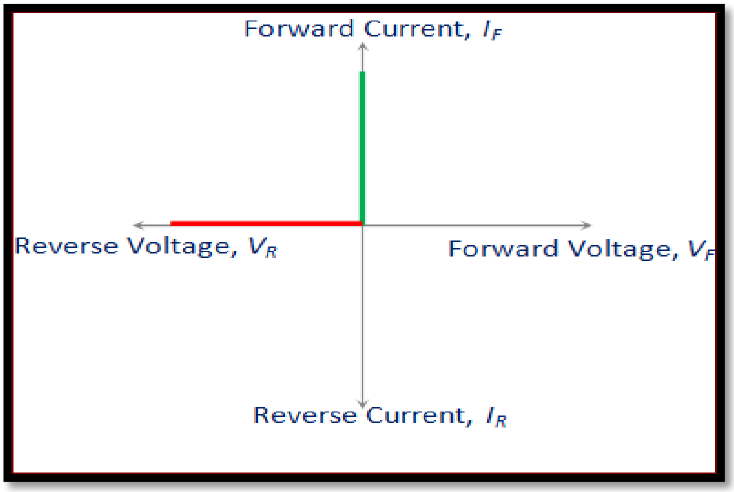
Fig. 1: Diode identification of polarity. (a) P-N junction (b) schematic symbol (c) diode packaging.

The P-N junction supports uni-directional 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 (due to holes crossing the junction and entering N-side of the diode, due to electrons 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 **–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 cannot continue indefinitely, thus a small current called reverse saturation current continues to flow 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 approximated as an open circuited switch.

The characteristic curves of an ideal diode and a real diode are seen in Figure 2.

(a)



(b)

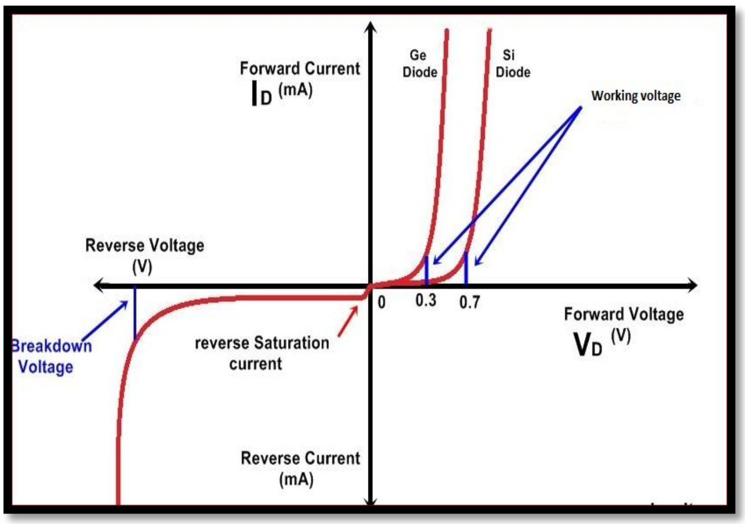


Fig. 2: characteristic curves of (a) an ideal diode and (b) a real diode.

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

$$I = I_0 \left(e^{\frac{V_D}{\eta \, V_T}} - 1 \right)$$

Where,

$\boldsymbol{I}$ = current flowing in the diode.

$\boldsymbol{I_0}$ = reverse saturation current.

$\boldsymbol{V_D}$ = Voltage applied to the diode.

$\boldsymbol{V_T}$ = the Thermal Voltage= k T/q = 26mV (@ room temp).

η=1 (for Ge) and 2 (for Si) .

Diode I-V Characteristics using x -y Mode

The x-y mode of the oscilloscope can be used to graphically display the I-V characteristics of a diode. A test circuit used in conjunction with an oscilloscope is shown in figure (5). This circuit uses a signal generator as the test signal. It should be adjusted for an approximate 100 hertz. In the x-y mode, the voltage appearing across the diode is applied to the horizontal input of the oscilloscope to **CH 1** and the voltage appearing across a current sampling resistor, R, is applied to the vertical input of the oscilloscope **CH 2**. The resistor in this circuit is being used to convert the voltage which can be displayed and measured with the oscilloscope into the current (which is the same in the resistor and the diode). The CH 2 signal is R I_{diode} so the vertical voltage sensitivity of the oscilloscope display (V/div) is automatically converted to mA/div.

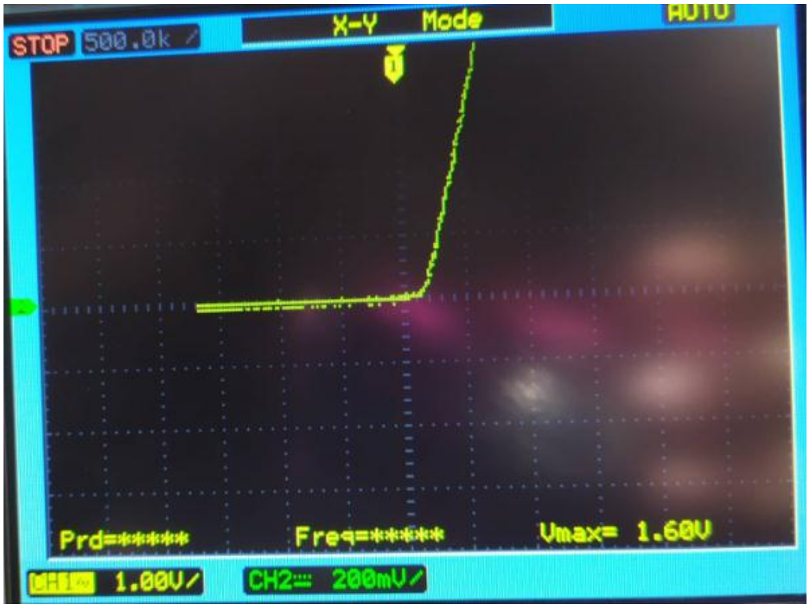


Fig. 3: IV Diode characteristics curve on oscilloscope using x-y mode.

4. PROCEDURE

A) Diode Characteristics (Forward bias of a normal diode).

Before you proceed, identify the **p**-side and **n**-side of the diode in order to connect properly in forward bias mode.

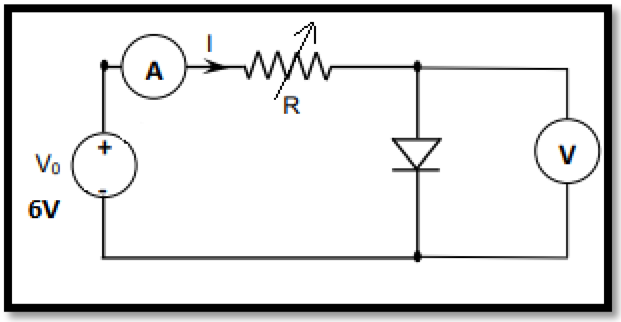


Fig. 4: Circuit for measuring.

1. Connect the circuit as shown in figure (4) using silicon PN Junction diode.
2. Using the DC power supply fixed the input voltage V_0 at 6 V.
3. vary the value of **R** as shown in the table and measure the current **I** and the voltage **V** of the diode, and fill the table below.

R ($k\Omega$)	100	50	20	15	10	6	5	4	3	2.5	2.1	1.8
I_D												
V_D												

R ($k\Omega$)	1.6	1.4	1.2	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
I_D												
V_D												

4. Now plot a graph between the voltage across the diode and the current flowing through the diode in forward bias, for Silicon diode. This graph is called the I-V characteristics of the diode.

5. Calculate the static and dynamic resistance of the diode in forward bias using the following formulae.

Static forward resistance, R = V/I
Dynamic forward resistance, r = $\Delta V/\Delta I$

6. Deduce the value of the working voltage of Silicon P-N Junction Diode from the curve.

B) Using x -y Mode of Oscilloscope to display Diode I-V Characteristics

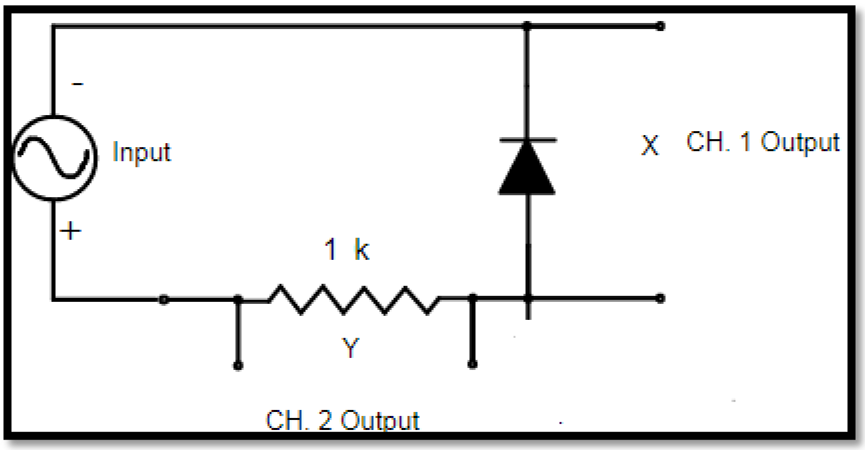


Fig. 5: Diode circuits for plotting the diode IV curve on oscilloscope.

1. Connect the circuit as shown in figure (5) using silicon PN Junction diode.
2. Set the function generator to a sine wave with 4Vpp. The frequency doesn't matter too much, but you may want to keep it low to minimize distortion or noise as some signal sources provide better performance and lower frequencies (for example 100Hz) .
3. Begin by applying the signal generator to the diode. Probe the voltage across the terminals of the diode with channel 1 (the X input), and the voltage through the resistor with channel 2 (the Y input). Then you can measure the voltage drop across a small-value shunt resistor and calculate the current drawn by using Ohm's law.
4. You will see the two signals as Volts -v- time, the "normal" oscilloscope view. You may want to Place Scope in the x-y mode by pressing the appropriate button on the front panel of the oscilloscope.
5. Slowly adjust the V/DIV of each channel until the flat I-V characteristic curve begins to to clearly display on the screen and then determine the working voltage of Silicon P-N Junction Diode from the curve.