Experiment No.2

Diode Charstristics

Object

The purpose of this experiment is to measure and plot the forward and reverse IV characteristics of a silicon diode, and to measure the DC and AC (dynamic) resistances of the diode.

Required Parts and Equipment's

1. DC Power Supply
2. Digital Multimeters
3. Electronic Test Board (M50)
4. Function Generator
5. Dual-Channel Oscilloscope
6. Small Signal Silicon Diode 1N4001
7. Resistors, $R_1 = 470\Omega, R_2 = 1K\Omega$
8. Leads and BNC Adaptors

Theory

When a P-type and N-type semiconductor materials are effectively made on the same crystal base, a diode is formed. The P-type side of the diode is called the anode, and the N-type side is called the cathode. When the diode’s anode is at a higher potential than the cathode, the diode is forward-biased, and current will flow through the diode from anode to cathode. On the other hand, if the anode is at a lower potential than the cathode, the diode is said to be reverse-biased, and only a very small reverse current flows from cathode to anode until breakdown occurs at a very high reverse voltage VBR, and a successive current may flow in the reverse direction. The breakdown voltage VBR is above 50V for typical diodes.

Unlike a resistor, in which the current is directly (linearly) proportional to the voltage across it, the diode is a nonlinear device. When the diode is forward-biased, a small voltage drop occurs across it. This voltage drop is called the barrier potential with an approximate value of 0.3V for germanium diodes, and 0.7V for silicon diodes.

Fig.1 presents the IV characteristics curve for a typical semiconductor diode. This characteristic curve can be approximately estimated in the forward-bias region from the equation:

$$I_D = I_S(e^{V_D/V_T} - 1)$$

Where:

I_D: is the diode current

V_D: is the diode voltage

I_S: is the diode reverse saturation current

V_T: is the thermal voltage, which is approximately 26 mV at room temperature

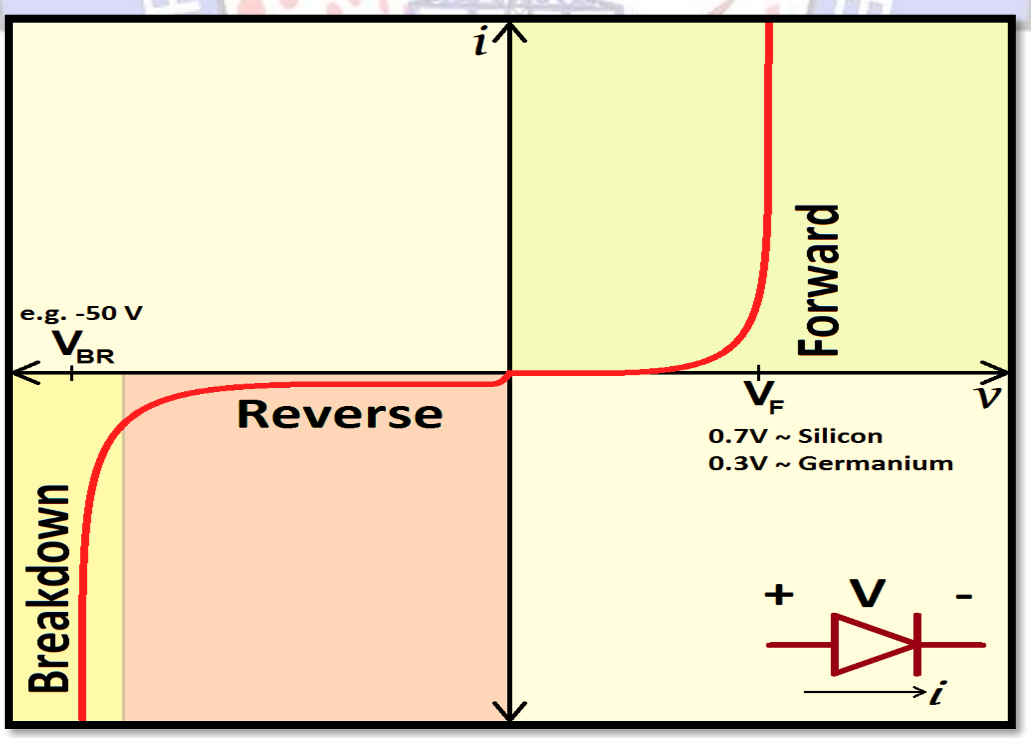


Figure 1: Diode IV Characteristics

The diode forward static (or DC) resistance at a particular DC operating point (Q) is given by:

$$R_{DC} = R_D = \frac{V_{DQ}}{I_{DQ}}$$

Where VDQ is the diode bias voltage, and IDQ is the diode operating current.

The diode dynamic (or AC) resistance can be found from the characteristic curve at the Q-Point as:

$$r_{ac} = r_d = \frac{\Delta V_D}{\Delta I_D}$$

Where ΔVD is a small increment in diode voltage around VDQ, and ΔID is a small increment in diode current around IDQ as depicted in Fig.2.

The dynamic resistance depends on the operating point, and can be calculated approximately from the equation:

$$r_d = \frac{V_T}{I_{DQ}}$$

Where VT is the thermal voltage, and IDQ is the diode operating current.

Fig.2 shows the determination of the dynamic resistance graphically.

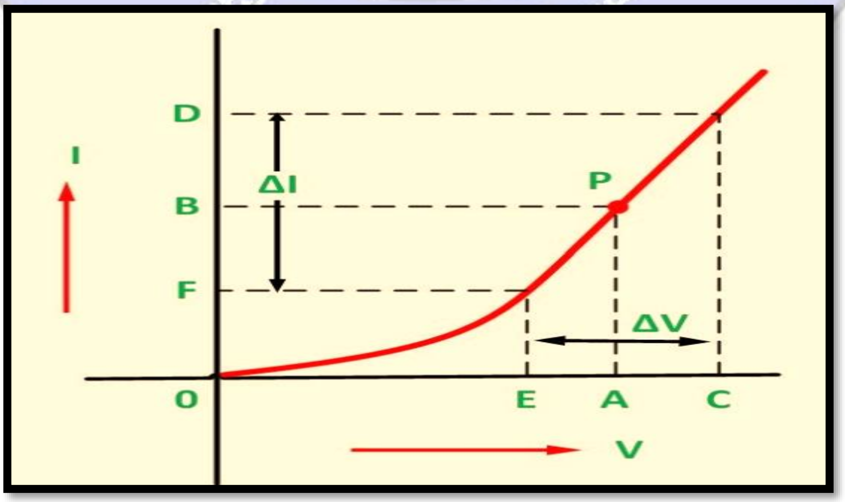


Figure 2: Graphical Determination of the Diode Dynamic Resistance

Procedure

1. Connect the diode circuit shown in Fig.3.

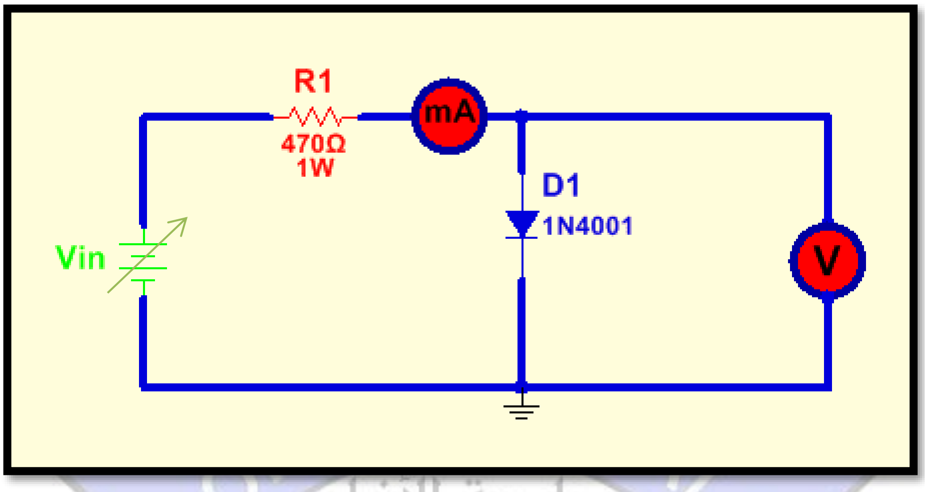


Figure 3: Diode Forward-Biased Circuit

2. Set the DC supply voltage V_{in} at 0V, and increase it gradually. Record diode voltage V_D and current I_D in each step according to Table 1 below.

Table 1: Recorded Data for the Forward-Biased Diode Circuit

I_D(mA)	V_D(V)
0	
0.5	
1	
2	
6	
10	
12	
18	
20	
22	

3. Connect the reverse-biased diode circuit shown in Fig.4. Set the DC power supply voltage V_{in} at 0V, and increase it gradually in several steps and record diode reverse voltage $V_R$and reverse current $I_R$as indicated in Table 2.

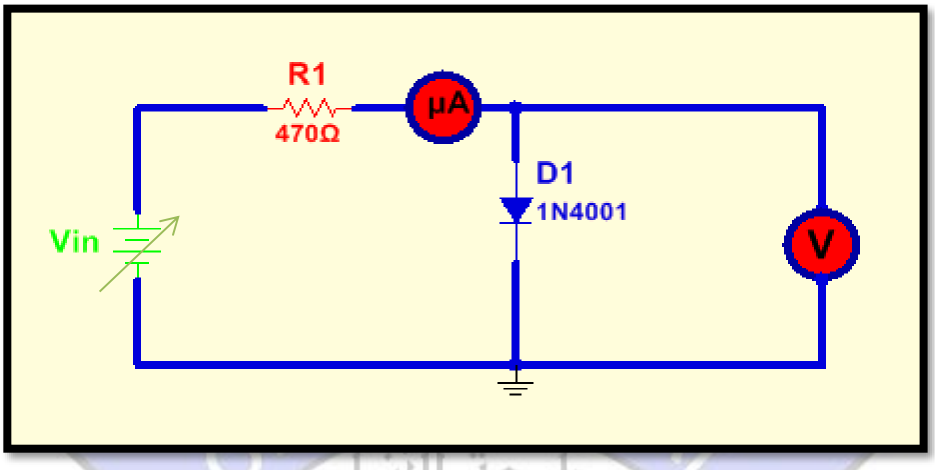
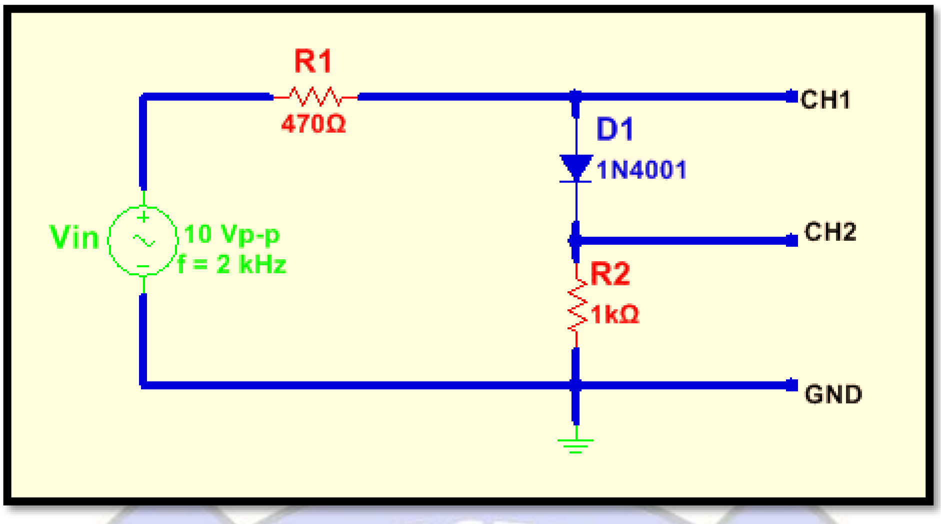


Figure 4: Diode Reverse-Biased Circuit

Table 2: Recorded Data for the Reverse-Biased Circuit

V_R(V)	I_R(μA)
0	
5	
10	
15	
20	
25	

4. Connect the circuit shown in Fig.5 to display the diode characteristics on the oscilloscope. Set the oscilloscope in the X-Y mode and vary the vertical and horizontal sensitivities of the oscilloscope to obtain the proper display.



Sketch the resulting characteristic curve. Record the voltage scale for channel 1 (X-channel), and channel 2 (Y-channel) after fixing the scope in the X-Y mode. The X-channel represents the diode voltage, and the Y-channel represents the diode current with the current scale obtained as:

$$Current\ sensitivity = \frac{Voltage\ sensitivity}{10\Omega}$$

Calculations and Discussion

1. Plot the diode forward characteristics from the results obtained, and determine the cut in voltage Vγ from the sketch.
2. From the sketched characteristic curve determine the static resistance of the diode R_{DC}
3. at I_{DQ} = 10mA. Determine also the diode dynamic resistance at I_{DQ} = 10mA, and compare it with the theoretical value obtained from the equation.
4. Plot the diode reverse characteristic, and estimate an approximate value for the reverse saturation current IS. From the results obtained in this experiment, compute the maximum power dissipated in the diode.
5. Explain how you could use an ohmmeter to identify the cathode of an unmarked diode.
6. Explain why a series resistor is necessary when a diode is forward-biased.

7. In a certain silicon diode, it was found that the diode current is 15mA when the diode voltage is 0.64V at room temperature. Determine the diode current when the voltage across it becomes 0.68V. Use the approximate diode characteristic equation.
8. From the approximate diode characteristic equation, derive an expression for the dynamic resistance rd.