Experiment

Normal and Zener diode characteristics

1 Objectives

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

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

2 Circuit components/equipment

1. Junction diodes (Si)
2. Zener diode
3. A current limiting Resistor (1 kΩ)
4. D.C. Power supply
5. 2 multimeters
6. Breadboard
7. Connecting wires

3 Theory

A diode is a nonlinear circuit element. The symbol of a diode and a real commercial diode is shown in figure 2. 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.

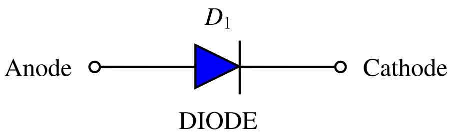
The theoretical equation for the diode current I_D is

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

where V_D is the diode voltage drop, I_S is the saturation current, η is the emission coefficient, and $V_T = kT/q (\approx 0.026\text{ V at } T = 300\text{ K})$ is the thermal voltage.

The emission coefficient accounts for recombinations of electrons and holes in the depletion region, which tend to decrease the current. For discrete diodes, it has the value η is 2.

(a)



(b)

Figure 1: (a) Picture of a diode. (b) Symbol of a diode.

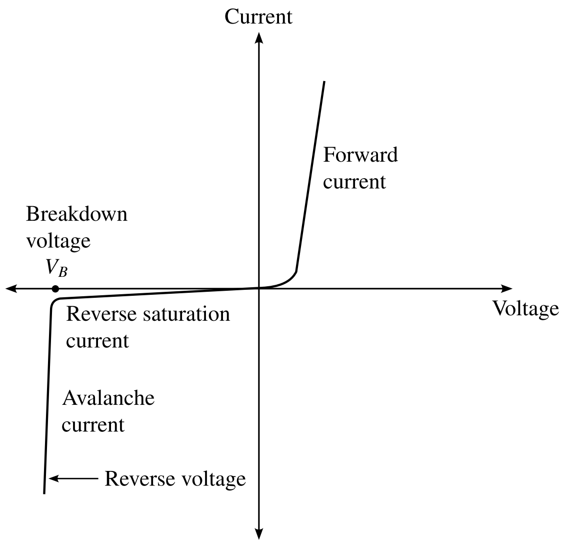
The IV characteristic of an ideal diode is shown in figure 2(a). Under forward biased condition of a real PN junction diode, the P-side is connected to the positive and N-side is connected to the negative terminal of the power supply. This reduces the potential barrier. As a result current flows from 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 (Figure 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 the 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 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).

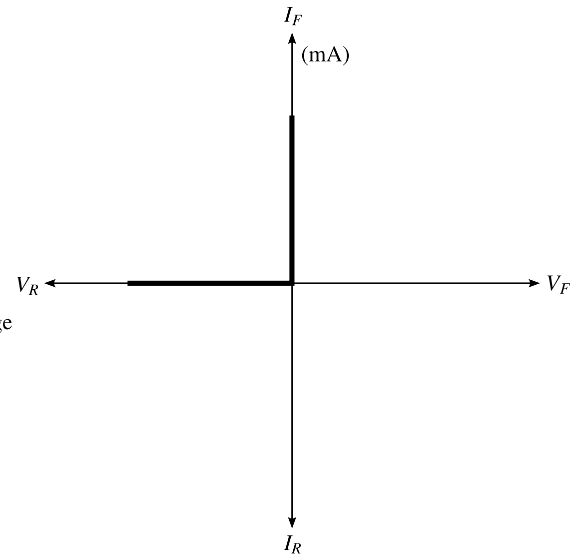
However, if the reverse bias is made too high, the current through the PN junction increases abruptly. The voltage at which this phenomenon occurs is known as the *break-down or reverse voltage* and the mechanism involved depends on the construction of the diode. In conventional diodes with a lightly doped junction, application of higher reverse voltage leads to a 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 a large number of electron-hole pairs. This phenomenon is called zener breakdown.

3.1 Zener diode

It is a reverse biased heavily doped PN junction diode generally operated in zener breakdown region. Zener voltage is the reverse voltage above which there is a controlled



(a)



(b)

Figure 2: (a) IV characteristics of a practical diode. (b) IV characteristics of an ideal diode.

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 figure 3.

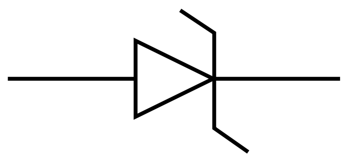


Figure 3: Symbol of a zener diode.

3.2 Static and dynamic resistance

At a given operating point, the static and dynamic resistance of a diode can be determined from its characteristics as shown in figure 4. The static or DC resistance, R_D, of the diode at the operating point (the point where the load line intersects the diode characteristics), Q, is simply the quotient of the corresponding levels of V_D and I_D. The DC resistance levels at the knee and below will be greater than the resistance levels obtained for the vertical rise section of the characteristics.

The diode circuits generally operate with varying inputs, which will move the instantaneous operating point up and down a region of the characteristics and defines a specific change in current and voltage. Dynamic or AC Resistance, r_d, is defined as the quotient of this change in voltage and change in current around the DC operating point.

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

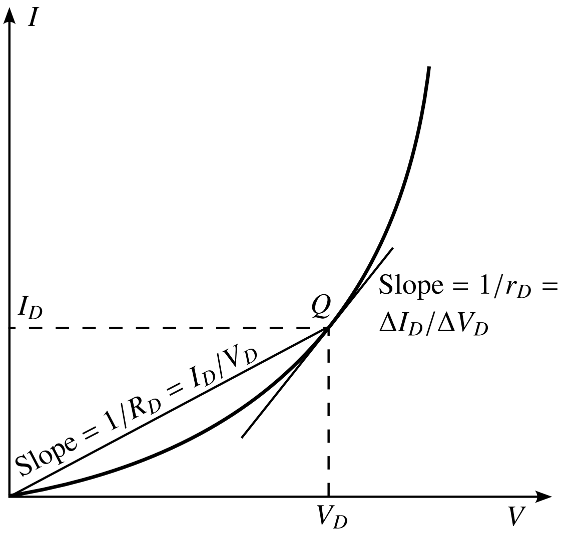


Figure 4: IV characteristics of a zener diode.

4 Circuit diagram

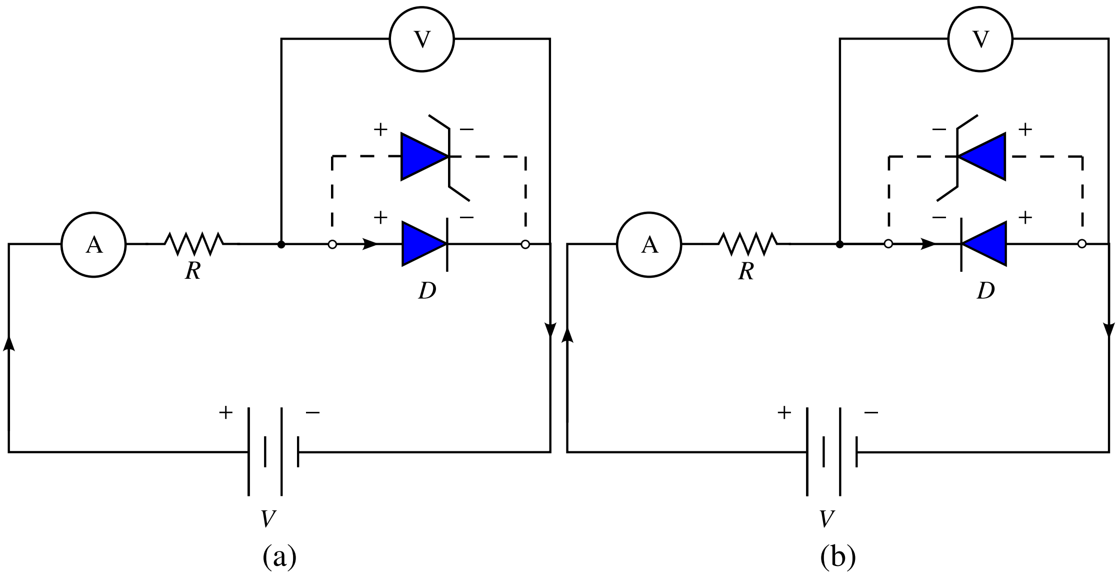


Figure 5: (a) Forward bias circuit. (b) Reverse bias circuit.

5 Procedure

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

5.1 Forward and reverse bias characteristics of a normal diode

5.1.1 Forward bias characteristics

1. Assemble the circuit on your breadboard as shown in figure 5(a). Connect to the 0 – 30 V DC power supply.

2. Switch on the power supply. Slowly increase the supply voltage in steps of 0.1 Volt using the fine adjustment knob 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 threshold point), increase the supply voltage in steps of 0.5 to note down current.

3. Using multimeter in appropriate modes, measure voltage drop across the diode and the current in the circuit. Switch off the supply after taking sufficient readings.

4. Plot the I-V characteristics and estimate the threshold voltage.

5. Choose two operating points below and above the threshold point and determine the static and dynamic resistance at each of the points.

5.1.2 Reverse bias characteristics

1. Assemble the circuit on your breadboard as shown in figure 5(b). Connect to the 0-30 V DC power supply.

2. Switch on the supply. Increase the supply voltage in steps of 0.5 Volt to note down the diode current.

3. Use multimeters for voltage and current measurements. Keep in mind that the magnitude of current flowing in the circuit will be very small, so choose current range properly. 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.

5.2 Forward and reverse bias characteristics of a Zener diode

5.2.1 Forward bias characteristics

1. Assemble the circuit on your breadboard as shown in figure 5(a). Use a zener diode this time in your circuit and repeat steps 2-4 of forward bias characteristics of normal diodes.

5.2.2 Reverse bias characteristics

1. Assemble the circuit on your breadboard with the zener diode, as shown in figure 5(b). Keep in mind that initially the magnitude of current flowing in the circuit will be very small.

2. 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.

3. Plot the IV characteristics on the same graph sheet and estimate the threshold and break-down voltages.

6 Observations

Code Number of diode:

1. Normal diode:
   _______ (Si)
   _______ (Ge)

2. Zener 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 1: 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 2: Normal diode (Ge)

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 3: Zener diode

7 Graphs

Plot IV characteristics for both the diodes and estimate the required parameters.

8 Results

1. Describe the behaviour of the IV curve for each diode.
2. Threshold voltage for normal diode is ______ V (What type of diode is Si/Ge?)
   Static resistance = ______, Dynamic resistance = ______ at operating point Q.
3. Threshold voltage for Zener diode = ______ V
   Zener Break-down voltage = ______ V

9 Precautions