EXPERIMENT 1
DIODE CHARACTERISTICS

Objective
To calculate, compare, draw, and measure the characteristics of a silicon and germanium diode.

Tools and Equipments Required

- DMM (Digital Multi Meter)
- DC Power Supply
- 1 kΩ x 1
- 1 MΩ x 1
- Silicon Diode x 1
- Germanium Diode x 1

Theory And Descriptions

Most multimeters can be used to determine the operating condition of a diode. They have scale denoted by a diode symbol that will indicate the condition of a diode in the forward- and reverse-bias regions. If connected to establish a forward-bias condition, the meter will display the forward voltage (offset voltage) across the diode in at a current level typically in the neighbourhood of 2 mA. If connected to establish a reverse-bias condition, an “OL” should appear on the display to support the open-circuit approximation frequently applied to this region. If the meter does not have diode-checking capability, the condition of the diode can also be checked by obtaining some measure of the resistance level in the forward- and reverse-bias regions. Both techniques for checking a diode will be introduced in the first part of the experiment.

The current-volt characteristics of a silicon or germanium diode have the general shape shown in Fig.1.1. Note the change in scale for both the vertical and horizontal axes. In the reverse-biased region the current increases quite rapidly with increasing diode voltage. Note that the curves are rising almost vertically at a forward-biased voltage of less than 1 V. the forward-biased diode current will be limited solely by the network in which the diode is connected or by the maximum current or power rating of the diode.
Figure 1.1 Diode Characteristic

The DC or static resistance of a diode at any point on the characteristics is determined by the ratio of the diode voltage at that point, divided by the diode current. That is,

\[ R_{DC} = \frac{V_D}{I_D} \text{ ohms} \quad \text{eq.1.1} \]

The AC resistance at a particular diode current or voltage can be determined using a tangent line. The resulting voltage (\(\Delta V\)) and current (\(\Delta I\)) deviations can then be measured and the following equation applied.

\[ r_D = \frac{\Delta V}{\Delta I} \text{ ohms} \quad \text{eq.1.2} \]

The application of differential calculus shows that the AC resistance of a diode in the vertical-rise section of the characteristics is given by

\[ r_D = \frac{26mV}{I_D} \text{ ohms} \quad \text{eq.1.3} \]

For levels of current at and below the knee of the curve, the AC resistance of a silicon diode is better approximated by

\[ r_D = 2\left(\frac{26mV}{I_D}\right) \text{ ohms} \quad \text{eq.1.4} \]
PROCEDURE

PART 1. Diode Test

a) Diode testing Scale

The diode-testing scale of a DMM can be used to determine the operating condition of a diode. With one polarity, the DMM should provide “offset voltage” of the diode, while the reverse connection should result in an “OL” response to support the open-circuit approximation.

Using the connections shown in fig1.2, the constant-current source of about 2 mA internal to the meter will forward bias the junction, and a voltage about 0.7 V (700mV) will be obtained for silicon and 0.3 V (300mV) for germanium. If the leads are reversed, an OL indication will be obtained.

If a low reading (less than 1 V) is obtained in both directions, the junction is shorted. If an OL indication is obtained in both direction, junction is open.

Perform the tests of table 1.1 for silicon and germanium diodes.

Table 1.1

<table>
<thead>
<tr>
<th>Test</th>
<th>Si</th>
<th>Ge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 2. Forward-bias Diode Characteristics

In this part of the experiment we will obtain sufficient data to plot the forward-bias characteristics of the silicon and germanium diodes on fig.1.4

a) Construct the network of fig.1.3 with the supply (E) set at 0 V. record the measured value of the resistor.

![Figure 1.3](image)

b) Increase the supply voltage E until $V_R$ (not E) reads 0.1 V. Then measure $V_D$ and insert its voltage in Table1.3. Calculate the value of the corresponding current $I_D$ using the equation shown in Table 1.3

<table>
<thead>
<tr>
<th>$V_R$ (V)</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_D$ (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_D = \frac{V_R}{R_{meas}}$ (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$V_R$ (V)</th>
<th>0.9</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_D$ (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_D = \frac{V_R}{R_{meas}}$ (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Replace the silicon diode by a germanium diode and complete table1.4

<table>
<thead>
<tr>
<th>$V_R$ (V)</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_D$ (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_D = \frac{V_R}{R_{meas}}$ (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
d) On fig 1.4, plot \( I_D \) versus \( V_D \) for the silicon and germanium diodes. Complete the curves by extending the lower region of each curve to the intersection of axis at \( I_D = 0 \) mA and \( V_D = 0 \) V. label each curve and clearly indicate data points.

<table>
<thead>
<tr>
<th>( V_R ) (V)</th>
<th>0.9</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_D ) (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_D = \frac{V_R}{R_{meas}} ) (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1.4
Part 3. Reverse Bias

a) In fig. 1.5 a reverse-bias condition has been established. Since the reverse saturation current will be relatively small, a large resistance of 1 MΩ is required if the voltage across R is to be of measureable amplitude. Construct the circuit of fig. 1.5 and record the measured value of R on the diagram.

![Figure 1.5](image)

b) Measure the voltage $V_R$. Calculate the reverse saturation current from $I_S = V_R / (R_{meas} / R_m)$. The internal resistance $R_m$ of the DMM is included because of the large magnitude of the resistance $R$, your instructor will provide the internal resistance of DMM for your calculations. If unavailable, use a typical value of 10 MΩ.

$$R_m = \text{___________}$$
$$V_R = \text{___________}$$
$$I_S = \text{___________}$$

c) Repeat Part 3(b) for the germanium diode.

$$V_R = \text{___________}$$
$$I_S = \text{___________}$$

d) Determine the DC resistance levels for the silicon diodes using the equation

$$R_{DC} = \frac{V_D}{I_D} = \frac{V_D}{I_S} = \frac{E - V_R}{I_S}$$

$R_{DC}$ (calculated) (Si) = _____________

$R_{DC}$ (calculated) (Ge) = _____________
Part 4. DC Resistance

a) Using the Si curve of fig.1.5, determine the diode voltage at the diode current levels indicated in table 1.5. Then determine the DC resistance at each current level. Show all calculations.

Table 1.5

<table>
<thead>
<tr>
<th>I_D (mA)</th>
<th>V_D</th>
<th>R_DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Repeat part 4(a) for germanium and complete table 1.6

Table 1.6

<table>
<thead>
<tr>
<th>I_D (mA)</th>
<th>V_D</th>
<th>R_DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 5. AC Resistance

a) Using the equation \( r_D = \frac{\Delta V}{\Delta I} \), determine the AC resistance of silicon diode at \( I_D = 9mA \) using the curve at figure 1.4. Show your all work.

\[
r_d \text{ (calculated)} = \]

b) Determine the AC resistance at \( I_D = 9 \text{ mA} \) using the equation \( r_D = \frac{26mV}{I_D} \) for the silicon diode. Show your all work.

\[
r_d \text{ (calculated)} = \]

Compare the results at parts 5(a) and 5(b)
c) Repeat part 5(a) for $I_D = 2$ mA for the silicon diode.

$$r_d \text{ (calculated)} = \text{___________}$$

d) Repeat part 5(b) for $I_D = 2$ mA for the germanium diode.

$$r_d \text{ (calculated)} = \text{___________}$$

Conclusion

Write in 2-3 sentences at maximum.

- Compare the two curves on fig 1.4. How do the two curves differ? What are their similarities?

- Compare $I_S$ levels of silicon and germanium diodes. Are the results as expected?

- Does DC resistance change as the current increase? How? Why?