Experiment 7

Zener-Diode Characteristics

1- Objects of the Experiment:

- Recording the current-voltage characteristic $I_Z = f(V_Z)$ of a Zener diode.
- Determining the quiescent point $Q(V_Z, I_Z)$
- Determining the differential resistance of a Zener diode.

2- Principles

Zener diodes are semiconductor diodes which are operated in the reverse direction via a series resistor connected upstream. The resistor serves to limit the current, i.e. to protect the diode.

When the applied voltage U exceeds a particular voltage V_{Z0} (breakdown voltage), which is dependent on the diode type, the barrier junction conducts and the current I_Z greatly increases. This happens for two reasons:

1- When the electric field strength exceeds approximately $2x10^5$V/cm in the barrier junction, which is only several μm thick, electrons in the crystal are ripped out of their fixed bonds and become available as charge carriers (as do the holes left behind). This process is known as the **Zener effect**. The Zener effect is only effective for diodes with a breakdown voltage (V_{Z0}) of up to approximately 6V.

2- The charge carriers of the reverse current experience such a strong acceleration under the high field that they collide with valence electrons at high speed, knocking them out of their fixed bonds. These electrons are then in turn accelerated and so the cycle is continually repeated. This effect is known as the **avalanche effect** because the number of charge carriers climbs in such a dramatic manner. The avalanche effect occurs in diodes with a breakdown voltage (V_{Z0}) greater than 6V.

The voltage V_Z of a Zener diode is not completely constant in the breakdown region; it is dependent on the current I_Z and the temperature.

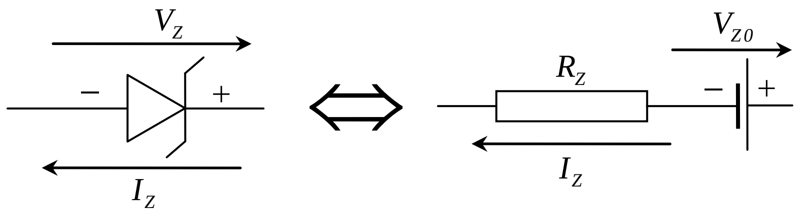

Figure 1. Circuit symbol of a Zener diodel and its equivalent circuit diagram for $V_Z > V_{Z0}$.

The breakdown voltage V_{Z0} can be calculated using the expression below for $V_Z > V_{Z0}$ (temperature effects have been ignored)

$$V_Z = V_{Z0} + r_Z I_Z \qquad with \qquad r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

3- Equipments

1 resistor 1Ω / 2W	
1 resistor 330Ω / 2W	577 380
1 Zener diode ZPD 9	578 55
2 multimeters	
1 Power supply unit	726 88
1 Plug-in board 297X300	72650
1 Set of bridging plugs 19mm	501 48
1 Set of connecting leads	501 532

4- Setup

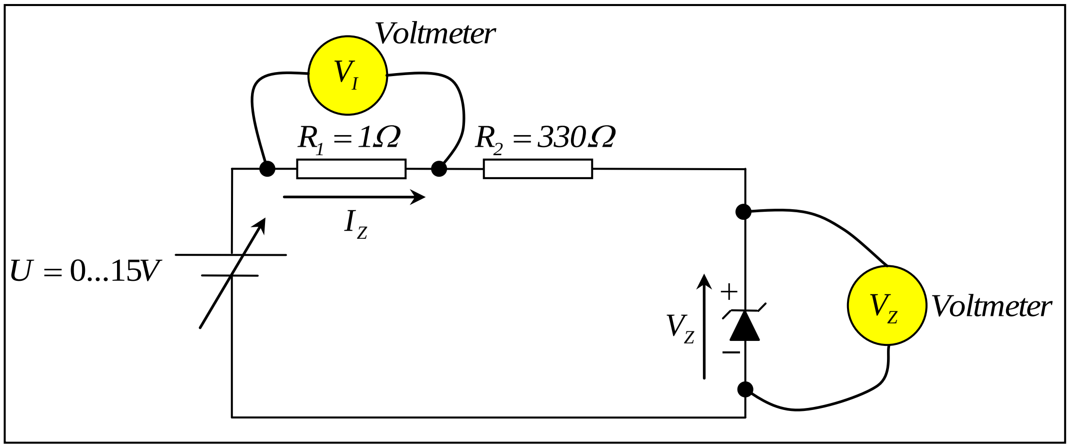

Figure 2.

5- Carrying out the experiment

5-1- Recording the current-voltage characteristic $I_D = f(V_D)$ of a Zener diode

- Assemble the circuit as shown in Figure 2 and carry out the measurements for the voltages given in Table 1.

Table 1

ZPD 9	
V_Z (V)	**I_Z (mA)=V_I/R_1**
1	
3	
5	
7	
8	
9	
9.5	
10	
10.5	
11	
12	

13	
14	

- Prepare a sheet of graph paper for plotting I_Z versus V_Z. You should make I_Z the vertical axis and V_Z the horizontal axis. Each axis should be labeled and appropriate units indicated. The graph should have a title.
- Plot your data on the graph and draw the corresponding current-voltage characteristic $I_Z=f(V_Z)$.
- What function does the series resistor R_2 have?
- Determine the breakdown voltage V_{Z0} of the diode by drawing a tangent to the approximately linear part of the curve and reading the voltage from the voltage axis where the tangent intersects it.

5-2- Determining the quiescent point $Q(V_Z, I_Z)$ and the differential resistance r_Z

The quiescent point or Q-point of a circuit is determined by the components used and the operating voltage. The Q-point is given by the intersection of the Zener diode characteristic with the series resistor characteristic (load line). The Zener diode characteristic is given by the manufacturer in a data manual or it can be determined by measurement. Two points are required in order to be able to construct the load line:

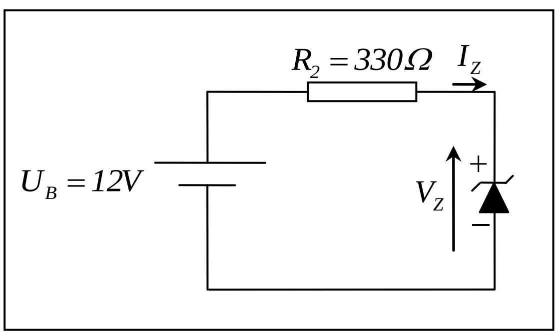

Figure 3

$$U_B = (R_1 + R_2)I_Z + V_Z \qquad \text{(Equation 1)}$$

$$U_B - V_Z = (R_1 + R_2)I_Z \qquad \text{(Equation 2)}$$

$$I_Z = -\frac{1}{R_1 + R_2}V_Z + \frac{U_B}{R_2} \qquad \text{(Equation 3)}$$

These two points A(V_{Z1},I_{Z1}), and B(V_{Z2},I_{Z2}) can be determined from Equation 3 and Figure 3. Plotting points A and B and tracing the line connecting the two points gives the load line.

- Construct the load line for the circuit shown in Figure 3 in the same sheet of graph paper and label the quiescent point (the quiescent point is the intersection between the I-V characteristics of Zener diode and the load line)
- Give the quiescent point Q(V_Z,I_Z).
- Draw a tangent to the Zener diode characteristic at the quiescent point and construct a right-angled triangle using the tangent.
- Determine the differential resistance r_Z from the intersections at the axes.

6- Conclusion

Make a general conclusion about the experiments and the results obtained.