National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

Department of Electrical Engineering

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Semester: 4th **Section:** D

EE215: ELECTRONIC DEVICES AND CIRCUITS

Lab 05: Zener diode and voltage regulation

		PLO4/CLO4		PLO5/CLO5	PLO8/CLO6	PLO9/CLO7
Name	**Reg. No**	**Viva /Quiz / Lab Performance** **5 marks**	**Analysis of data in Lab Report** **5 marks**	**Modern Tool Usage** **5 marks**	**Ethics and Safety** **5 marks**	**Individual and Teamwork** **5 marks**
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Lab 05: Zener diode and voltage regulation

Objective:

- Study of I-V characteristics of Zener diode in reverse biased region.
- Using Zener diode as voltage regulator.

EQUIPMENT REQUIRED

The following components and test equipment is required.

- Zener diode
- Oscilloscope
- Function Generator
- Resistors
- DC Power Supply

The Experiment:

The experiment is broken down into three exercises. It involves the calculation of required parameters in the circuit given. Second exercise involves the simulation of the circuit on PSpice using OrCAD-Capture module. The third one involves the practical setup of the circuit and making required measurements, tabulation, and its analysis.

Theory:

The very steep i–v curve that the diode exhibits in the breakdown region and the almost-constant voltage drop that this indicates suggest that diodes operating in the breakdown region can be used in the design of voltage regulators. Voltage regulators are circuits that provide a constant dc output voltage in the face of changes in their load current and in the system power-supply voltage. This in fact turns out to be an important application of diodes operating in the reverse breakdown region, and special diodes are manufactured to operate specifically in the breakdown region. Such diodes are called breakdown diodes or, more commonly, as noted earlier, Zener diodes.

Figure 4.18 shows the circuit symbol of the Zener diode. In normal applications of Zener diodes, current flows into the cathode, and the cathode is positive with respect to the anode.

Thus, I_Z and V_Z in Fig. 4.18 have positive values.

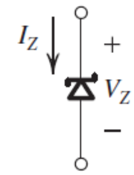


Fig 4.18

Figure 4.19 shows details of the diode i–v characteristic in the breakdown region. We observe that for currents greater than the **knee current** I_{ZK} (specified on the data sheet of the zener diode), the i–v characteristic is almost a straight line. The manufacturer usually specifies the voltage across the zener diode V_Z at a specified test current, I_{ZT}. We have indicated these parameters in Fig. 4.19 as the coordinates of the point labeled Q. Thus a 6.8-V zener diode will exhibit a 6.8-V drop at a specified test current of, say, 10 mA. As the current through the zener deviates from I_{ZT}, the voltage across it will change, though only slightly. Figure 4.19 shows that corresponding to current change ΔI the zener voltage changes by ΔV, which is related to ΔI by

$$\Delta V = r_z \Delta I$$

where r_z is the inverse of the slope of the almost-linear i–v curve at point Q. Resistance r_z is the **incremental resistance** of the zener diode at operating point Q. It is also known as the **dynamic resistance** of the zener, and its value is specified on the device data sheet. Typically, r_z is in the range of a few ohms to a few tens of ohms. Obviously, the lower the value of r_z is, the more constant the zener voltage remains as its current varies, and thus the more ideal its performance becomes in the design of voltage regulators. In this regard, we observe from Fig. 4.19 that while r_z remains low and almost constant over a wide range of current, its value increases considerably in the vicinity of the knee. Therefore, as a general design guideline, one should avoid operating the zener in this low-current region.

Zener diodes are fabricated with voltages V_Z in the range of a few volts to a few hundred volts. In addition to specifying V_Z (at a particular current I_{ZT}), r_z, and I_{ZK}, the manufacturer

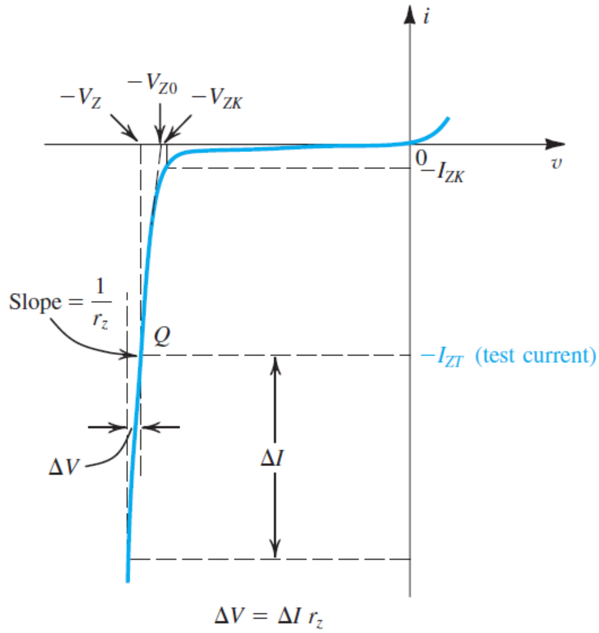


Figure 4.19 The diode i–v characteristic with the breakdown region shown in some detail.

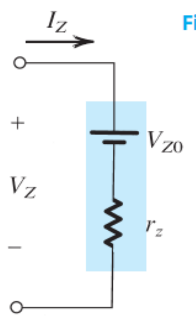


Figure 4.20 Model for the zener diode.

also specifies the maximum power that the device can safely dissipate. Thus a 0.5-W, 6.8-V zener diode can operate safely at currents up to a maximum of about 70 mA.

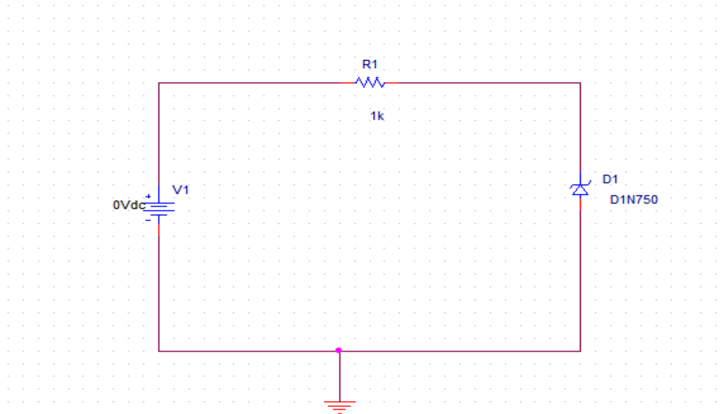
The almost-linear i–v characteristic of the zener diode suggests that the device can be modeled as indicated in Fig. 4.20. Here V_{Z0} denotes the point at which the straight line of slope $1/r_z$ intersects the voltage axis (refer to Fig. 4.19). Although V_{Z0} is shown in Fig. 4.19 to be slightly different from the knee voltage V_{ZK}, in practice their values are almost equal. The equivalent circuit model of Fig. 4.20 can be analytically described by

$$V_Z = V_{Z0} + r_z I_Z \tag{4.20}$$

and it applies for $I_Z > I_{ZK}$ and, obviously, $V_Z > V_{Z0}$.

Simulation:

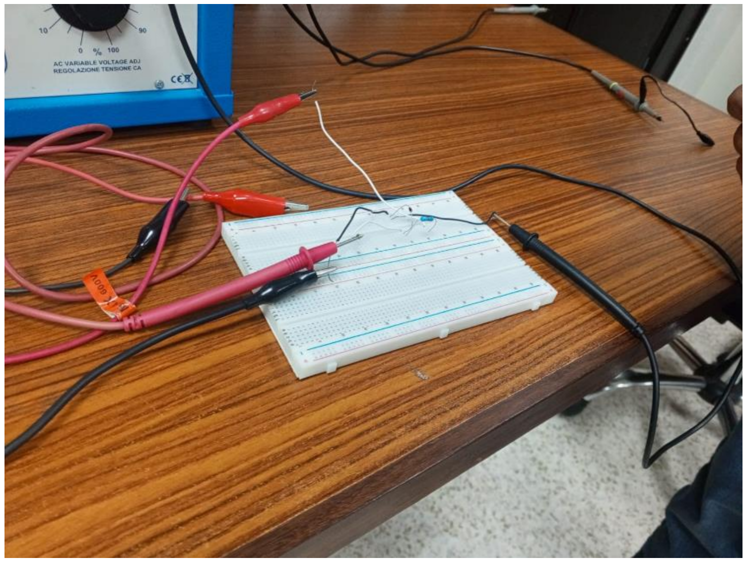
- Draw a graph of the I-V relationship of zener diode in reverse breakdown region using PSpice; this may be accomplished by using the DC sweep analysis mode of the simulation.



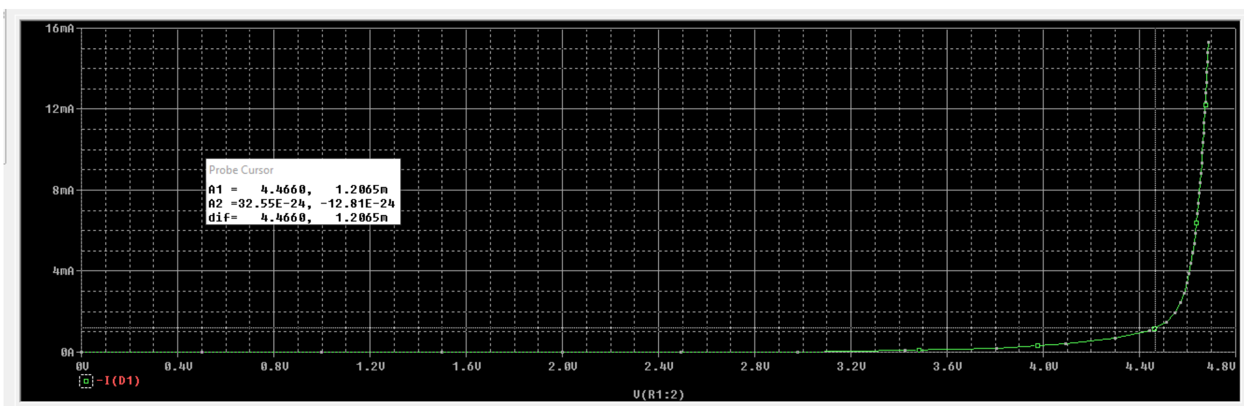

```
*
*
.model D1N750    D(Is=880.5E-18 Rs=.25 Ikf=0 N=1 Xti=3 Eg=1.11 Cjo=175p M=.5516
+                Vj=.75 Fc=.5 Isr=1.859n Nr=2 Bv=4.7 Ibv=20.245m Nbv=1.6989
+                Ibvl=1.9556m Nbvl=14.976 Tbvl=-21.277u)
*                Motorola        pid=1N750       case=DO-35
*                89-9-18 gjg
*                Vz = 4.7 @ 20mA, Zz = 300 @ 1mA, Zz = 12.5 @ 5mA, Zz =2.6  @ 20mA
```

- The part no of zener diode is given as D1N750.
- Value of V_z for this speccific model at particulat test current I_{Zt} is can be found out by right clicking on diode and selecting Edit PSpice model
- Make sure you have connected zener diode in reverse biased configuration.
- Use the DC sweep Analysis Settings: Start value = 0 , End value = 20, Increment = .5
- Place the current marker/probe at the cathode (upper pin) of the diode and run the simulation.
- Now in plot window change the x-axis variable to V(R1:2) to get a graph of I_D VS V_D Attach the screenshot of plot obtained

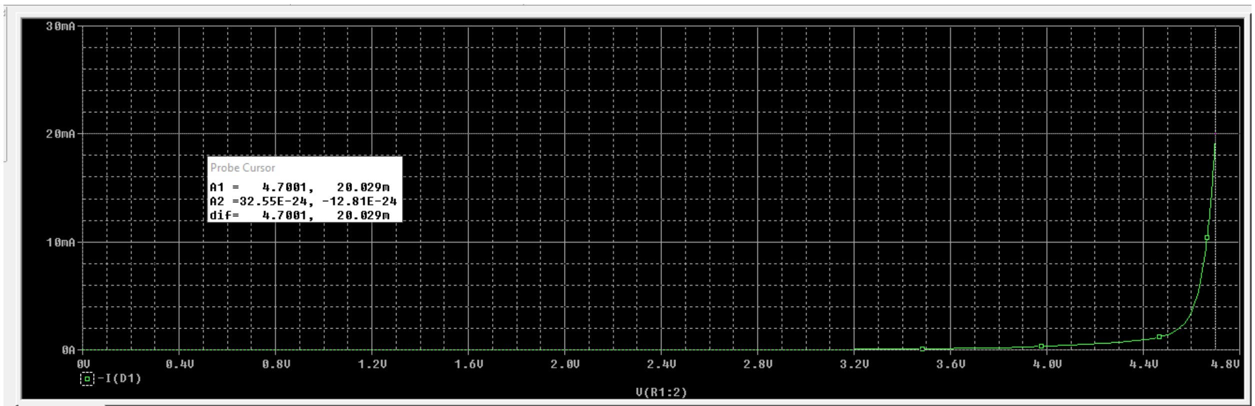
Hardware Implementation:



- Answer the following questions
  - Spot the knee current I_{zk} of the diode from I-V characteteristic graph, corresponding value of diode voltage at this knee current would be V_{zk}.



  - Find out the reverse breakdown voltage across zener diode V_z on the I-V curve at a test current of I_{zt} specified by the manufacturer.



- Find out the value of dynamic resistance r_z in the vicinity of I_{zk} & $I_{zt.}$

26 Ohm

- Explain the behaviour r_z keeping in view the value of r_z at I_{zk} & $I_{zt.}$

Rz plays a crucial role in understanding how the zener diode behaves in voltage regulation applications. At lower currents (Izk), rz is higher, leading to less effective voltage regulation, while at the test current (Izt), rz is minimized, resulting in more stable voltage regulation characteristics

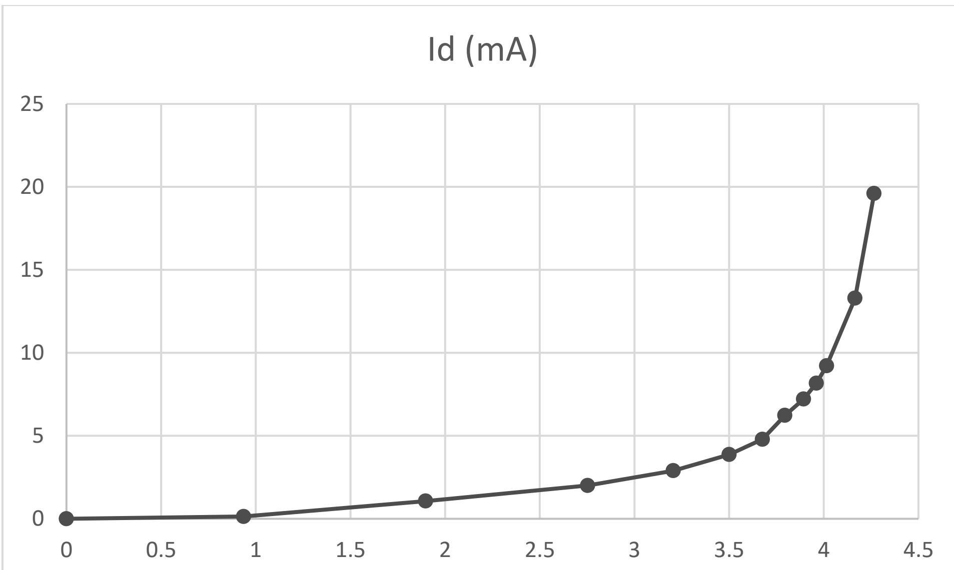
Implementation:

- On breadboard, setup the circuit given in simulation.
- Appl the input voltagee gradually increasing it from 0V and onwards, in step of 1V
- Measure and tabulate the value of I_z and V_z until V_z becomes almost constant.

Observations/Measurements:

- Plot I_z vs V_z reverse characteristics using both linear scale and logarithmic scale. Please make sure that you use MS Word/excel features for both linear scale and logarithmic scale plot and include the plot in your lab report. Please follow the lab report format provided by the instructor.
- Determine the reverse breakdown voltage of the diode and explain.
  Calculate the values of r_z at different input voltages.

Vs (V)	Vd (V)	Id (mA)
0	0.0001	0
1	0.9357	0.1349
2	1.897	1.0637
3	2.7532	2.005
4	3.205	2.8967
5	3.5	3.869
6	3.676	4.789
7	3.795	6.23
8	3.8938	7.215
9	3.961	8.165
10	4.0153	9.217
14	4.165	13.29
20	4.266	19.6



Conclusion:

In conclusion, our experiment on the I-V characteristics of Zener diodes in the reverse biased region provided valuable insights into their voltage regulation capabilities. By observing a nearly constant voltage drop across the diode over a wide range of reverse bias voltages, we confirmed its suitability for voltage regulation applications. Our findings underscore the importance of Zener diodes in stabilizing output voltages despite fluctuations in input voltage, highlighting their significance in electronic circuit design. Further exploration into temperature effects and circuit configurations could enhance our understanding of Zener diode behavior and improve voltage regulation efficiency. Overall, this experiment contributes to our knowledge of Zener diodes' practical applications and their role in ensuring circuit reliability and stability.