

Başkent University
Department of Electrical and Electronics Engineering
EEM 214 Electronics I
Experiment 5

Zener Diode Characteristics & Zener Diode Voltage Regulator

Aim:

The aim of this experiment is investigate the i - v characteristics of zener diodes and application of zener diode for voltage regulation.

Theory:

A zener diode is a special type of diode where the diode has been optimized for operation in the reverse or avalanche region which is shown in Fig.2. This is completely the opposite of normal diodes or rectifiers where every effort is made to keep the diode from breaking down in the reverse direction. The break-down voltage can be well controlled and yields a device which exhibits a constant breakdown voltage over a wide range of currents. In the forward direction, the zener diode acts as a normal forward biased diode.

Consider the i - v characteristics in **the breakdown region** ; it is observed that current greater than the knee current I_{ZK} , the i - v characteristic is almost a straight line. The zener voltage(voltage across the zener) is usually specified at test current I_{ZT} . Thus for example, 6.8 V zener diode will exhibit a 6.8 V drop at a specified test current of, say, 10mA. As the current through the zener deviates from I_{ZT} , the voltage across it will change, though slightly. Fig.2 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 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 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 this regard, it is observed from Fig.2 that while r_z remains low and almost constant over a wide range of current, its value increases considerably 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 , r_z , and I_{ZK} , maximum power that the device can safely dissipate is also specified.

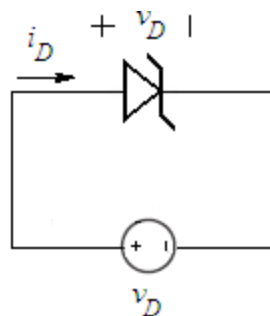


figure_1 Zener diode with applied voltage v_D

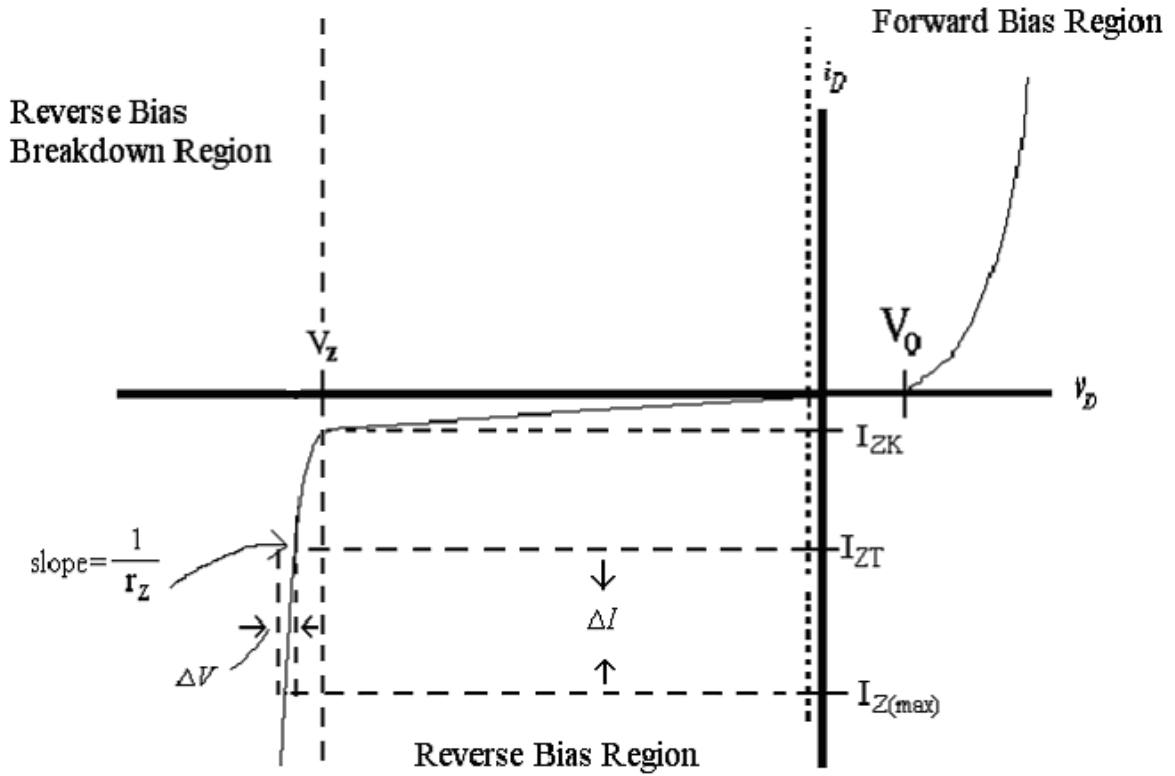


figure_2 i-v characteristics of zener diode

Zener Diode Equivalent Models

Zener diodes can be modeled as follows;

figure_3 i-v characteristics of constant voltage drop model of zener diode

figure_4 i-v characteristics of piecewise linear model of zener diode

r_f = average resistance of the diode when the conduction is established

r_z = zener resistance

$$r_z = \frac{\Delta V_{d2}}{\Delta I_{d2}} \quad r_f = \frac{\Delta V_{d1}}{\Delta I_{d1}}$$

Figure_5 Defining the piecewise linear equivalent circuit using straight-line segments to approximate the characteristic curve

Zener Diode Voltage Regulator

In Fig.6, an often used Zener diode voltage regulator is shown. The function of a voltage regulator is to provide a constant low ripple output voltage under varying load current conditions. While very high quality voltage regulators are available in integrated circuits, at times it may be sufficient and convenient to use a simple Zener diode regulator. Since the Zener diode will conduct in the reverse direction for any V_{out} greater than V_Z , V_{out} can never exceed V_Z . As the load current changes, the Zener diode will conduct sufficient current to maintain a voltage drop of $V_S - V_{out}$ across the series dropping resistor R_S . The selected Zener diode must have a reverse breakdown voltage equal to the desired output voltage and be capable of dissipating the power that results when R_L is very large. This type of regulator is generally not good for output voltages less than 5 volts or so because low voltage diodes with a sharp knee at reverse breakdown are not available. The difference between V_S and V_{out} should be selected as small as possible but must be large enough to prevent the voltage drop across R_S from exceeding $V_S - V_{out}$, when I_L is maximum. It is clear that a smaller value for R_S translate to a smaller value for $V_S - V_{out}$; however, a smaller value for R_S will result in a greater diode current when R_L is large and this will increase the power dissipation requirement of the diode.

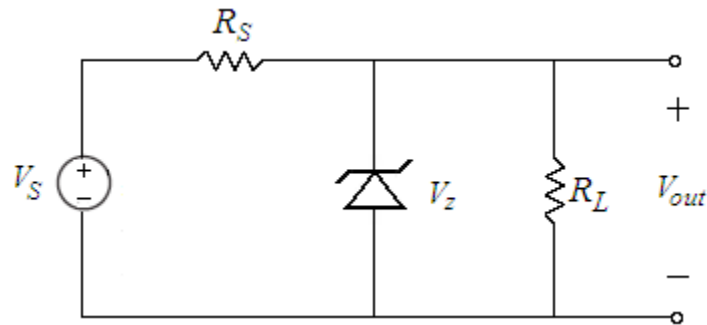


Figure_6

Two parameters can be used to measure how well the regulator is performing its function: **line regulation and the load regulation**. The line regulation is defined as the change in V_{out} (output voltage) corresponding to a 1-V change in V_S (input voltage),

$$\text{Line regulation} = \frac{\Delta V_{out}}{\Delta V_S}$$

and is usually expressed in mV/V. The load regulation is defined as the change in V_{out} corresponding to a 1 mA change in I_L (Load Current).

$$\text{Load regulation} = \frac{\Delta V_{out}}{\Delta I_L}$$

Preliminary Work:

- 1) Review sections 3.6 and 3.12 from the text book.
- 2) Construct the circuit in Fig.7 using PSPICE. Generate a graph of diode current versus diode voltage(*i-v* characteristics of zener diode), where V_{in} ranges between -20V and 10V with $R=1k$ and 1N750 zener diode. (Simulate using **DC Sweep Analysis** for this purpose and don't forget to change the axis variable.)

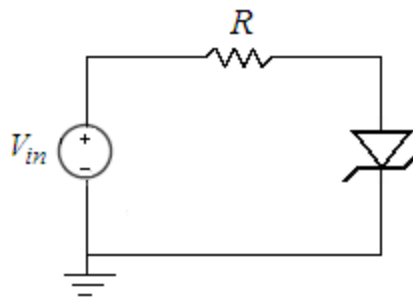


Figure_7

- 3) Briefly describe the difference between a Zener diode and a standard diode.
- 4) Consider the circuit in Fig.6, zener diode is specified to has 6.8V voltage drop at $I_{ZT} = 5mA$, $r_z = 20\Omega$, and $I_{ZK} = 0.2mA$. The supply voltage V_S is nominally 10V but can vary $\pm 1V$.
 - a) Find V_Z .
 - b) Find V_{out} with no load and with $V_S = 10V$, $R_S = 0.5k\Omega$.
 - c) Find the change in V_{out} resulting from the $\pm 1V$ change in V_S .
 - d) Find the change in V_{out} resulting from connecting a load resistance $R_L = 2k\Omega$
 - e) Find the value of V_{out} when $R_L = 0.5k\Omega$
 - f) What is the minimum value of R_L for which diode still operates in breakdown region?
- 5) Read the experimental work.

Experimental Work:

Part I Zener Diode Test

A zener diode can be checked for functionality using a DMM. This is because the voltage supplied by the DMM is less than 3 volts and (provided that the zener voltage is greater than 3 volts) the zener acts as a normal diode in the forward direction. In the reverse direction, the zener does not reach the avalanche point and looks high resistance. To select the diode check function, push the  button on function scale of DMM.

- 1) When zener the diode is connected in Fig.8a, so that it is forward biased, forward current flow is established and a good zener diode will produce a voltage(forward voltage drop) reading on the display which is between 0.500 to 0.900 for zener diode(silicon diode).

When the zener diode connected in Fig.8b, so that it is reversed biased. If the zener diode under the test is good, “000.0” will be flickered.

Check whether the diode is good or defective and record the values displayed.

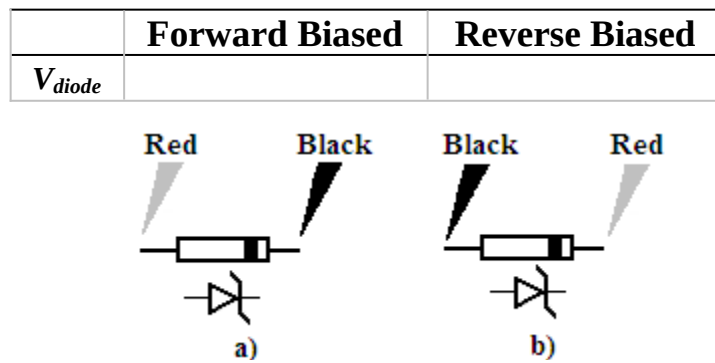


Figure_8

Part II Forward & Reverse Characteristics of Zener Diode

- 1) Setup the circuit in Fig.7 with $R = 330\Omega$ and BZX55C(6.2V) zener diode, to obtain the forward $i-v$ characteristics of diode. Increase the voltage on power supply until the voltage across the diode indicates .35 volts. Record voltage across the diode and diode current. Continue increasing the voltage across the diode(by increasing supply voltage) and measure and record the current for the voltage values shown in following table.

Diode Volts	Diode Volts (mesured)	Current in mA BZX55C (measured)
.35		
.45		
.55		
.60		
.65		
.70		
.75		
.80		

- 2) Consider the circuit that you construct at previous step. Reverse the zener diode and measure the voltages and currents obtained for the voltage values shown in following table.

$V_{applied}$ in Volts	V_{zener} in Volts (measured)	I_{zener} in mA (measured)
3.5		
4		
4.5		
5		
5.5		
6		
6.5		
7		
7.5		
8		
9		
10		
11		
12		
13		
14		
15		

- 3) Plot the i - v characteristics of zener diode in millimetric paper. Clearly indicate the regions. You are free to use Excel.

Part III Zener Regulator

- 1) Construct the circuit below, with the Zener diode BZX55C (6.2 V) and $R_S = 390\Omega$.

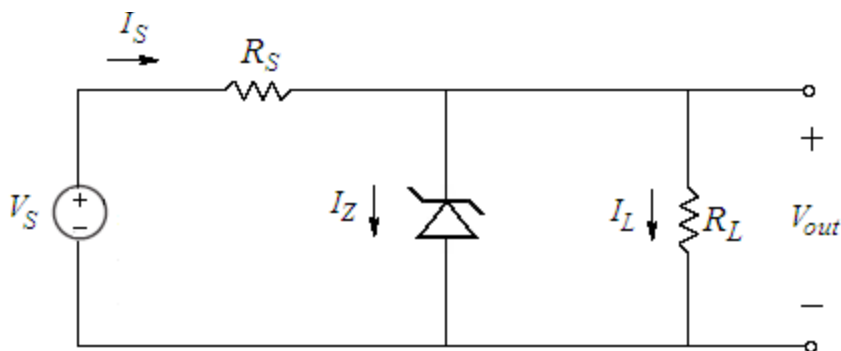


Figure_9

- [illegible]

- 3) a) Repeat steps 1 and 2 with $R_S = 620\Omega$.
b) Repeat steps 1 and 2 with $R_S = 100\Omega$.

	V_{out}			
	$V_S = 12$		$V_S = 8$	
	$R_L = 820\Omega$	$R_L = 330\Omega$	$R_L = 820\Omega$	$R_L = 330\Omega$
$R_S = 620\Omega$				
$R_S = 390\Omega$				
$R_S = 100\Omega$				

- 4) For each value of V_S , calculate I_L and I_Z for each of the 12 combinations of resistors (R_S and R_L).
- 5) For each of the values of R_S , calculate the line regulation for $R_L = 330\Omega$ and then for $R_L = 820\Omega$.
- 6) For each of the values of R_S , calculate the load regulation for $V_S = 12 V_{DC}$ and then for $V_S = 8 V_{DC}$.
Remember you will have the maximum load current flowing through the minimum resistance and the minimum current through the maximum resistance.

$$\text{Line Regulation} = \frac{1000(V_{outmax} - V_{outmin})}{(V_{Smax} - V_{Smin})} \Big|_{R_L = Constant} \left(\frac{mV}{V} \right)$$

$$\text{Load Regulation} = \frac{V_{outmax} - V_{outmin}}{(I_{Lmax} - I_{Lmin})} \Big|_{V = Constant} \left(\frac{mV}{mA} \right)$$

- 7) Check the results for cases where the zener diode drops out of regulation. That is I_Z goes to zero or close to zero so the diode is no longer on the steep part of the reverse breakdown curve. In this case the output voltage depends on the value of V_S , R_S , and R_L and not on V_Z . Comment on the results.
- 8) Calculate P_Z and P_{R_S} for each of the 12 sets of data. Compare the results to the maximum power rating of the components.
- 9) What voltage do you expect would be across the Zener diode if it was accidentally reversed in the voltage regulator circuit?
- 10) Which value of R_S gives the best overall regulation operation? Explain why the regulation is worse at the other values of R_S .

Lab Instruments:	Components:
Breadboard	1 BZX55C 6.2 V
Multimeter	1 100 Ω
DC Power Supply	1 390 Ω 1 620 Ω
	1 330 Ω 1
	820 Ω

Experiment Results

Diode Volts	Diode Volts (mesured)	Current in mA BZX55C (measured)
.35		
.45		
.55		
.60		
.65		
.70		
.75		
.80		

$V_{applied}$ in Volts	V_{zener} in Volts (measured)	I_{zener} in mA (measured)
3.5		
4		
4.5		
5		
5.5		
6		
6.5		
7		
7.5		
8		
9		
10		
11		
12		
13		
14		
15		

	V_{out}			
	$V_S = 12$		$V_S = 8$	
	$R_L = 820 \Omega$	$R_L = 330 \Omega$	$R_L = 820 \Omega$	$R_L = 330 \Omega$
$R_S = 620 \Omega$				
$R_S = 390 \Omega$				
$R_S = 100 \Omega$				

Student Name :

Number :

Signature.....