Objective:

To study and verify the functionality of Zener diode in forward bias and reverse bias and

1. Plot Volt-Ampere Characteristics of Zener Diode.
2. Find Zener Breakdown Voltage in Reverse Biased conditions.
3. Calculate static and dynamic resistance of the Zener diode in both forward and reverse biased conditions (before, after break down voltages).
4. To construct a zener diode voltage regulator power supply and measure its line and load regulation.

Theory

The Zener diode is like a general-purpose signal diode. When biased in the forward direction it behaves just like a normal signal diode, but when a reverse voltage is applied to it, the voltage remains constant for a wide range of currents.

Avalanche Breakdown: When the diode is in the reverse bias condition, the width of the depletion region is more. If both p-side and n-side of the diode are lightly doped, depletion region at the junction widens. In reverse bias, the minority charge carrier current flows through junction. As the applied reverse voltage increases the minority carriers acquire sufficient energy to collide with the carriers in the covalent bonds inside the depletion region. As a result, the bond breaks and electron hole pairs are generated. The process becomes cumulative and leads to the generation of a large number of charge carriers resulting in Avalanche Breakdown. At this stage maximum current will flow through the zener diode. This breakdown point is referred as "**Zener voltage**".

Zener Break down: If both p-side and n-side of the diode are heavily doped, depletion region at the junction reduces compared to the width in normal doping. Applying a reverse bias causes a strong electric field get applied across the device. As the reverse bias is increased, the Electric field becomes strong enough to rupture covalent bonds and generate large number of charge carriers. Such sudden increase in the number of charge carriers due to rupture of covalent bonds under the influence of strong electric field is termed as Zener breakdown.

The Zener Diode is used in its "reverse bias". From the I-V Characteristics curve we can study that the zener diode has a region in its reverse bias characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current I_Z (min) and the maximum current rating I_Z (max).

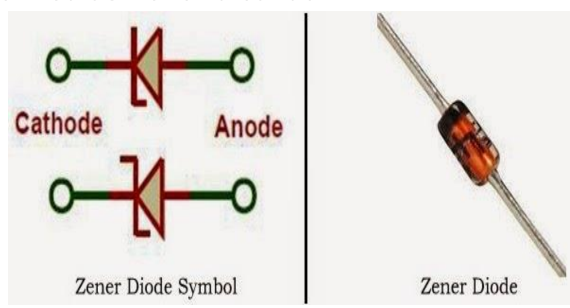


Fig 1: Zener diode

This ability to control itself can be used to great effect to regulate or stabilize a voltage source against supply or load variations. The fact that the voltage across the diode in the breakdown region is almost constant turns out to be an important application of the zener diode as a voltage regulator

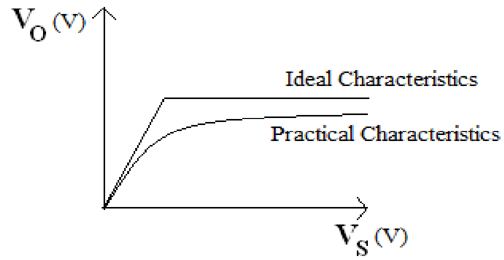
Zener diodes are available from about 2.4 to 200 volts as 2.4, 2.7, 3.0 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1, 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, etc. All Zener diodes have a power rating, Pz. From Watt's law the maximum current is $I_{Z(MAX)}=P_Z / V_Z$*. Zener diodes are typically available with power ratings of 0.25, 0.4, 0.5, 1, 2, 3, and 5 watts although other values are available. We also carry Zener diodes with nominal working voltage up to 1 kV. Forward (drive) current can have a range from 200 uA to 200 A, with the most common forward (drive) current being 10 mA or 200 mA.*

Line Regulation: In this type of regulation, series resistance and load resistance are fixed, only input voltage is changing. Output voltage remains the same as long as the input voltage is maintained above a minimum value.

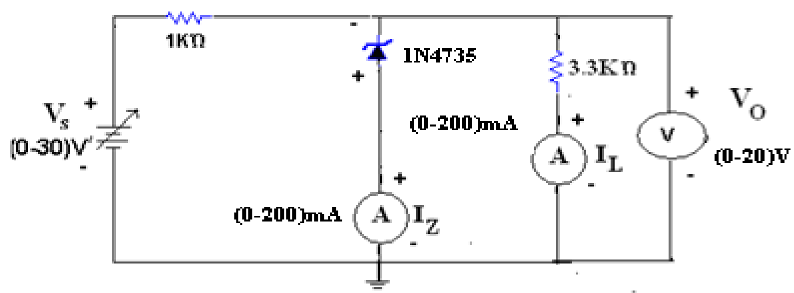
Percentage of line regulation can be calculated by

$= \frac{\Delta Vout}{\Delta Vin}$ x100

where V_{out} is the output voltage and V_{in} is the input voltage and ΔV_{out} is the change in output voltage for a particular change in input voltage ΔV_{in}



Circuit Diagram of Zener Diode as Line Regulator:



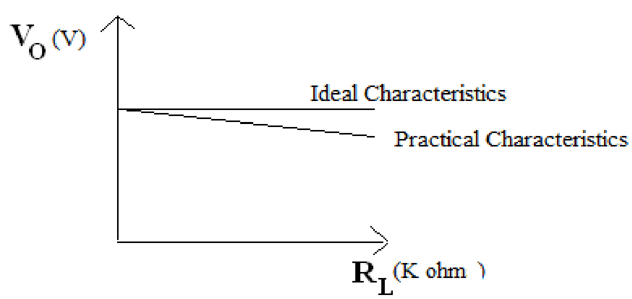
Line Regulation Table (at Load Resistance:)			
Unregulated Power Supply Vs (V)	Zener Current Iz (mA)	Load Current IL (mA)	Regulated Output Voltage Vo (V)

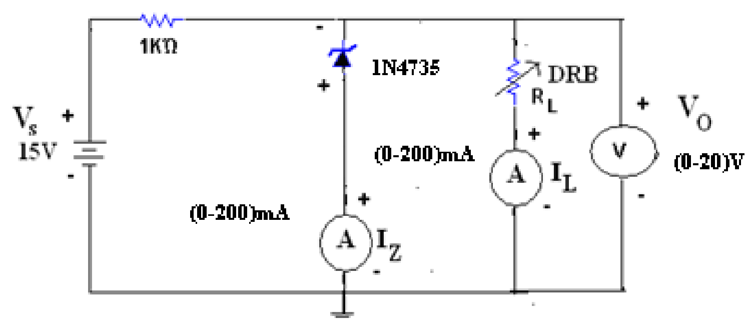
Load Regulation: In this type of regulation, input voltage is fixed and the load resistance is varying. Output volt remains same, as long as the load resistance is maintained above a minimum value.

Percentage of load regulation

$= \frac{VNL - VFL}{VNL}$ x100

Where V_{NL} is the null load resistor voltage (ie. remove the load resistance and measure the voltage across the Zener Diode) and V_{FL} is the full load resistor voltage.





Circuit Diagram of Zener Diode as Load Regulator

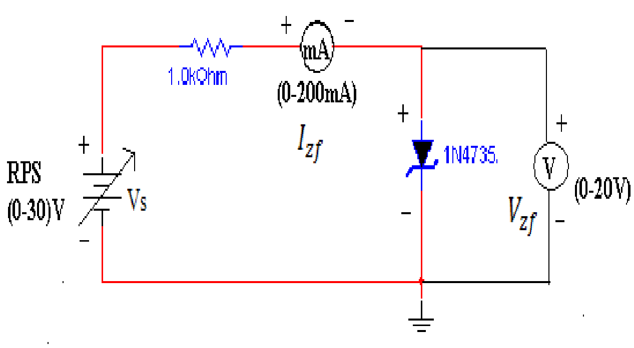
Load Regulation: Input Supply Voltage VS = ___ Volts, No-load DC Voltage, VNL = ___ Volts				
Load Resistance RL (KΩ)	Zener Current Iz (mA)	Load Current IL (mA)	Regulated Output Voltage Vo (V)	% Voltage Regulation

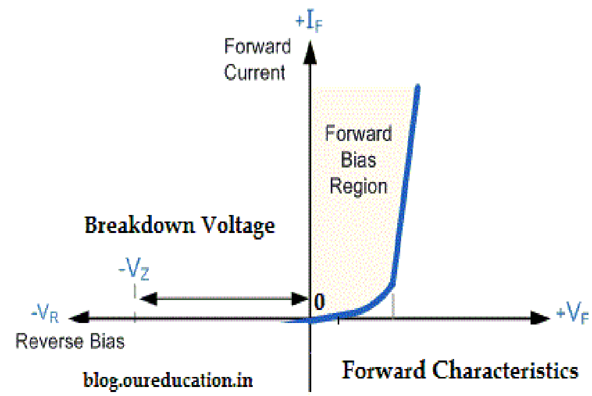
Plot Volt-Ampere Characteristics of Zener Diode;

Circuit Diagram:

a) Forward Bias Condition:

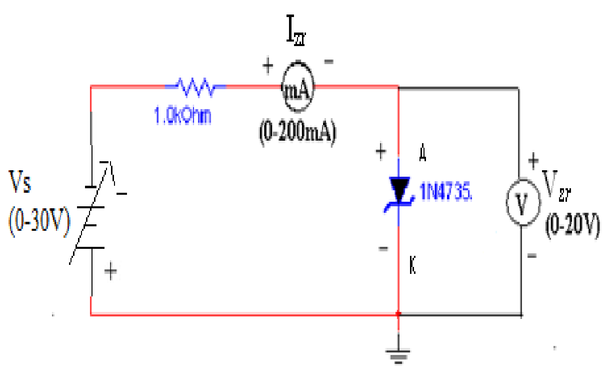
1. Connect the circuit as shown in figure
2. Initially vary V_s in steps of 0.1V. Once the current starts increasing vary V_s in steps of 1V up to 12V. Note down the corresponding readings of V_{zf} and I_{zf}.

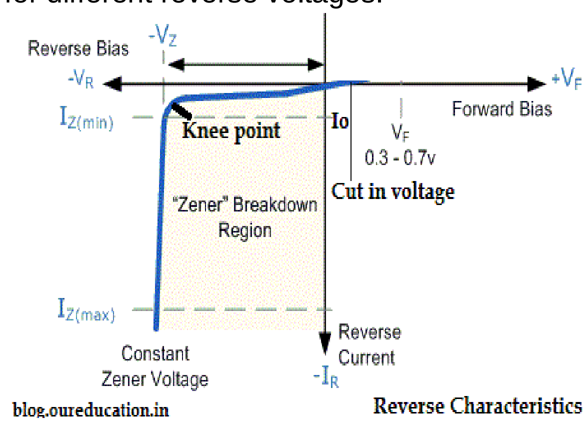




b) Reverse Bias Condition:

1. Connect the circuit as shown in figure
2. Vary V_s gradually in steps of 1V up to 12V and note down the corresponding readings of V_{zr} and I_{zr}.
3. Tabulate different reverse currents obtained for different reverse voltages.





Calculations from Graph:

The Knee voltage or Cut-in Voltage (V_y) = V

Static forward Resistance $R_{dc} = V_f / I_f \ \Omega$

Dynamic Forward Resistance

$r_{ac} = \Delta V_f / \Delta I_f \ \Omega$

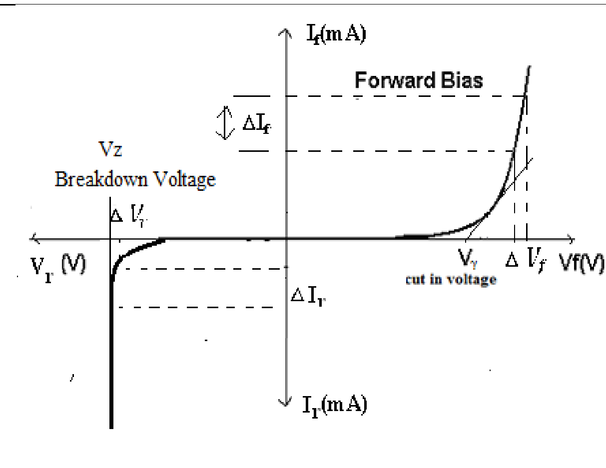
Static Reverse Resistance

$R_{dc} = V_r / I_r \ \Omega$

Dynamic Reverse Resistance

$r_{ac} = \Delta V_r / \Delta I_r \ \Omega$

Zener Breakdown Voltage (V_Z) = Volts.



Viva Questions:

1. What is the difference between p-n Junction diode and zener diode?

Ans: A zener is designed to operate stably in reverse breakdown, which is designed to be at a low voltage, between 3 volts and 200 volts. The breakdown voltage is specified as a voltage with a tolerance, such as 10 volts ±5%, which means the breakdown voltage (or operating voltage) will be between 9.5 volts and 10.5 volts.
A signal diode or rectifier will have a high reverse breakdown, from 50 to 2000 volts, and is NOT designed to operate in the breakdown region. So exceeding the reverse voltage may result in the device being damaged. In addition, the breakdown voltage is specified as a minimum only. Forward characteristics are similar to both, although the zener's forward characteristics is usually not specified, as the zener will never be used in that region. A signal diode or rectifier has the forward voltage specified as a max voltage at one or more current levels.

2. What is break down voltage?

Ans: The breakdown voltage of a diode is the minimum reverse voltage to make the diode conduct in reverse.

3. What are the applications of Zener diode?

Ans: Zener diodes are widely used as voltage references and as shunt regulators to regulate the voltage across small circuits.

4. What is cut-in-voltage ?

Ans: The forward voltage, at which the current through the junction starts increasing rapidly, is called the knee voltage or cut-in voltage. It is generally 0.6v for a Silicon diode.

5. What is voltage regulator?

Ans: A voltage regulator is an electronic circuit that provides a stable dc voltage independent of the load current, temperature and ac line voltage variations.