Special Diodes

Zener region

Note the sharp change in the characteristics at the reverse bias potential V_Z. When the applied reverse potential becomes more and more negative, a few free minority carriers have developed sufficient velocity to release additional carriers through ionization. That is, they collide with the valence electron and get sufficient energy to them to permit them to leave the parent atom. These additional carriers can then aid the ionization process to the point where a high avalanche breakdown region determined. The avalanche region (V_Z) can be brought closer to the vertical axis by increasing the dopping levels in the P and N.

When V_Z decrease to very low levels such as (-5V), another mechanism called Zener breakdown, will sharp change in characteristics. It occurs because there is a strong electric field in the region of the junction that can destroy the bounding forces within the atom and generate carriers.

Diodes employing this unique portion of the characteristics of a P-N junction are called ZENER DIODES.

1-Zener diode

The zener diode is a device that is designed to make full use of zener region. Zener region occurs at a reverse bias potential of V_Z for the diode of Fig. 3.1.

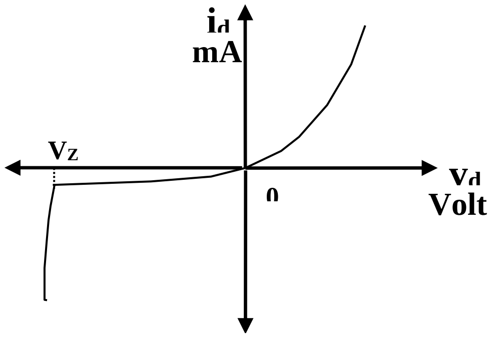


Fig. 3.1

- Any voltage from 0 to V_Z will result in an open circuit equivalent as occurred below V_T for the silicon diode.
- Silicon diode maintains its open cct in the reverse bias region but the zener diode assume short circuit state in once the reverse voltage is reached (1.e V_d=V_Z for short cct.)
- The application of a voltage V_Z with the polarity shown in Fig. 3.2 will cause the zener device to switch from the open cct to short cct .

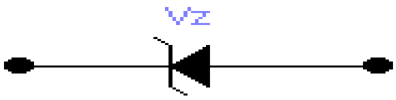


Fig. 3.2

- The location of the zener region can be controlled by varying the doping level.
- An increase in doped, producing an increase in the number of added impurities will decrease the zener potential.

  (zener diodes rating) → (2.4 – 200)V
  ↘ (1/4 - 50)W
- Zener diode equivalent cct short in Fig. 3.3 ((in the zener region)) includes a small dynamic resistance and dc battery equal to the zener potential.

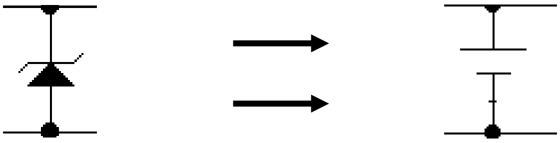


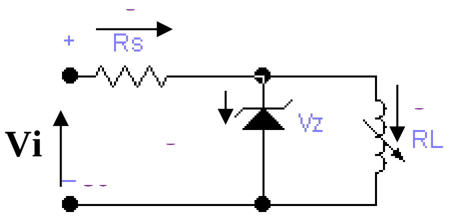
Fig .3.3 approximation

❖ Zener diode application

The most common application of the zener diode is to established a fixed reference voltage for biasing and comparison purposes. The zener diode used to maintain a fixed voltage V_Z across the load for variations in V_i or R_L.

➢ Fixed V_i variable R_L

Due to the offsest voltage V_Z there is a specific range of resistor values (load current) which will ensure that the Zener is in the ON STATE.



To determine the minimum load resistance (maximum load current) that will turn the Zener diode ON.

By removing the Zerer diode as shown in Fig. 3.4 and calculate the value of R_L that will result in a load voltage.

$V_L = V_Z = R_L V_i / R_L + R_S$

$\therefore V_Z (R_L + R_S) = R_L V_i$

$\therefore R_L(V_i - V_Z) = V_z R_S$

$\therefore R_{L(min)} = R_S V_Z / (V_i - V_Z)$ …(3-1)

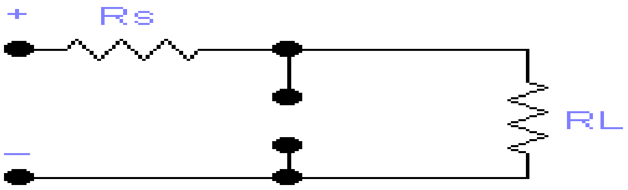


Fig. 3.4

The condition established by equation (3.1), defined the minimum R_L and the maximum I_L

$\therefore I_{L(max)} = \frac{V_L}{R_L} = V_Z / R_{L(min)}$ …(3-2)

Any resistance value greater than the R_L obtained from equation (3.1) will ensure that the Zener diode in the on state and the diode can be replaced by its V_Z source equivalent as shown in Fig. 3.5. Once the diode is in the on state.

$\mathbf{V_{RS}= V_i - V_Z}$

$\mathbf{I_{RS}}= \frac{V_{RS}}{R_S}$

$\mathbf{I_Z = I_{RS} - I_L}$ ….. (3-3)

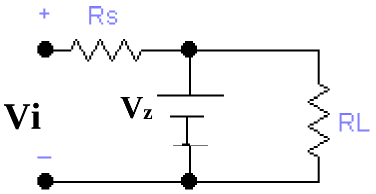


Fig. 3.5

Thus, a maximum I_Z when I_L is a minimum value since I_{RS} is constant. I_Z is limited to I_{Zm} as provided from factory, it does affect the range of R_L and I_L, rewrite equation (3-3)

$\therefore I_{Lmin} = I_{Rs} - I_{Zm}$ ... (3-4)

and $R_{lmax} = V_Z / I_{L(min)}$ … (3-5)

Example:

A) For the network of Fig. 3.6 determine the range of R_L and I_L that will result in V_{RL} being maintained at 10V.

b) Determine the maximum wattage rating of the diode as a regulator.

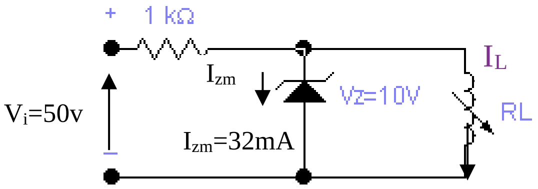


Fig. 3.6

Solution

A) To determine the value of R_{Lm} that will ran the Zener diode ON, using Eq. 3.1

$R_{(Lmin)} = R_S V_Z / (V_i - V_Z) = (1k\Omega)\ (10) / 50 - 10 = 250\Omega$

Using Eq. 5.2 to determine $I_{L\ max}$

$\therefore I_{L(max)} = V_L / R_{Lmin} = V_Z / R_{Lmin} = 10/250 = 40\ mA$

OR –NOTE $I_{Rs} = I_{L(max)} = \frac{V_{RS}}{R_s} = 50 - 10 / 1k\Omega = 40$ mA

B) The minimum level of I_L is than determine by Eq. 3.4

$I_{L(min)} = I_{RS} - I_{Zm} = 40 - 32 = 8mA$

Using Eq. 5.5 to determine $R_{L(max)}$

$\therefore R_{Lmax} = V_Z / I_{Lmin} = 10/8mA = 1.25\ k\Omega$

$P_{max} = V_Z I_{ZM} = 10\ (32mA) = 320mW$

- **Fixed R_L variable V_i**

For fixed values of R_L in Fig. 3.7, the voltage V_i must sufficiently large to turn the Zener diode on. The turn on voltage is determined by

$$\mathbf{V_L = V_Z = R_L V_i / R_L + R_S}$$

$$\therefore \mathbf{V_{i\ min} = (R_L + R_S) V_Z / R_L} \qquad \ldots(3\text{-}6)$$

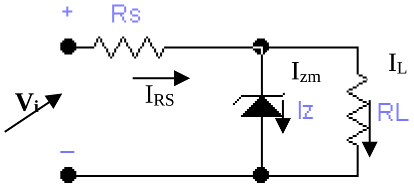


Fig. 3.7

When I_Z = the maximum value of V_i is limited by the maximum Zener current I_{ZM}.

$I_{ZM} = I_{RS} - I_L$

-: $I_{L(max)} = I_{ZM} + I_L \qquad \ldots(3\text{-}7)$

since $I_L = \frac{V_Z}{R_L}$ (this load current is fixed due to V_Z and fixed R_L)

$V_{i\ max} = V_{R\ max} + V_Z = I_{R\ max} R_S + V_Z$

$V_{i\ max} = (I_{ZM} + I_L) R_S + V_Z \qquad \ldots(3\text{-}8)$

Example: Determine the range of value of V_i that will maintain the Zener diode of Fig. 3.8 in the on state.

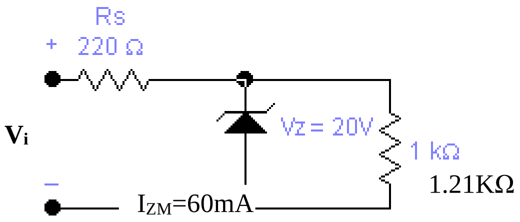


Fig. 3.8

Solution:

Using Eq. 5.6 to find $V_{i\ min}$

$\therefore V_{i\ min} = (R_L + R_S) V_Z / R_L$

$$V_{i\ min} = \frac{(1200 + 200)(20)}{1200} = 23.67V$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{20}{1.2K\Omega} = 16.67mA$$

Using Eq. 5.7 to calculate $I_{R\ max}$

$I_{RS\ max} = I_{Zm} + I_L = 60 + 16.67 = 76.67$ mA

Using Eq. 5.8 to calculate $V_{i\ max}$, V_L

$V_{i\ max} = I_{Rmax} R_S + V_Z = (76.67\text{mA})\ (0.22\ \text{k}\Omega) + 20 = 36.87\text{V}$

2. Varactor diode

Varactor or varicap as voltage variable capacitance or tuning diodes are semiconductor, voltage dependent variable capacitors. Their mode of operation depends on the capacitance that exists at the (P-N) junction when the element is reversed biased. Under reverse bias conditions, there is a region of positive and negative ions on both sides of the junction that together make up the depletion region. The transition capacitance C_T is determined by

$$C_T = E\ \frac{A}{W_d}$$

where E = permitivity of the semiconductor material,

A = the P-N junction area,

W_d = the depletion width.

As the reverse bias potential increase the width of depletion region increase than in turn reduce the capacitance. The characteristics of a typical commercially varactor is shown in Fig. 3.9. Varactor diode symbols

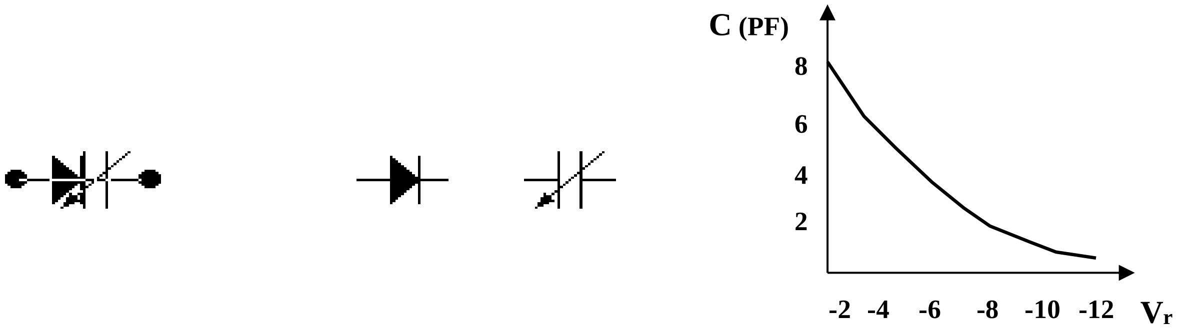


Fig. 3.9

3. Power diode

There are a number of diodes designed to handle the high power and high temperature demands of some applications. The most frequent se of power diode in the rectification process to convert ac signal to dc. The majority of the power diode are constructed using silicon because of its higher current, temperatures, and PIV rating. The higher current demand, require the junction area be larger in order to get low resistance for forward region. The current capability of power diode can be increased by placing two or more in parallel and the PIV rating can be increased by placing two or more in series.

4. Photo, Infrared emitting and light emitting diodes

The light sensitive devices have been increased as an almost exponential rate and the resulting field of optoelectronics. The light source offers a unique source of energy. This energy transmitted as discrete packages called photons has a level directly related to the frequency of the traveling light wave as determined by the following equation:

$$W = hf \quad \text{Joules}$$

where h is called Planck’s constant and is equal to $6.624x10^{-30}$ joules,

f = frequency of the traveling wave.

The frequency is directly related to the wavelength of the traveling wave

N

$$\lambda = \frac{V}{f}$$

when λ = wavelength and V= velocity of light $=3x10^{8}$ m /s

A-The photo diode

The photodiode is a semiconductor P-N junction device whose region of operation is limited to the reverse bias region. The basic biasing arrangement construction and symbol for the device as shown in Fig. 3.10.

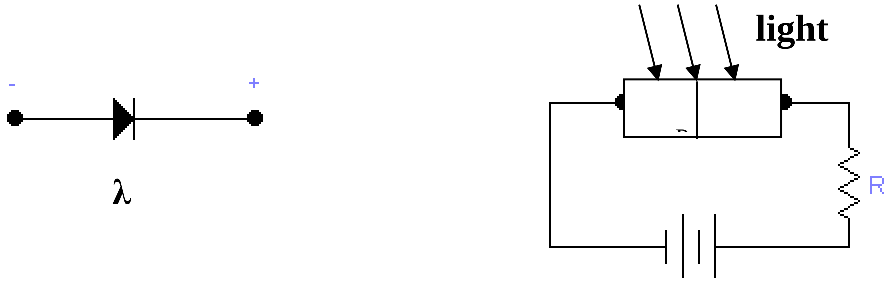


Fig. 3.10

The application of light to the junction will result in a transfer of energy from the incident traveling light waves (in the form of photons) to the atomic structure, resulting in an increased number of minority carriers and an increased level of reverse current. The photodiodes can be used for high-speed counting or switching application.

B-Light emitting diode (LED)

Current flows through a forward biased PN junction, free electrons cross from the N side and recombine with hole on the P side. These free electrons are in conduction band and therefore have great energy than holes, which are in the valance band when an electron in the conduction band recombines with a hole in the valence band, it releases energy as it falls into that lower energy state. The energy is released in the form of heat and light. In some materials, such S_i, most of the energy converted to heat, while in others it is in the form of light and if the light energy released is visible then, a PN junction having those properties is called light emitting diode (LED). If the light energy spectrum released in the infrared region of the light spectrum, the a PN junction is called Infrared Emitted.

Since Infrared is not visible, and since almost energy is released as heat, S_i is not used in the fabrication of light emitting diodes and IR emitters. For the same reason Ge is not used. Instead, gallium or senide (GaAs), gallium phosphide (Gap), and gallium arsenide phosphide (Ga Asp) are commonly used. The color of the light emitted by the type and dgree of doping, Red, green and yellow LED are commonly available.

LED are used in visual displays of all kinds.

Infrared emitters are soiled state gallium arsenide devices, used in night vision systems and intrusion alarm.