The filtered dc output voltage is:

$$V_{dc} = \left(1 - \frac{0.00417}{R_L C}\right) V_{p(in)}$$

$$= \left(1 - \frac{0.00417}{22 \times 10^3 \times 5 \times 10^{-6}}\right) 14.86V$$

$$= (1 - 0.0379)14.86V = 14.3V$$

The rms ripple voltage

$$V_r = \frac{0.0024}{R_L C} V_{p(in)}$$

$$= \frac{0.0024}{22 \times 10^3 \times 5 \times 10^{-6}} (14.86V) = 0.324V$$

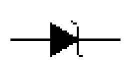
The Ripple Factor

$$r = \frac{V_r}{V_{dc}} = \frac{0.324V}{14.3V} = 0.0227$$

Meaning 2.27% of ripple.

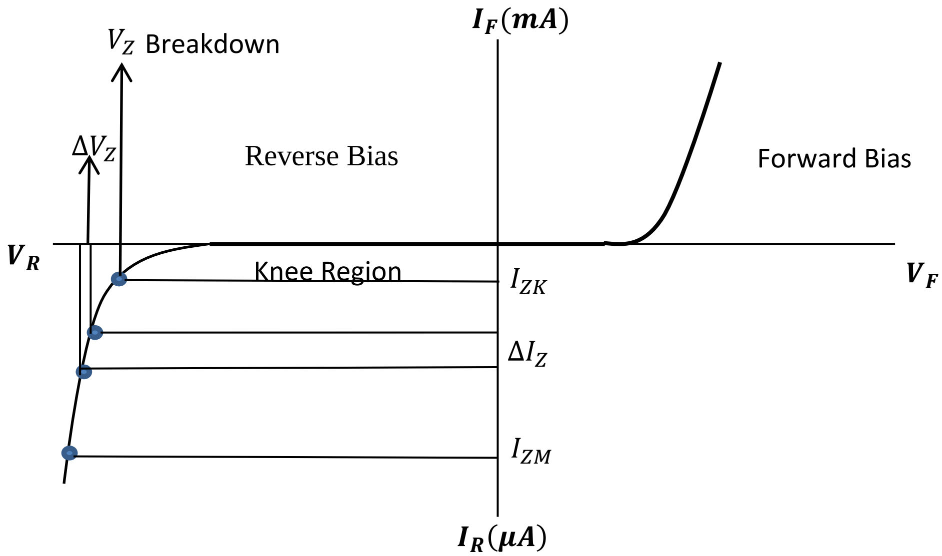
Zener Diodes

- The Zener diode is used for voltage regulation (power supply applications).
- Zener diode symbol is:



Zener Diode Symbol

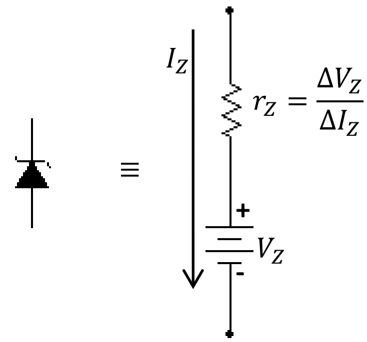
- It is optimized for operation in reverse breakdown region. The breakdown voltage is set by controlling the doping level during manufacture.
- When the Zener diode reaches reverse breakdown, its voltage remains almost constant even though the current may change drastically.



$$r_z = \frac{\Delta V_z}{\Delta I_z}$$

A. Zener Breakdown

- There are two types of reverse breakdown in Zener diodes. One is the Avalanche Breakdown which occurs at high reverse voltage. The other type is Zener breakdown which occurs at low reverse voltages.
- Zener diode is heavily doped to reduce the breakdown voltage. This causes a very narrow depletion layer. As a result, an intense electric field exists within the depletion layer.
- Near the breakdown voltage V_Z , the field is intense enough to pull electrons from their valence bands and create current.
- Zener diodes with breakdown voltages of less than approximately 5V operate in zener breakdown Zener diodes that operate at breakdown voltages higher than 5V do operate in the Avalanche breakdown region.



Example: A certain zener diode exhibits a 50 mV change in V_Z for a 2 mA in I_Z , What is the zener resistance ?

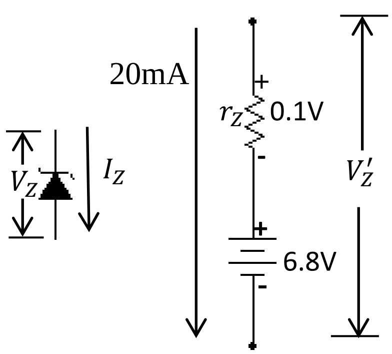
$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} = \frac{50\ mV}{2\ mA} = 25\ \Omega$$

Example: A 6.8V zener diode has a resistance of 5Ω, What is the actual voltage across its terminals when the current is 20 mA.

The 20 mA current causes a voltage across r_Z as follows:

$$I_Z r_Z = (20mA)(5\Omega) = 100mV$$

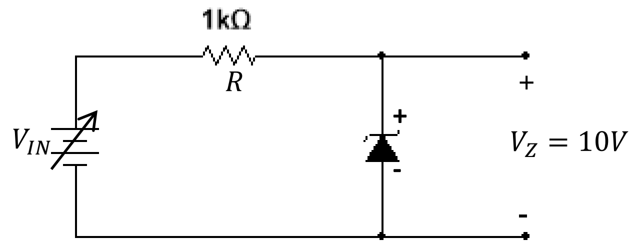
$$V_Z' = V_Z + I_Z r_Z = 6.8V + 100mV = 6.9V$$



B: Zener Voltage Regulation

B1: Regulation with Varying Input

- Suppose we can maintain regulation (using zener) over a current range of 4mA – 40mA.



- For a minimum current (4 mA) across R.

$$V_R = (4mA)(1k\Omega) = 4V$$
$$V_{IN} = V_R + V_Z = 4V + 10V = 14V$$

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