Junction Diode

Lecture - 5

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B.Sc (Electronics)
TDC PART - I
Paper – 1 (Group – B)
Unit – 5
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➢ Barrier Voltage of Contact Potential Across the P-N Junction (PART – 1)

⇨ As mentioned in **previous Lecture - 3** that due to the **Positively charged** region on N – type side and **Negatively charged** region on P – type side, there exists a **space charge** near the P-N Junction. The variation of potential arising out of space charge is shown below in **Figure (1)** and **Figure (2).**

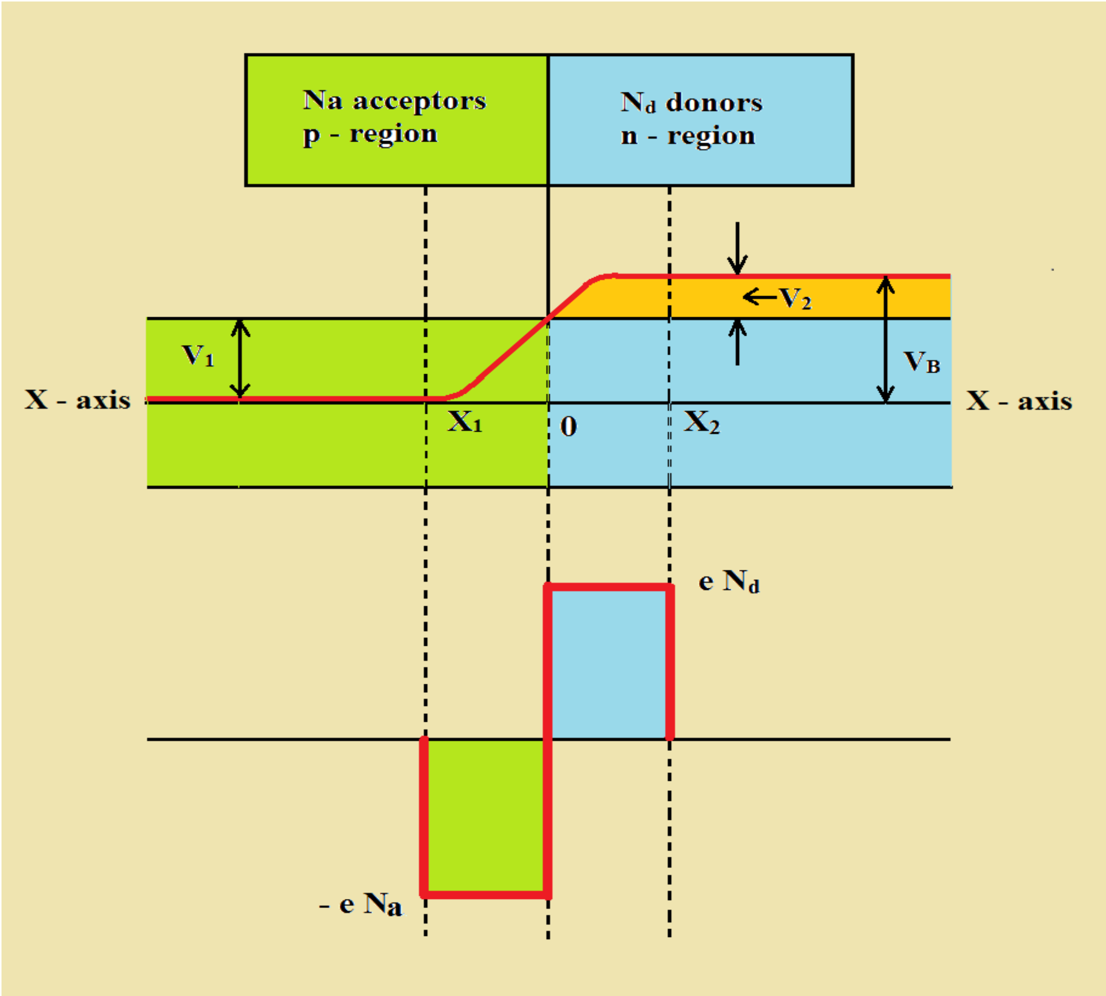

Fig. (1) Shown an Abrupt P-N Junction, i.e., which changes Abruptly from **p - region** to **n - region** at **X = 0.**

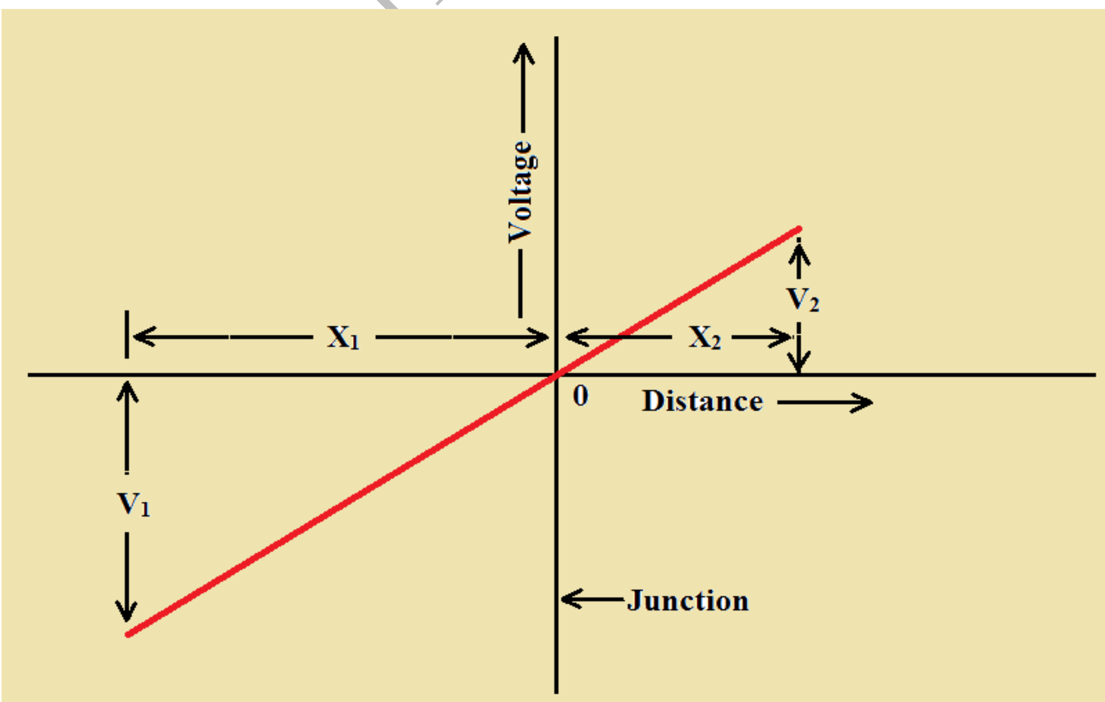

Fig. (1) Shown Space Charge Region around the P-N Junction.

⇨ It is shown that **Barrier Potential** is $V_B = |V_1| + |V_2|$ and the **Total Width** of **Space Charge Region** $X = X_1 + X_2$, where, X_1 and X_2 are the **Width of Space Charge Region** in the P – sides and N – sides respectively.

⇨ To find the **Distribution Barrier Potential** in the **Space Charge Region,** we proceed with **Poisson's Equation,**

$$\frac{d^2V}{dx^2} = -\frac{\rho}{\epsilon} \quad \text{..........} \quad \mathbf{(1)}$$

in one dimension.

⇨ Here ρ **is the Volume Density of charge** and ϵ **is the Permittivity of the medium.**

⇨ The **Charge Density** in P – side of the **Space Charge Region** is given by $\rho = -eN_a$ where, N_a **is the Density of Negatively charged (ionised) accepter atoms.**

⇨ Now Putting the value of $\rho = -eN_a$ in above **Equation (1)**, then the **Potential Variation** in P – side region is given by,

$$\frac{d^2V}{dx^2} = \frac{e\,N_a}{\epsilon} \quad \text{..........} \quad \mathbf{(2)}$$

⇨ Now **Integrating** the above **Equation (2),** then we get,

$$\frac{dV}{dx} = \frac{e\,N_a\,x}{\epsilon} + C_1 \quad \text{..........} \quad \mathbf{(3)}$$

⇨ where, C_1 **is a constant of Integration.**

⇨ Applying the **Boundary Condition**: at $x = -X_1$, $\frac{dV}{dx} = 0$, to above **Equation (3),** we arrive at,

$$C_1 = \frac{e\,N_a\,X_1}{\epsilon} \quad \text{..........} \quad \mathbf{(4)}$$

⇨ Now putting the value of C_1 into above **Equation (3),** then we get,

$$\frac{dV}{dx} = \frac{e\,N_a\,x}{\epsilon} + \frac{e\,N_a\,X_1}{\epsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(5)}$$

⇨ Now **Integrating** the above **Equation (5),** we find that,

$$V = \frac{e\,N_a\,x^2}{2\,\epsilon} + \frac{e\,N_a\,X_1\,x}{\epsilon} + C_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(6)}$$

⇨ where C_2 **is another constant of Integration.**

⇨ Now applying the **Boundary Condition:** at $x = 0$, $V = 0$, to above **Equation (6),** we find that $C_2 = 0$, so that putting the value of C_2 into above **Equation (6),** then we get,

$$V = \frac{e\,N_a\,x^2}{2\,\epsilon} + \frac{e\,N_a\,X_1\,x}{\epsilon} + 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(7)}$$

$$V = \frac{e\,N_a\,x^2}{2\,\epsilon} + \frac{e\,N_a\,X_1\,x}{\epsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(8)}$$

⇨ At $x = -X_1$, $V = V_1$, giving,

$$\boxed{V_1 = \frac{e\,N_a\,X_1^2}{2\,\epsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(9)}}$$

⇨ Similarly, for the **Potential Distribution** in **Space Charge Region** on N – side, we apply the equation,

$$\frac{d^2V}{dx^2} = \frac{e\,N_d}{\epsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(10)}$$

⇨ where N_d **is the Density of the Positively charged (ionised) Donor atoms.**

⇨ The solution of above **Equation (10),** on applying the **Boundary Condition** is at

$x = 0, V = 0 \text{ and } x = X_2, \frac{dV}{dx} = 0$, then we get,

$$V = \frac{e N_d x^2}{2 \epsilon} + \frac{e N_d X_2 x}{\epsilon} \quad \text{...} \quad \mathbf{(11)}$$

⇨ But at $x = X_2, V = V_2$, so that,

$$\boxed{V_2 = \frac{e N_d X_2^2}{2 \epsilon} \quad \text{...} \quad \mathbf{(12)}}$$

(A) Barrier Potential

⇨ Therefore, **Height of Potential Barrier** across the **P-N Junction** is given by,

$$V_B = |V_1| + |V_2| \quad \text{...} \quad \mathbf{(12\ a)}$$

⇨ Now Putting the value of $V_1 \text{ and } V_2$ in above **Equation (12 a)**, then the **Potential Variation** in P – side region is given by,

$$V_B = \frac{e N_a X_1^2}{2 \epsilon} + \frac{e N_d X_2^2}{2 \epsilon} \quad \text{...} \quad \mathbf{(13)}$$

$$V_B = \frac{e (N_a X_1^2 + N_d X_2^2)}{2 \epsilon} \quad \text{...} \quad \mathbf{(14)}$$

⇨ Since the **Crystal (P-N Junction)** as a whole is **electrically neutral**, we get the charge **Neutrality Condition,**

$$N_a X_1 = N_d X_2 \quad \text{...} \quad \mathbf{(15)}$$

⇨ Putting for X_2, from above **Equation (15)** in **Equation (14)**, then we get,

$$V_B = \frac{e\,N_a}{2\,\epsilon}\,X_1^2\left(1 + \frac{N_a}{N_d}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(16)}$$

⇨ By simplify the above **Equation (16)** we can obtained the expression of **X_1**

$$X_1 = \left[\frac{2\,\epsilon\,V_B}{e\,N_a\left(1+\frac{N_a}{N_d}\right)}\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(17)}$$

⇨ **Similarly,** we can obtain the expression of **X_2**

$$X_2 = \left[\frac{2\,\epsilon\,V_B}{e\,N_d\left(1+\frac{N_d}{N_a}\right)}\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(18)}$$

⇨ In the next **Lecture - 6,** we will discuss the detailed of the **Barrier Width and Junction Capacitance of Contact Potential across the P-N Junction (PART – 2)**.

to be continued ....

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