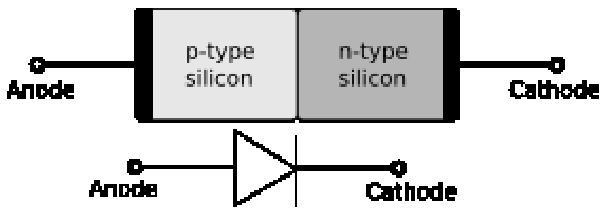
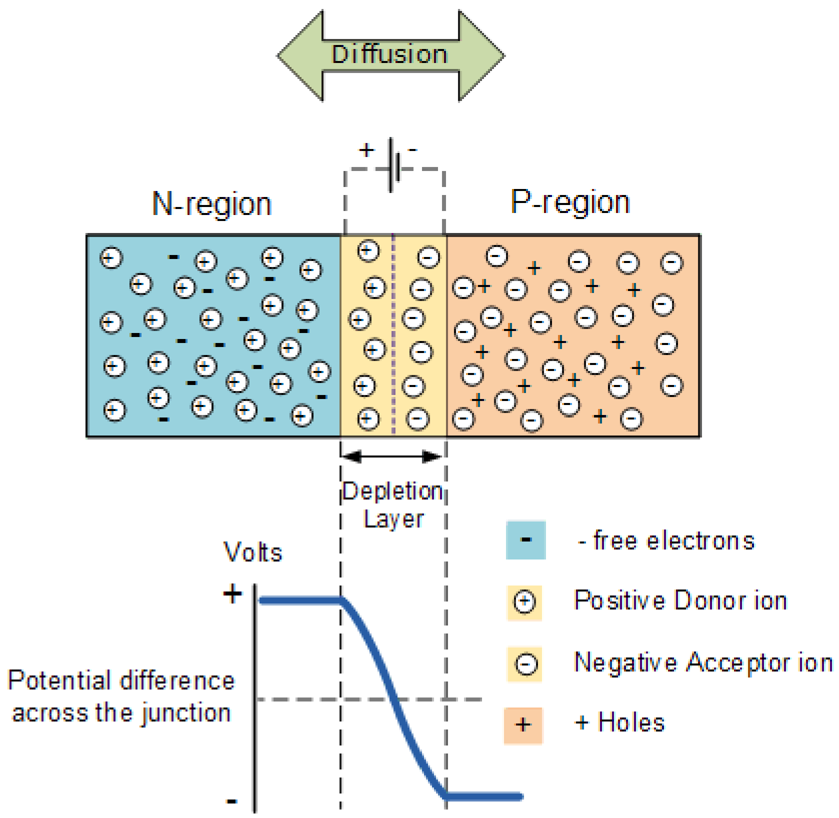
p–n Junction

A p–n junction is a boundary or interface between two types of semiconductor material, p-type and n-type, inside a single crystal of semiconductor. The "p" (positive) side contains an excess of holes, while the "n" (negative) side contains an excess of electrons. The p-n junction is created by doping.

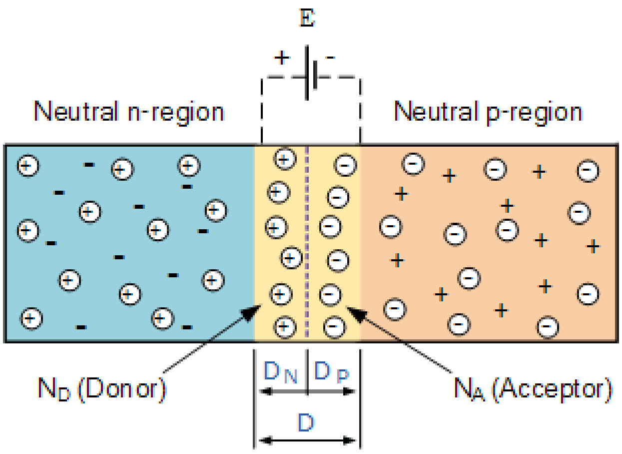


The PN junction



The total charge on each side of a PN Junction must be equal and opposite to maintain a neutral charge condition around the junction. If the depletion layer region has a distance D, it therefore must therefore penetrate into the silicon by a distance of Dp for the positive side, and a distance of Dn for the negative side giving a relationship between the two of Dp.NA = Dn.ND in order to maintain charge neutrality also called equilibrium.

PN Junction Distance



As the N-type material has lost electrons and the P-type has lost holes, the N-type material has become positive with respect to the P-type. Then the presence of impurity ions on both sides of the junction cause an electric field to be established across this region with the N-side at a positive voltage relative to the P-side. The problem now is that a free charge requires some extra energy to overcome the barrier that now exists for it to be able to cross the depletion region junction.

This electric field created by the diffusion process has created a “built-in potential difference” across the junction with an open-circuit (zero bias) potential of:

$$E_o = V_T \ln\left(\frac{N_D \cdot N_A}{n_i^2}\right)$$

PN junction potential

Where: E_o is the zero bias junction voltage, VT the thermal voltage of 26mV at room temperature, ND and NA are the impurity concentrations and ni is the intrinsic concentration.

A suitable positive voltage (forward bias) applied between the two ends of the PN junction can supply the free electrons and holes with the extra energy. The external voltage required to overcome this potential barrier that now exists is very much dependent upon the type of semiconductor material used and its actual temperature.

Typically at room temperature the voltage across the depletion layer for silicon is about 0.6 – 0.7 volts and for germanium is about 0.3 – 0.35 volts. This potential barrier will always exist even if the device is not connected to any external power source, as seen in diodes.

The significance of this built-in potential across the junction, is that it opposes both the flow of holes and electrons across the junction and is why it is called the potential barrier. In practice, a PN junction is formed within a single crystal of material rather than just simply joining or fusing together two separate pieces.

The result of this process is that the PN junction has rectifying current–voltage (IV or I–V) characteristics. Electrical contacts are fused onto either side of the semiconductor to enable an electrical connection to be made to an external circuit. The resulting electronic device that has been made is commonly called a PN junction Diode or simply Signal Diode.

Then we have seen here that a PN junction can be made by joining or diffusing together differently doped semiconductor materials to produce an electronic device called a diode which can be used as the basic semiconductor structure of rectifiers, all types of transistors, LED's, solar cells, and many more such solid state devices.

In the next tutorial about the PN junction, we will look at one of the most interesting applications of the PN junction is its use in circuits as a diode. By adding connections to each end of the P-type and the N-type materials we can produce a two terminal device called a PN Junction Diode which can be biased by an external voltage to either block or allow the flow of current through it.