

In P-type conductivity, the charges that carry electric current across the crystal act as if they were positive charges. We know that electricity is always carried by drifting electrons in any material, and that there are no mobile positively charged carriers in a solid. Positive charge carriers can exist in gases and liquids in the form of positive ions but not in solids. The positive character of the current flow in the semiconductor crystal may be thought of as the movement of vacancies (called holes) in the covalent lattice. These holes drift from positive toward negative in an electric field, behaving as if they were positive carriers.

P-type conductivity in semiconductors result from adding acceptor impurities (Group III elements) such as boron to silicon to the semiconductor crystal. In this case, boron atoms, with three valence electrons, enter the tetravalent silicon lattice. Since the covalent bonds cannot be satisfied by only three electrons, each acceptor atom leaves a hole in the lattice which is deficient by one electron. These holes readily accept electrons introduced by external sources or created by radiation or heat, as shown in Figure 1-1C. Hence the name acceptor ion or acceptor impurity. When an external circuit is connected, electrons from the current source "fill up" these holes from the negative end and jump from hole to hole across the crystal or one may think of this process in a slightly different but equivalent way, that is as the displacement of positive holes toward the negative terminal. It is this drift of the positively charged holes which accounts for the term P-type conductivity.

When semiconductor regions of N- and P-type conductivities are formed in a semiconductor crystal adjacent to each other, this structure is called a PN junction.; Such a junction is responsible for the action of both zener diodes and rectifier devices, and will be discussed in the next section.

The Semiconductor Diode

In the forward-biased PN junction, Figure 1-2A, the P region is made more positive than the N region by an external circuit. Under these conditions there is a very low resistance to current flow in the circuit. This is because the holes in the positive P-type material are very readily attracted across the junction interface toward the negative N-type side. Conversely, electrons in the N-type are readily attracted by the positive polarity in the other direction.

When a PN junction is reverse biased, the P-type side is made more negative than the N-type side. Figure 1-2B. At voltages below the breakdown of the junction, there is very little current flow across the junction interface. At first thought one would expect no reverse current under reverse bias conditions, but several effects are responsible for this small current.

Under this condition the positive holes in the P-type semiconductor are repelled from the junction interface by the positive polarity applied to the N side, and conversely, the electrons in the N material are repelled from the interface by the negative polarity of the P side. This creates a region extending from the junction interface into both P- and N-type materials which is completely free of charge carriers, that is, the region is depleted of its charge carriers. Hence, this region is usually called the depletion region.

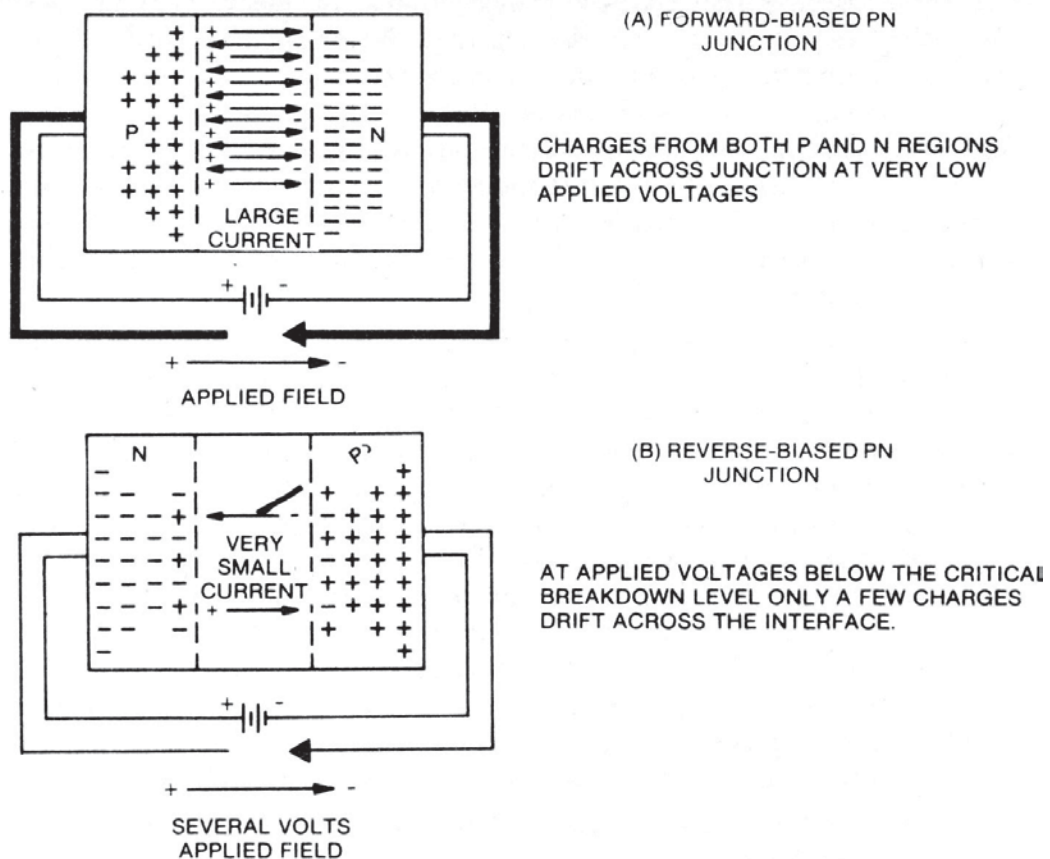


Figure 1-2 Effects of Junction Bias

Although the region is free of charge *carriers*, the P-side of the depletion region will have an excess negative charge due to the presence of acceptor ions which are, of course, fixed in the lattice; while the N-side of the depletion region has an excess positive charge due to the presence of donor ions. These opposing regions of charged ions create a strong electric field across the PN junction responsible for the creation of reverse current.

The semiconductor regions are never perfect; there are always a few free electrons in P material and few holes in N material. A more significant factor, however, is the fact that great magnitudes of electron-hole pairs may be thermally generated at room temperatures in the semiconductor. When these electron-hole pairs are created within the depletion region, then the intense electric field mentioned in the above paragraph will cause a small current to flow. This small current is called the reverse saturation current, and tends to maintain a relatively constant value for a fixed temperature at all voltages. The reverse saturation current is usually negligible compared with the current flow when the junction is forward biased. Hence, we see that the PN junction, when not reverse biased beyond breakdown voltage, will conduct heavily in only one direction. When this property is utilized in a circuit we are employing the PN junction as a rectifier. Let us see how we can employ its reverse breakdown characteristics to an advantage.