Varactor diode

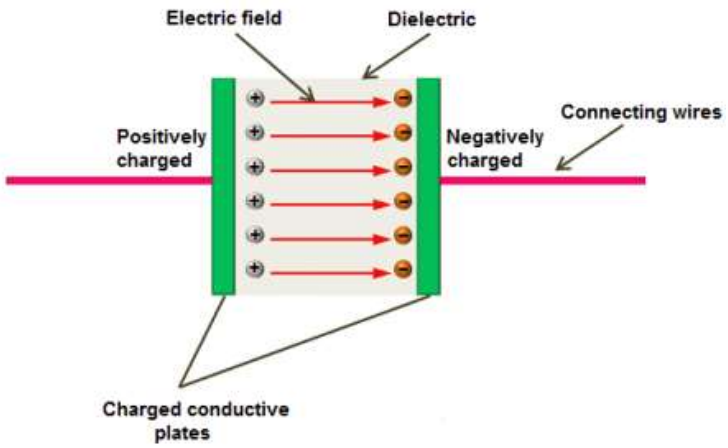
Varactor diode definition

Varactor diode is a p-n junction diode whose capacitance is varied by varying the reverse voltage. Before going to varactor diode, let's first take a look at the capacitor.

What is a capacitor?

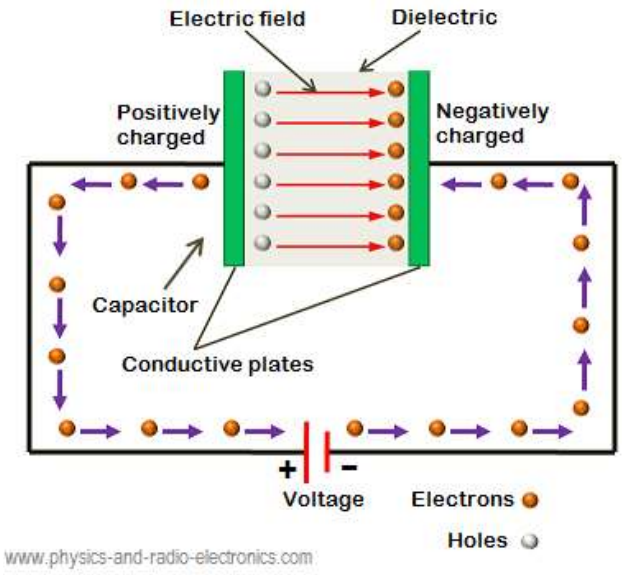
A capacitor is an electronic component that stores electrical energy or electric charge in the form of an electric field.

The basic capacitor is made up of two parallel conductive plates separated by a dielectric. The two conductive plates acts like electrodes and the dielectric acts like an insulator.



The conductive plates are good conductors of electricity so they easily allow electric current through them. On the other hand, a dielectric is poor conductor of electricity so it does not allow electric current through it but it allows electric field or electric force.

When voltage is applied to the capacitor in such a way that the negative terminal of the battery is connected to the right side electrode or plate and the positive terminal of the battery is connected to the left side electrode, the capacitor starts storing electric charge.



Because of this supply voltage, a large number of electrons start flowing from the negative terminal of the battery through a conductive wire. When these electrons enter into the right side plate, a large number of atoms in the right side plate gains extra electrons. We know that any object that has a larger number of electrons (negative charge carriers) than protons (positive charge carriers) is said to be negatively charged. The right side plate has a larger number of electrons than protons. So the right side plate becomes negatively charged because of the gaining of extra electrons.

The free electrons in the right side plate or electrode will try move into the dielectric. However, dielectric blocks these electrons.

As a result, a large number of electrons are built up on the right side plate. Thus, the right side plate becomes a negatively charged

electrode.

The dielectric blocks flow of charge carriers (free electrons) but allows electric force exerted by the negatively charged electrode.

On the other hand, the electrons on the left side plate experience a strong attractive force from the positive terminal of the battery. As a result, a large number of electrons leave the left side plate and flow towards the positive terminal of the battery. As a result, a positive charge is accumulated on the left side plate.

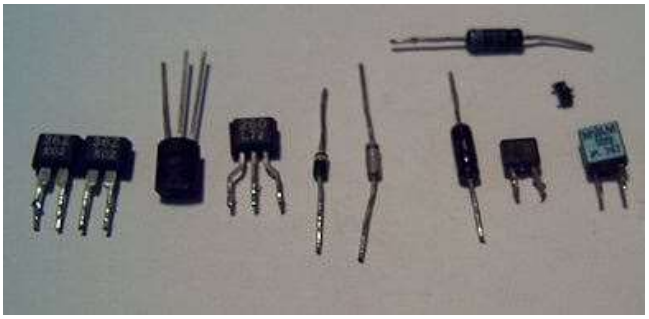
The positive and negative charges accumulated on both plates exert attractive force on each other. This attractive force between the plates is nothing but the electric field between the plates.

We know that the capacitance is the ability to store electric charge. So at both plates, the charge is stored. Thus, there exists a capacitance at both the plates.

What is varactor diode?

The term varactor is originated from a variable capacitor. Varactor diode operates only in reverse bias. The varactor diode acts like a variable capacitor under reverse bias.

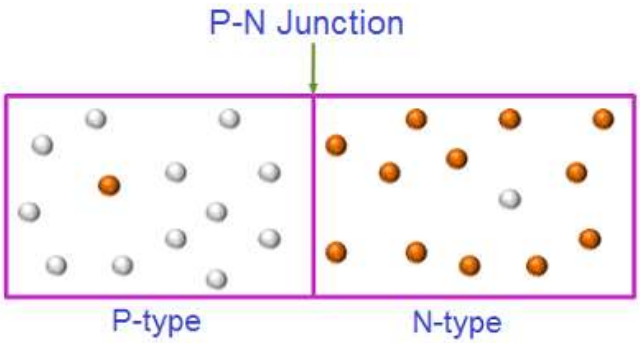
Varactor diode is also sometimes referred to as varicap diode, tuning diode, variable reactance diode, or variable capacitance diode.



The varactor diode is manufactured in such as way that it shows better transition capacitance property than the ordinary diodes.

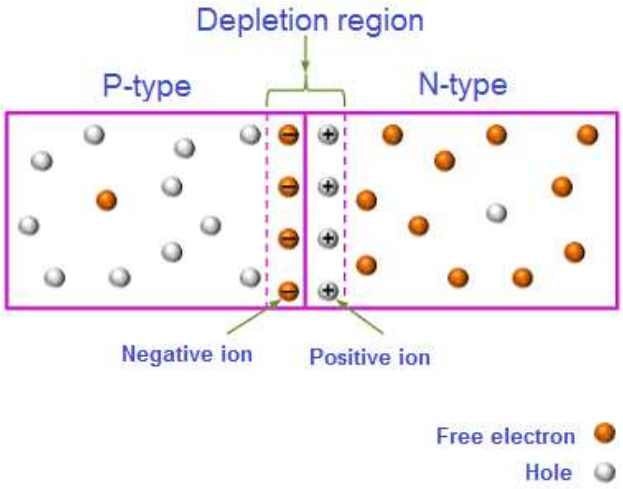
Varactor diode construction

The varactor diode is made up of the p-type and n-type semiconductor. In the n-type semiconductor, free electrons are the majority carriers and holes are the minority carriers. So the free electrons carry most of the electric current in n-type semiconductor. In the p-type semiconductor, holes are the majority carriers and free electrons are the minority carriers. So the holes carry most of the electric current in p-type semiconductor.



When a p-type semiconductor is in contact with the n-type semiconductor, a p-n junction is formed between them. This p-n junction separates the p-type and n-type semiconductor.

At the p-n junction, a depletion region is created. A depletion region is a region where mobile charge carriers (free electrons and holes) are absent.



The depletion region is made up of positive and negative ions (charged atoms). These positive and negative ions does not move from one place to another place.

The depletion region blocks free electrons from n-side and holes from p-side. Thus, depletion region blocks electric current across the p-n junction.

Varactor diode symbol

The symbol of a varactor diode is shown in the below figure. The circuit symbol of the varactor diode is almost similar to the normal p-n junction diode.

Varactor diode symbol

Two parallel lines at the cathode side represents two conductive plates and the space between these two parallel lines represents dielectric.

Unbiased varactor diode

We know that in the n-type semiconductor, a large number of free electrons are present and in the p-type semiconductor, a large number of holes are present. The free electrons and holes always try to move from a higher concentration region to a lower concentration region.

For free electrons, n-region is the higher concentration region and p-region is the lower concentration region. For holes, p-region is the higher concentration region and n-region is the lower concentration region.

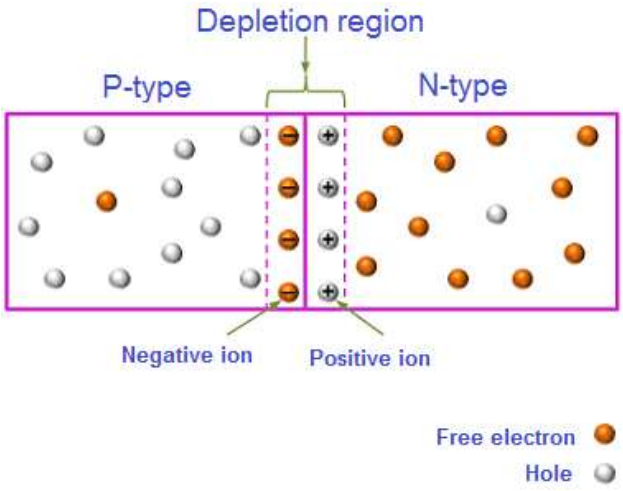
Therefore, the free electrons always try to move from n-region to p-region similarly holes always try to move from p-region to n-region.

When no voltage is applied, a large number of free electrons in the n-region get repelled from each other and move towards the p-region.

When the free electrons reach p-n junction, they experience an attractive force from the holes in the p-region. As a result, the free

electrons cross the p-n junction. In the similar way, holes also cross the p-n junction. Because of the flow of these charge carriers, a tiny current flows across diode for some period.

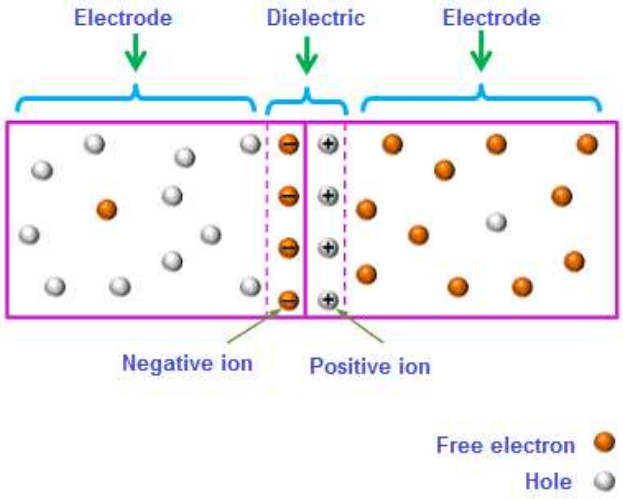
During this process, some neutral atoms near the junction at n-side loses electrons and become positively charged atoms (positive ions) similarly some neutral atoms near the junction at p-side gains extra electrons and become negatively charged atoms (negative ions). These positive and negative ions created at the p-n junction is nothing but depletion region. This depletion region prevents further current flow across the p-n junction.



The width of depletion region depends on the number of impurities added (amount of doping).

A heavily doped varactor diode has a thin depletion layer whereas a lightly doped varactor diode has a wide depletion layer.

We know that an insulator or a dielectric does not allow electric current through it. The depletion region also does not allow electric current through it. So the depletion region acts like a dielectric of a capacitor.



We know that electrodes or conductive plates easily allow electric current through them. The p-type and n-type semiconductor also easily allow electric current through them. So the p-type and n-type semiconductor acts like the electrodes or conductive plates of the capacitor. Thus, varactor diode behaves like a normal capacitor.

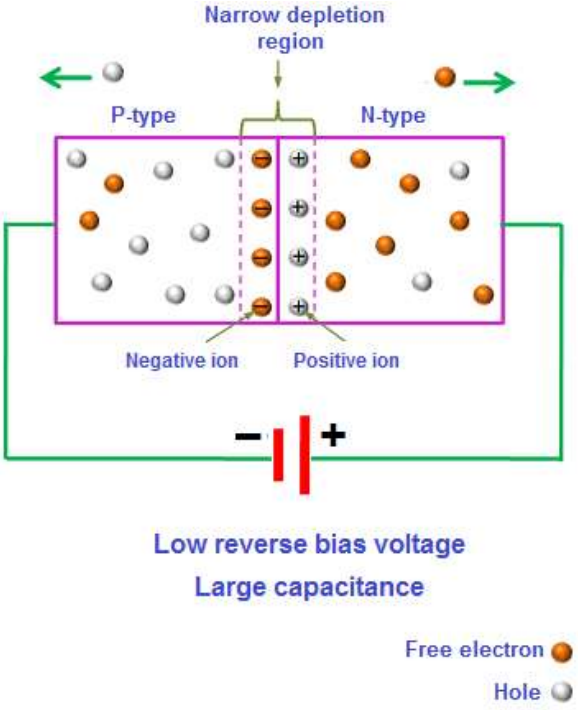
In an unbiased varactor diode, the depletion width is very small. So the capacitance (charge storage) is very large.

How varactor diode works?

The varactor diode should always be operated in reverse bias. Because in reverse bias, the electric current does not flow. When a forward bias voltage is applied, the electric current flows through the diode. As a result, the depletion region becomes negligible. We know that depletion region consists of stored charges. So stored charges becomes negligible which is undesirable.

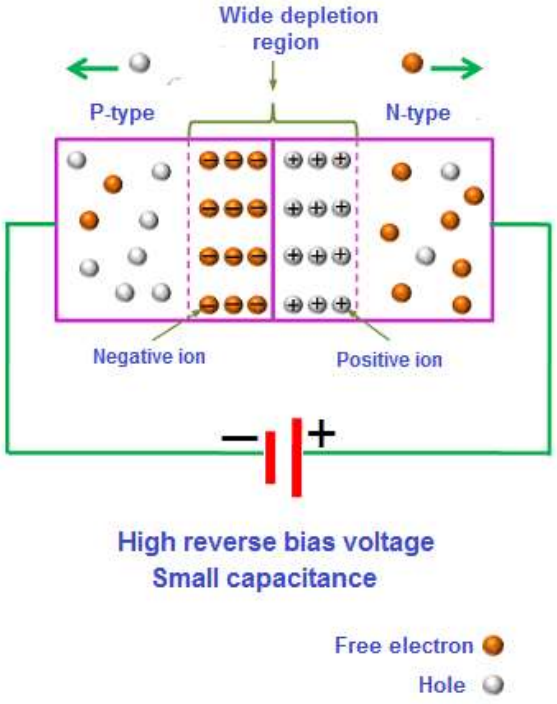
A varactor diode is designed to store electric charge not to conduct electric current. So varactor diode should always be operated in reverse bias.

When a reverse bias voltage is applied, the electrons from n-region and holes from p-region moves away from the junction. As a result, the width of depletion region increases and the capacitance decreases.



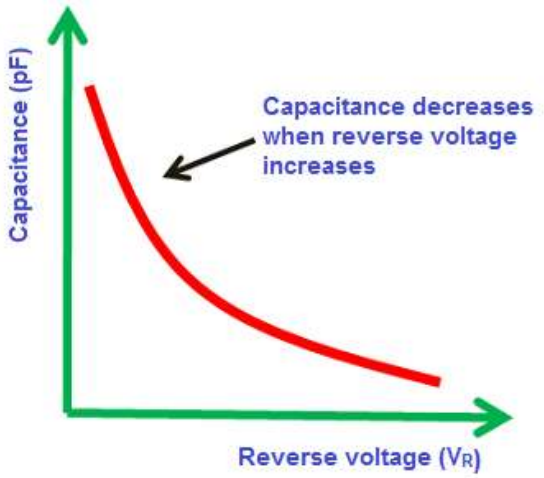
However, if the applied reverse bias voltage is very low the capacitance will be very large.

The capacitance is inversely proportional to the width of the depletion region and directly proportional to the surface area of the p-region and n-region. So the capacitance decreases as the as the width of depletion region increases.



If the reverse bias voltage is increased, the width of depletion region further increases and the capacitance further decreases.

On the other hand, if the reverse bias voltage is reduced, the width of depletion region decreases and the capacitance increases.



Thus, an increase in reverse bias voltage increases the width of the depletion region and decreases the capacitance of a varactor diode.

The decrease in capacitance means the decrease in storage charge. So the reverse bias voltage should be kept at a minimum to achieve large storage charge. Thus, capacitance or transition capacitance can be varied by varying the voltage.

In a fixed capacitor, the capacitance will not be varied whereas, in variable capacitor, the capacitance is varied.

In a varactor diode, the capacitance is varied when the voltage is varied. So the varactor diode is a variable capacitor. The capacitance of a varactor diode is measured in picofarads (pF).

Applications of varactor diode

- Varactor diode is used in frequency multipliers.
- Varactor diode is used in parametric amplifiers.
- Varactor diode is used in voltage-controlled oscillators.

Types of Diodes

The various types of diodes are as follows:

1. Zener diode
2. Avalanche diode
3. Photodiode
4. Light Emitting Diode
5. Laser diode
6. Tunnel diode
7. Schottky diode
8. Varactor diode
9. P-N junction diode

PREV NEXT