Semiconductor
Lecture 5

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Clipping Circuit:

Clipping circuit are used to transmit a part of a waveform laying above or below a reference level. Such circuit are also called amplitude selector or slicers. When $v_{in} < (v_R + v_r\ )$ where v_r is the cut in voltage of diode D, the diode in question is off. Since there is no current through the resistance under this condition $v_{out} = v_{in}$.

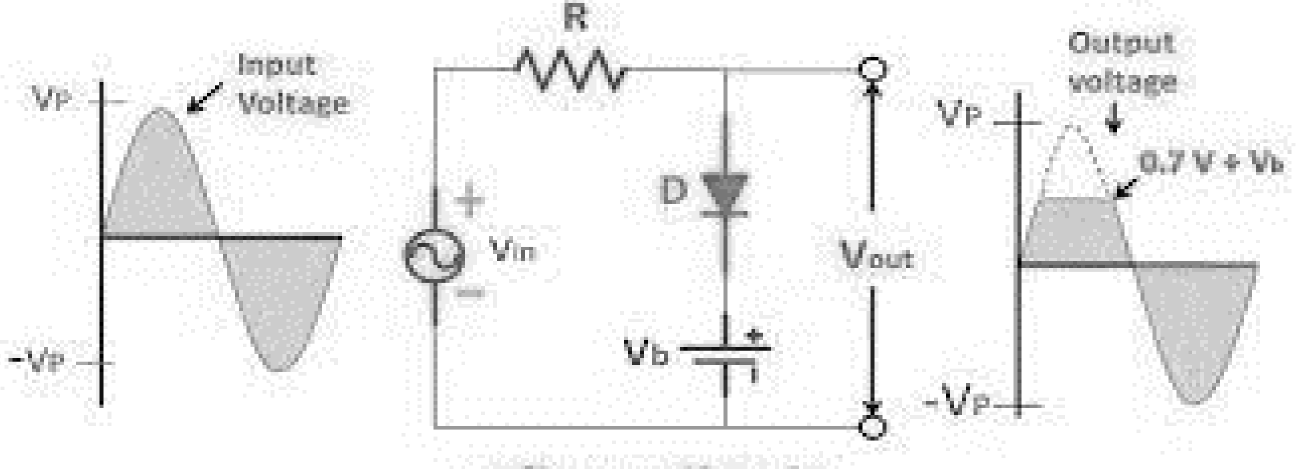

Fig 1

When $v_{in} > (v_R + v_r)$ then the diode D is on and behaves like a battery voltage v_r is series with the diode resistance R_f . Let ∂v_{in} be the increment in the input voltage. The corresponding increment in the output voltage v_{out} is

$$\partial v_{out} = \frac{R_f \partial v_{in}}{R_f + R} \rightarrow (i)$$

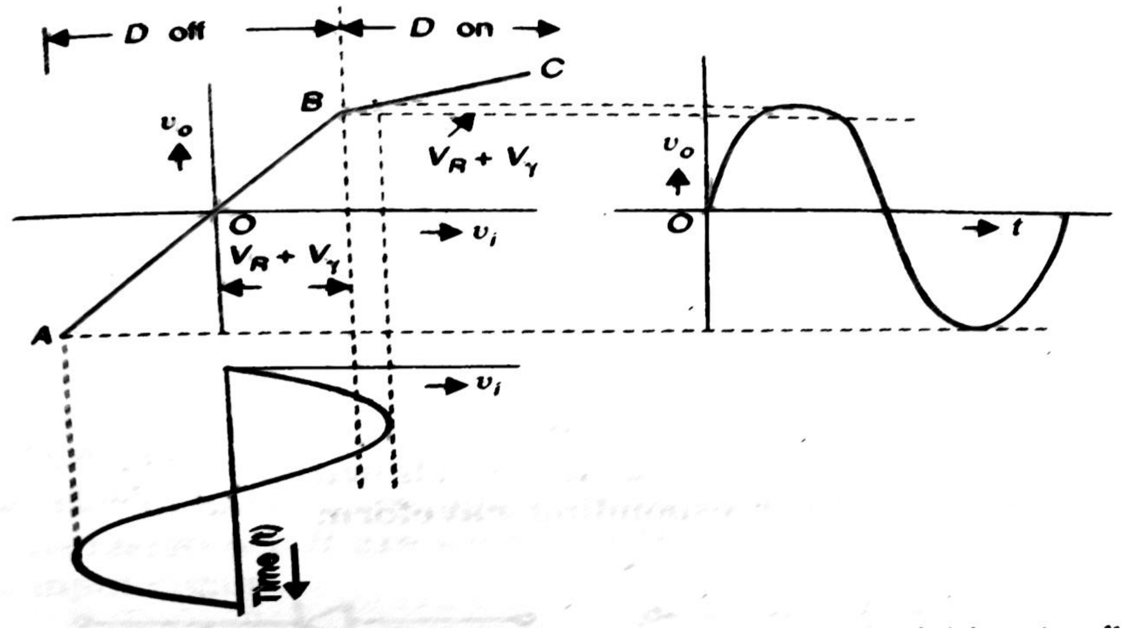

Fig 2

Let v_{in} be a sinusoidal voltage. As shown in *Fig2,* the portion AOB of the transfer characteristic is obtained. This part is straight line with slop of unity. Again the part BC of the transfer characteristic is obtained for $v_{in} > (v_R + v_r)$. This part of the characteristic is also linear has a slop of $\frac{R_f}{R_f+r}$. Let v_{in} be a sinusoidal voltage. It is clear from *Fig2* that the positive part of the output voltage v_{out} exceeding $v_R + v_r$ is suppressed. If $R \gg R_f$ the positive peak of v_{out} is sharply clipped or sliced at the voltage $v_R + v_r$. Furthermore if $v_r \ll v_R$, v_R is the limiting reference voltage.

Clamping Circuit:

The circuit that insert a component into a signal is termed a clamping circuit or a DC restorer. Such circuit are used in television amplifiers. *Fig3* shows a clamping circuit. The diode D is assumed to have a small forward resistance and cut in voltage.

The capacitance C and the resistance R are such that the time constant RC is very large compared to the period of the input signal. Considering a square wave applied at the input. When the diode D conducts and the capacitor is charged quickly to the peak value v_P of v_{in}, the time constant for charging being very small.

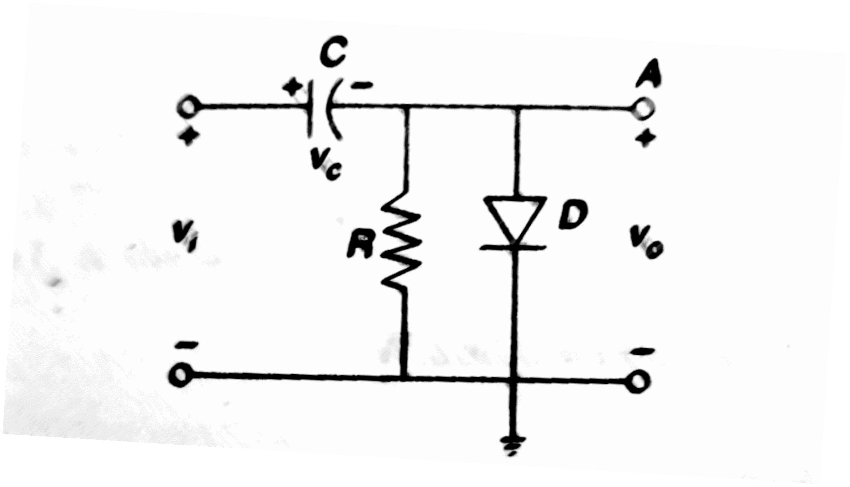

Fig3

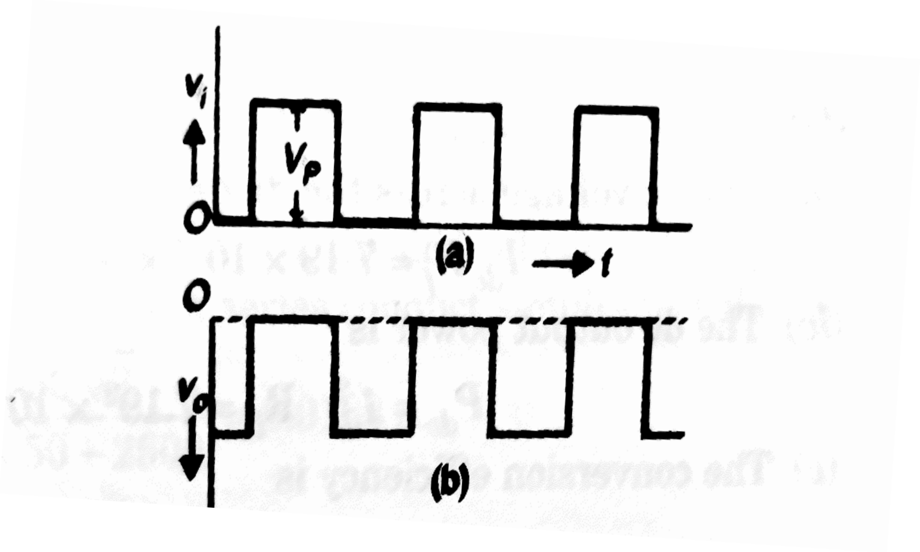

Fig4

The output voltage v_{out} is given by

$$v_{out} = v_{in} - v_c = v_i - v_P \rightarrow (ii)$$

The peak of the output voltage is then zero, the low resistance conducting diode connecting the point A to the ground when v_{in} . The output voltage waveform is shown in Fig4. when v_{in} drops to zero, the capacitor charge can not change instantaneously and the voltage across it (v_c) remains at v_p. Hence

$$v_{out} = 0 - v_P = -v_P \rightarrow (iii)$$

The potential at the point A thus becomes $-v_P$. The diode stops connecting now. Since the RC time constant is large, the capacitor C can not discharge significantly in the negative interval and potential at A stays at $-v_P$. When v_{in} rises again to v_P the output voltage v_{out} swings to zero. Clearly the positive peaks of the input are clamped at zero at the output.

If the diode is reversed the negative peaks can be clamped at zero. By applying a bias voltage in series with the diode the signal peaks can be clamped at other potential.

Light Emitting Diodes (LED):

The increasing use of digital displays in calculator, watches and all forms of instrumentation has contributed to an extensive in structures that emit light when biased. The two types in common use to perform this function are the light emitting diode (LED) and light crystal diode (LCD).

The LED is a diode that gives off visible or invisible(infrared) light when energized. In any forward biased p-n junction there is within the structure and primarily close to the junction, a recombination of holes and electrons.

This recombination requires that the energy possessed by the unbound free electron be transferred to another state. In all semiconductor p-n junctions some of this energy is given off in the form of heat and some in the form of photons

In Si and Ge diodes the greater percentage of the energy converted during recombination at the junction is dissipated in the form of heat within the structure and the emitted light is insignificant. For this reason Si and Ge are not used in construction of LED devices. On the other hand diodes constructed of GaAs emit light in the infrared zone during the recombination process at the p-n junctions. Even though the light is not visible infrared LED have numerous application where visible light is not a desirable effect.

Though other combinations of elements a coherent visible light can be generated. The basic construction of an LED with the standard symbol used for the device. The external metallic conducting surface connected to the p-type material is smaller to permit the emergence of the maximum number of photons of light energy when the device is forward biased. It is also noted that the recombination of the injected carrier due to the forward biased junction result in emitted light at the site of recombination. There will be some absorption of some package of photon energy in the structure itself, but a very large percentage can leave. It is interesting to note that invisible light has a lower frequency spectrum than visible light.

The two quantities are related by

$$\lambda = \frac{c}{f} \rightarrow (iv)$$

Here c is the speed of light, λ is wavelength in meters and f is the frequency in Hertz

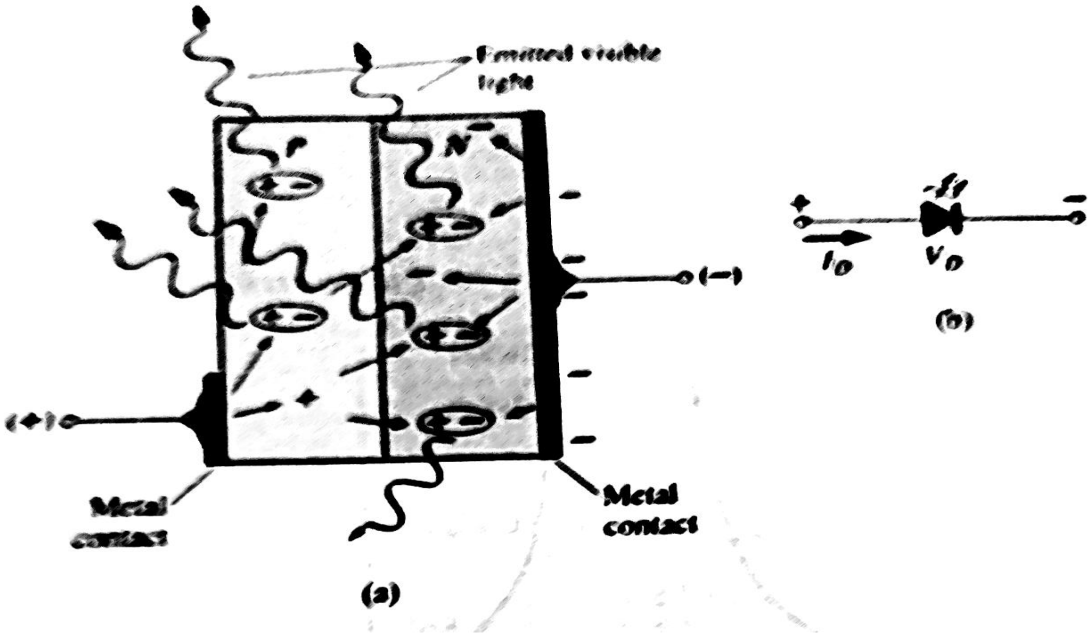

Fig5

It is mentioned that GaAs with its higher energy gap of 1.43 eV made it suitable for electromagnetic radiation of visible light where Si is only 1.1eV resulted primarily in heat dissipation on recombination. The effect of this difference in energy gap can be explained to some degree by realizing that to move an electron from one discrete energy level to anther requires a specific amount of energy. The amount of energy involved is given by

$$E_g = \frac{hc}{\lambda} \rightarrow (v)$$

Where h is known as Plank's Constant and is equal to 6.626$\times 10^{-34} Js$. If we substitute the energy gap of level 1.43eV then $\lambda = 869nm$

This certainly places GaAs in the wavelength zone typically used in infrared devices. For a compound material such as GaAsP with a band gap of 1.9eV the resulting wavelength is 654 nm which is the centre of red zone making it excellent compound semiconductor for LED production. Therefore in general, the wavelength and frequency of light of a specific colour are directly related to the energy band gap of the material.

The light intensity of an LED will increase with forward current until a point of saturation arrives where any further increase in current will not effectively increase the level of illumination. One of the major concerns when using an LED is the reversed bias breakdown voltage, which is typically between 3V and 5V.

For many years the only coulor available were green, yellow, orange and red permitting the average values of V_F=2V and I_F=20 mA for obtaining an approximate operating level. However blue and white were introduced, but for these case the two parameters are changed. For blue the average forward bias voltage can be as high as 5V and for white about 4.1V , although both have a typical operating current of 20mA or more. Now we have LED of white light. Today white LED can generate about 25 lm/w, but in 2012 they are forecast to reach 150lm/w to 400lm/w. At this rate 7w of power will someday be able to generate 1000lm of light.

Photo Diode:

A photo diode is a semiconductor p-n junction device that converts the light into electrical current. The current is generated when photons are absorbed in photo diode.

Larger the intensity of incident light, larger be the change in conductivity of the semiconductor. Therefore by measuring the resistance of the semiconductor one can measure the intensity of the optical signal.

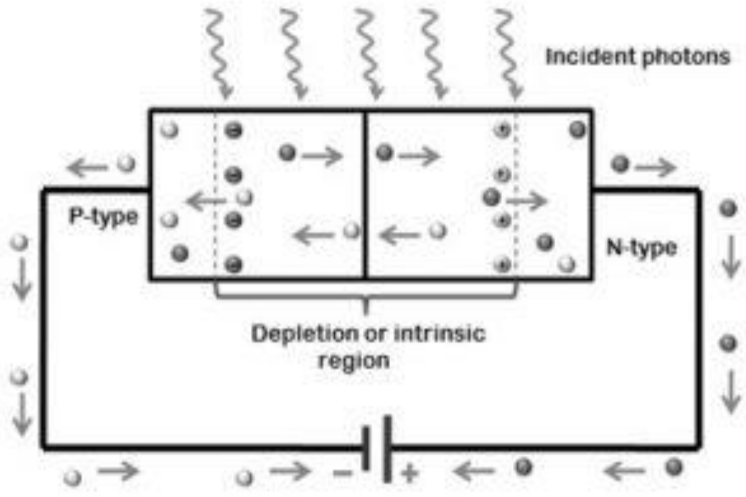

Fig6

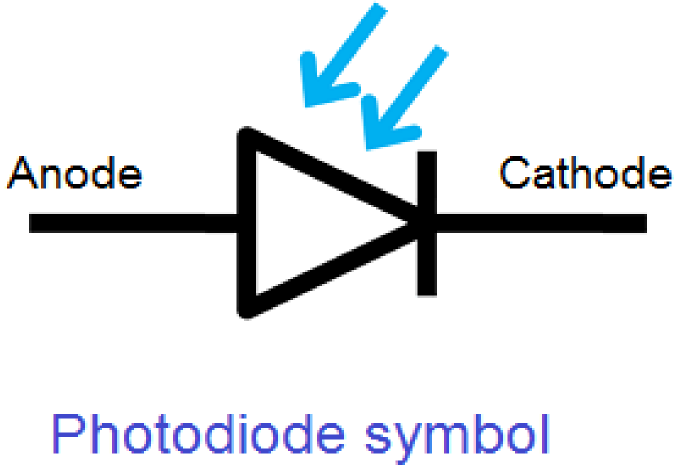

Fig7

The simplest photo diode is a reversed biased p-n diode. If such an p-n diode is illuminated with light photons having energy $h\nu = E_g$ and having different intensities I_1, I_2, I_3, e.t.c. the electron hole pair generated in the depletion layer or near the junction will be separated by junction field and made to flow across the junction. There would be a change in the reverse saturation current measuring which on illumination can give the values of light intensity. A photo diode is one kind of light detector used to convert the light into current or voltage based on mode of operation of the device. It comprises optical fibres built in lenses and also surface area. Photo diode have a slow response time when the surface area of the photo diode increases.

Photo diodes are alike to regular semiconductor diode, but that they may be either visible to let light reach the delicate part of the device.

Although there are numerous type of photo diode available in the market and they are all work on same basic principle, though some are improved by other effects. The working of different type of photo diodes works in a slightly different way, but the basic principle of these diodes remains the same. The types of photo diodes can be classified on their construction and functions as follows-

a) PN photo diode

b) Schottky photo diode

c) PIN photo diode

d) Avalanche photo diode

Solar Cell:

The solar cell is branded as a large area photo diode because it converts solar energy into electrical energy, though solar cell works on bright light. When sunlight strikes a solar cell electron in the silicon are ejected which results formation of holes. If this happens in electric field, the field will move electron to the n-type and holes to the p-type.

It is the form of photo voltaic cell defined as a device whose electrical characteristic such as current, voltage or resistance vary when exposed to light. Individual solar cell devices are often the electrical building blocks of photovoltaic modules popularly known as solar panel.

The common single junction silicon solar cell can produce a maximum open circuit voltage 0.5 to 0.6 volts approximately. Solar cell are described as being photovoltaic irrespective of the source is sunlight or artificial light. In addition to producing energy they can be used as a photo detector, detecting light or other electromagnetic radiation near the visible range or measuring light intensity. Multiple solar cell in an integrated group all oriented in one plans constitute a solar voltaic panel or module. Photovoltaic module often have a sheet of glass on the sun facing side allowing light to pass while protecting the semiconductor wafers. Solar cell are usually connected in series creating additive voltage. Connecting cells in parallel yields a higher current.

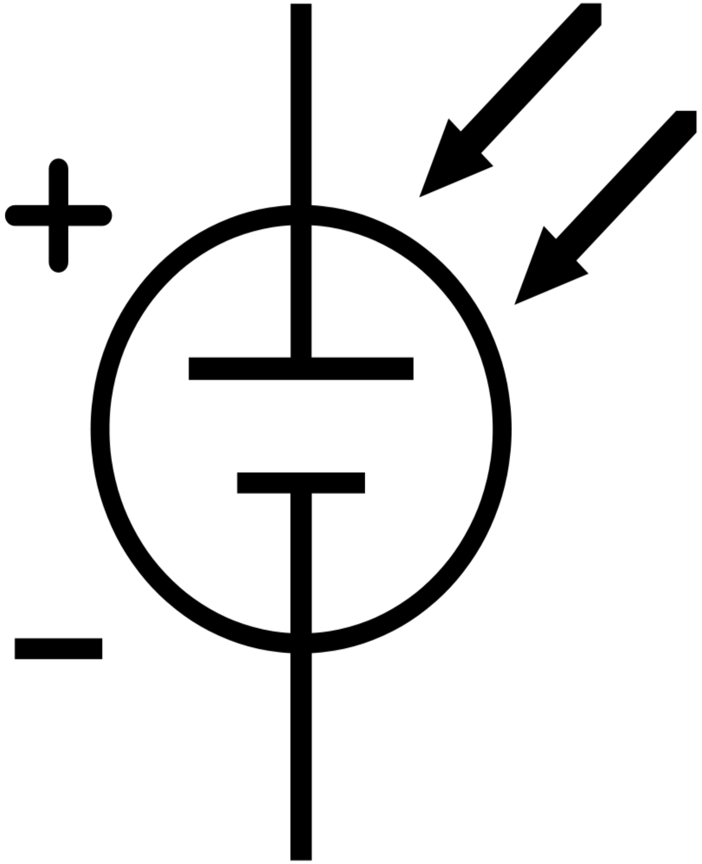

Fig8

Fig9

Solar cell efficiency may be broken down into reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency and conductive efficiency. The overall efficiency is the product of these individual matrices. The power conversion efficiency of a solar cell is a parameter which is defined by the fraction of incident power converted into electricity. A solar cell has a voltage dependent efficiency curve, temperature coefficient and allowable shadow angle.

Due to difficulty in measuring these parameters directly other parameter are substituted as thermodynamic efficiency, quantum efficiency, integrated quantum efficiency v_{oc} ratio and fill factor. The fill factor is the ratio of actual maximum obtainable power to the product of open circuit voltage and short circuit current. This is the key parameter in evaluating performance.