Diode applications

Rectifier efficiency:

Rectifier efficiency is defined as the ratio of DC power to the applied input AC power.

For Half Wave – Rectifier Efficiency calculation:

If r_f is the diode resistance and R_L is the load resistance, then:

DC output power = $P_{dc} = I_{dc}^2 \times R_L = (I_m / \pi)^2 \times R_L$

AC input power = $P_{ac} = I_{rms}^2 (r_f + R_L)$

For a half-wave rectified wave: $I_{rms} = I_m / 2$

Therefore, $P_{ac} = (I_m/2)^2 \times (r_f + R_L)$

So, Efficiency = $[(I_m/\pi)^2 x R_L] / [(I_m/2)^2 x (r_f + R_L)]$

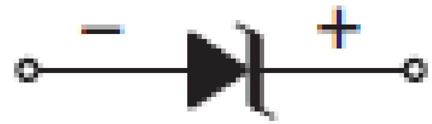
$= 0.406 R_L / (r_f + R_L)$

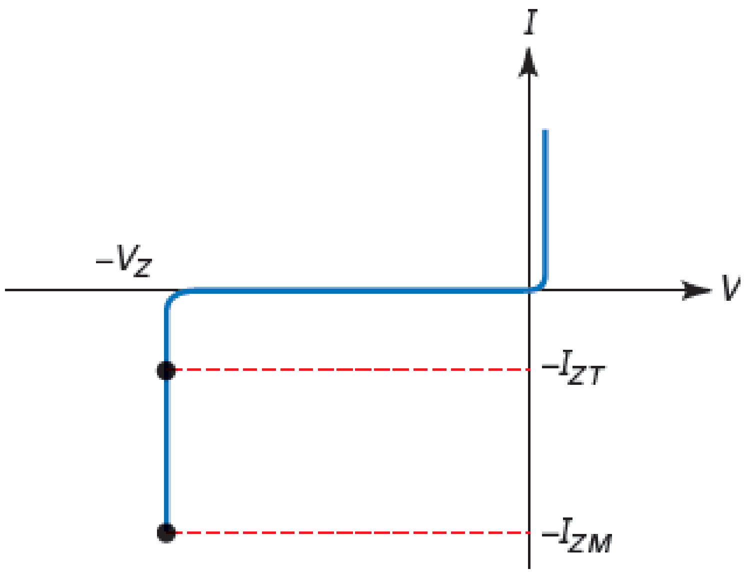
$= 0.406 / (1 + r_f/R_L)$

The efficiency will be maximum if r_f is negligible as compared to R_L.

Therefore, maximum rectifier efficiency = 40.6%.

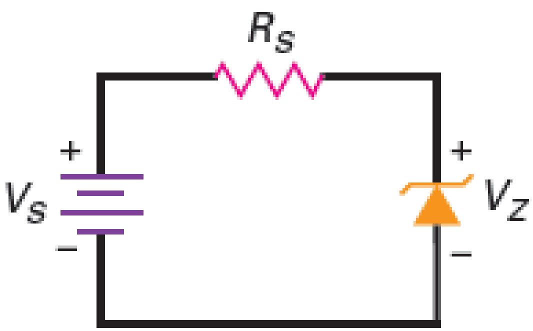
The Zener Diode





Zener Regulator:

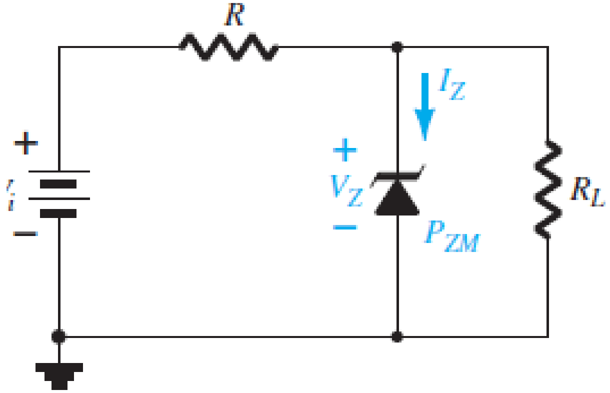
A zener diode is sometimes called a *voltage-regulator diode* because it maintains a constant output voltage even though the current through it changes.

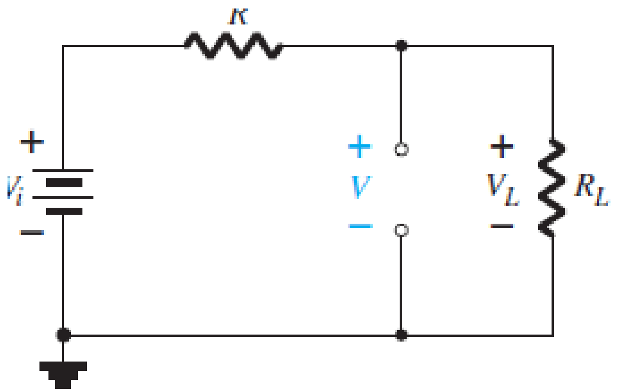


$$I_S = \frac{V_S - V_Z}{R_S}$$

Loaded Zener Regulator

The zener diode operates in the breakdown region and holds the load voltage constant. Even if the source voltage changes or the load resistance varies, the load voltage will remain fixed and equal to the zener voltage.





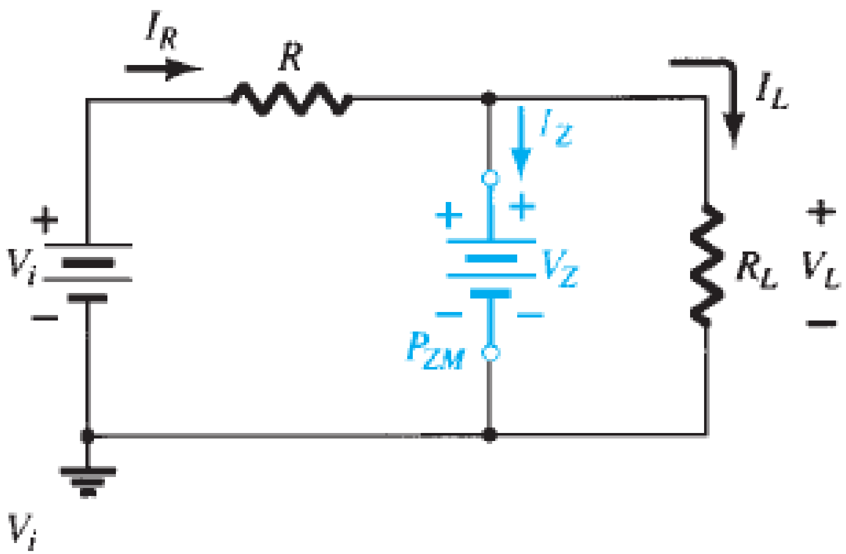
The applied dc voltage is fixed, as is the load resistor.

Determine the state of the Zener diode by removing it from the network and calculate the voltage across the resulting open circuit

$$V = V_L = \frac{R_L V_i}{R + R_L}$$

If $V > V_Z$, the Zener diode is on,
If $V < V_Z$, the diode is off

Substitute the appropriate equivalent circuit and solve for the desired unknowns



$$\boxed{V_L = V_Z}$$

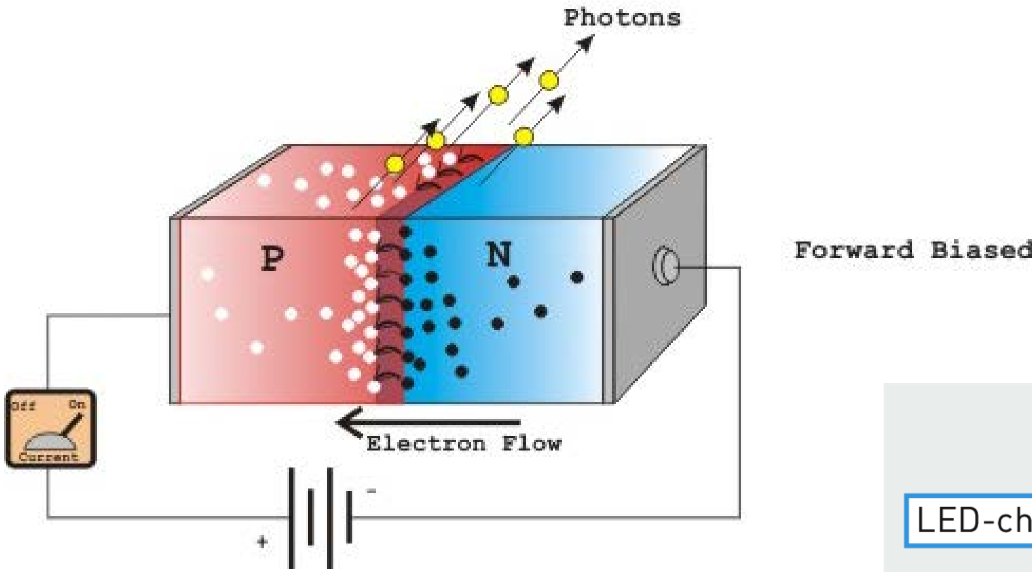
$$I_R = I_Z + I_L$$

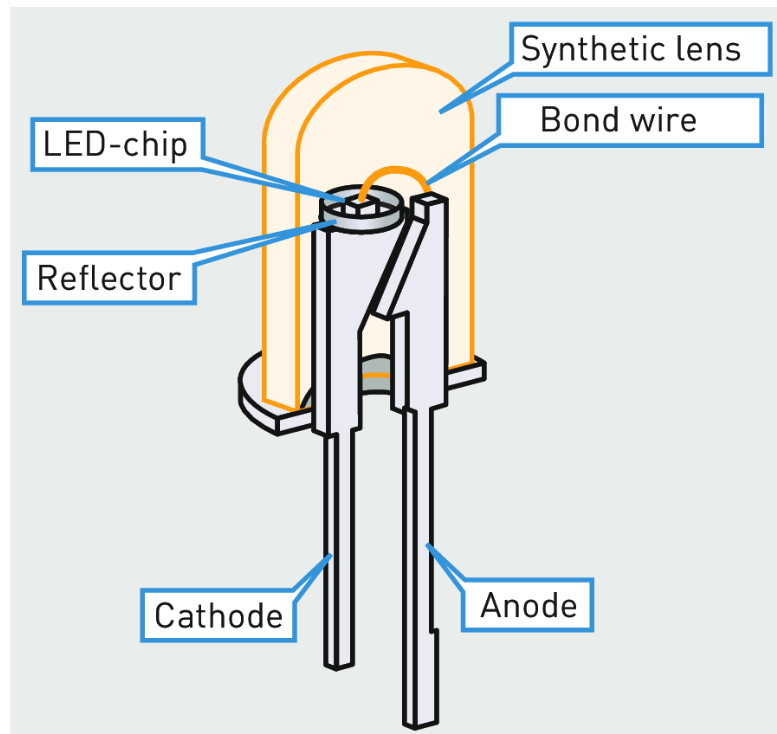
$$\boxed{I_Z = I_R - I_L}$$

$$I_L = \frac{V_L}{R_L} \quad \text{and} \quad I_R = \frac{V_R}{R} = \frac{V_i - V_L}{R}$$

Light Emitting Diode (LED)

A Light Emitting Diode (LED) is a special type of PN junction diode. This diode can emit light when it is in the forward biased state. Electron-hole recombine and emits energy in the form of light although not all recombination gives light. LED converts electrical energy into light energy. LED is surrounded by a transparent, hard plastic epoxy resin hemispherical shaped shell or body which protects the LED from both vibration and shock. The epoxy resin body is constructed in such a way that the photons of light emitted by the junction are reflected away from the surrounding substrate base to which the diode is attached and are focused upwards through the domed top of the LED, which itself acts like a lens concentrating the amount of light. This is why the emitted light appears to be brightest at the top of the LED.


Photons
P
N
Forward Biased
Off
On
Current
Electron Flow
+
-


Synthetic lens
Bond wire
LED-chip
Reflector
Cathode
Anode

Photodiodes

It is a form of light sensor that converts light energy into electrical voltage or current. Photodiode is a type of semi conducting device with PN junction. Between the p (positive) and n (negative) layers, an intrinsic layer is present. The photo diode accepts light energy as input to generate electric current. It is also known as photodetector or photosensor.

The working principle of a photodiode is, when a photon of ample energy strikes the diode, it makes a couple of an electron-hole. This mechanism is also called the inner photoelectric effect. If the absorption arises in the depletion region junction, then the carriers are removed from the junction by the inbuilt electric field of the depletion region. Therefore, holes in the region move toward the anode, and electrons move toward the cathode, and a photocurrent will be generated. The entire current through the diode is the sum of the absence of light and the photocurrent. So the absent current must be reduced to maximize the sensitivity of the device.

Solar Cell

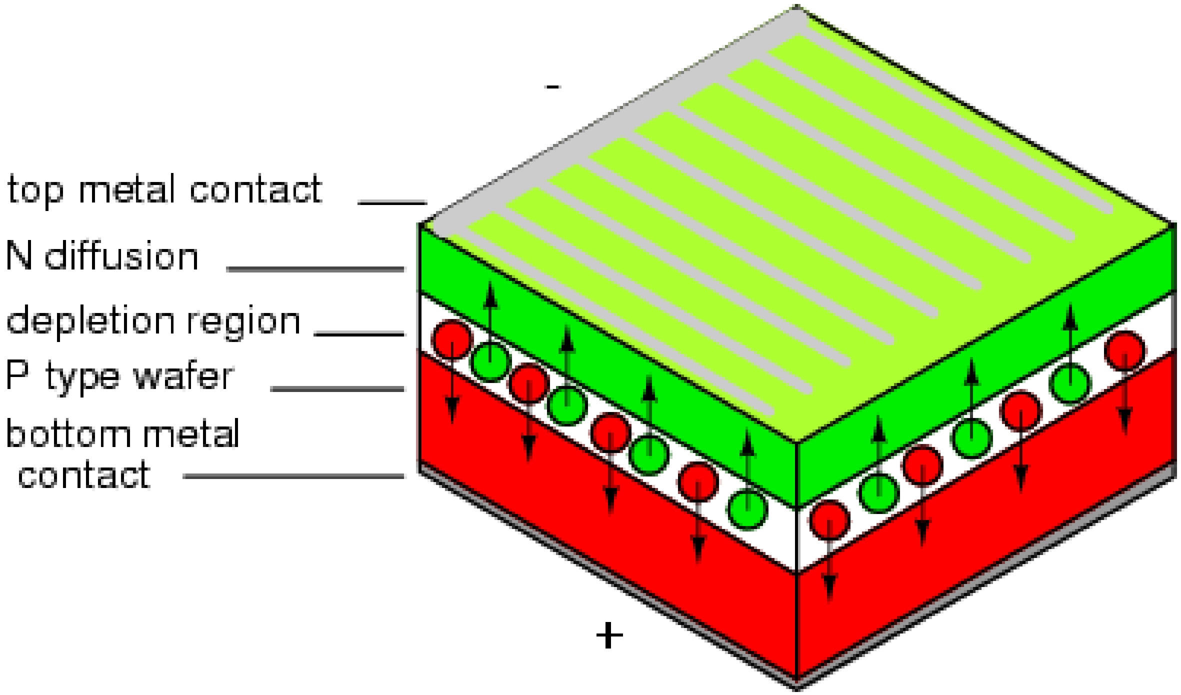
Solar cell, also called photovoltaic cell, any device that directly converts the energy of light into electrical energy through the photovoltaic effect.

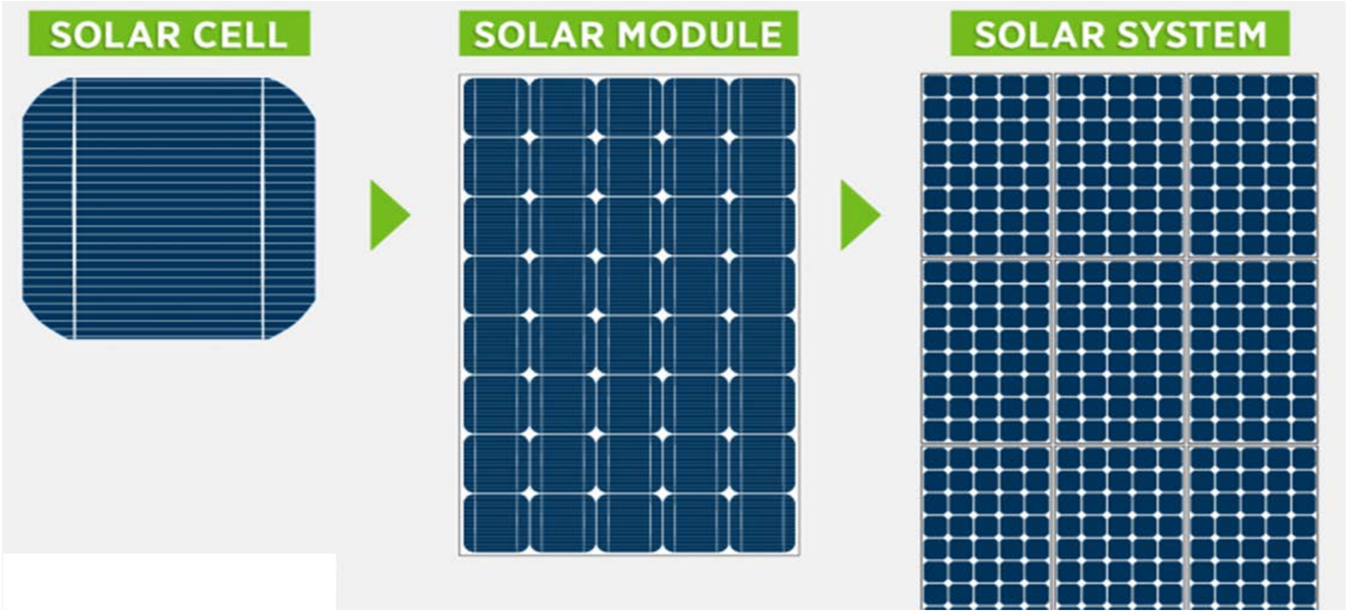
Difference between Solar Cell and Photodiode:

Photodiodes are optimized for light detection while solar cells are optimized for energy conversion efficiency.

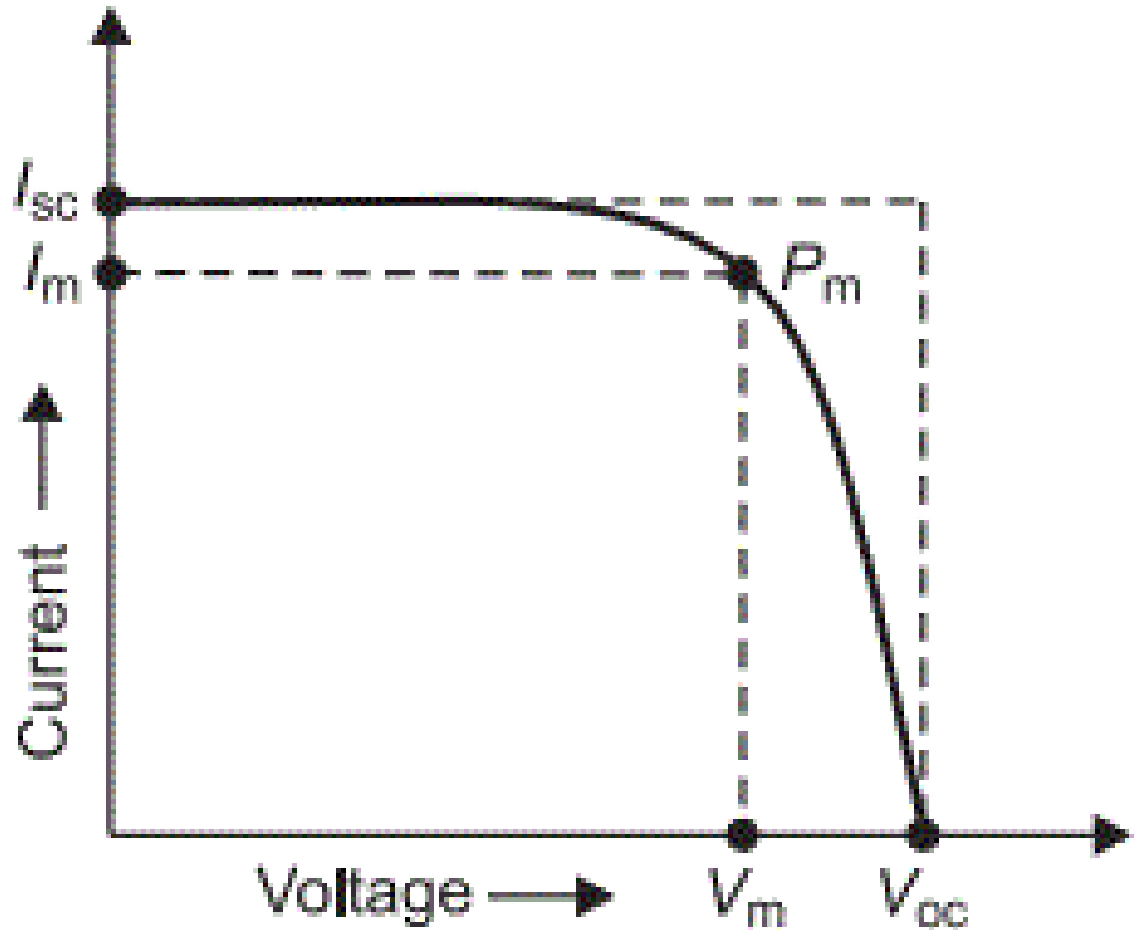
Photodiodes are optimized for sensitivity and/or speed, often small. Furthermore, they may use particular materials in order to be particularly or only sensitive to certain wavelengths.

Solar cells are meant as power sources, i.e. to convert light into power (without any regard to speed). They are therefore designed for maximum power yield: with a large area, avoiding unnecessary exclusion of any wavelength where sunlight carries a meaningful amount of energy, and used with zero bias.


top metal contact
N diffusion
depletion region
P type wafer
bottom metal contact
-
+


SOLAR CELL
SOLAR MODULE
SOLAR SYSTEM

Solar Cell current-voltage characteristics



I_{SC} – Short Circuit current, V_{OC} – Open circuit voltage, Pm – maximum power point with maximum voltage V_m and Maximum Current I_m

The **fill factor** (FF) of a p-i-n cell is defined by

$$FF = \frac{I_m V_m}{I_{sc} V_{oc}}$$

The **conversion efficiency (η)** of solar cell is defined by the ratio of the maximum power output (***P***) to incident power of illumination (P_{in})

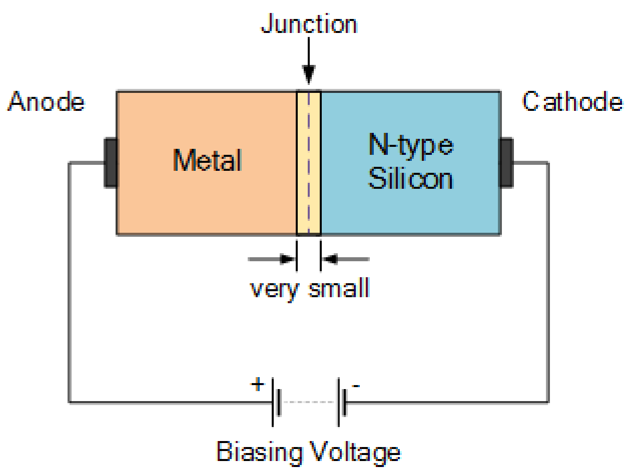
$$\eta = \frac{P_{out}}{P_{in}} \times 100 \quad \%$$

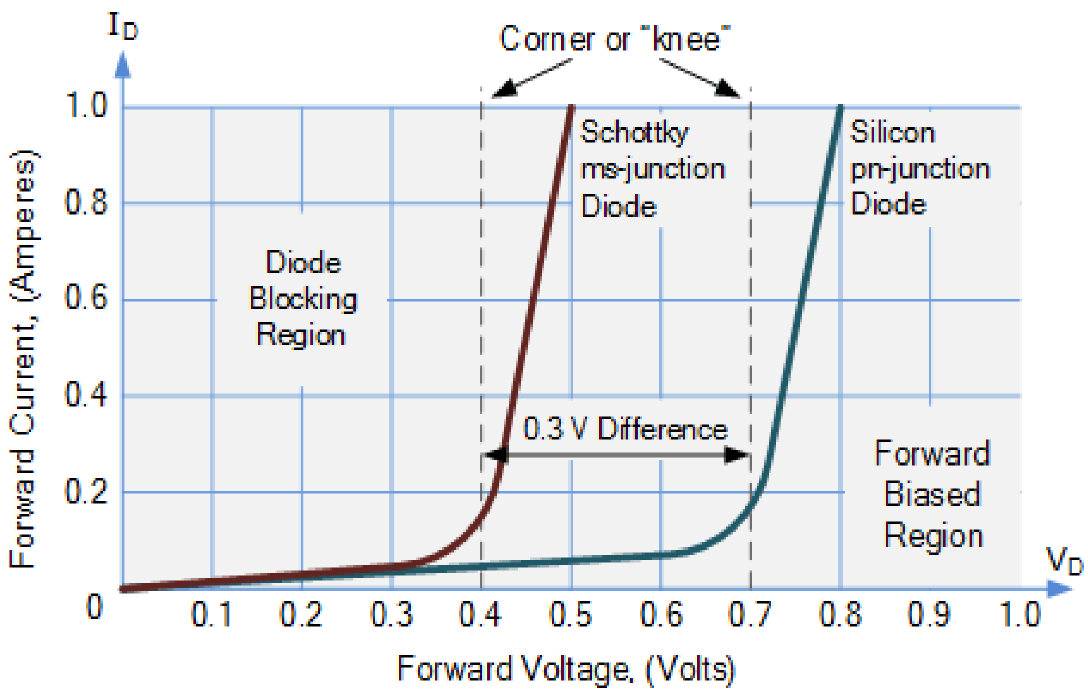
$$= \frac{I_m V_m}{P_{in}} \times 100\ \% \quad = \frac{FF . I_{sc} V_{oc}}{P_{in}} \times 100 \quad \%$$

Normally P_{in} is 100 mW/cm²

Schottky Diode

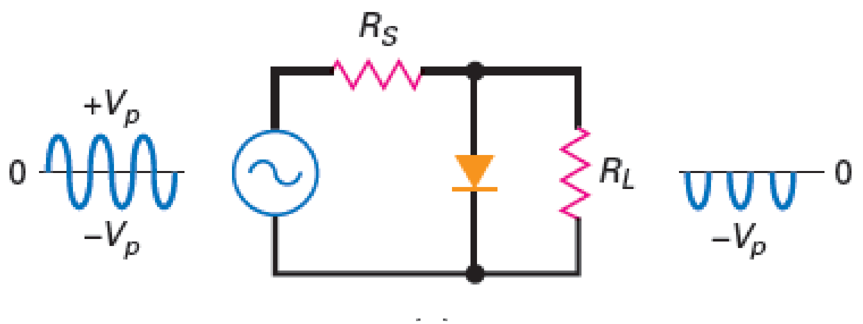
A Schottky Diode is a metal-semiconductor diode with a low forward voltage drop and a very fast switching speed. The Schottky Diode is another type of semiconductor diode but have the advantage that their forward voltage drop is substantially less than that of the conventional silicon pn-junction diode.



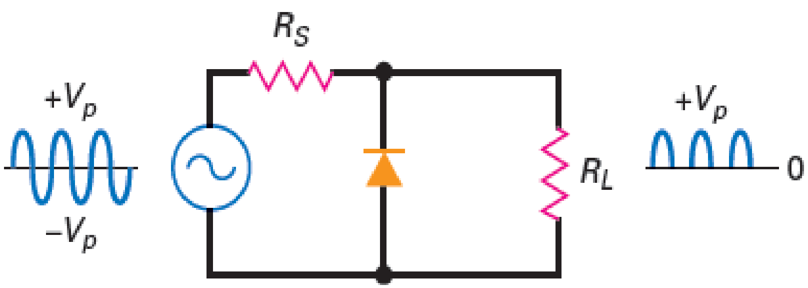


Clippers

A clipper is a circuit that removes either positive or negative parts of a waveform. If the circuit removes all the positive parts of the input signal it is called positive clipper.

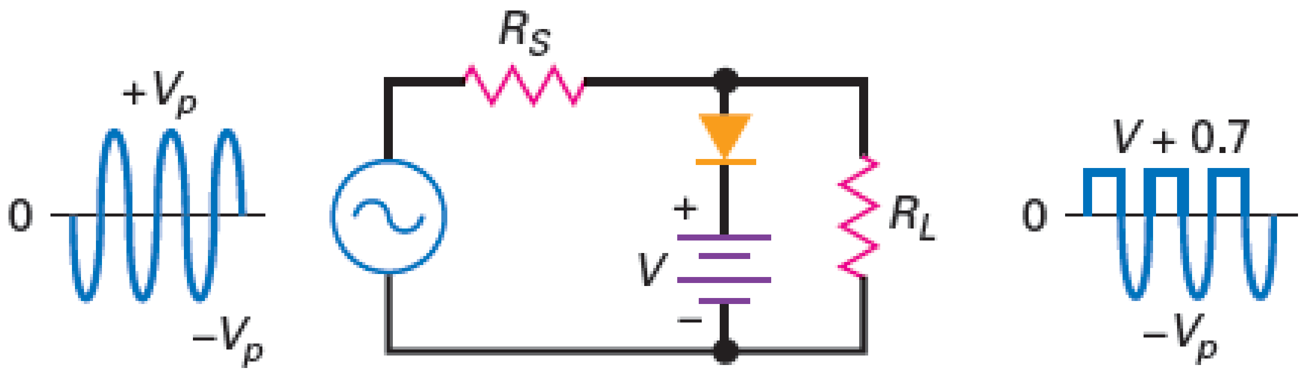


Positive clipper

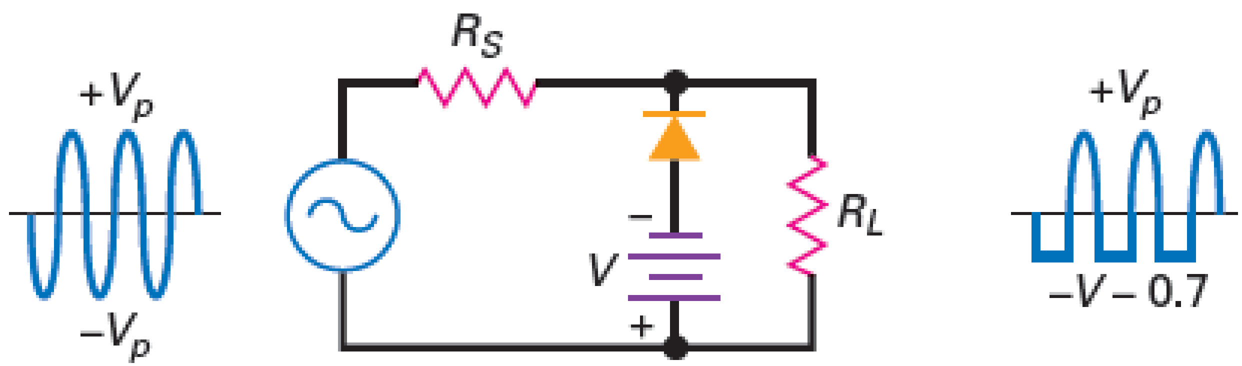


Negative clipper

Biased Clipper



Biased positive clipper

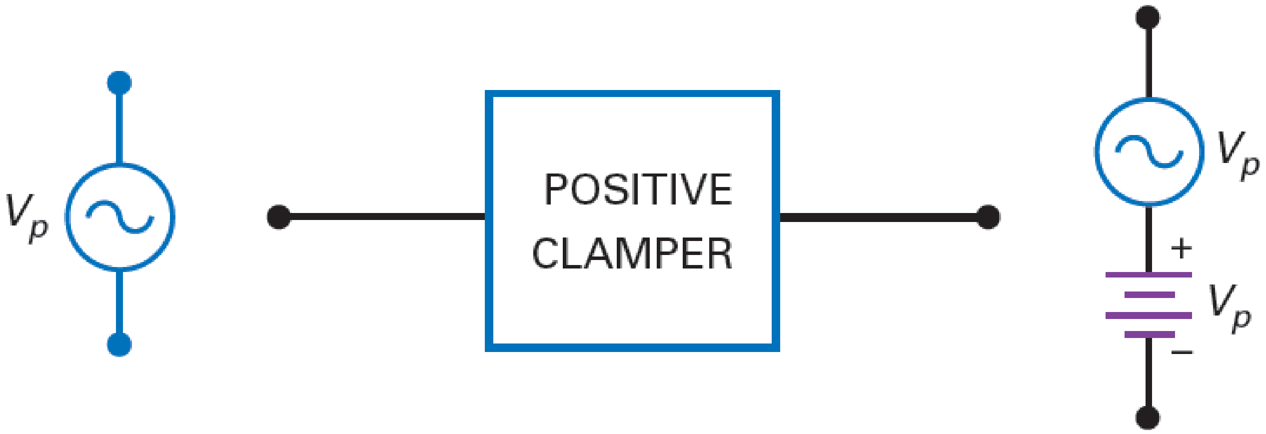


Biased negative clipper

Clampers

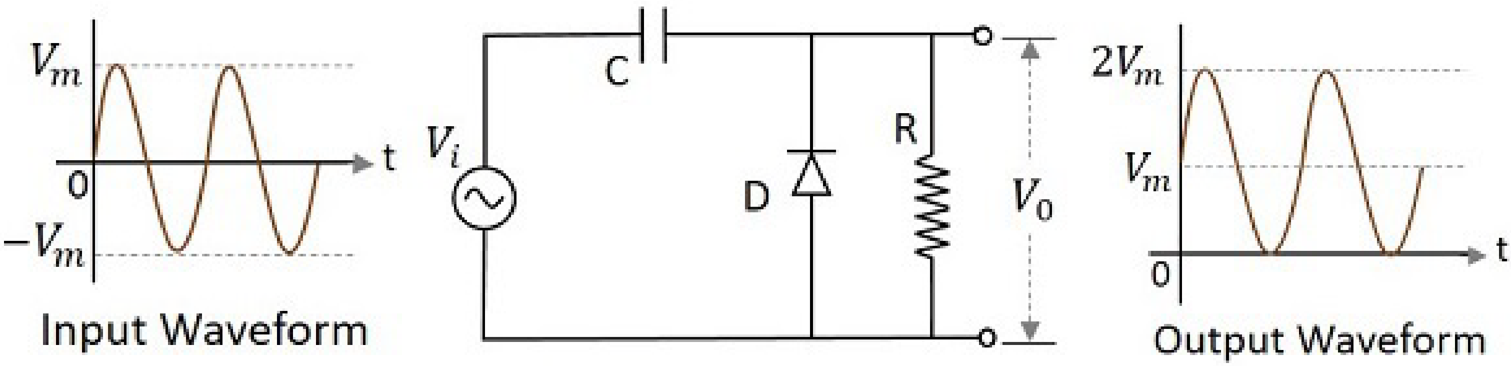
Positive Clamper:

Positive clamper shifts waveform upward



Positive clamper adds a dc component to signal

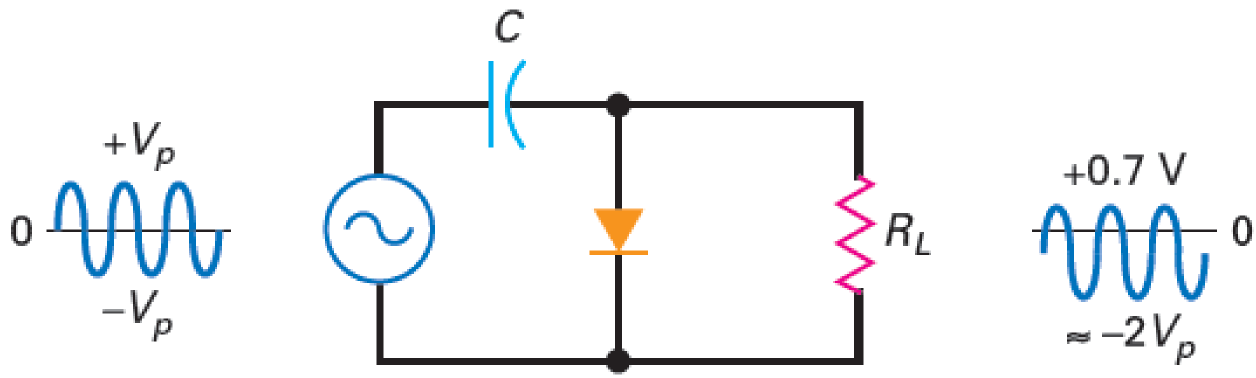
Positive clamper



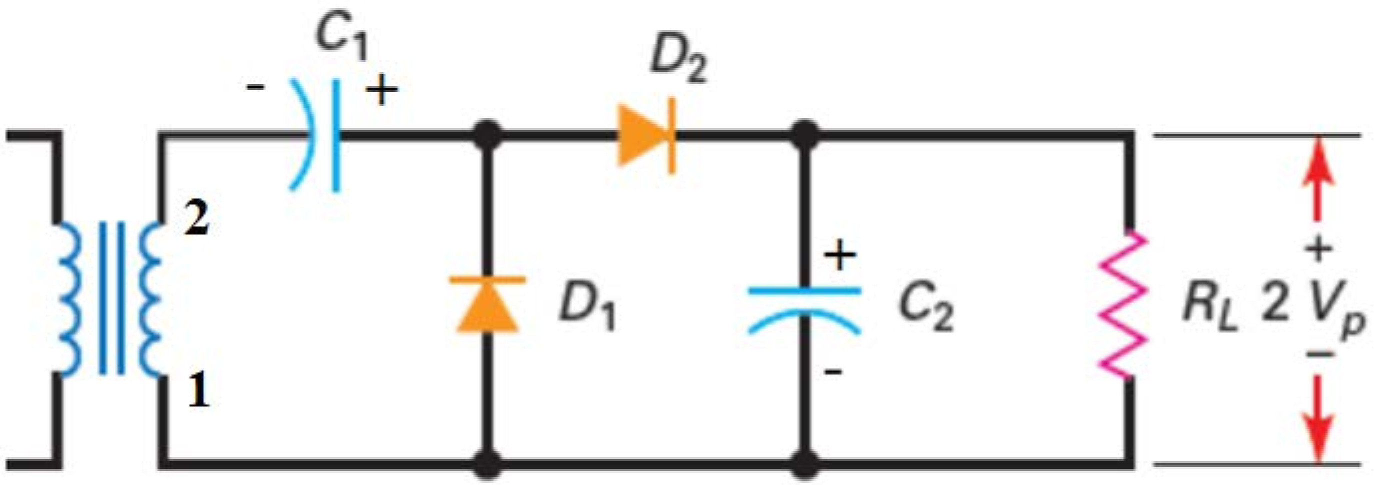
Positive Clamper circuit

Initially when the input is given, the capacitor is not yet charged and the diode is reverse biased. The output is not considered at this point of time. During the negative half cycle, at the peak value, the capacitor gets charged with negative on one plate and positive on the other. The capacitor is now charged to its peak value V_m. The diode is forward biased and conducts heavily. During the next positive half cycle, the capacitor is charged to positive V_m while the diode gets reverse biased and gets open circuited. The output of the circuit at this moment will be, $V_O=V_i+V_m$

Negative clamper



Voltage multiplier



For one half cycle, let's say end 1 of transformer is +ve, so D_1 conducts and the capacitor C_1 is charged to the peak voltage V_P with the polarity shown. For the next half cycle D_2 will conduct charging C_2. Summing the voltage in the outer loop , the peak voltage across C_2 will be $2V_P$.