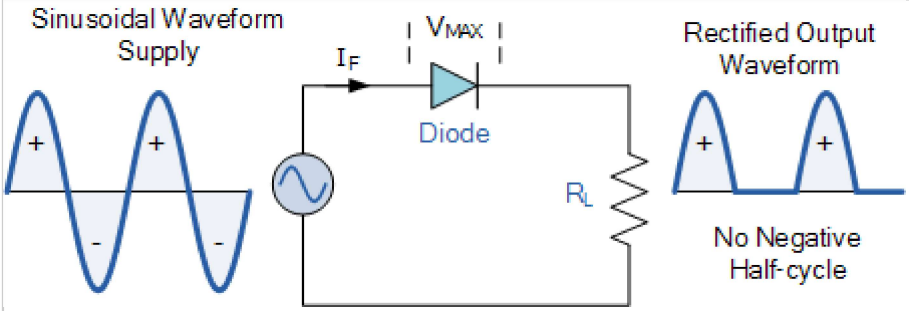


Power Diodes and Rectifiers

Power Diodes are semiconductor pn-junctions capable of passing large currents at high voltage values for use in rectifier circuits

In the previous tutorials we saw that a semiconductor signal diode will only conduct current in one direction from its anode to its cathode (forward direction), but not in the reverse direction acting a bit like an electrical one way valve.

A widely used application of this feature and diodes in general is in the conversion of an alternating voltage (AC) into a continuous voltage (DC). In other words, *Rectification*.

We could use small signal diodes in low-power, low current (less than 1-amp) rectification and power supply applications. However, were larger forward bias currents or higher reverse bias blocking voltages are required, the PN junction of a small signal diode would eventually overheat and become destroyed. Then for high power applications larger more robust **Power Diodes** must be used instead.

The power semiconductor diode, known simply as the **Power Diode**, has a much larger PN junction area compared to its smaller signal diode cousin, resulting in a high forward current capability of up to several hundred amps (KA) and a reverse blocking voltage of up to several thousand volts (KV).

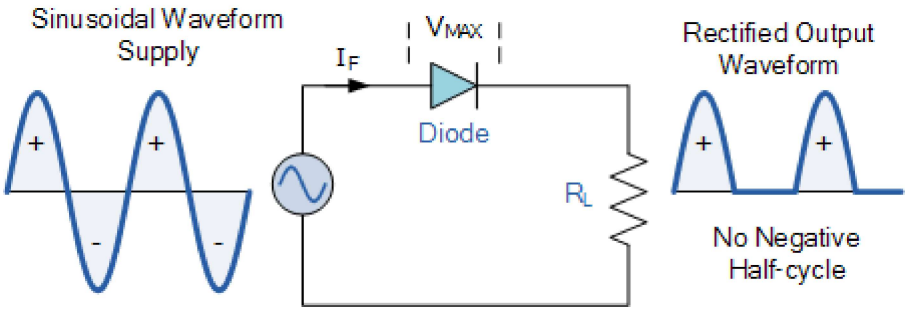
Since the power diode has a large PN junction, it is not suitable for high frequency applications above 1MHz, but special and expensive high frequency, high current diodes are available. For high frequency, low voltage rectifier applications, *Schottky Diodes* are generally used because of their short reverse recovery time and low voltage drop in their forward bias condition.

Power diodes provide uncontrolled rectification of power and are used in applications such as battery charging and DC power supplies as well as AC rectifiers and inverters. Due to their high current and voltage characteristics they can also be used as free-wheeling diodes and snubber networks.

Power diodes are designed to have a forward “ON” resistance of fractions of an Ohm while their reverse blocking resistance is in the mega-Ohms range. Some of the larger value power diodes are designed to be “stud mounted” onto heatsinks reducing their thermal resistance to between 0.1 to 1^{o}C/Watt.

If an alternating voltage is applied across a power diode, during the positive half cycle the diode will conduct passing current and during the negative half cycle the diode will not conduct blocking the flow of current. Then conduction through the power diode only occurs during the positive half cycle and is therefore unidirectional i.e. DC as shown.

Power Diode Rectifier



Power diodes can be used individually as above or connected together to produce a variety of rectifier circuits such as “Half-Wave”, “Full-Wave” or as “Bridge Rectifiers”. Each type of rectifier circuit can be classed as either uncontrolled, half-controlled or fully controlled where an uncontrolled rectifier uses only power diodes, a fully controlled rectifier uses thyristors (SCRs) and a half controlled rectifier is a mixture of both diodes and thyristors.

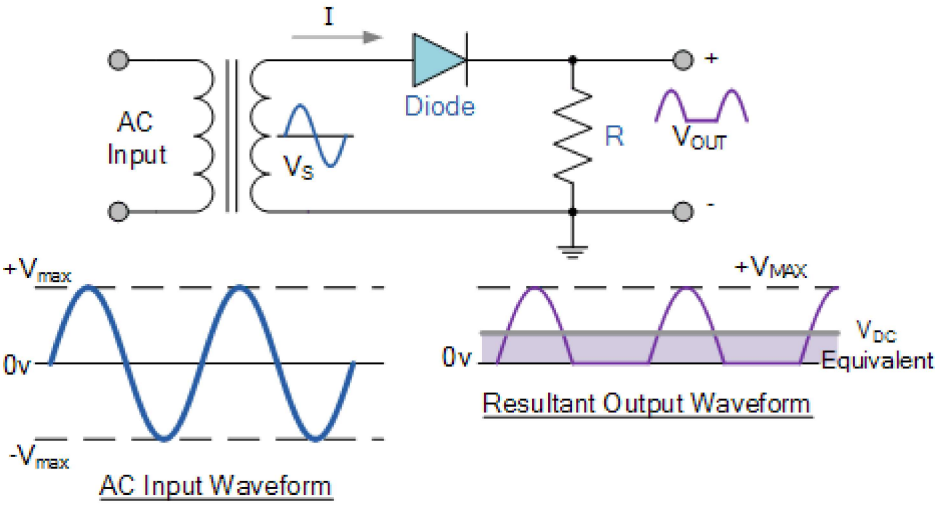
The most commonly used individual power diode for basic electronics applications is the general purpose 1N400x Series Glass Passivated type rectifying diode with standard ratings of continuous forward rectified current of about 1.0 ampere and reverse blocking voltage ratings from 50v for the 1N4001 up to 1000v for the 1N4007, with the small 1N4007GP being the most popular for general purpose mains voltage rectification.

Half Wave Rectification

A rectifier is a circuit which converts the *Alternating Current* (AC) input power into a *Direct Current* (DC) output power. The input power supply may be either a single-phase or a multi-phase supply with the simplest of all the rectifier circuits being that of the **Half Wave Rectifier**.

The power diode in a half wave rectifier circuit passes just one half of each complete sine wave of the AC supply in order to convert it into a DC supply. Then this type of circuit is called a “half-wave” rectifier because it passes only half of the incoming AC power supply as shown below.

Half Wave Rectifier Circuit



During each “positive” half cycle of the AC sine wave, the diode is *forward biased* as the anode is positive with respect to the cathode resulting in current flowing through the diode.

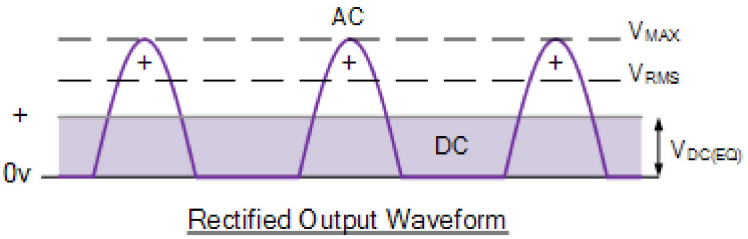
Since the DC load is resistive (resistor, R), the current flowing in the load resistor is therefore proportional to the voltage (Ohm´s Law), and the voltage across the load resistor will therefore be the same as the supply voltage, Vs (minus Vf), that is the “DC” voltage across the load is sinusoidal for the first half cycle only so Vout = Vs.

During each “negative” half cycle of the AC sinusoidal input waveform, the diode is *reverse biased* as the anode is negative with respect to the cathode. Therefore, NO current flows through the diode or circuit. Then in the negative half cycle of the

supply, no current flows in the load resistor as no voltage appears across it so therefore, Vout = 0.

The current on the DC side of the circuit flows in one direction only making the circuit **Unidirectional**. As the load resistor receives from the diode a positive half of the waveform, zero volts, a positive half of the waveform, zero volts, etc, the value of this irregular voltage would be equal in value to an equivalent DC voltage of 0.318*Vmax of the input sinusoidal waveform or 0.45*Vrms of the input sinusoidal waveform.

Then the equivalent DC voltage, V_{DC} across the load resistor is calculated as follows.



Rectified Output Waveform

$$V_{d.c.} = \frac{V_{MAX}}{\pi} = 0.318V_{MAX} = 0.45V_{RMS}$$

Where V_{MAX} is the maximum or peak voltage value of the AC sinusoidal supply, and V_{RMS} is the RMS (Root Mean Squared) value of the supply voltage.

Power Diode Example No1

Calculate the voltage drop V_{DC} and current I_{DC} flowing through a 100Ω resistor connected to a 240 Vrms single phase half-wave rectifier as shown above. Also calculate the average DC power consumed by the load.

$$V_{MAX} = V_{RMS} \times 1.414, \quad \text{or} \quad V_{RMS} = V_{MAX} \times 0.7071$$

$$V_{DC} = 0.45 V_{RMS} = 0.45 \times 240 = 108 \text{ Volts}$$

or

$$V_{DC} = 0.318 V_{MAX} = 0.318 \times (240 \times 1.414) = 108 \text{ Volts}$$

$$I_{DC} = \frac{V_{DC}}{R} = \frac{108V}{100\Omega} = 1.08 \text{ Amps}$$

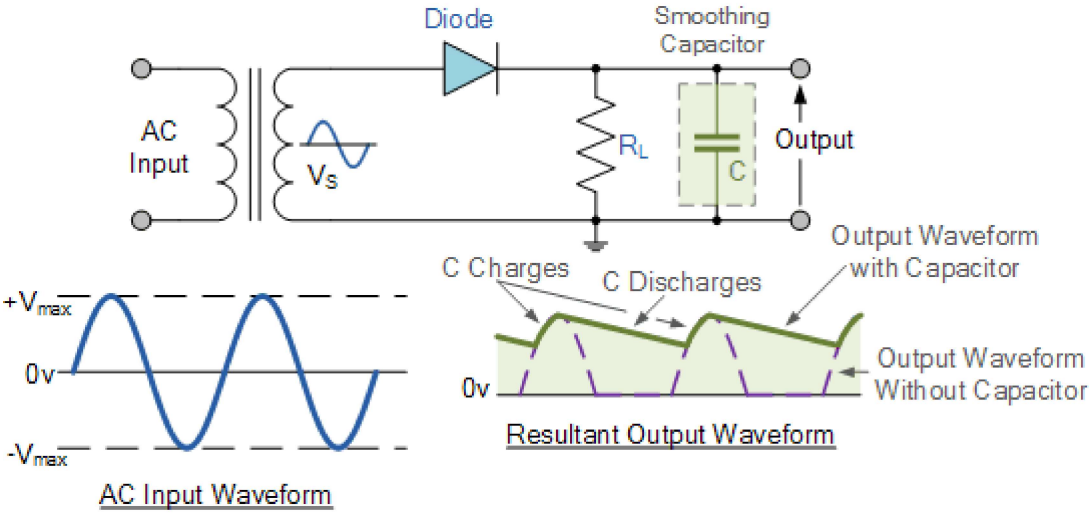
$$\text{Power} = I^2 R = 1.08^2 \times 100 = 116 \text{ Watts}$$

During the rectification process the resultant output DC voltage and current are therefore both “ON” and “OFF” during every cycle. As the voltage across the load resistor is only present during the positive half of the cycle (50% of the input waveform), this results in a low average DC value being supplied to the load.

The variation of the rectified output waveform between this “ON” and “OFF” condition produces a waveform which has large amounts of “ripple” which is an undesirable feature. The resultant DC ripple has a frequency that is equal to that of the AC supply frequency.

Very often when rectifying an alternating voltage we wish to produce a “steady” and continuous DC voltage free from any voltage variations or ripple. One way of doing this is to connect a large value Capacitor across the output voltage terminals in parallel with the load resistor as shown below. This type of capacitor is known commonly as a “Reservoir” or *Smoothing Capacitor*.

Half-wave Rectifier with Smoothing Capacitor



When rectification is used to provide a direct voltage (DC) power supply from an alternating (AC) source, the amount of ripple voltage can be further reduced by using larger value capacitors but there are limits both on cost and size to the types of smoothing capacitors used.

For a given capacitor value, a greater load current (smaller load resistance) will discharge the capacitor more quickly (RC Time Constant) and so increases the ripple obtained. Then for single phase, half-wave rectifier circuit using a power diode it is not very practical to try and reduce the ripple voltage by capacitor smoothing alone. In this instance it would be more practical to use “Full-wave Rectification” instead.

In practice, the half-wave rectifier is used most often in low-power applications because of their major disadvantages being. The output amplitude is less than the input amplitude, there is no output during the negative half cycle so half the power is wasted and the output is pulsed DC resulting in excessive ripple.

To overcome these disadvantages a number of **Power Diode** are connected together to produce a Full Wave Rectifier as discussed in the next tutorial.

Read more Tutorials inDiodes

118 Comments

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Email Address

Write your comment here

Notify me of follow-up comments by email.

Submit

- *Ahmed Mohammed*

  What is the function of any each diode on ac to dc electric power converter?

  Posted on February 19th 2022 | 11:36 am
  Reply
- *Sahan Jayasinghe*

  I have project operate a 6 DC motors. Please explain and give a components list for operate the motors. details are below
  1. Supply Voltage= 230 VAC / 50 Hz
  2. Motor Details = 200-220 VDC, 205 W, 1.4 Amp

  Posted on August 05th 2021 | 11:50 am
  Reply
  - *Wayne Storr*

    One rectifier and six relays

    Posted on August 05th 2021 | 12:13 pm
    Reply
- *Ochizi*

  Nice one,i love that

  Posted on June 30th 2021 | 3:02 pm
  Reply
- *Zaid Ahmed*

  Q/A 100 V battery is to be charged via a single diode and series resistor from an ac supply with a peak voltage of 200V. Calculate the value of the series resistor which will result in an average charging current of 1 amp. Assume that the diode has a constant forward resistance of 2 and that battery has a constant EMF of 100V and negligible internal resistance.

  Posted on March 13th 2021 | 5:38 pm
  Reply
- *ADAMU ADAMU*

  Please, show me the drivation of d.c power rectifier

Posted on March 12th 2021 | 6:13 pm
Reply

- *Saiyon*

  Thank you.very.mush.

  Posted on March 11th 2021 | 4:52 am
  Reply
- *Asad Ullah*

  Make pdf of these topics

  Posted on March 07th 2021 | 5:42 am
  Reply
- *Nisar Alam Khan*

  Best

  Posted on February 23rd 2021 | 7:04 pm
  Reply
- *Jayantha Rathnayake*

  Can we series a rectifire diode to 230 V primary of a transformer to get a lower voltage than specified in the secondary ?

  Posted on December 30th 2020 | 11:18 am
  Reply
- *Mukkera Vikas*

  half-wave rectifier is used to supply 24 V dc to a resistive load of 500 W and the diode has a forward resistance of 50 W. Calculate the maximum value of the ac voltage required at the input. *

  Posted on December 01st 2020 | 5:15 am
  Reply
- *derek*

  ooga booga

  Posted on November 12th 2020 | 12:43 pm
  Reply
  - *namık kemal*

    monke

    Posted on January 11th 2021 | 8:25 am
    Reply
- *Oladepo Ayodele*

  Just joining

  Posted on September 16th 2020 | 3:56 am
  Reply
- *Aqib ismail*

  I am join this

  Posted on August 28th 2020 | 3:44 am
  Reply
- *Mar Pie*

Hi. You stated here that Vdc value is equal to 0.45Vrms which is not true. Let's clarify this shortly. 1Vpeak (in reality only when pure undistorted sine wave, otherwise it is slightly more complex to be precise) translate to 0.707Vrms (1Vpeak / 1.414) and according of the RMS definition this is already a DC equivalent. Here is a citation from the book which is also freely available online "RMS to DC conversion application guide" by Charles Kitchin and Lew Counts from Analog Devices, so "RMS definition: the RMS value assigned to an AC signal is the amount of DC required to produce an equivalent amount of heat in the same load. For example: an AC signal of 1Vrms will produce the same amount of heat in a resistor as a 1Vdc signal."

Posted on August 21st 2020 | 10:59 am
Reply

- *ramadhani mpanda*

  i want the summerised nots about rectifier and rectification circits

  Posted on July 07th 2020 | 1:20 am
  Reply

- *Shbam singh*

  Sir/madam I have a PCB board and there is three diodes are set in PCB board input supply 1no doide and 2nd no diode of gets input supply and 3 no diode are nutral.how do I know how much input vac supply both diodes getting.

  Posted on June 26th 2020 | 10:34 pm
  Reply

- *Dr. RJ*

  Hi … there is some error in calculation
  For HW : V(rms) = Vm /2
  but for FW: V(rms) = Vm/sqrt(2)

  Posted on April 15th 2020 | 5:11 am
  Reply
    - More

- *havizul*

  Dear sir, If i want to make a half wave rectifiers to illuminate string of leds, led say 1 string consist of many leds, 1 led is 2Volt. How many leds should i use ? 74 leds so the total voltage drop in the string is 148V and then i use 200 ohm resistor to get 10mA of current, or i use 53 leds so the total voltae accros the string is 106 volt and then i use 100 ohm resistor to limit the current ? Which voltage value should i use as the reference source voltge, 108V or 150V ? As it is very impact in the design to determine resistance and power rating of the resistor ? If i choose 108V as reference value, and then the actual value is 150 ohm then the resistor will burn as it was used above the maximum power rating ?
  Thanks

  Posted on April 12th 2020 | 6:04 am
  Reply

- *Frankline kipkoech langat.*

  Awesome points.

  Posted on February 13th 2020 | 6:10 pm
  Reply

- *Andrew deng*

  Gud
  Hmm
  I wanna know why there are three different shape of graphs (sinusodial, square and pyramid) when sketching the input voltage in either Halfwave, full wave rectifier or clippper?
  I wanna know the idea , please ?

Posted on January 09th 2020 | 4:43 pm
Reply