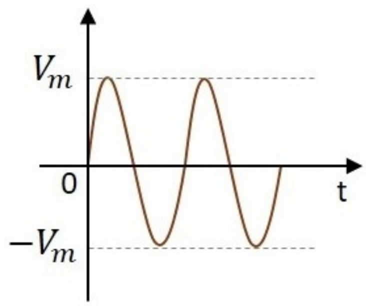
Rectifiers

Whenever there arises the need to convert an AC to DC power, a rectifier circuit comes for the rescue. A simple PN junction diode acts as a rectifier. The forward biasing and reverse biasing conditions of the diode makes the rectification.

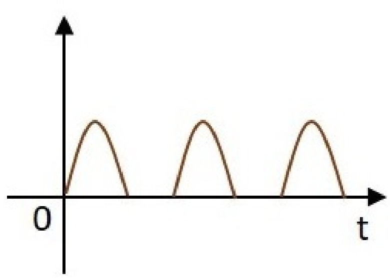
Rectification

An alternating current has the property to change its state continuously. This is understood by observing the sine wave by which an alternating current is indicated. It raises in its positive direction goes to a peak positive value, reduces from there to normal and again goes to negative portion and reaches the negative peak and again gets back to normal and goes on.



During its journey in the formation of wave, we can observe that the wave goes in positive and negative directions. Actually it alters completely and hence the name alternating current.

But during the process of rectification, this alternating current is changed into direct current DC. The wave which flows in both positive and negative direction till then, will get its direction restricted only to positive direction, when converted to DC. Hence the current is allowed to flow only in positive direction and resisted in negative direction, just as in the figure below.



The circuit which does rectification is called as a **Rectifier circuit**. A diode is used as a rectifier, to construct a rectifier circuit.

Types of Rectifier circuits

There are two main types of rectifier circuits, depending upon their output. They are

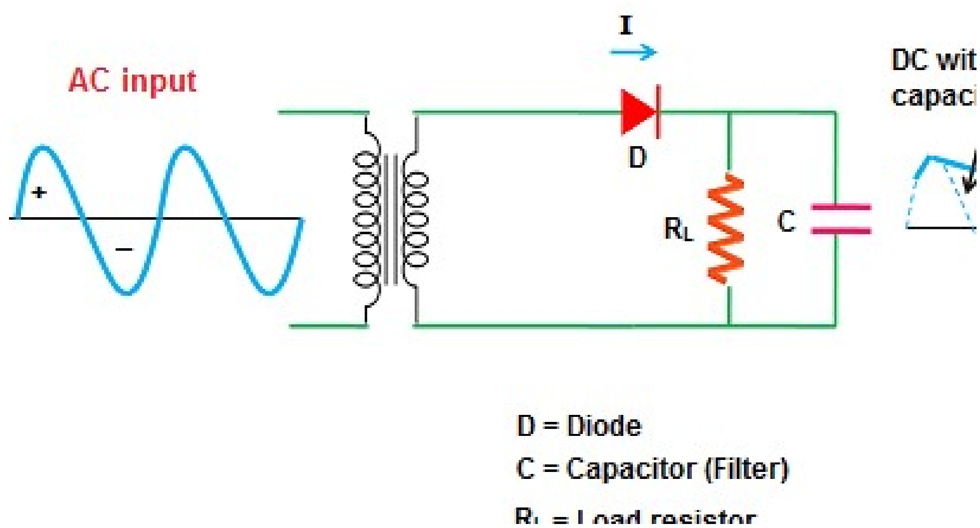
- Half-wave Rectifier
- Full-wave Rectifier

A Half-wave rectifier circuit rectifies only positive half cycles of the input supply whereas a Full-wave rectifier circuit rectifies both positive and negative half cycles of the input supply.

Half-Wave Rectifier

The name half-wave rectifier itself states that the **rectification** is done only for **half** of the cycle. The AC signal is given through an input transformer which steps up or down according to the usage. Mostly a step down transformer is used in rectifier circuits, so as to reduce the input voltage.

The input signal given to the transformer is passed through a PN junction diode which acts as a rectifier. This diode converts the AC voltage into pulsating dc for only the positive half cycles of the input. A load resistor is connected at the end of the circuit. The figure below shows the circuit of a half wave rectifier.



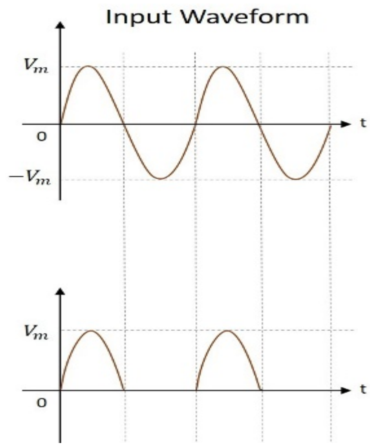
Working of a HWR

The input signal is given to the transformer which reduces the voltage levels. The output from the transformer is given to the diode which acts as a rectifier. This diode gets ON conducts for positive half cycles of input signal. Hence a current flows in the circuit and there will be a voltage drop across the load resistor. The diode gets OFF doesn't conduct for negative half cycles and hence the output for negative half cycles will be, i_D=0 and V_o=0.

Hence the output is present for positive half cycles of the input voltage only neglectingthereverseleakagecurrentneglectingthereverseleakagecurrent. This output will be pulsating which is taken across the load resistor.

Waveforms of a HWR

The input and output waveforms are as shown in the following figure.



Hence the output of a half wave rectifier is a pulsating dc. Let us try to analyze the above circuit by understanding few values which are obtained from the output of half wave rectifier.

Analysis of Half-Wave Rectifier

To analyze a half-wave rectifier circuit, let us consider the equation of input voltage.

Vo(t) = VmSin(wt) , $0 \le t \le T/2$ [for Ideal Diode]

Vo(t) = [Vm – 0.7V]Sin(wt) , $0 \le t \le T/2$ [for Si Diode]

Vo(t) = [Vm – 0.3V] Sin(wt) , $0 \le t \le T/2$ [for Ge Diode]

$$V_{dc} = \frac{1}{T}\int_0^T Vo(t)dt = \frac{1}{T}\left[\int_0^{T/2} Vo(t)dt + \int_{T/2}^{T} Vo(t)dt\right]$$

$$= \frac{1}{T}\int_0^{T/2} Vo(t)dt \qquad (\because \text{ No output wave form in the –Ve half cycle })$$

$$\Rightarrow \quad V_{dc} = \frac{1}{T}\int_0^{T/2} Vo(t)dt = \frac{1}{T}\int_0^{T/2} VmSin(wt)dt = \frac{Am}{T}\int_0^{T/2} Sin(\frac{2\pi t}{T})dt$$

$$\Rightarrow \quad = -\frac{Vm}{T}\frac{Cos\frac{2\pi t}{T}\Big]}{\frac{2\pi}{T}}$$

$$= -\frac{Vm}{2\pi}\left[Cos\left(\frac{2\pi}{T}\times\frac{T}{2}\right) - Cos\left(\frac{2\pi}{T}\times 0\right)\right] = -\frac{Vm}{2\pi}\left[Cos(\pi) - Cos(0)\right] = -\frac{Vm}{2\pi}[-1-1] = \frac{Vm}{\pi}$$

=0.318Vm(Ideal)

$\boxed{V_{dc}=0.318Vm(Ideal)}$

Similarly, The dc voltage for Si,Ge are

$\boxed{V_{dc}=0.318(Vm - 0.7V)\ (Si)}$
$\boxed{V_{dc}=0.318(Vm - 0.3V)\ (Ge)}$
$\boxed{\text{Here } V_{max} = V_m}$
$\boxed{V_{dc} = \frac{V_m}{\pi}}$

$$\boxed{I_{dc} = \frac{V_{dc}}{R_L} = \frac{V_m}{\pi R_L}}$$

$$I_{max} = \frac{V_{max}}{R_F+R_L} = \frac{V_{max}}{R_L} \quad (\,Since\ R_F \ll R_L)$$

RMS value of the output voltage

$$I_{rms}{}^2 = \frac{1}{2\pi}\left[\int_0^{2\pi} I_{max}{}^2 \sin^2\omega t d(\omega t) + \int_\pi^{2\pi} 0 d(\omega t)\right] = \frac{I_{max}{}^2}{4}$$

$$I_{rms} = \frac{I_{max}}{2}$$

$$V_{rms} = I_{rms}R_L$$

$$P_{dc} = I_{dc}{}^2 R_L = \left(\frac{I_{max}}{\pi}\right)^2 R_L$$

$$P_{ac} = I_{rms}{}^2(R_F + R_L) = \frac{I_{max}{}^2}{4}(R_F + R_L)$$

$$\text{Efficiency } \boldsymbol{\eta} = \frac{d.c.power\ delivered\ to\ the\ load}{a.c.input\ power\ from\ the\ transformer\ secondary}$$

$$= \frac{P_{dc}}{P_{ac}} = \frac{0.406}{1 + \frac{R_F}{R_L}}$$

$$\boldsymbol{\eta}\% \approx 40.6\%$$

Ripple Factor

The rectified output contains some amount of AC component present in it, in the form of ripples. This is understood by observing the output waveform of the half wave rectifier.

Ripple factor $\gamma = \sqrt{\left[\frac{I_{rms}}{I_{dc}}\right]^2 - 1} \cong 1.21$

The ripple factor gives the waviness of the rectified output.

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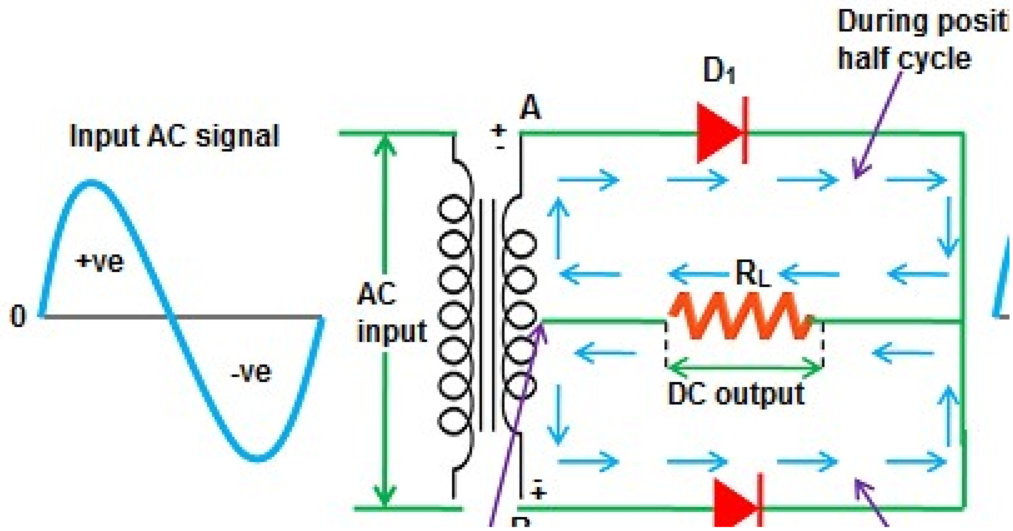
CENTER-TAPPED FULL-WAVE RECTIFIER

The center-tapped transformer with two rectifier diodes is used in the construction of a **Center-tapped full wave rectifier**. The circuit diagram of a center tapped full wave rectifier is as shown below.

When the positive half cycle of the input voltage is applied, the point A at the transformer secondary becomes positive with respect to the point B. This makes the diode $\mathbf{D_1}$forward biased. Hence current $\mathbf{i_1}$ flows through the load resistor from A to B. We now have the positive half cycles in the output.

When the negative half cycle of the input voltage is applied, the point A at the transformer secondary becomes negative with respect to the point B. This makes the diode $\mathbf{D_2}$ forward biased. Hence current $\mathbf{i_2}$ flows through the load resistor from A to B. We now have the positive half cycles in the output, even during the negative half cycles of the input.



$$I_{dc} = \frac{I_m}{\pi} + \frac{I_m}{\pi} = \frac{2I_m}{\pi} = 0.636I_m$$

$$V_{dc} = I_{dc} \times R_L = \frac{2 \times I_m R_L}{\pi} = 0.636 I_m R_L$$

$$I_{rms} = \sqrt{\left[\frac{1}{2\pi}\int_0^{2\pi} i^2 \, d(\omega t)\right]}$$

$$I_{rms} = \sqrt{\frac{{I_m}^2}{\pi}\int_0^{\pi} sin^2\,(\omega t) d(\omega t)}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$P_{ac} = \frac{(V_{rms})^2}{R_L} = \left(\frac{V_m}{\sqrt{2}}\right)^2$$

$$P_{dc} = \frac{{V_{dc}}^2}{R_L} = \left(\frac{2V_m}{\pi}\right)^2$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\left(\frac{2V_m}{\pi}\right)^2}{\left(\frac{V_m}{\sqrt{2}}\right)^2} = \frac{8}{\pi^2}$$

0.812=81.2%

$$\gamma = \sqrt{\left[\frac{I_{rms}}{I_{dc}} - 1\right]}$$