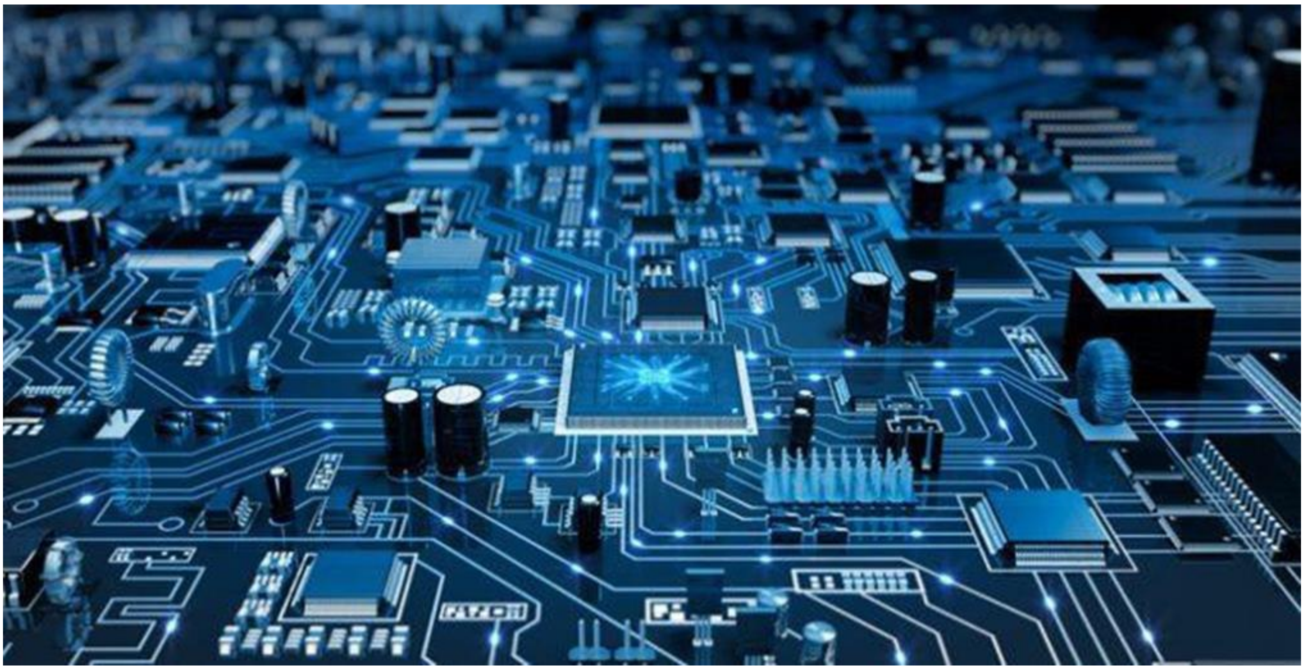
Al-Mustaqbal University
Department of Medical Instrumentation Techniques Eng
Class: Third
Subject: Medical Communication Systems
Lecturer: Prof. Adnan Ali
Lecture: 2

Mode Unit 2

Regulated Power Supplies (Part 1)

For
Students of Third Stage
Department of Medical Instrumentation Techniques Engineering



By

Adnan Ali
Professor
Dep. Medical Instrumentation
Techniques Engineering

2025

1. Overview

a. Target population:

For students of third class of Department of Medical Instrumentation Techniques Engineering, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq.

b. Rationale:

A regulated power supply converts unregulated AC (Alternating Current) to a constant DC (Direct Current). A regulated power supply is used to ensure that the output remains constant even if the input changes.

c. Objectives:

The student will be able after finishing lecture on:

- Identify the main components of regulated power supply.

2. Introduction:

A **regulated power supply** converts unregulated AC (Alternating Current) to a constant DC (Direct Current). A regulated power supply is used to ensure that the output remains constant even if the input changes. A regulated DC power supply is also known as a linear power supply, it is an embedded circuit and consists of various blocks.

The regulated power supply will accept an AC input and give a constant DC output. The figure below shows the block diagram of a typical regulated DC power supply.

The basic building blocks of a regulated DC power supply are as follows:

1. A step-down transformer
2. A rectifier
3. A DC filter
4. A regulator

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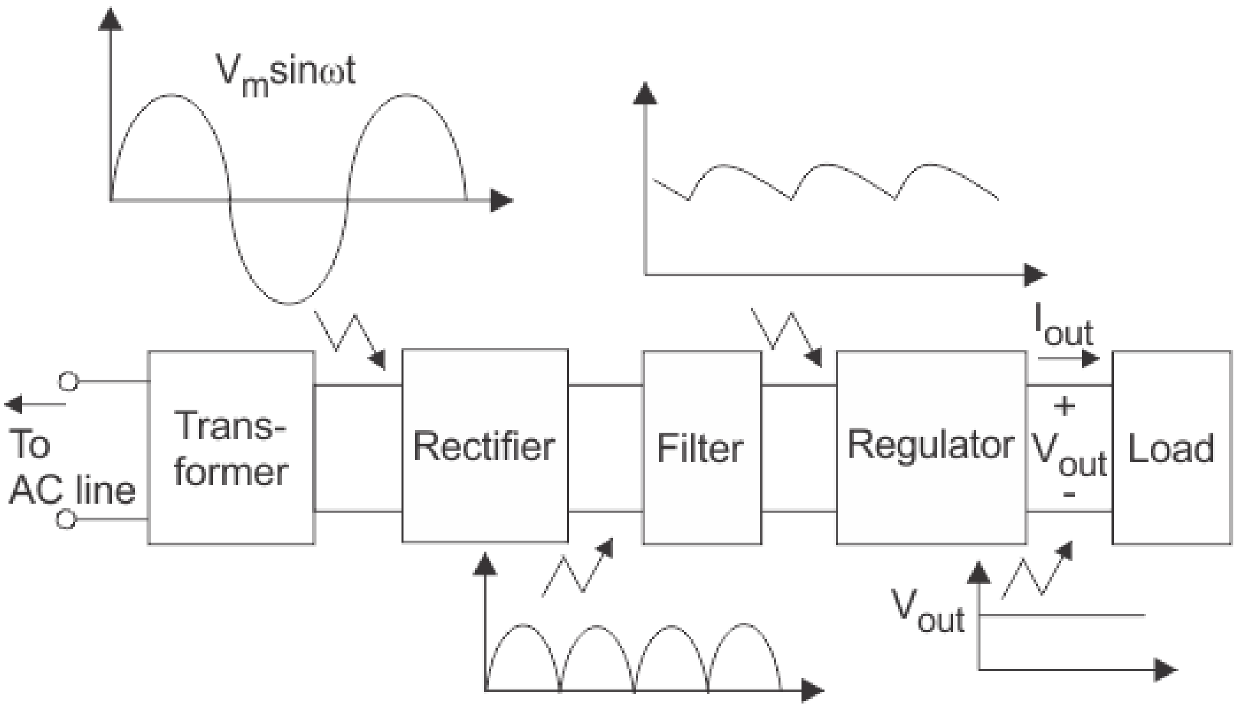

Components of typical linear power supply

Operation of Regulated Power Supply

Step Down Transformer

A step down transformer will step down the voltage from the ac mains to the required voltage level. The turn's ratio of the transformer is so adjusted such as to obtain the required voltage value. The output of the transformer is given as an input to the rectifier circuit.

Rectification

Rectifier is an electronic circuit consisting of **diodes** which carries out the rectification process. Rectification is the process of converting an alternating voltage or current into corresponding direct (DC) quantity. The input to a rectifier is AC whereas its output is unidirectional pulsating DC.

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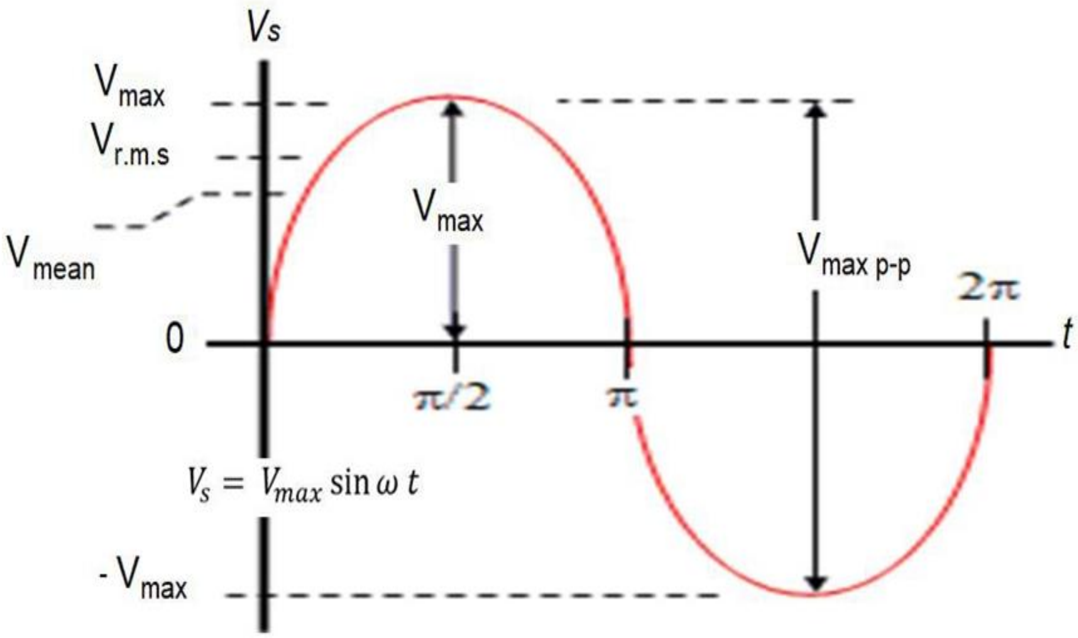
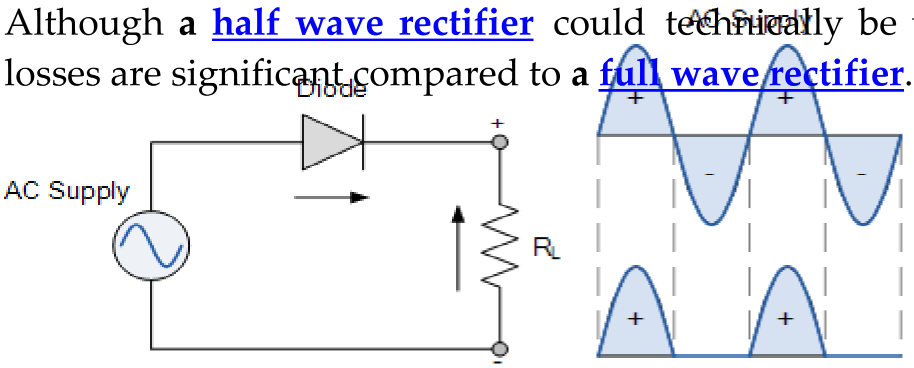
There are a number of ways in which the amplitude of a sinewave is referenced, usually as peak voltage (V_{pk}, V_p or V_{max}) peak-to-peak voltage ($V_{p.p}$), average voltage (V_{avg}), and root-mean-square voltage (V_{rms}). Peak voltage and peak-to-peak voltage are apparent by looking at the above plot. Root-mean-square and average voltage are not so apparent.



As the name implies, V_{rms} is calculated by taking the square root of the mean average of the square of the voltage in an appropriately chosen interval. In the case of symmetrical waveforms like the sinewave, a quarter cycle faithfully represents all four quarter cycles of the waveform. Therefore, it is acceptable to choose the first quarter cycle, which goes from 0 radians (0°) through p/2 radians (90°).

V_{rms} is the value indicated by the vast majority of AC voltmeters. It is the value that, when applied across a resistance, produces that same amount of heat that a direct current (DC) voltage of the same magnitude would produce. For example, 1 V applied across a 1 Ω resistor produces 1 W of heat. A 1 V_{rms} sinewave applied across a 1 Ω resistor also produces 1 W of heat. That 1 V_{rms} sinewave has a peak voltage of √2 V (≈1.414 V), and a peak-to-peak voltage of 2√2 V (≈2.828 V).

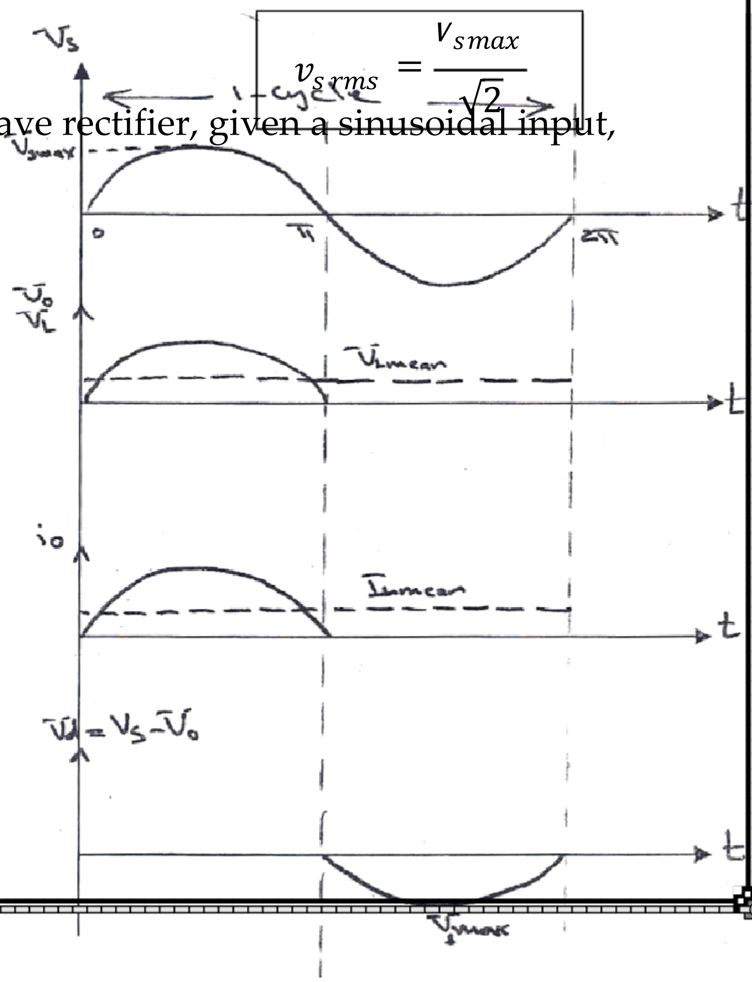
Average voltage or mean voltage (V_{mean}) is calculated by taking the average of the voltage in an appropriately chosen interval. Therefore, it is acceptable to choose the first quarter cycle, which goes from 0 radians (0°) through p/2 radians (90°).
As with the V_{rms} formula, a full derivation for the V_{mean} formula is given here as well.
Although **a** half wave rectifier could technically be used, its power losses are significant compared to **a** full wave rectifier.



Rectified Output Waveform
No Negative Half-cycle

$$v_{s\,rms} = \frac{V_{s\,max}}{\sqrt{2}}$$

The output DC voltage of a half wave rectifier, given a sinusoidal input, can be calculated with the following ideal equations:



V_{av} or V_{dc} or V_{lmean}

$$= \frac{1}{T}\int_0^T f(t)dt$$

$$= \frac{1}{2\pi}\int_0^\pi V_{s\,max}\sin\theta d\theta$$

$$= \frac{V_{s\,max}}{2\pi}\int_0^\pi \sin\theta d\theta = \frac{V_{s\,max}}{2\pi}[-\cos\theta]_0^\pi$$

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$$\therefore\ V_{lmean} = \frac{V_{smax}}{\pi}$$

$$\therefore\ I_{lmean} = \frac{V_{lmean}}{R}$$

$$v_{o\,rms} = \sqrt{\frac{1}{T}\int_0^T V^2(t)dt}$$

$$v_{0\,rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_{smax}{}^2 sin^2\theta d\theta}$$

$$= V_{smax}\sqrt{\frac{1}{2\pi}\int_0^{\pi}\frac{1}{2}(1 - cos2\theta)d\theta}$$

$$sin^2\theta = \frac{1}{2}(1 - cos2\theta)$$

$$= V_{smax}\sqrt{\frac{1}{4\pi}\int_0^{\pi} 1d\theta - \frac{1}{2}\int_0^{\pi} cos2\theta\, d\theta} = V_{smax}\sqrt{\frac{1}{4\pi}\int_0^{\pi}(1 - cos2\theta)d\theta}$$

$$= V_{smax}\sqrt{\frac{1}{4\pi}\left[\theta - \frac{sin2\theta}{2}\right]_0^{\pi}}$$

$$= V_{smax}\sqrt{\frac{1}{4\pi}\left[\pi - \frac{sin2\pi}{2} - 0 + \frac{sin2\times 0}{2}\right]}$$

$$== V_{smax}\sqrt{\frac{1}{4\pi}[\pi]}$$

$$v_{0\,rms} = \frac{V_{smax}}{2}$$

$$\therefore\ i_{0\,rms} = \frac{v_{o\,rms}}{R}$$

Rectification efficiency ($\mathcal{J}$) $= \frac{P_{dc}}{P_{ac}} = \frac{I_{mean}.V_{mean}}{i_{rms}.v_{rms}}$

Ex1: For the 1-φ half wave rectifier circuit shown in Figure below, $R = 1.3K\Omega$, $V_s = 150\ sinwt$. Calculate V_{Lmean}, I_{Lmean}, $v_{s_{r.m.s}}$, $v_{o_{r.m.s}}$, $i_{o_{r.m.s}}$, $form\ factor\ (FF) and\ ripple\ factor\ (RF)$.

Solution: الحل بعد االشتقاق

$$V_{lmean} = \frac{V_{s\,max}}{\pi} = \frac{150}{3.14} = 47.7\ V$$

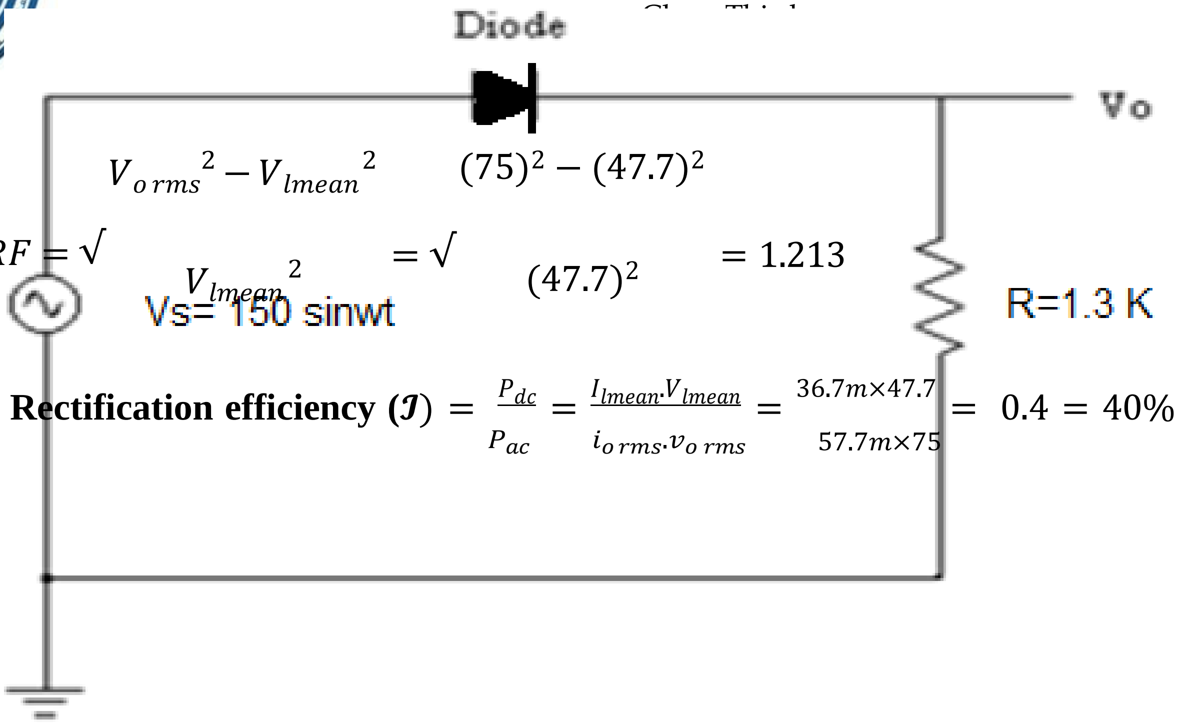
$$I_{lmean} = \frac{V_{lmean}}{R} = \frac{47.7}{1.3k} = 36.7\ mA$$

$$v_{s\,rms} = \frac{V_{s\,max}}{\sqrt{2}} = \frac{150}{\sqrt{2}} = 106.06\ V$$

$$v_{o\,rms} = \frac{V_{s\,max}}{2} = \frac{150}{2} = 75\ V$$

$$i_{o\,rms} = \frac{v_{o\,rms}}{R} = \frac{75}{1.3k} = 57.7\ mA$$

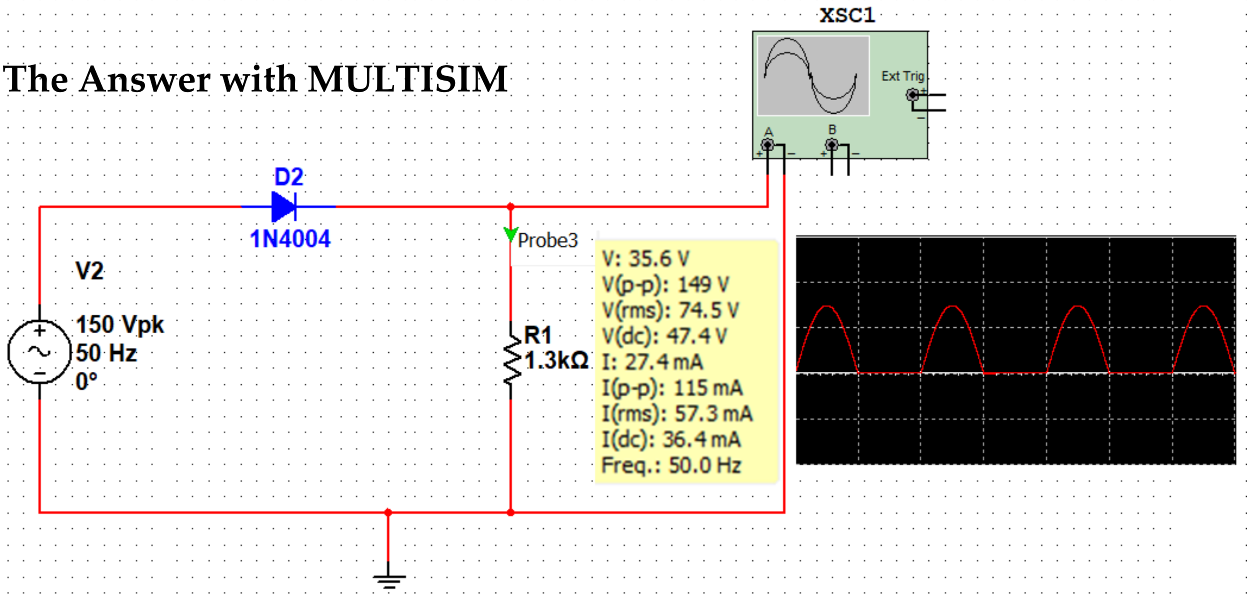
$$FF = \frac{v_{o\,rms}}{V_{lmean}} = \frac{75}{47.7} = 1.57$$



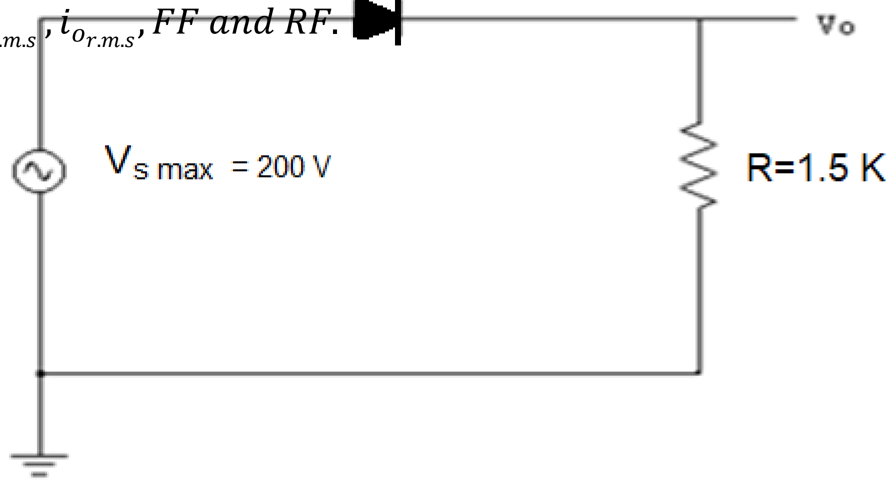
$$RF = \sqrt{\frac{V_{o\,rms}{}^{2} - V_{lmean}{}^{2}}{V_{lmean}{}^{2}}} = \sqrt{\frac{(75)^2 - (47.7)^2}{(47.7)^2}} = 1.213$$

Rectification efficiency $(\mathcal{J}) = \frac{P_{dc}}{P_{ac}} = \frac{I_{lmean}.V_{lmean}}{i_{o\,rms}.v_{o\,rms}} = \frac{36.7m \times 47.7}{57.7m \times 75} = 0.4 = 40\%$

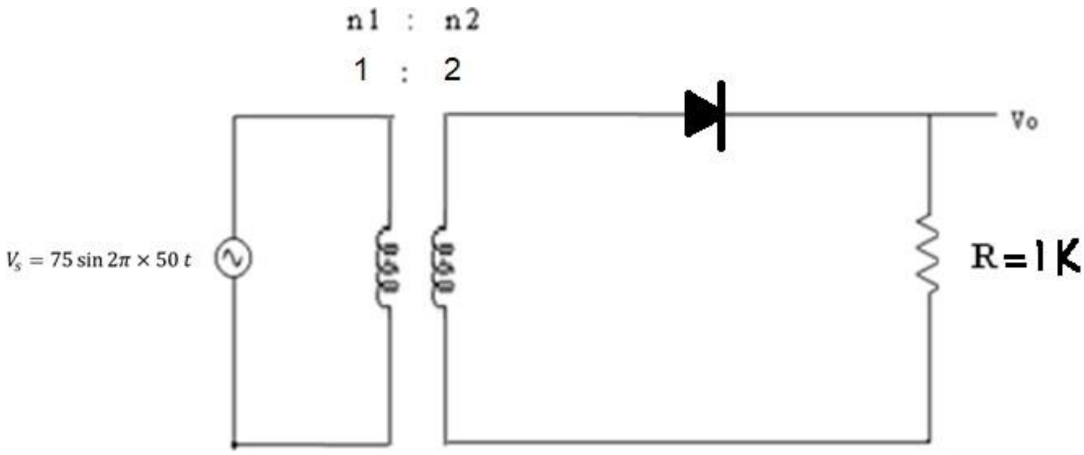
The Answer with MULTISIM



Ex2: (H.W) For the 1-φ half wave rectifier circuit shown in Figure below, $R = 10\Omega$, $V_s = 200$ volt. Determine V_{Lmean}, I_{Lmean}, $v_{s_{r.m.s}}$, $v_{o_{r.m.s}}$, $i_{o_{r.m.s}}$, FF and RF.

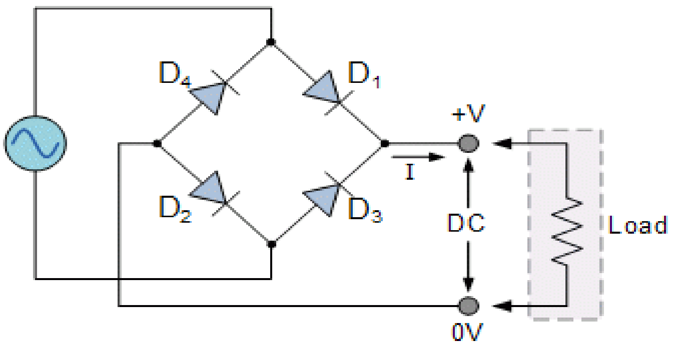


Ex3 (H.W): For the 1-φ half wave rectifier circuit shown in Figure below,



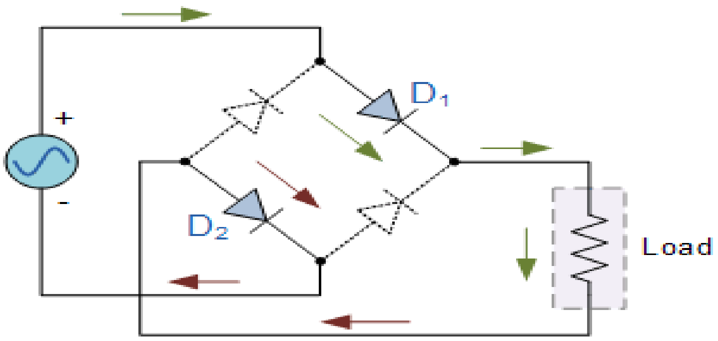
has a purety resistor load of *R*=1K, determine

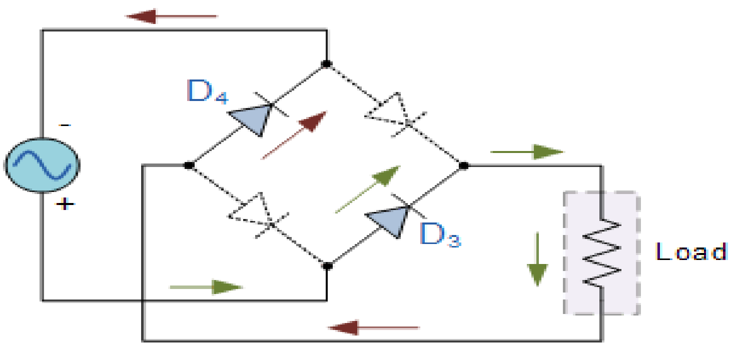
1. Efficiency.
2. FF.
3. RF.



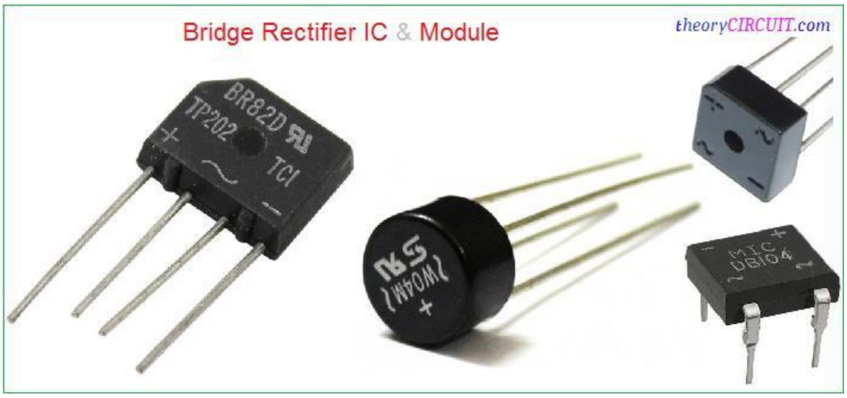
A full wave rectifier or a **bridge rectifier** is used to rectify both the half cycles of the ac supply (full wave rectification). The figure below shows a full wave bridge rectifier.

A bridge rectifier consists of four **p-n junction diodes** connected in the manner shown above. In the positive half cycle of the supply, the voltage induced across the secondary of the **electrical transformer** i.e. VMN is positive. Therefore point E is positive with respect to F. Hence, diodes D_3 and D_2 are reversed biased and diodes D_1 and D_2 are forward biased. The **diode** D_3 and D_4 will act as open switches (practically there is some **voltage drop**) and diodes D_1 andD_2 will act as closed switches and will start conducting.





Hence a rectified waveform appears at the output of the rectifier as shown in the first figure. When voltage induced in secondary i.e. VMN is negative than D_3 and D_4 are forward biased with the other two reversed biased and a positive **voltage** appears at the input of the filter.



Ex4: For the 1-φ full wave rectifier circuit shown in Figure below, $R = 10k\Omega$, $V_{smax} = 200$ volt. Determine V_{Lmean}, I_{Lmean}, $v_{o_{r.m.s}}$, $i_{o_{r.m.s}}$, RF and rectifier efficiency.

$$V_{lmean} = \frac{1}{2\pi}\int_0^{\pi} V_{s\,max} sin\theta d\theta \times 2$$

$$= \frac{V_{s\,max}}{\pi}\int_0^{\pi} sin\theta d\theta$$

$$= -\frac{V_{s\,max}}{\pi}[cos\pi - cos0]$$

$$V_{lmean} = \frac{2 \times 200}{3.14} = 127.3\ V$$

$$\therefore\ I_{lmean} = \frac{V_{lmean}}{R}$$

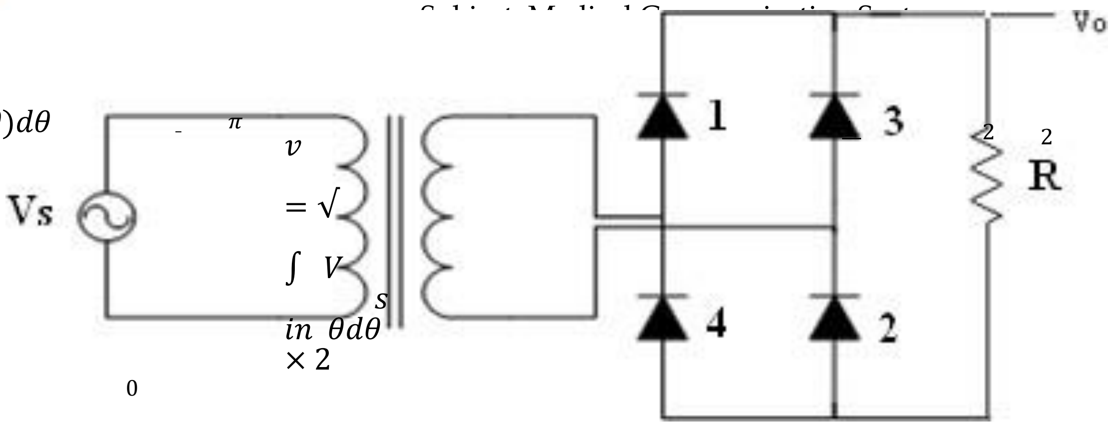
$$= \frac{172.3}{10k} = 12.7\ mA$$

$$v_{s\,rms} = \frac{V_{s\,max}}{\sqrt{2}}$$

$\overline{V}_{smax}\sqrt{}$

$\pi \int$

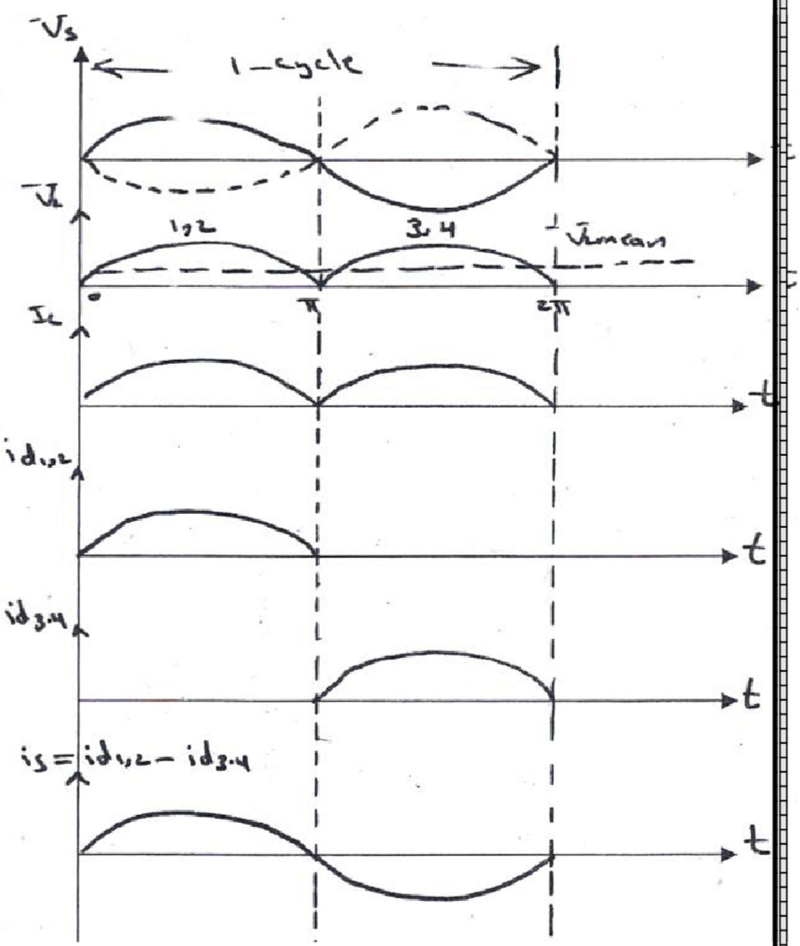
1 $\qquad$ $^{\pi}$ 1



2 $(1 - cos2\theta)d\theta$ π

$v = \sqrt{\int V_s in \ \theta d\theta \times 2}$

0



$$= \frac{V_{s\,max}}{\pi}[-cos\theta]_0^{\pi}$$

$$\therefore \ V_{lmean} = \frac{2\,V_s}{max}$$

$$sin^2\theta = \frac{1}{2}(1 - cos2\theta)$$

$$= V_{smax}\sqrt{\frac{1}{2\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}}$$

$$= V_{smax}\sqrt{\frac{1}{2\pi}\left[\pi - \frac{\sin 2\pi}{2} - 0 + \frac{\sin 2\times 0}{2}\right]}$$

$$== V_{smax}\sqrt{\frac{1}{2\pi}[\pi]}$$

$$\boxed{v_{0\,rms} = \frac{V_{smax}}{\sqrt{2}}}$$

$$= \frac{200}{\sqrt{2}} = 141.4\ V$$

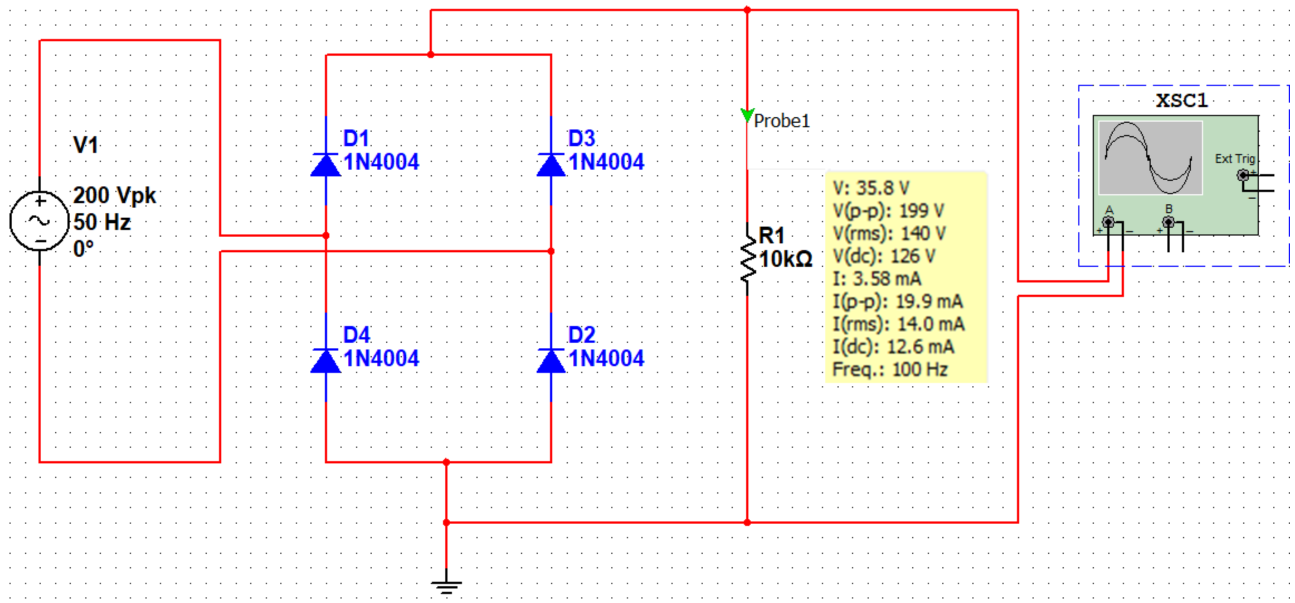
$$\boxed{\therefore\ i_{0\,rms} = \frac{v_{o\,rms}}{R}}$$

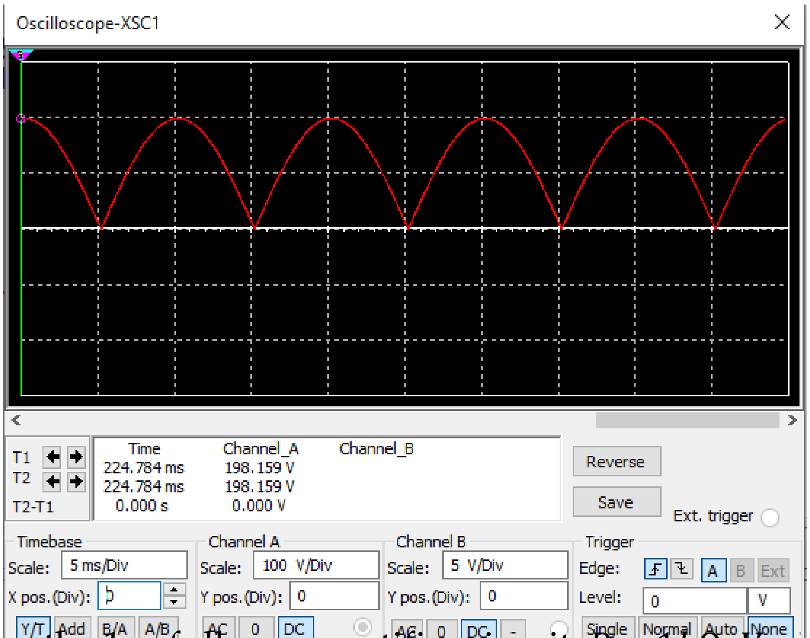
$$= \frac{141.4}{10k} = 14.14\ mA$$

$$RF = \sqrt{\frac{V_{o\,rms}{}^2 - V_{lmean}{}^2}{V_{lmean}{}^2}} = \sqrt{\frac{(141.4)^2 - (127.3)^2}{(127.3)^2}} = 0.48$$

Rectification efficiency $(\mathcal{J}) = \frac{P_{dc}}{P_{ac}} = \frac{I_{lmean}.V_{lmean}}{i_{o\,rms}.v_{o\,rms}} = \frac{12.7m\times127.3}{14.14m\times141.4} = 0.8 = 80\%$

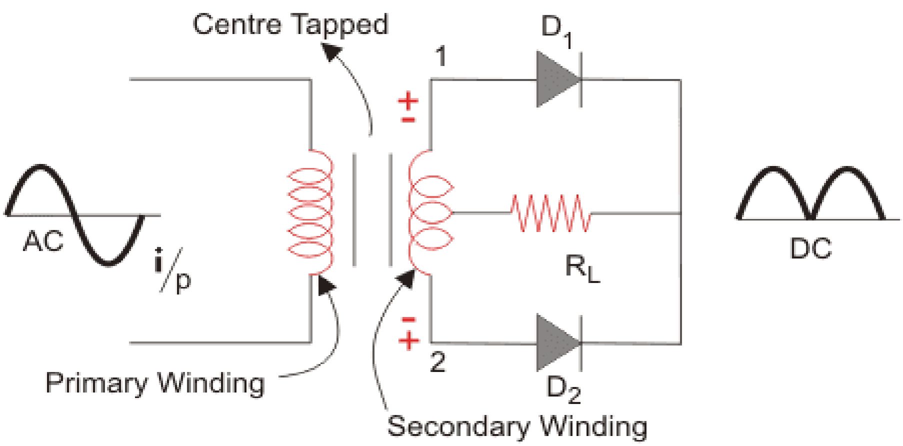
The Answer with MULTISIM



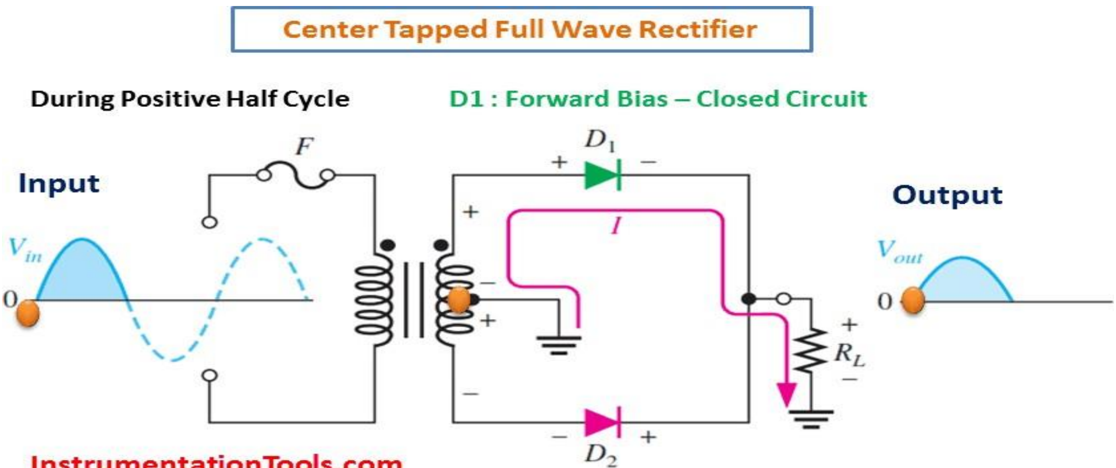


Ex5 (H.W): For the 1-φ full wave rectifier circuit, $R = 1k\Omega$, $V_s = 100 \sin wt$. Determine $V_{Lmean}, I_{Lmean}, v_{o_{r.m.s}}$ *and* $i_{o_{r.m.s}}$

A **center-tapped rectifier** is a type of full-wave rectifier that uses two diodes connected to the secondary of a center-tapped transformer, as shown in Below Figure. The input voltage is coupled through the transformer to the center-tapped secondary. Half of the total secondary voltage appears between the center tap and each end of the secondary winding as shown.

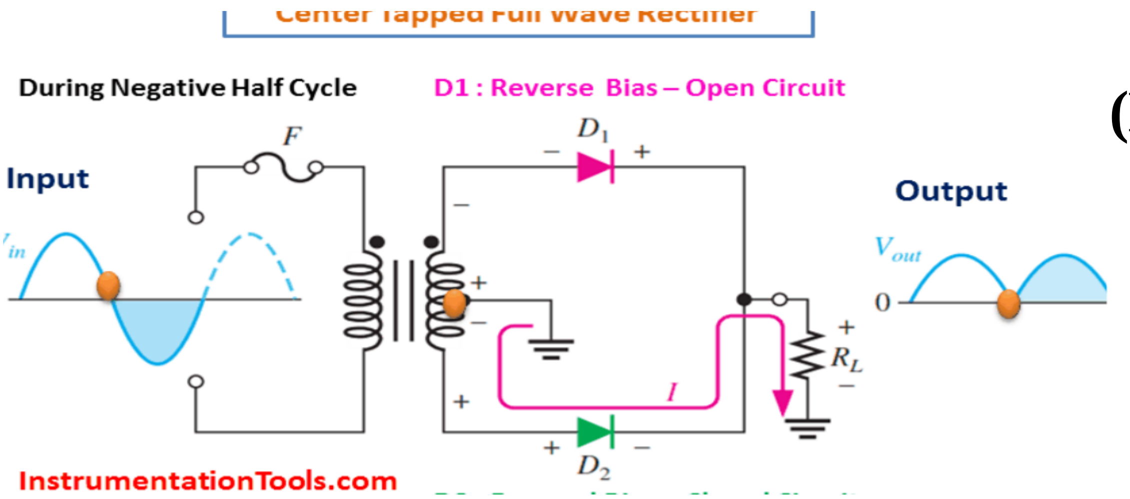


Centre Tapped Full Wave Rectifier
Figure - 1



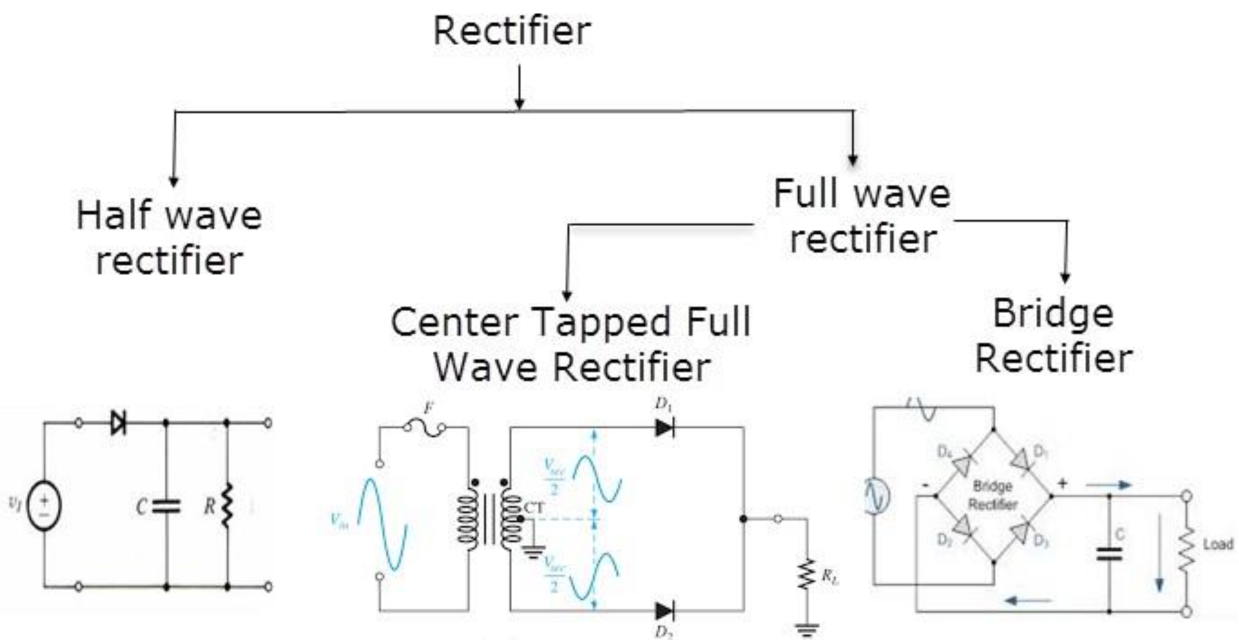
For a positive half-cycle of the input voltage, the polarities of the secondary voltages are as shown in Figure (a). This condition forward-biases diode D1 and reverse-biases diode D2. The current path is through D1 and the load resistor RL, as indicated.

For a negative half-cycle of the input voltage, the voltage polarities on the secondary are as shown in Figure (b). This condition reverse-biases D1 and forward-biases D2. The current path is through D2 and RL, as indicated. Because the output current during both the positive and negative portions of the input cycle is in the same direction through the load, the output voltage developed across the load resistor is a full-wave rectified dc voltage, as shown.



(B)

(b) During negative half-cycles, D2 is forward-biased and D1 is reverse-biased.



Comparison of Rectifiers

Properties	Half Wave Rectifier	Full Wave Center Tap Rectifier	Full Wave Bridge Rectifier
Number of Diodes	1	2	4
D.C Current	Im / π	2 Im / π	2 Im / π
Transformer Necessary	No	Yes	No
Max Value of Current	Vm / (rf + RL)	Vm / (rf + RL)	Vm / (2rf + RL)
Ripple Factor	1.21	0.482	0.482
O/P Frequency	fin	2 fin	2 fin