Ministry of Higher Education
University of Al-Maarif
Medical Instruments Engineering Techniques Department

Medical electronic systems

For
Students of Third class

Unit ONE
Regulated power supplied

By

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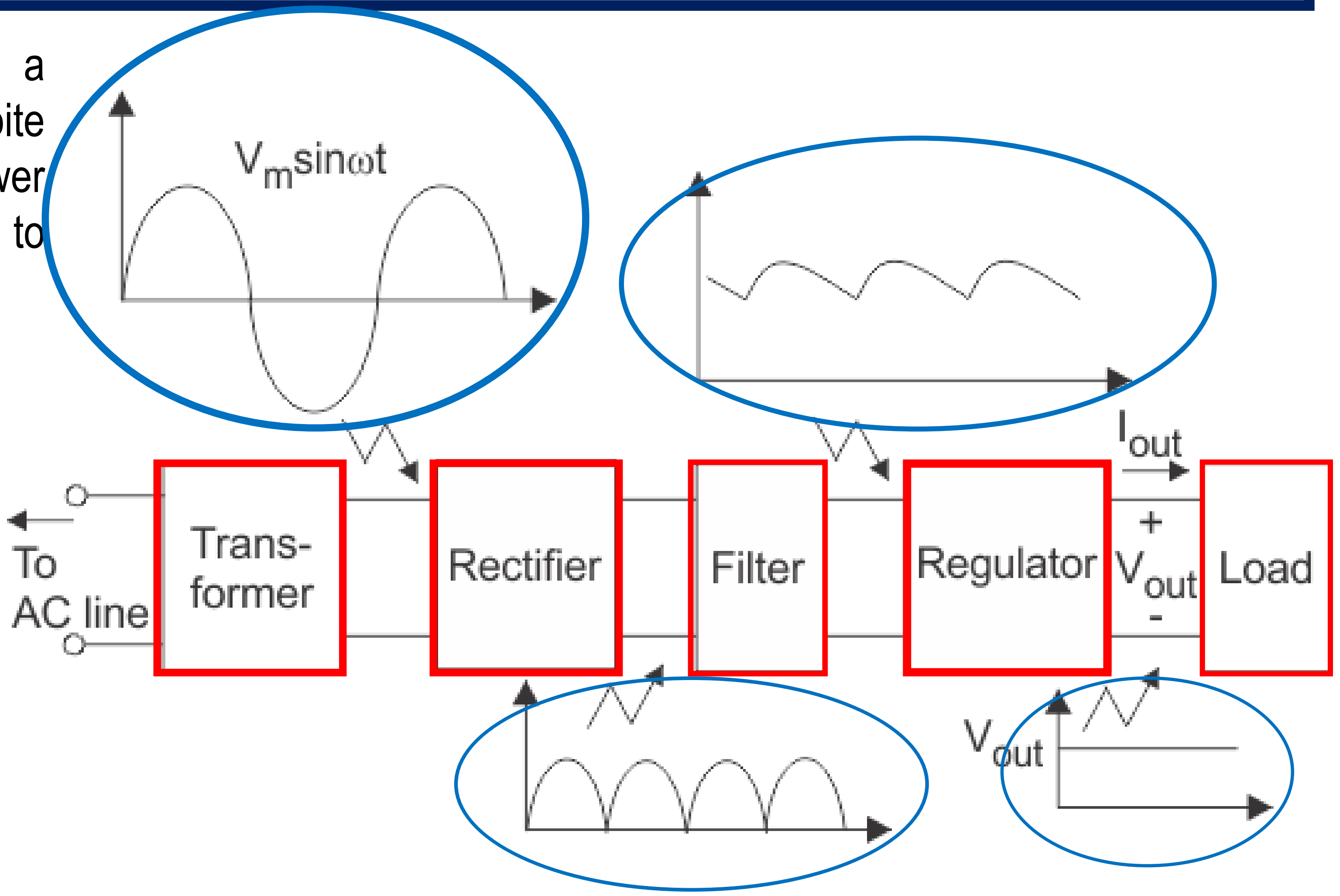
Regulated power supply

A **regulated power supply** converts AC to a **stable** DC output, ensuring consistency despite input fluctuations. Also called a linear power supply, it consists of various circuit blocks to maintain a constant DC output from an AC input.

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**

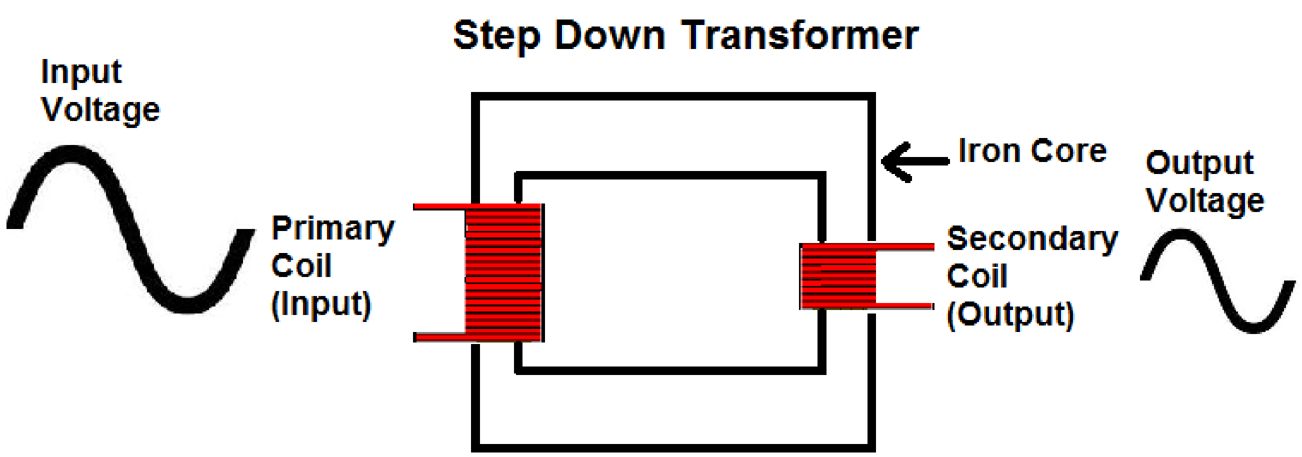


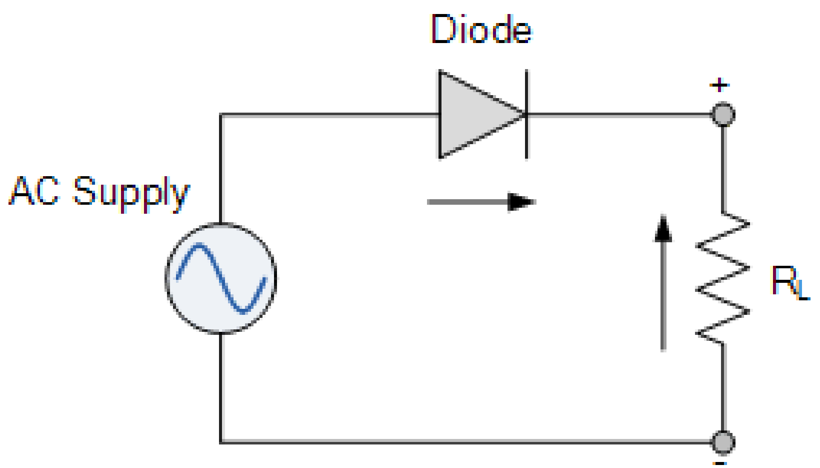
Components of typical linear power supply

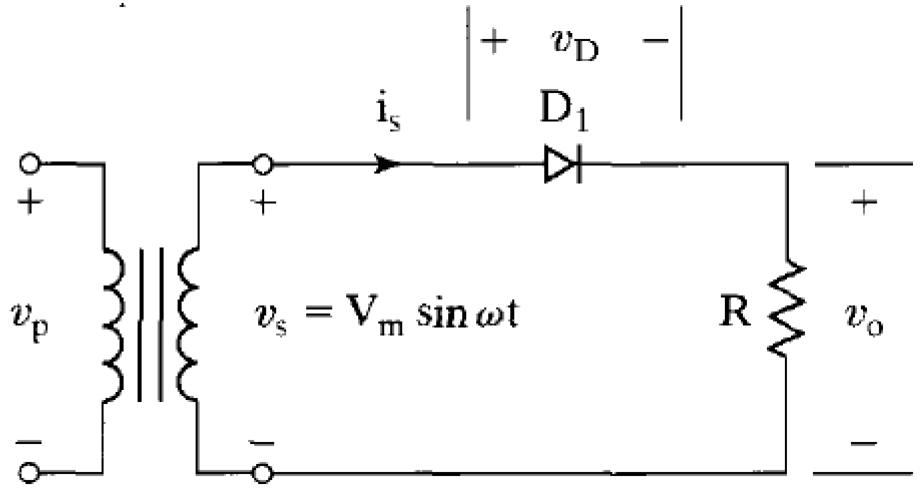
Regulated power supply

A step-down transformer reduces AC mains voltage to the required level for the rectifier circuit.

$$\therefore \frac{V_{s1\,max}}{V_{s2\,max}} = \frac{n_1}{n_2}$$



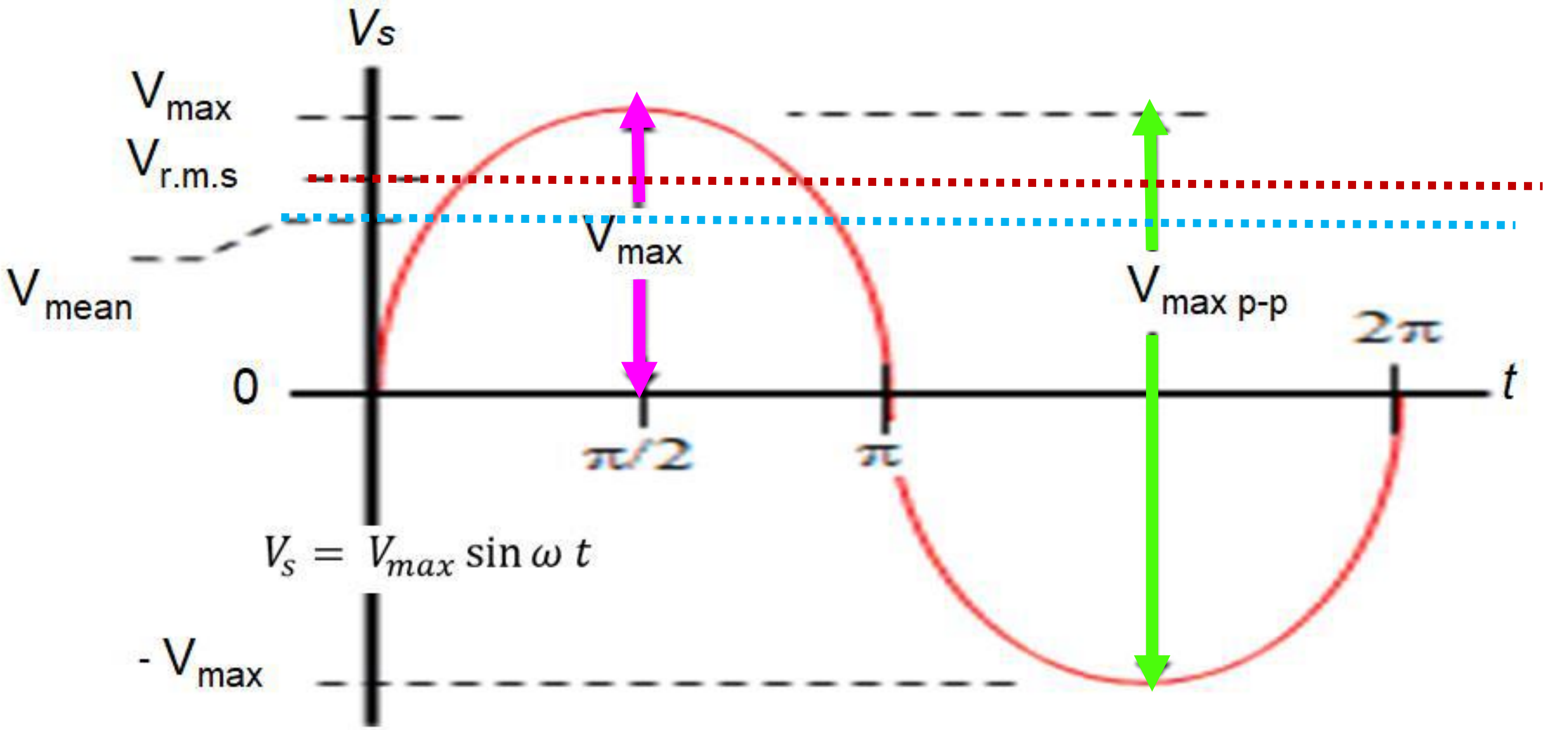




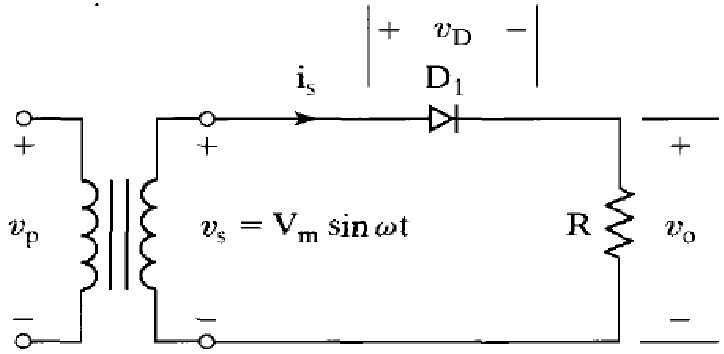
Regulated power supply

A rectifier is a circuit with diodes that converts AC into pulsating DC. It transforms alternating voltage or current into direct current. Key voltage measures include **peak voltage**, **peak-to-peak voltage**, **average voltage**, and **root-mean-square voltage**. Peak and peak-to-peak voltages are visible on plots, while average and RMS voltages are less apparent.

$$Vs\,rms = \frac{Vs\,max}{\sqrt{2}}$$



Single phase Half wave Rectifier



$$V_{L\,mean} = \frac{1}{T}\int_0^T f(t)dt$$

$$V_{L\,mean} = \frac{1}{2\pi}\int_0^\pi Vs\,max\ \ Sin\theta d\theta$$

$$V_{L\,mean} = \frac{Vs\,max}{2\pi}\int_0^\pi Sin\theta d\theta$$

$$V_{L\,mean} = \frac{Vs\,max}{2\pi} . -\cos\theta\Big|_0^\pi$$

$$V_{L\,mean} = \frac{Vs\,max}{2\pi} . -(-1-1)$$

$$V_{L\,mean} = \frac{Vs\,max}{2\pi} . 2$$

$$V_{L\,mean} = \frac{Vs\,max}{\pi}$$

$$I_{L\,mean} = \frac{V_{L\,mean}}{R}$$

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

$$V_{o\,rms} = \sqrt{\frac{1}{2\pi}\int_0^\pi (Vs\,max\ \ Sin\theta)^2 d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi}\int_0^\pi Sin\theta^2 d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi}\int_0^\pi Sin\theta^2 d\theta}$$

Hint $Sin\theta^2 = \frac{1}{2}(1 - Cos2\theta)$

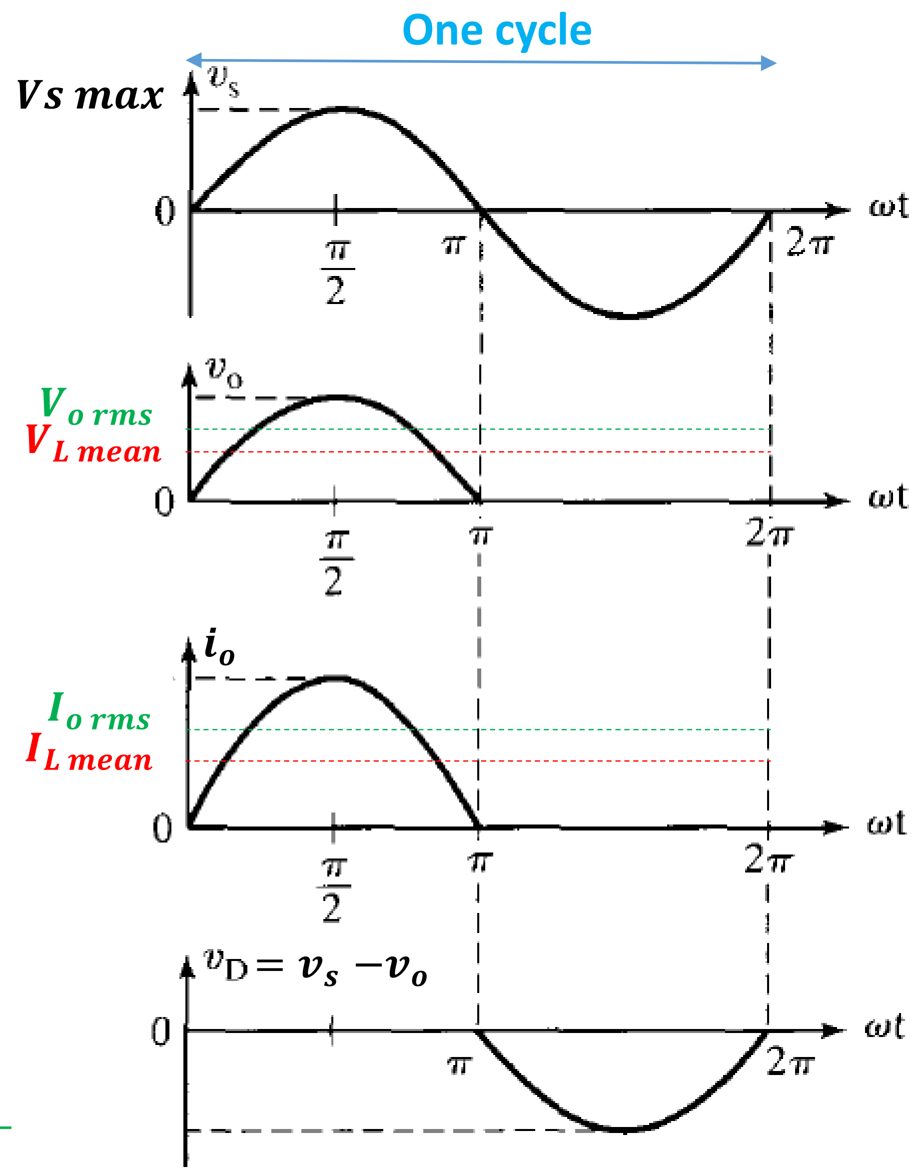
$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi}\int_0^\pi \frac{1}{2}(1 - Cos2\theta)\ d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi} . \frac{1}{2}\int_0^\pi (1 - Cos2\theta)\ d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi} . \frac{1}{2} . \left(\theta - \frac{1}{2}Sin2\theta\right)\Big|_0^\pi}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi} . \frac{1}{2} . \left(\pi - \frac{1}{2}Sin2\pi - \left[0 - \frac{1}{2}Sin0\right]\right)}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2\pi} . \frac{\pi}{2}} \Rightarrow V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{4}} \Rightarrow$$



$$V_{o\,rms} = \frac{Vsmax}{2}$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{R}$$

$$Form\ Factor, FF = \frac{V_{rms}}{V_{L\,mean}}$$

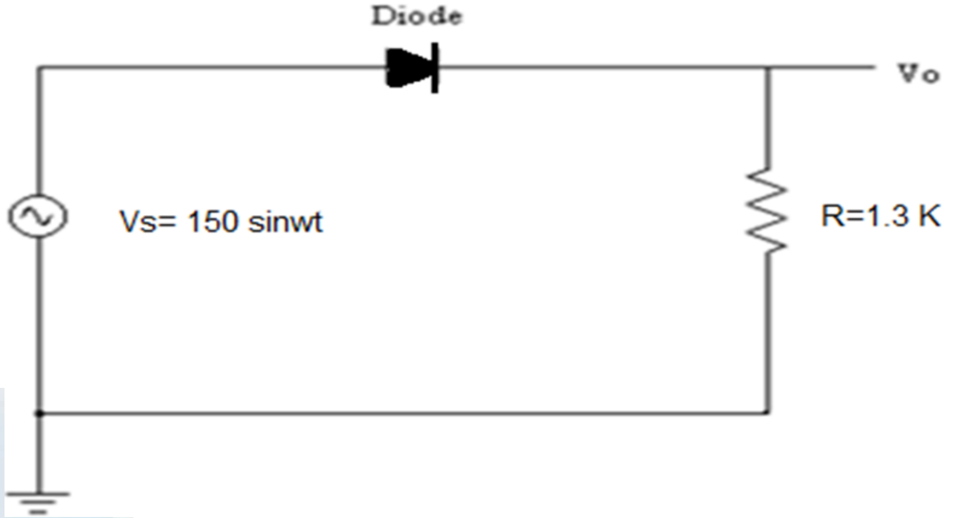
$V_{L\,mean}$ or V_{av} or V_{DC}

$$Ripple\ Factor, \quad RF = \sqrt{\left(\frac{V_{rms}}{V_{L\,mean}}\right)^2 - 1.}$$

$$RF = \sqrt{FF^2 - 1.}$$

$$Rectification\ efficiency \quad \eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{L\,mean}V_{L\,mean}}{I_{o\,rms}V_{o\,rms}}$$

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



Sol: الحل بعد الاشتقاق

$$V_{L\,mean} = \frac{Vs\,max}{\pi}$$

$$V_{L\,mean} = \frac{150}{\pi}$$

$$\boxed{V_{L\,mean} = 47.7\ V}$$

$$I_{L\,mean} = \frac{V_{L\,mean}}{R}$$

$$I_{L\,mean} = \frac{47.7}{1.3\ K}$$

$$\boxed{I_{L\,mean} = 36.7\ mA}$$

$$V_{o\,rms} = \frac{Vsmax}{2}$$

$$V_{o\,rms} = \frac{150}{2}$$

$$\boxed{V_{o\,rms} = 75\ V}$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{R}$$

$$I_{o\,rms} = \frac{75}{1.3K}$$

$$\boxed{I_{o\,rms} = 57.7\ mA}$$

$$Form\ Factor, FF = \frac{V_{rms}}{V_{L\,mean}}$$

$$Form\ Factor, FF = \frac{75}{47.7} = 1.572$$

$$RF = \sqrt{\left(\frac{V_{rms}}{V_{L\,mean}}\right)^2 - 1.}$$

$$RF = \sqrt{\left(\frac{75}{47.7}\right)^2 - 1.}$$

$$\boxed{RF = 1.213}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{L\,mean}V_{L\,mean}}{I_{o\,rms}V_{o\,rms}}$$

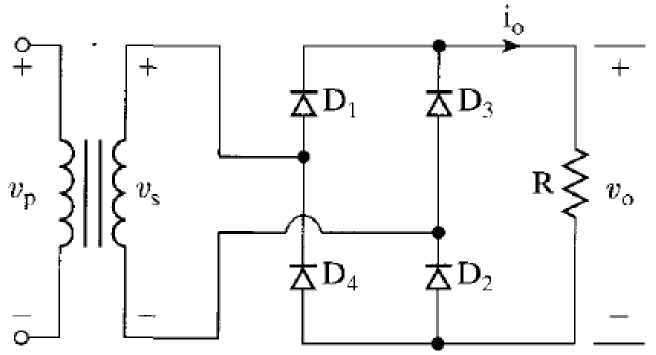
$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{36.7 \times 47.7}{57.7 \times 75}$$

$$\boxed{\eta = \frac{P_{dc}}{P_{ac}} = 40\%}$$

$$Vs\ rms = \frac{Vs\ max}{\sqrt{2}}$$

$$Vs\ rms = \frac{150}{\sqrt{2}} = 106.06\ V$$

Single phase Full wave Rectifier



$$V_{L\,mean} = \frac{1}{T}\int_0^T f(t)\,dt$$

$$V_{L\,mean} = \frac{1}{2\pi}\int_0^{\pi} Vs\,max\ \ Sin\theta \times 2d\theta$$

$$V_{L\,mean} = \frac{2Vs\,max}{2\pi}\int_0^{\pi} Sin\theta\, d\theta$$

$$V_{L\,mean} = \frac{Vs\,max}{\pi}\ .\ -\cos\theta\Big|_0^{\pi}$$

$$V_{L\,mean} = \frac{Vs\,max}{\pi}\ .\ -(-1-1)$$

$$V_{L\,mean} = \frac{Vs\,max}{\pi}\ .\ 2$$

$$V_{L\,mean} = \frac{2Vs\,max}{\pi}$$

$$I_{L\,mean} = \frac{V_{L\,mean}}{R}$$

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

$$V_{o\,rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} (Vs\,max\ \ Sin\theta)^2 \times 2d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{2Vs\,max^2}{2\pi}\int_0^{\pi} Sin\theta^2\,d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{\pi}\int_0^{\pi} Sin\theta^2\,d\theta}$$

Hint $Sin\theta^2 = \frac{1}{2}(1 - Cos2\theta)$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{\pi}\int_0^{\pi} \frac{1}{2}(1 - Cos2\theta)\ d\theta}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{\pi}\ .\ \frac{1}{2}\int_0^{\pi} (1 - Cos2\theta)\ d\theta}$$

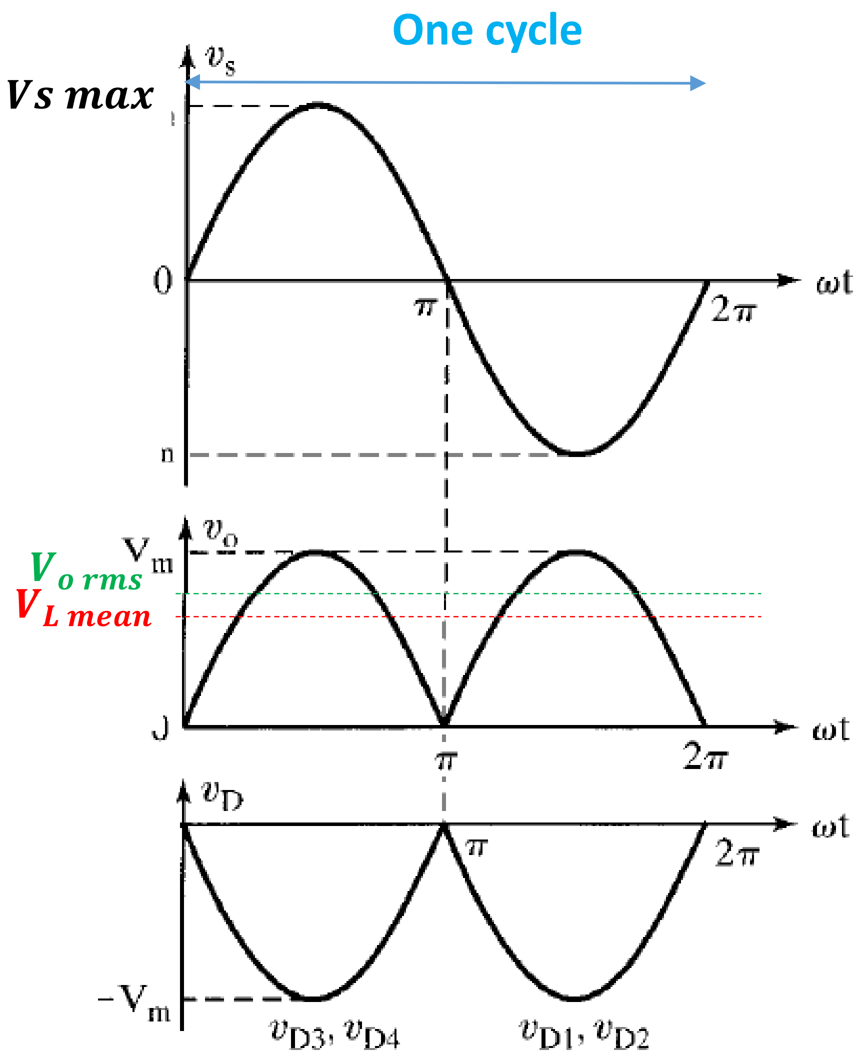
$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{\pi}\ .\ \frac{1}{2}\ .\ \left(\theta - \frac{1}{2}Sin2\theta\right)\Big|_0^{\pi}}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{\pi}\ .\ \frac{1}{2}\ .\ \left(\pi - \frac{1}{2}Sin2\pi - \left[0 - \frac{1}{2}Sin0\right]\right)}$$

$$V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{\pi}\ .\ \frac{\pi}{2}} \ \Rightarrow\ V_{o\,rms} = \sqrt{\frac{Vs\,max^2}{2}} \ \Rightarrow$$

$$V_{o\,rms} = \frac{Vsmax}{\sqrt{2}}$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{R}$$



$$Form\ Factor, FF = \frac{V_{rms}}{V_{L\,mean}}$$

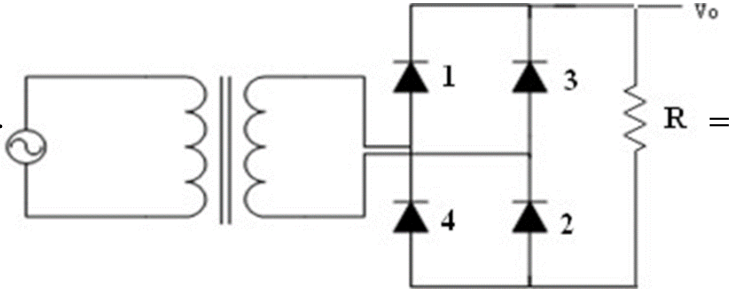
$$V_{L\,mean} \quad or \quad V_{av} \quad or \quad V_{DC}$$

$$Ripple\ Factor, \qquad RF = \sqrt{\left(\frac{V_{rms}}{V_{L\,mean}}\right)^2 - 1.}$$

$$RF = \sqrt{FF^2 - 1.}$$

$$Rectification\ efficiency \qquad \eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{L\,mean}V_{L\,mean}}{I_{o\,rms}V_{o\,rms}}$$

Ex2: For the 1-φ full wave rectifier circuit shown in Figure below, $R = 10k\Omega$, $Vsmax = 200$ volt. Determine V_{Lmean}, I_{Lmean} , v_{orms}, i_{orms}, RF and rectifier efficiency.



Sol: الحل بعد الاشتقاق

$$V_{L\,mean} = \frac{2Vs\,max}{\pi}$$

$$V_{L\,mean} = \frac{2(200)}{\pi}$$

$$V_{L\,mean} = 127.3\ V$$

$$V_{o\,rms} = \frac{Vsmax}{\sqrt{2}}$$

$$V_{o\,rms} = \frac{200}{\sqrt{2}}$$

$$V_{o\,rms} = 141.4\ V$$

$$I_{L\,mean} = \frac{V_{L\,mean}}{R}$$

$$I_{L\,mean} = \frac{127.3}{10\ K}$$

$$I_{L\,mean} = 12.73\ mA$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{R}$$

$$I_{o\,rms} = \frac{141.4}{10\ K}$$

$$I_{o\,rms} = 14.14\ mA$$

$$Form\ Factor, FF = \frac{V_{rms}}{V_{L\,mean}}$$

$$Form\ Factor, FF = \frac{141.4}{127.3} = 1.11$$

$$RF = \sqrt{\left(\frac{V_{rms}}{V_{L\,mean}}\right)^2 - 1.}$$

$$RF = \sqrt{\left(\frac{141.4}{127.3}\right)^2 - 1.}$$

$$RF = 0.48$$

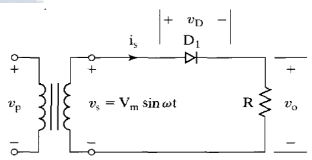
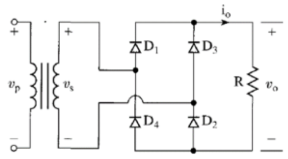
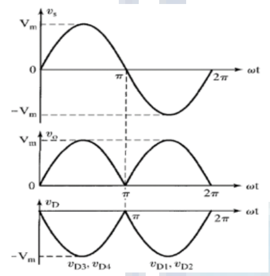
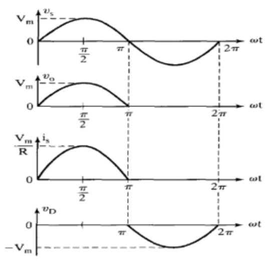
$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{L\,mean}V_{L\,mean}}{I_{o\,rms}V_{o\,rms}}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{12.73 \times 127.3}{14.14 \times 141.4}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = 80\%$$

Summary

Comparison between half wave rectifier and full wave rectifier :

Half wave rectifier	Full wave rectifier
	
	
$Vs\ rms = \frac{Vs\ max}{\sqrt{2}}$	$Vs\ rms = \frac{Vs\ max}{\sqrt{2}}$
$V_{L\ mean} = \frac{Vs\ max}{\pi}$	$V_{L\ mean} = \frac{2Vs\ max}{\pi}$
$I_{L\ mean} = \frac{V_{L\ mean}}{R}$	$I_{L\ mean} = \frac{V_{L\ mean}}{R}$
$V_{o\ rms} = \frac{Vsmax}{2}$	$V_{o\ rms} = \frac{Vsmax}{\sqrt{2}}$
$I_{o\ rms} = \frac{V_{o\ rms}}{R}$	$I_{o\ rms} = \frac{V_{o\ rms}}{R}$
$FF = \frac{V_{rms}}{V_{L\ mean}}$	$FF = \frac{V_{rms}}{V_{L\ mean}}$
$RF = \sqrt{FF^2 - 1.}$	$RF = \sqrt{FF^2 - 1.}$
$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{L\ mean}V_{L\ mean}}{I_{o\ rms}V_{o\ rms}}$	$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{L\ mean}V_{L\ mean}}{I_{o\ rms}V_{o\ rms}}$