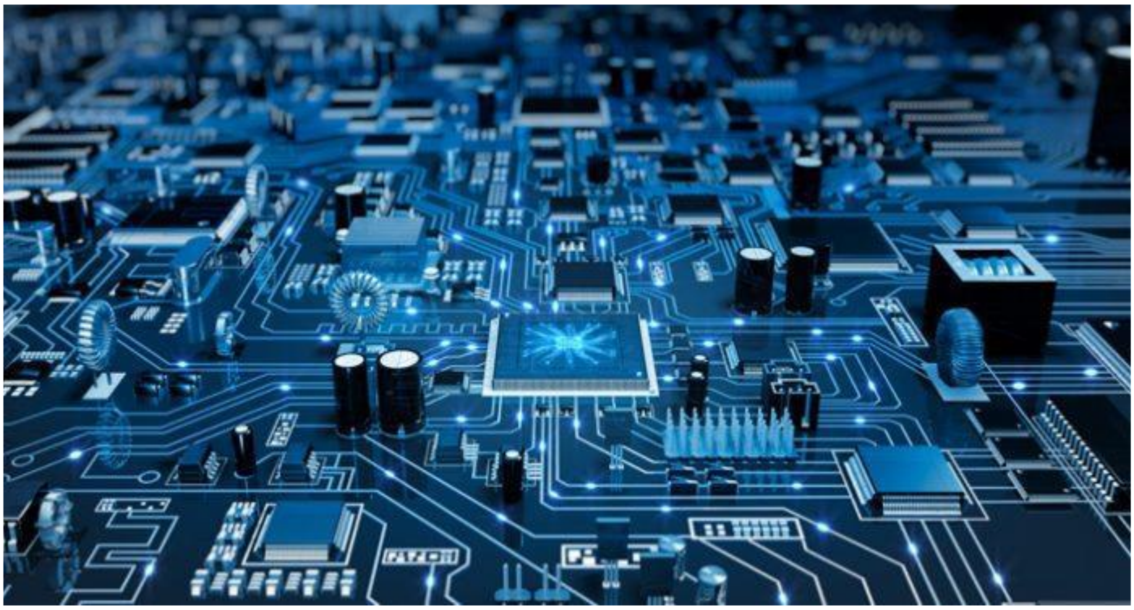
Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Systems
Lecturer: Prof. Adnan Ali
Lecture:3

Mode Unit 3

Regulated Power Supplies (Part 2)

For
Students of Third Stage
Department of Medical Instrumentation Techniques Engineering



By

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2025

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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.

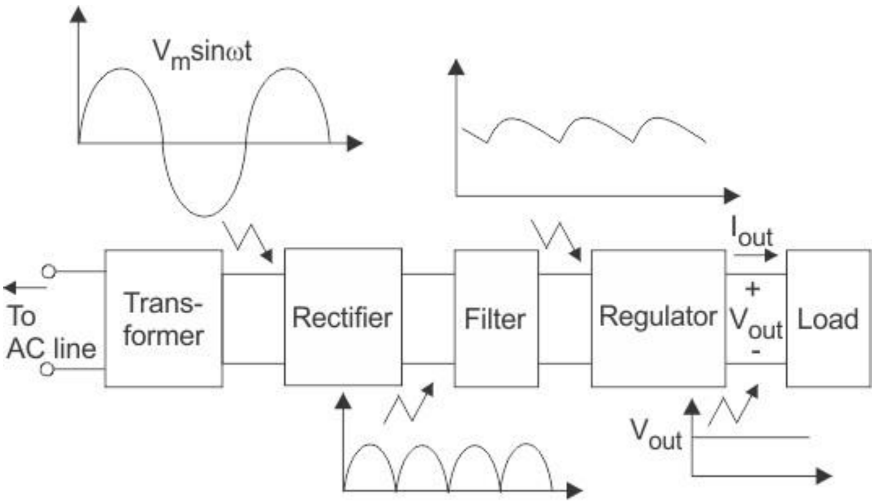
2. Introduction:

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:

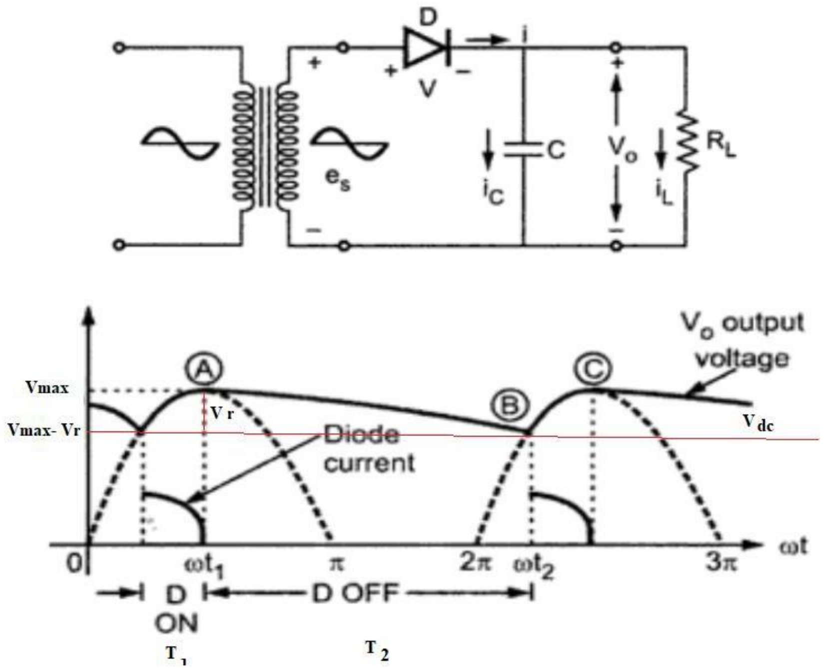
1. A step-down transformer
2. A rectifier
3. A DC filter
4. A regulator



Components of typical linear power supply

DC Filtration (Capacitor Filter)

The rectified voltage from the rectifier is a pulsating DC voltage having very high ripple content. But this is not we want, we want a pure ripple free DC waveform. Hence a filter is used. Different types of filters are used such as capacitor filter, LC filter, Choke input filter, π type filter. The figure below shows a capacitor filter connected along the output of the **half-wave rectifier** and the resultant output waveform.



During the time interval T_1 the diode is conducting and the capacitor C is getting charged.

While in the time interval T_2, the diode is reverse biased and the capacitor discharges through the load resistance R_L.

$T = T_1 + T_2$, $T_2 \gg T_1$,
From Figure above $T_2 \approx 0.8\, T$

At T_2 (discharging of C), the charge lost $Q = C\, V_{r(p.p)}$

The current through C is

$$i = \frac{dQ}{dt}$$

$$\int dQ = \int i\, dt$$

$$= \frac{V_{dc}}{1.25\, R_l\, C\, F}$$

$$Q = \int_0^{T_2} i\, dt = I_{dc}\, T_2$$

$$C\, V_r = I_{dc}\, T_2$$

$$V_r = \frac{I_{dc}\, T_2}{C} = \frac{I_{dc}}{1.25\, C\, F}$$

$$V_{dc} = V_{max} - V_{r\,(p)}$$

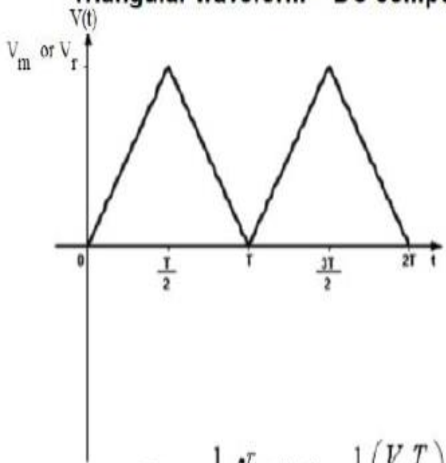
$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{2.5\, R_l\, C\, F}}$$

$$V_{r\,(p)} = \frac{V_{r\,(p.p)}}{2}$$

$$V_{dc} = V_{max} - \frac{\frac{V_{dc}}{1.25\, R_l\, C\, F}}{2} = V_{max} - \frac{V_{dc}}{2.5\, R_l\, C\, F}$$

$$V_{rms} = \frac{V_{r(p.p)}}{2\sqrt{3}}$$

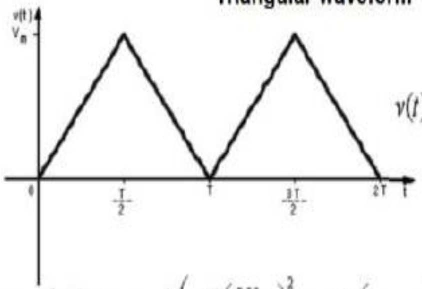
Triangular waveform – DC component



$$V_{DC} = \frac{1}{T}\int_0^T v(t)dt = \frac{1}{T}\left(\frac{V_m T}{2}\right)$$

$$\boxed{V_{DC} = \frac{V_m}{2}}$$

Triangular waveform – RMS value



$$v(t) = \begin{cases} \frac{2V_m}{T}t, & 0 \le t < T/2 \\ 2V_m - \frac{2V_m}{T}t, & T/2 \le t < T \end{cases}$$

$$V_{rms}^2 = \frac{1}{T}\int_0^T v^2(t)dt = \frac{1}{T}\left(\int_0^{T/2}\left(\frac{2V_m}{T}t\right)^2 dt + \int_{T/2}^T\left(2V_m - \frac{2V_m}{T}t\right)^2 dt\right)$$

$$= \frac{1}{T}\left(\frac{4V_m^2}{T^2}\int_0^{T/2} t^2 dt + 4V_m^2\int_{T/2}^T\left(1-\frac{1}{T}t\right)^2 dt\right) = \frac{4V_m^2}{T^3}\int_0^{T/2} t^2 dt + \frac{4V_m^2}{T}\int_{T/2}^T\left(1-\frac{2}{T}t+\frac{1}{T^2}t^2\right)dt$$

$$= \frac{4V_m^2}{T^3}\left[\frac{t^3}{3}\right]_0^{T/2} + \frac{4V_m^2}{T}\left[t-\frac{t^2}{T}+\frac{t^3}{3T^2}\right]_{T/2}^T$$

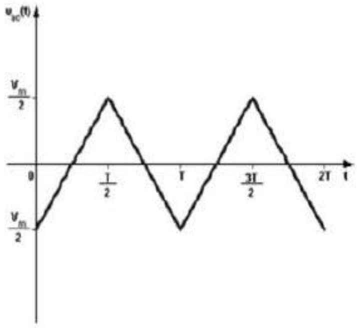
$$= \frac{4V_m^2}{T^3}\frac{T^3}{24} + \frac{4V_m^2}{T}\left[\frac{T}{2}-\frac{3T^2}{4T}+\frac{7T^3}{24T^2}\right]$$

$$= \frac{V_m^2}{6} + 4V_m^2\left[\frac{1}{2}-\frac{3}{4}+\frac{7}{24}\right] = \frac{V_m^2}{3}$$

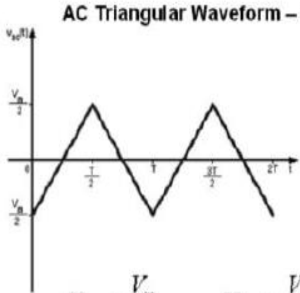
$$\boxed{V_{rms} = \frac{V_m}{\sqrt{3}}}$$

Triangular waveform – AC component

$$\boxed{v_{ac}(t) = v(t) - V_{DC} = v(t) - V_m/2}$$



AC Triangular Waveform – RMS value



$$V_{rms} = \frac{V_m}{\sqrt{3}} \qquad V_{DC} = \frac{V_m}{2}$$

$$(V_{ac})_{rms}^2 = V_{rms}^2 - V_{DC}^2$$

$$= \frac{V_m^2}{3} - \frac{V_m^2}{4}$$

$$= \frac{V_m^2}{12}$$

$$\boxed{(V_{ac})_{rms} = \frac{V_m}{2\sqrt{3}}}$$

$$\text{Ripple factor } (r) = \frac{V_{rms}}{V_{dc}} = \frac{\frac{V_{r(p.p)}}{2\sqrt{3}}}{V_{dc}} = \frac{\frac{\frac{V_{dc}}{1.25\, R_l\, C\, F}}{2\sqrt{3}}}{V_{dc}} = \boxed{\frac{1}{2.5\sqrt{3}\, R_l\, C\, F}}$$

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Ex1: For the half-wave rectifier circuit below, determine $V_{r\,(p.p)}, V_{dc}$ and ripple factor (r)

Ans:

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

$$V_{s\,max} = 24 \times \sqrt{2} = 33.94\,V$$

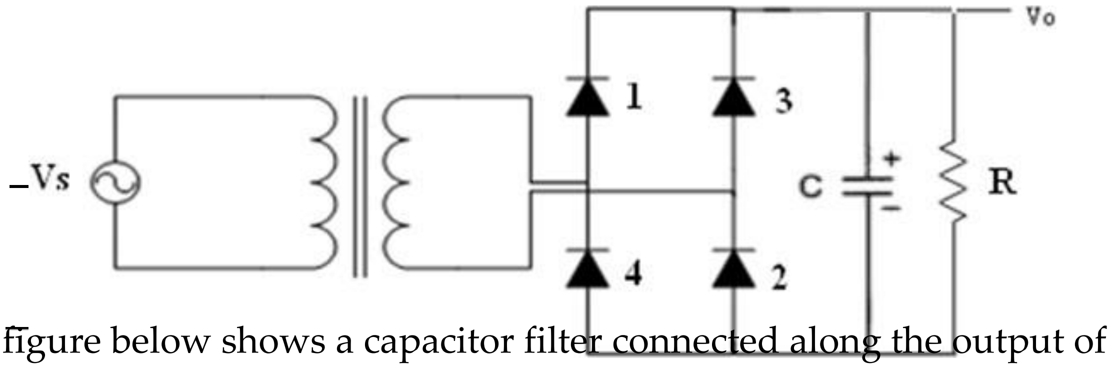
$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{2.5\,R_l\,C\,F}} = \frac{33.94}{1 + \frac{1}{2.5 \times 220 \times 100 \times 10^{-6} \times 50}} = 24.96\,V$$

The Answer with MULTISIM

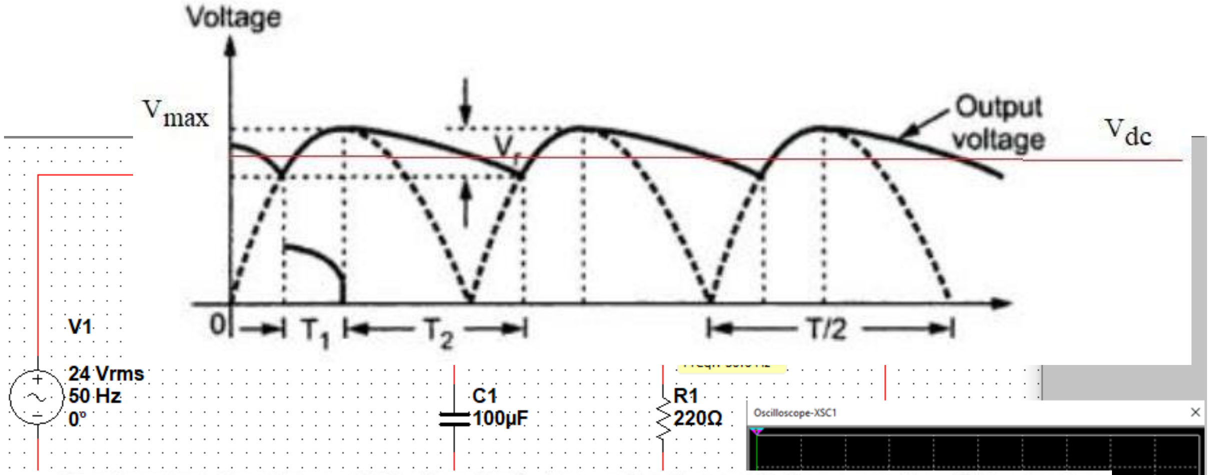
$$V_r = \frac{V_{dc}}{1.25\,R_l\,C\,F} = \frac{24.96}{1.25 \times 50 \times 220 \times 100 \times 10^{-6}} = 18.1$$

$$r = \frac{1}{2.5\sqrt{3}\,R_l\,C\,F} = \frac{1}{2.5\sqrt{3} \times 220 \times 100 \times 10^{-6} \times 50} = 0.21$$

Ex2 (H.W): For the half-wave rectifier circuit above, change C to 200 μF and load resistor R to 500 Ω and determine V_{dc} , $V_{r\,(p.p)}$, $V_{r\,(p)}$ and ripple factor (r).



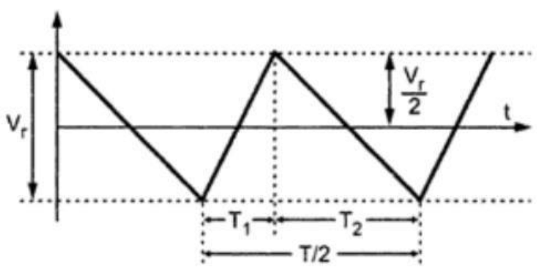
The figure below shows a capacitor filter connected along the output of the **full-wave rectifier** and the resultant output waveform.



During the time interval T_1 the diode is conducting and the capacitor C is getting charged.

While in the time interval T_2 , the diode is reverse biased and the capacitor discharges through the load resistance R_L .

Let V_r be the peak to peak value of ripple voltage, which is assumed to be triangular as shown in the Fig.



It can be shown mathematically that the r.m.s. value of such a triangular waveform is

$$V_{rms} = \frac{V_r}{\ }$$

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$T/2 = T_1 + T_2$, $T_2 \gg T_1$,

From the output waveform of the full wave rectifier $T_2 \approx T/2 =$

At T_2 (discharging of C), the charge lost $Q = C\, V_{r(p.p)}$

The current through C is

$$i = \frac{dQ}{dt}$$

$$\int dQ = \int i\, dt$$

$$= \frac{V_{dc}}{2\, R_l\, C\, F}$$

$$Q = \int_0^{T_2} i\, dt = I_{dc}\, T_2$$

$$C\, V_r = I_{dc}\, T_2$$

$$V_r = \frac{I_{dc}\, T_2}{C} = \frac{I_{dc} T}{2C}$$

$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{4\, R_l\, C\, F}}$$

$$V_{dc} = V_{max} - V_{r(p)}$$

$$V_{dc} = V_{max} - \frac{V_{dc}}{2\, R_l\, C\, F}/2$$

$$\because V_{rms} = \frac{V_{r(p.p)}}{2\sqrt{3}}$$

$$\text{Ripple factor } (r) = \frac{V_{rms}}{V_{dc}} = \frac{\frac{V_{r(p.p)}}{2\sqrt{3}}}{V_{dc}} = \frac{\frac{\frac{V_{dc}}{2\, R_l\, C\, F}}{2\sqrt{3}}}{V_{dc}} = \frac{1}{4\sqrt{3}\, R_l\, C\, F}$$

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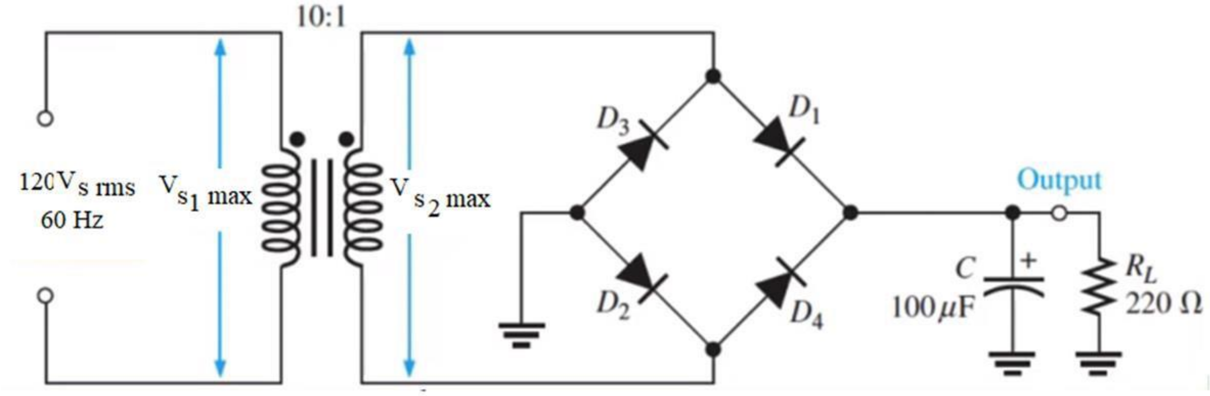
Ex3: For the full-wave rectifier circuit below, determine $V_{r\,(p.p)}$, V_{dc} and ripple factor (r)



Ans:

$$V_{s1\,max} = 120 \times \sqrt{2} = 169.71\ V$$

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

$$\frac{169.71}{V_{s2\,max}} = \frac{10}{1}$$

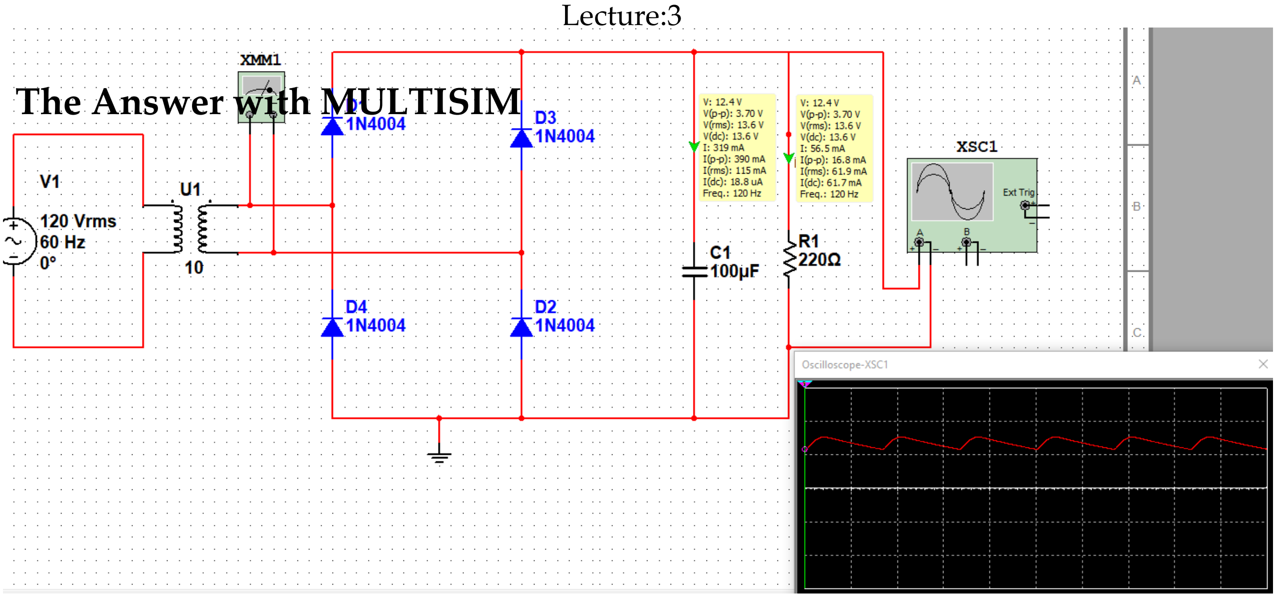
$$V_{s2\,max} = 16.97\ V$$

$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{4\,R_l\,C\,F}} = \frac{V_{s2\,max}}{1 + \frac{1}{4\,R_l\,C\,F}} = \frac{16.97}{1 + \frac{1}{4 \times 220 \times 100 \times 10^{-6} \times 60}} = 14.2V$$

$$V_r = \frac{V_{dc}}{2\,R_l\,C\,F} = \frac{V_{dc}}{2\,R_l\,C\,F} = \frac{14.2}{2 \times 220 \times 100 \times 10^{-6} \times 60} = 5.3$$

$$r = \frac{1}{4\sqrt{3}\,R_l\,C\,F} = \frac{1}{4\sqrt{3} \times 220 \times 100 \times 60} = 0.109$$

The Answer with MULTISIM



Ex. 4 : *A 100 µF capacitor, when used as filtering element, has 12 V, d.c. across it with a terminal load resistance of 2 k Ω . If the rectifier is full-wave and supply frequency is 50 Hz, what is the percentage of ripple in the output ? Draw the neat circuit diagram.*

Sol. : The circuit diagram is shown in the Fig.

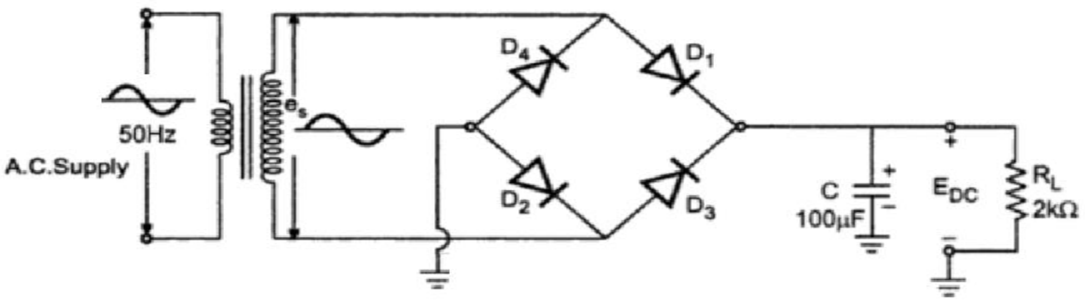


Fig. 3.28

Given : $R_L = 2k\,\Omega$, $C = 100\,\mu F$, $E_{DC} = 12$ V, Supply frequency = 50 Hz

$$\text{Ripple factor} = \frac{1}{4\sqrt{3}\, f\, C\, R_L} = \frac{1}{4\sqrt{3}\,[50][100\times 10^{-6}\,][2\times 10^{3}\,]}$$

$$= \frac{1}{4\sqrt{3}\,(50)\,(2\times 10^{-1}\,)} = 0.01443$$

$\therefore$ % of ripple in the output $= 0.01443 \times 100 = 1.443\ \%$

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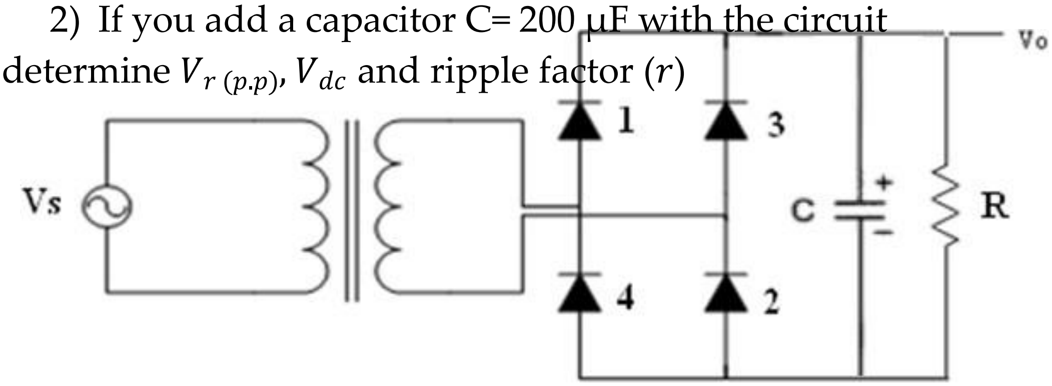
Ex5 (H.W): For the full-wave rectifier circuit below,

1) For only resistive load, Calculate $V_{Lmean}, I_{Lmean}, v_{o_{r.m.s}}, i_{o_{r.m.s}}$, *and ripple factor* (RF).

2) If you add a capacitor C= 200 µF with the circuit determine $V_{r\ (p.p)}, V_{dc}$ and ripple factor (r)



Ex6 (H.W): A full-wave bridge rectifier supplies a load with 50 V dc, 100mA using 100 µF of filtering capacitor. Assume ideal diodes and $V_s = V_{smax} \sin 314\ t$, determine $V_{r(p.p)}$, $V_{s\ max}$ **and** $V_{s\ rms}$.