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 (PART 2)
DC Filtration Stage

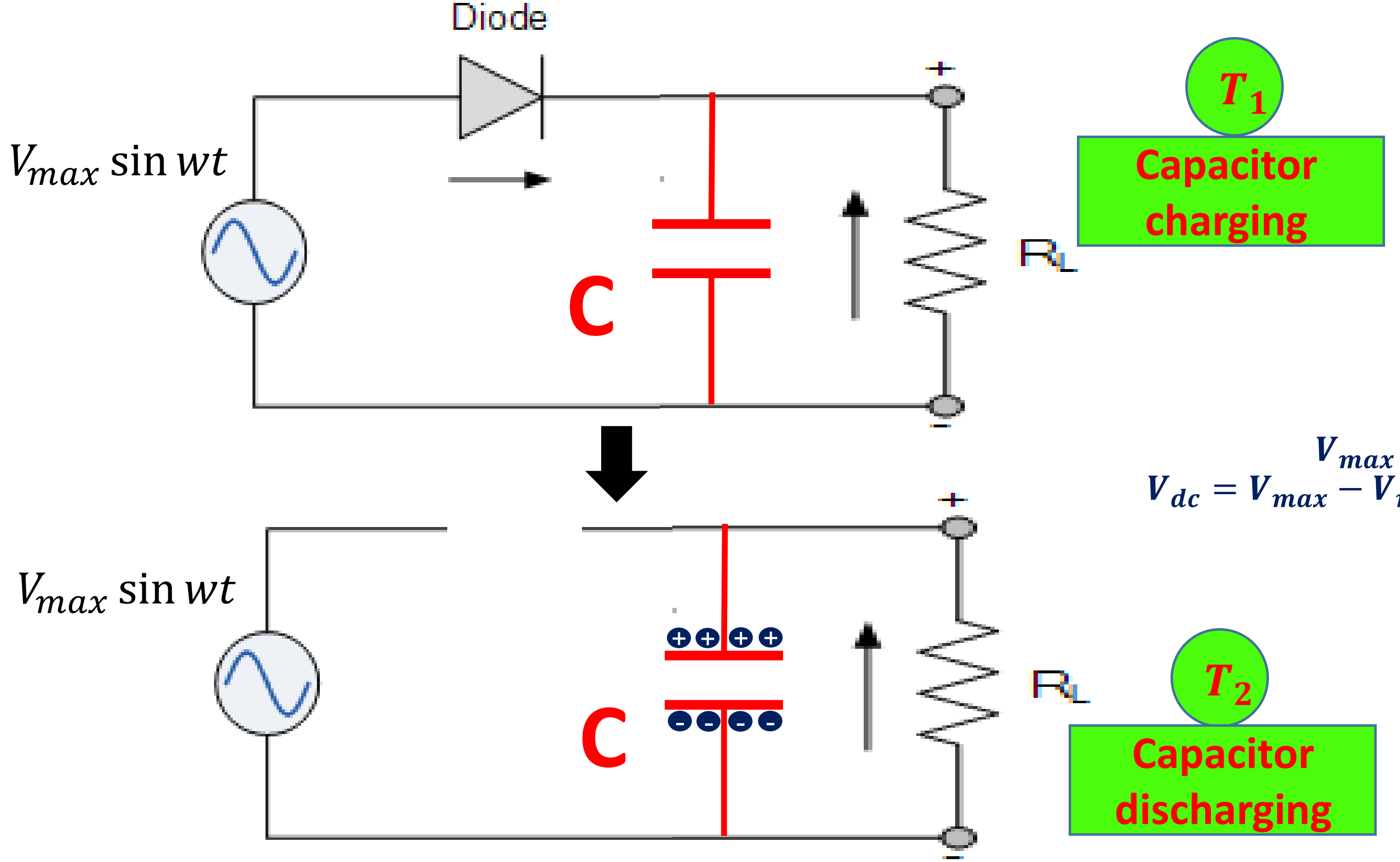
By
Mr. Abdulla Saleh

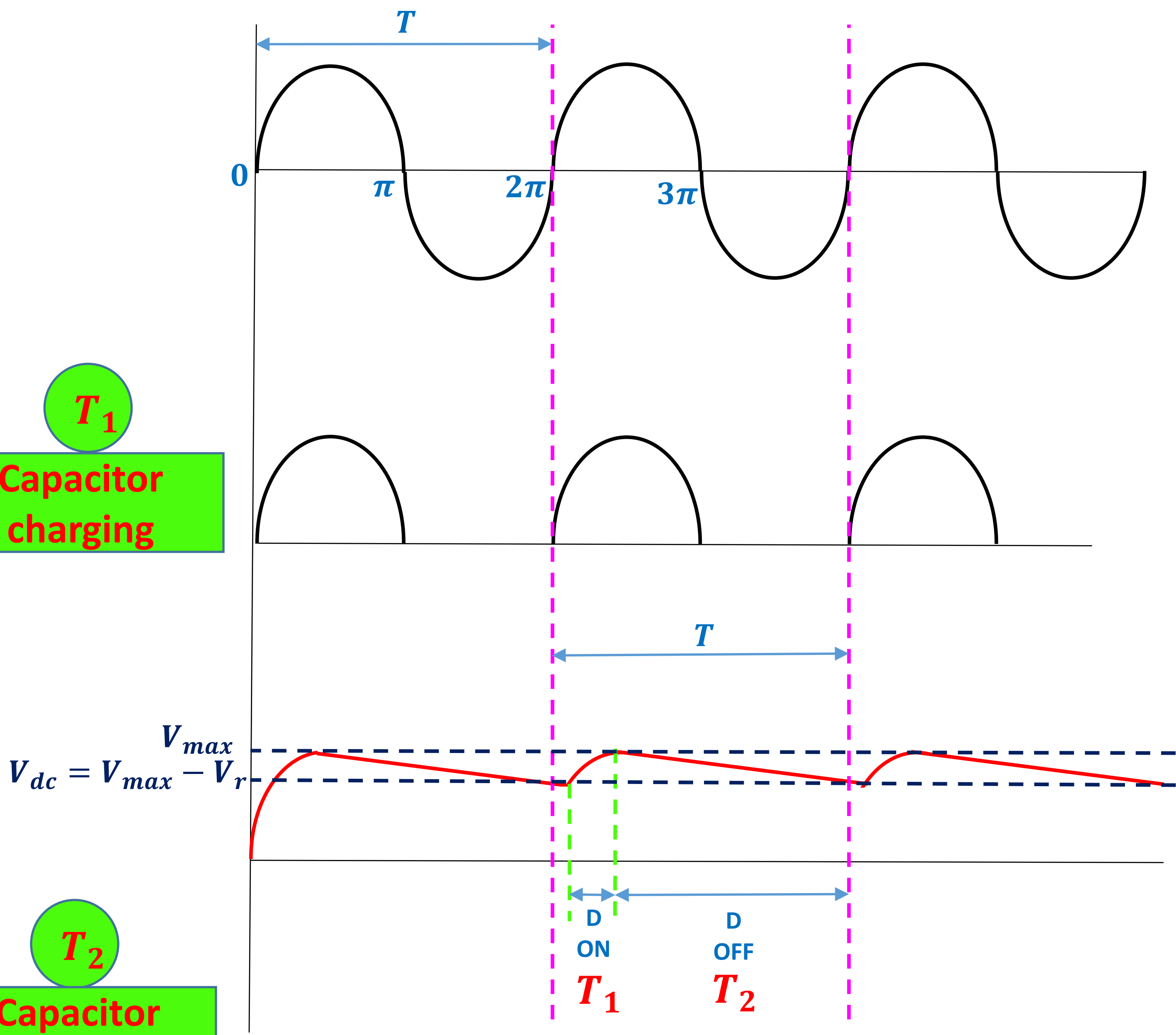
Department of Medical Instrumentation Engineering Techniques
2024-2025

DC Filtration (Capacitor Filter)

- **Rectified voltage** from rectifier has **high ripple** content.
- **Desired** output is a pure, **ripple-free** DC waveform.
- **Filters** are used to remove ripples.
- Types of filters: **capacitor filter**, **LC filter**, **choke input filter**, **π type filter**.

half-wave rectifier with capacitor Filter





$$T_1 + T_2 \cong 0.8T$$

$T_2 \gg T_1$ $\quad$ $T_2 \cong 0.8T$

At T_2 (discharging of C), the charge lost $\quad Q = C\,V_{r(p.p)}$ ...(1)

The current through C

$$i = \frac{dQ}{dt} \Rightarrow dQ = i\,dt \Rightarrow \int dQ = \int_0^{T_2} i\,dt \Rightarrow Q = i\int_0^{T_2} dt$$

$$Q = I_{dc}t\Big|_0^{T_2} \Rightarrow Q = I_{dc}T_2 \ldots(2) \Rightarrow sub\,(2)\;\; in\,(1)$$

$$\Rightarrow I_{dc}T_2 = C\,V_{r(p.p)} \qquad T_2 \cong 0.8T$$

$I_{dc} = \frac{V_{dc}}{R_l}$ $\quad$ $T = \frac{1}{F}$

$$I_{dc} \times 0.8T = C\,V_{r(p.p)} \quad \div C \Rightarrow Vr(p.p) = \frac{I_{dc} \times 0.8T}{C}$$

$$Vr(p.p) = I_{dc} \times T \times \frac{0.8}{C} \Rightarrow Vr(p.p) = \frac{V_{dc}}{R_l} \times \frac{1}{F} \times \frac{0.8}{C}$$

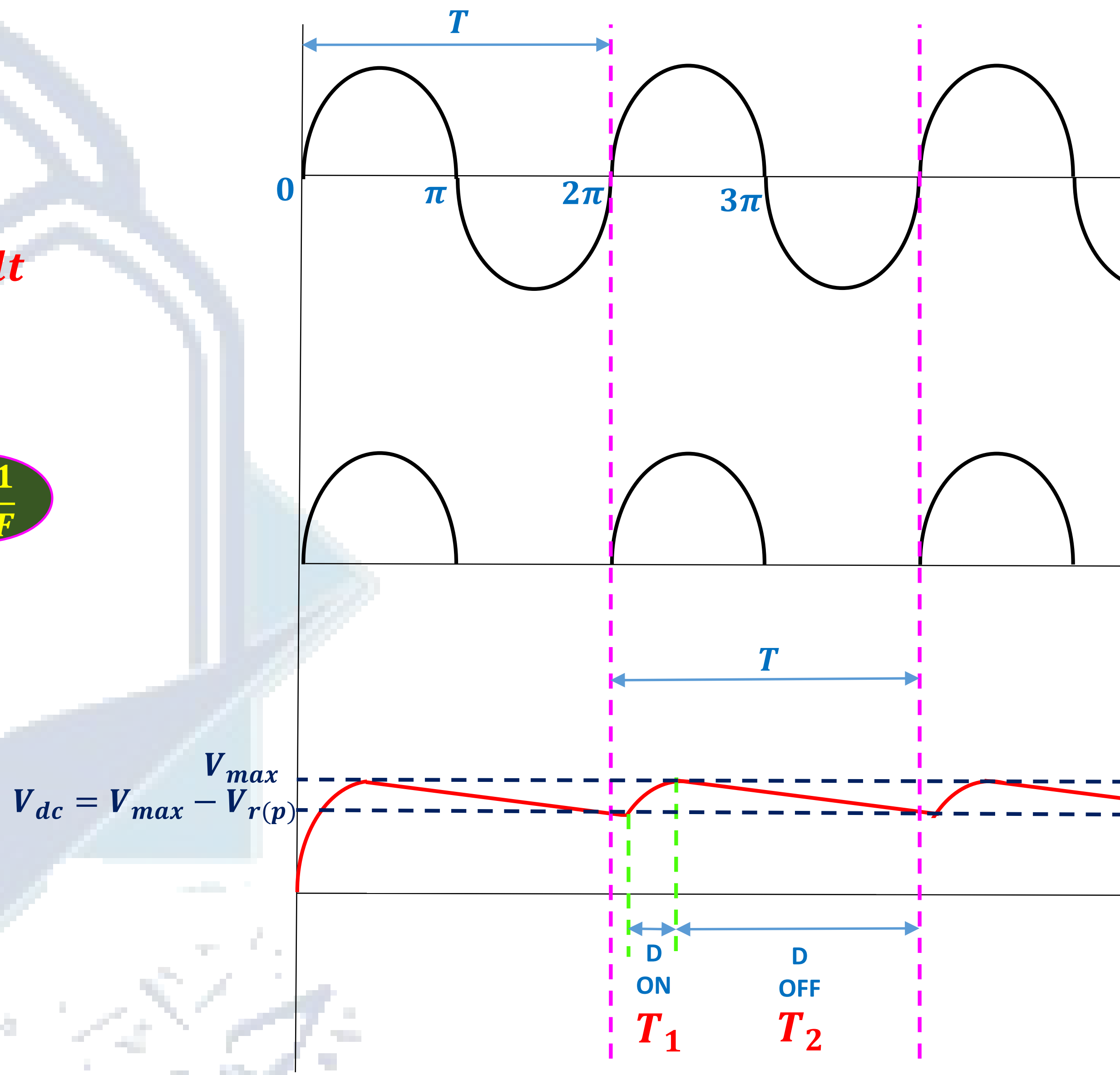
$$Vr(p.p) = \frac{V_{dc} \times 0.8}{R_l F C} \quad \begin{matrix}\div 0.8\\ \div 0.8\end{matrix}$$

$$Vr(p.p) = \frac{V_{dc}}{1.25R_l F C} \ldots(3)$$

$$V_{dc} = V_{max} - V_{r(p)} \quad \ldots(4)$$

$$V_{r(p)} = \frac{Vr(p.p)}{2} \quad \ldots(5)$$

$$sub\,(5)\;\; in\,(4) \Rightarrow V_{dc} = V_{max} - \frac{Vr(p.p)}{2} \ldots(6)$$



$$T_1 + T_2 = 0.8T$$

from above equations sub (3) in (6)

$$Vr(p.p) = \frac{V_{dc}}{1.25R_lFC} \quad \dots (3)$$

$$V_{dc} = V_{max} - \frac{Vr(p.p)}{2} \quad \dots (6)$$

$$V_{dc} = V_{max} - \frac{\frac{V_{dc}}{1.25R_lFC}}{2} \Rightarrow V_{dc} = V_{max} - \frac{V_{dc}}{2.5R_lFC}$$

$$V_{dc} + \frac{V_{dc}}{2.5R_lFC} = V_{max} \Rightarrow V_{dc}\left(1 + \frac{1}{2.5R_lFC}\right) = V_{max}$$

$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{2.5R_lFC}}$$

The r.m.s Voltage equal to :

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

Ripplefactor $R.F = \frac{V_{rms}}{V_{dc}}$

$$R.F = \frac{V_{rms}}{V_{dc}} \qquad V_{rms} = \frac{Vr(p.p)}{2\sqrt{3}}$$

$$R.F = \frac{\frac{Vr(p.p)}{2\sqrt{3}}}{V_{dc}} \Rightarrow R.F = \frac{Vr(p.p)}{2\sqrt{3}V_{dc}}$$

$$R.F = \frac{Vr(p.p)}{2\sqrt{3}V_{dc}} \qquad Vr(p.p) = \frac{V_{dc}}{1.25R_lFC}$$

$$R.F = \frac{\frac{V_{dc}}{1.25R_lFC}}{2\sqrt{3}V_{dc}}$$

$$R.F = \frac{1}{2.5\sqrt{3}R_lFC}$$

Summary

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

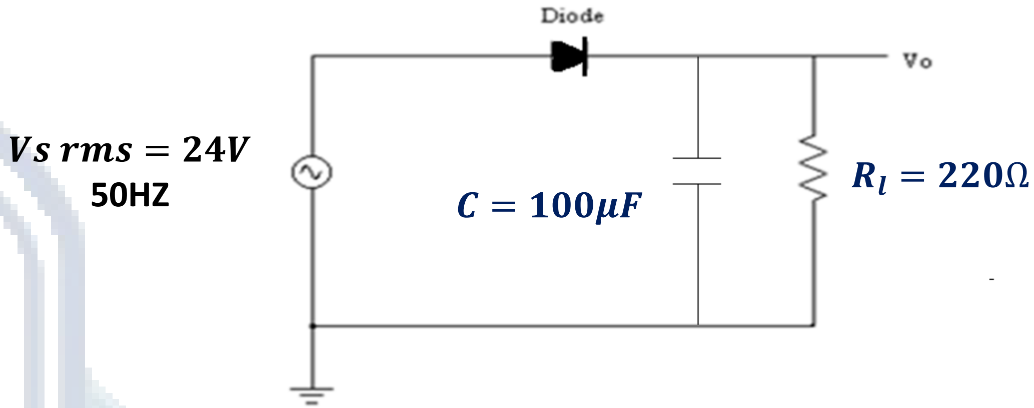
$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{2.5 R_l F C}}$$

$$Vr(p.p) = \frac{V_{dc}}{1.25 R_l F C}$$

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

$$R.F = \frac{1}{2.5\sqrt{3} R_l F C}$$

Ex1: For the half-wave rectifier circuit below, determine Vdc, Vr $(p.p)$ and ripple factor (r)



Sol:

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

$$24 = \frac{Vs\ max}{\sqrt{2}}$$

$$Vs\ max = 24\sqrt{2}$$

$$\boxed{Vs\ max = 33.94V}$$

i

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

$$V_{dc} = \frac{33.94V}{1 + \frac{1}{2.5 * 220 * 50 * 100 * 10^{-6}}}$$

$$\boxed{V_{dc} = 24.96\ V}$$

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$$Vr(p.p) = \frac{V_{dc}}{1.25 R_l F C}$$

$$Vr(p.p) = \frac{24.96}{1.25 * 220 * 50 * 100 * 10^{-6}}$$

$$\boxed{Vr(p.p) = 18.1\ V}$$

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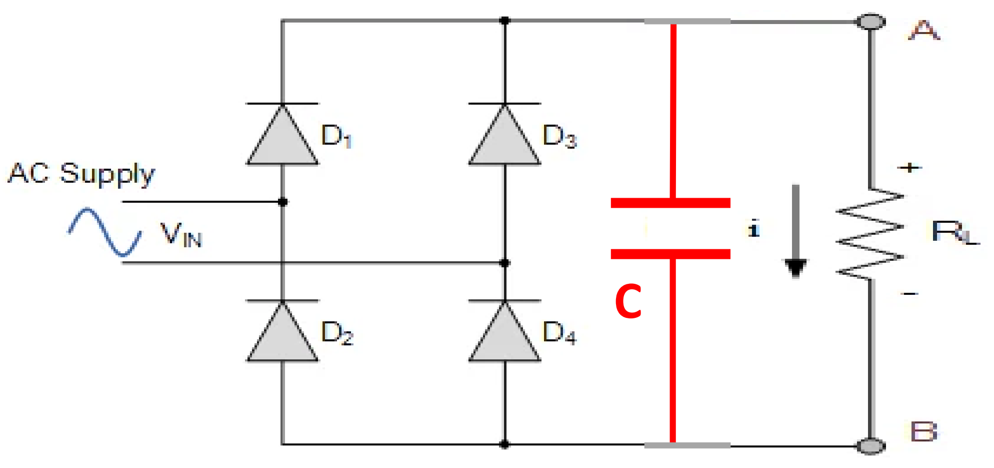
$$R.F = \frac{1}{2.5\sqrt{3} R_l F C}$$

$$R.F = \frac{1}{2.5\sqrt{3} * 220 * 50 * 100 * 10^{-6}}$$

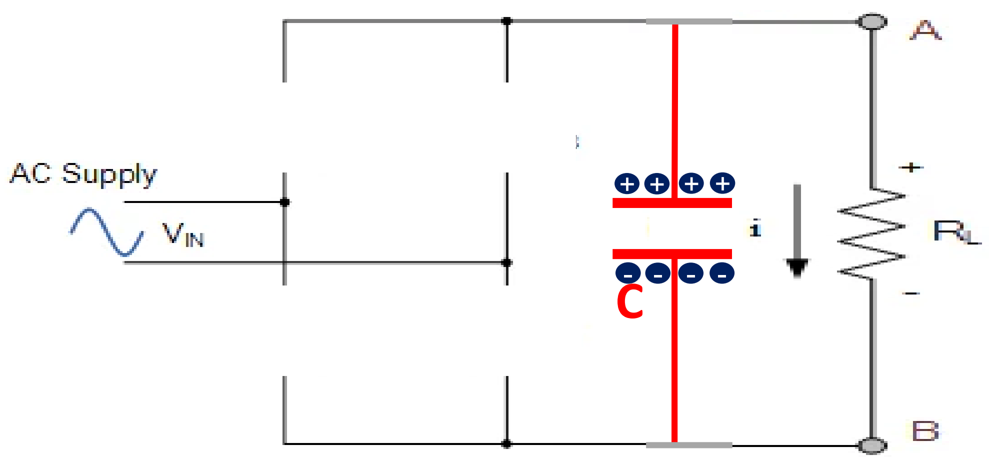
$$\boxed{R.F = 0.21}$$

full-wave rectifier with capacitor Filter



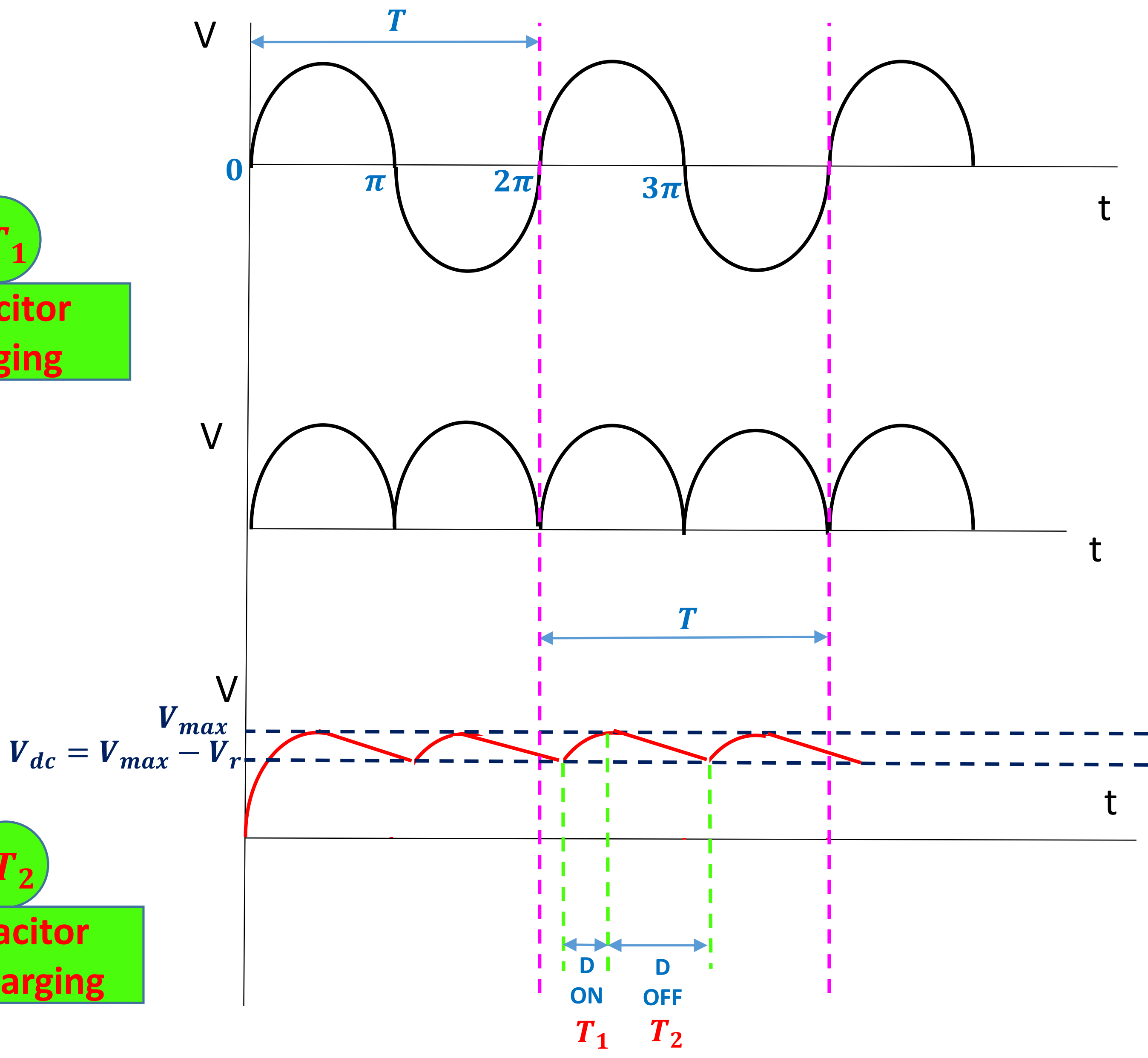
T_1

Capacitor charging



T_2

Capacitor discharging



$$T_1 + T_2 = \frac{T}{2}$$

$T_2 \gg T_1$

$$T_2 \cong \frac{T}{2}$$

At T_2 (discharging of C), the charge lost $Q = C\,V_{r(p.p)}$ ...(1)

The current through C

$$i = \frac{dQ}{dt} \Longrightarrow dQ = i\,dt \Longrightarrow \int dQ = \int_0^{T_2} i\,dt \Longrightarrow Q = i\int_0^{T_2} dt$$

$$Q = I_{dc}\,t\Big|_0^{T_2} \Longrightarrow Q = I_{dc}T_2 \ \dots(2) \Longrightarrow \ sub\ (2)\ \ in\ (1)$$

$$\Longrightarrow I_{dc}T_2 = C\,V_{r(p.p)}$$

$$T_2 \cong \frac{T}{2}$$

$$I_{dc} = \frac{V_{dc}}{R_l} \qquad T = \frac{1}{F}$$

$$I_{dc} \times \frac{T}{2} = C\,V_{r(p.p)} \quad \div C \Longrightarrow Vr(p.p) = \frac{I_{dc} \times T}{2C}$$

$$Vr(p.p) = I_{dc} \times T \times \frac{1}{2C} \Longrightarrow Vr(p.p) = \frac{V_{dc}}{R_l} \times \frac{1}{F} \times \frac{1}{2C}$$

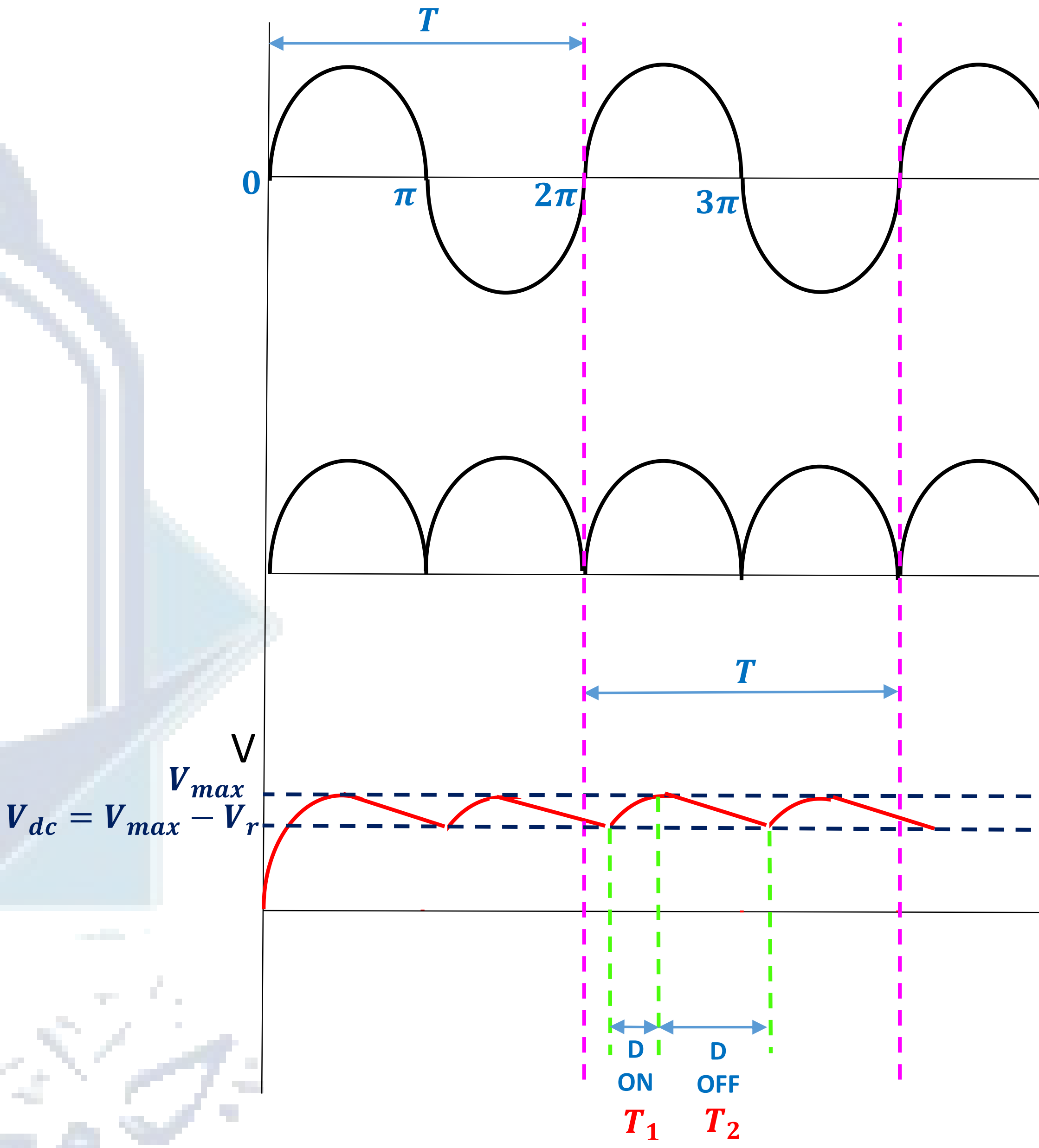
$$Vr(p.p) = \frac{V_{dc}}{2R_l F C}$$

$$Vr(p.p) = \frac{V_{dc}}{2R_l F C} \ \dots(3)$$

$$V_{dc} = V_{max} - V_{r(p)} \quad \dots(4)$$

$$V_{r(p)} = \frac{Vr(p.p)}{2} \quad \dots(5)$$

$$sub\ (5)\ \ in\ (4) \Longrightarrow V_{dc} = V_{max} - \frac{Vr(p.p)}{2} \ \dots(6)$$



$$T_1 + T_2 = \frac{T}{2}$$

from above equations sub (3) in (6)

$$Vr(p.p) = \frac{V_{dc}}{2R_lFC} \quad \dots (3)$$

$$V_{dc} = V_{max} - \frac{Vr(p.p)}{2} \quad \dots (6)$$

$$V_{dc} = V_{max} - \frac{\frac{V_{dc}}{2R_lFC}}{2} \Rightarrow V_{dc} = V_{max} - \frac{V_{dc}}{4R_lFC}$$

$$V_{dc} + \frac{V_{dc}}{4R_lFC} = V_{max} \Rightarrow V_{dc}\left(1 + \frac{1}{4R_lFC}\right) = V_{max}$$

$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{4R_lFC}}$$

The r.m.s Voltage equal to :

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

Ripplefactor $R.F = \frac{V_{rms}}{V_{dc}}$

$$R.F = \frac{V_{rms}}{V_{dc}} \qquad \left(V_{rms} = \frac{Vr(p.p)}{2\sqrt{3}} \right)$$

$$R.F = \frac{\frac{Vr(p.p)}{2\sqrt{3}}}{V_{dc}} \Rightarrow R.F = \frac{Vr(p.p)}{2\sqrt{3}V_{dc}}$$

$$R.F = \frac{Vr(p.p)}{2\sqrt{3}V_{dc}} \qquad \left(Vr(p.p) = \frac{V_{dc}}{2R_lFC} \right)$$

$$R.F = \frac{\frac{V_{dc}}{2R_lFC}}{2\sqrt{3}V_{dc}}$$

$$R.F = \frac{1}{4\sqrt{3}R_lFC}$$

Summary

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

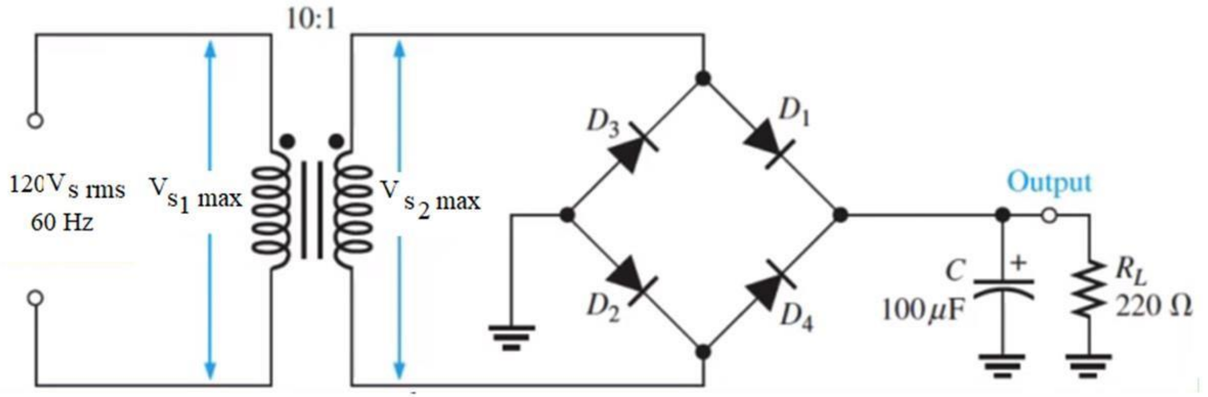
$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{4R_l FC}}$$

$$Vr(p.p) = \frac{V_{dc}}{2R_l FC}$$

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

$$R.F = \frac{1}{4\sqrt{3}R_l FC}$$

Ex3: For the full-wave rectifier circuit below, determine Vr (p.p), Vdc and ripple factor (r)



Sol:

$$Vs1\ rms = \frac{Vs1\ max}{\sqrt{2}}$$

$$120 = \frac{Vs1\ max}{\sqrt{2}}$$

$$Vs1\ max = 120\sqrt{2}$$

$$Vs1\ max = 169.71\ V$$

$$\frac{Vs1\ max}{Vs2\ max} = \frac{n_1}{n_2} \qquad \frac{169.71}{Vs2\ max} = \frac{10}{1}$$

$$Vs2\ max = 16.971\ V$$

i

$$V_{dc} = \frac{V_{max}}{1 + \frac{1}{4R_l FC}}$$

$$V_{dc} = \frac{16.971\ V}{1 + \frac{1}{4 * 220 * 60 * 100 * 10^{-6}}}$$

$$V_{dc} = 14.2\ V$$

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$$Vr(p.p) = \frac{V_{dc}}{2R_l FC}$$

$$Vr(p.p) = \frac{14.2\ V}{2 * 220 * 60 * 100 * 10^{-6}}$$

$$Vr(p.p) = 5.3V$$

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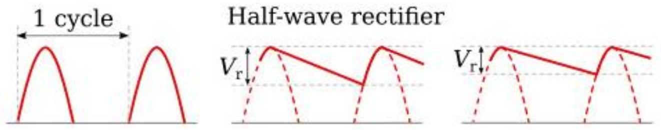
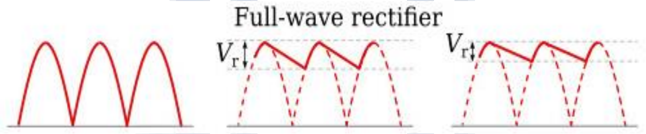
$$R.F = \frac{1}{4\sqrt{3}R_l FC}$$

$$R.F = \frac{1}{4\sqrt{3} * 220 * 60 * 100 * 10^{-6}}$$

$$R.F = 0.109$$

Summary

Comparison between capacitor filter in case of half wave rectifier and full wave rectifier

Capacitor filter with Half wave rectifier	Capacitor filter with Full wave rectifier
	
$T_2 \cong 0.8T$	$T_2 \cong \frac{T}{2}$
$V_{r(p)} = \frac{V_{dc}}{1.25 R_l C f}$	$V_{r(p)} = \frac{V_{dc}}{2 R_l C f}$
$V_{dc} = \frac{V_{max}}{1 + \frac{1}{2.5 R_l C f}}$	$V_{dc} = \frac{V_{max}}{1 + \frac{1}{4 R_l C f}}$
$V_{rms} = \frac{V_{r(p.p)}}{2\sqrt{3}}$	$V_{rms} = \frac{V_{r(p.p)}}{2\sqrt{3}}$
$RF = \frac{1}{2.5\sqrt{3} R_l C f}$	$RF = \frac{1}{4\sqrt{3} R_l C f}$