ELEMENTS OF ELECTRICAL ENGINEERING (UE24EE141B)

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Unit 2 – Lecture 24 - Analysis of Single-Phase AC circuits with C Load

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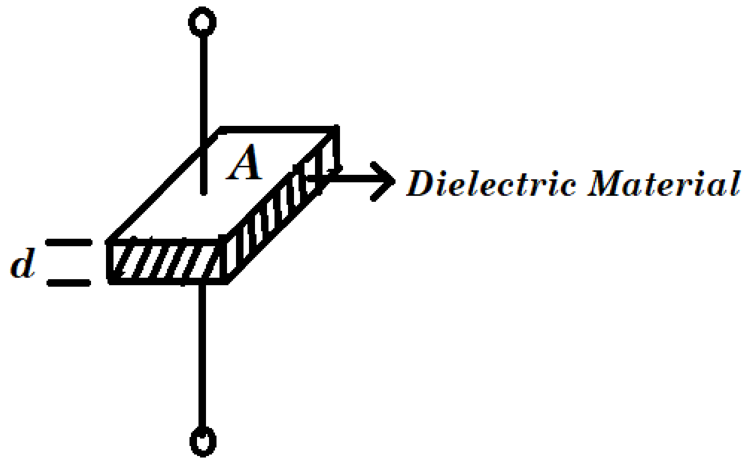
Capacitor & the concept of Capacitance

A Capacitor is obtained by placing a dielectric medium between the conducting plates.



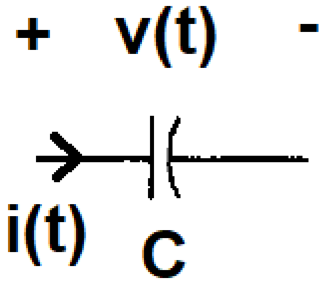
Capacitance, C $= \dfrac{\varepsilon A}{d}$ Farad

Where, A is the area of each of the plates in m^2

d is the distance between the plates in m

ε is the permittivity of the dielectric medium in F/m

Voltage – Current relationship in a Capacitor



The charge on the plates of a capacitor is directly proportional to the voltage across its terminals.

i.e., $q(t) \propto v(t) \Rightarrow q(t) = Cv(t)$

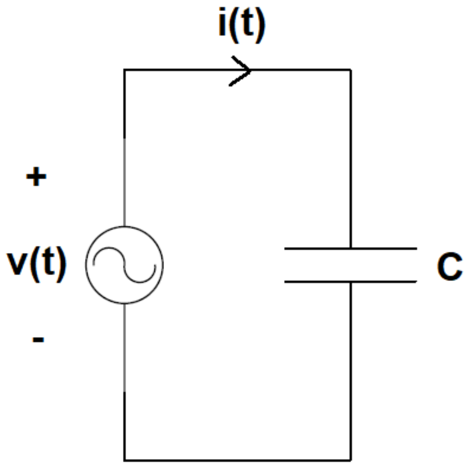
The constant of proportionality 'C' is called Capacitance of the Capacitor.

Hence, current, $i(t) = \frac{dq(t)}{dt} = C\frac{dv(t)}{dt}$

Therefore, v(t) can be expressed as

$$v(t) = \frac{1}{C}\int i(t)dt$$

Response of Pure Capacitor to Sinusoidal Supply



Let the supply voltage be $v(t) = V_m \sin(\omega t)$

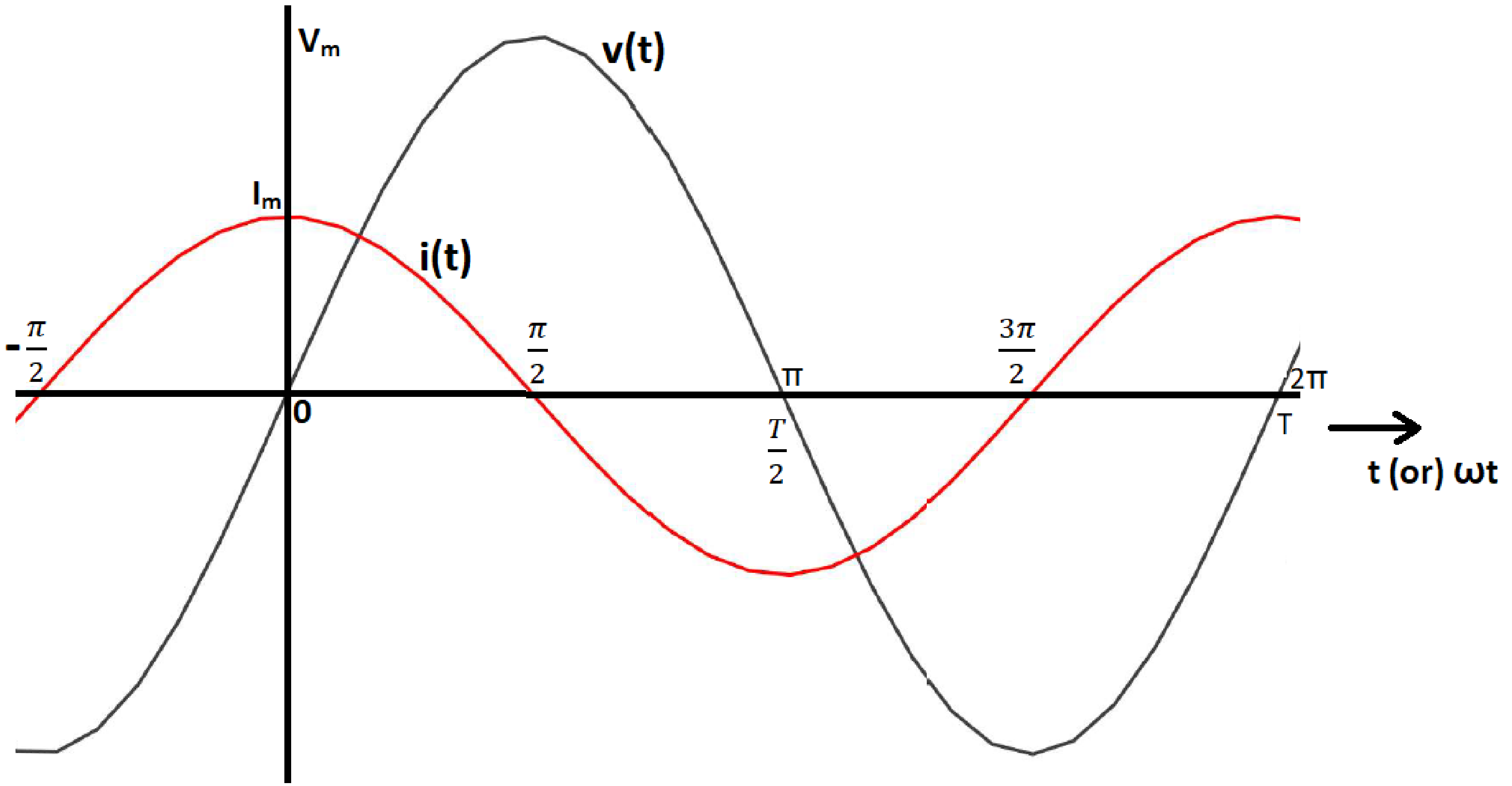
In a pure capacitor, $i(t) = C\dfrac{dv(t)}{dt}$

$$= CV_m \omega \cos(\omega t)$$

$$= I_m \sin(\omega t + 90°)$$

Where, $I_m = V_m \omega C$ is the peak value of current

Response of Pure Capacitor to Sinusoidal Supply



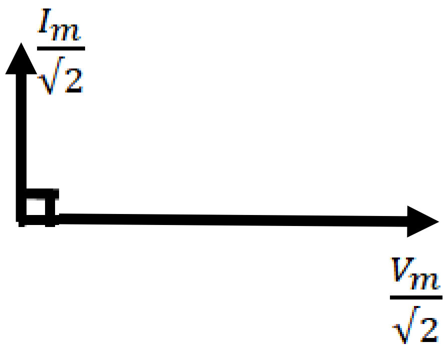
In a pure capacitor, current **leads** voltage by 90°

Response of Pure Capacitor to Sinusoidal Supply

$v(t)=V_m\sin(\omega t) \Rightarrow \bar{V}=\frac{V_m}{\sqrt{2}}\angle 0°$

$i(t)=I_m\sin(\omega t+90°) \Rightarrow \bar{I}=\frac{I_m}{\sqrt{2}}\angle 90°$

Phasor Diagram:



$$Z=\frac{\bar{V}}{\bar{I}}=\frac{\frac{V_m}{\sqrt{2}}\angle 0°}{\frac{I_m}{\sqrt{2}}\angle 90°}=\frac{1}{\omega C}\angle -90°=-jX_C \quad \Omega$$

Where, $X_C=\frac{1}{\omega C}$ is called '**Capacitive Reactance**'

Numerical Example

Question:

A Capacitor of Capacitance 100μF is connected across an AC voltage source 100sin(100πt) V. Determine

i) Capacitive Reactance
ii) Impedance
iii) Instantaneous expression for the current

Also, draw the phasor diagram.

Numerical Example

Solution: Given, $V(t) = 100\sin(100\pi t)$ V

Hence, $\omega = 100\pi$ rad/s

i) Capacitive Reactance, $X_c = \dfrac{1}{\omega C} = 31.83\Omega$

ii) Impedance, $Z = -jX_c = -j31.83\Omega$

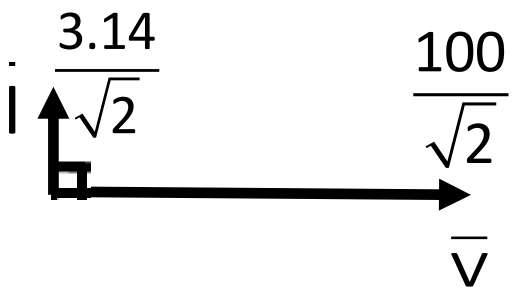
iii) Instantaneous current, $i(t) = V_m\omega C\sin(\omega t + 90°)$ A

$$= 3.14\sin(\omega t + 90°) \text{ A}$$

Phasor Diagram:

$$\bar{V} = \frac{100}{\sqrt{2}}\angle 0° \text{ V}$$

$$\dot{I} = \frac{3.14}{\sqrt{2}}\angle 90° \text{ A}$$



Text Book & References

Text Book:

"Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 11th Edition, Pearson Education, 2012.

Reference Books:

1. "Basic Electrical Engineering - Revised Edition", D. C. Kulshreshta, Tata- McGraw-Hill, 2012.
2. "Basic Electrical Engineering", K Uma Rao, Pearson Education, 2011.
3. "Engineering Circuit Analysis", William Hayt Jr., Jack E. Kemmerly & Steven M. Durbin, 8th Edition, McGraw-Hill, 2012.

THANK YOU

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