16.202: COURSE OVERVIEW

- Focus: Circuits driven by time-varying current and voltage sources.
- Of particular interest:
  - Sinusoidal Currents and Voltages: Alternating Currents (AC Circuits)
  - $i(t) = I_m sin(\omega t \ + \ \psi)$ or $v(t) = V_m cos(\omega t \ + \ \psi)$
- Why Sinusoids?
  - Practical Reasons.
    - AC systems: Basis on which power is generated, transmitted and consumed.
    - AC systems more efficient than DC: can generate high voltages/low transmission losses
  - Theoretical Reasons
    - Analysis of circuits driven by AC sources will allow us to evaluate response of circuit to *non-sinusoidal* time-varying sources.

Basic Concepts to be Covered

- Transforming voltages and currents in time-domain to frequency domain
- Understanding analysis of circuits in the frequency domain
- Transforming solutions in the frequency domain back to time domain

Special Topics

- Representing sources in the frequency domain: **Laplace Transforms**
- Describing and examining response of a circuit to variation in frequency: **Frequency Response**

Main Topics

- Concept of *Complex Impedance* representation of R,L,C circuit elements
- Apply KVL, KCL, Nodal/Mesh, Thevenin/Norton, Superposition concepts
- Concept of *Power*: Instantaneous, Average, Root Mean Square (RMS)
- Concept of transfer functions frequency response

Applications

- Three-Phase (Polyphase) Circuits
- Transformers : Magnetic Coupling, Mutual Inductance
- Filter Design and Analysis
- Two-Port Networks

Sinusoids

$v(t) \;=\; V_m \, sin(\omega t \;+\; \psi)$

V_m : Peak Amplitude

ψ : Phase

ω : Angular Frequency : Radians per second

$\omega = 2\pi f$: f Frequency in Hertz

Time Period $T \;=\; 1/f$ (seconds)

$\omega \;=\; \frac{2\pi}{T}$

Periodicity Property: $v(t) \;=\; v(t + nT) \quad n = -\infty, ... -1, 1, 2, ..\infty$

Note: $v(t + T) \;=\; V_m \, sin(\omega t \;+\; \omega T) \;=\; v(t)$

Apply $\omega T \;=\; 2\pi$ and use:

$sin(A \pm B) = sinA \; cosB \;\pm\; cosA \; sinB$

$cos(A \pm B) = cosA \; cosB \;\mp\; sinA \; sinB$

Concept of Phase

$v_1(t) = V_m sin(\omega t)$

$v_2(t) = V_m sin(\omega t \ + \ 30^o)$

- v_1 and v_2 are out of phase
- v_1 **Leads** v_2 by 30^o
- v_2 **Lags** v_1 by 30^o

Note: Useful Formulae

$$sin(\omega t \pm \pi/2) = \pm cos(\omega t)$$

$$cos(\omega t \pm \pi/2) = \mp sin(\omega t)$$

$$sin(\omega t \pm \pi) = -sin(\omega t)$$

$$cos(\omega t \pm \pi) = -cos(\omega t)$$

Complex Variables

$Z \; = \; X \; + \; jY$

Z : Complex Variable

X : Real Part: Re[Z]

Y : Imaginary Part: Im[Z]

$Z \; = \; |Z| \angle \phi \; = \; |Z| e^{j\phi}$

$|Z|$ Magnitude of Z : $\sqrt{X^2 + Y^2}$ $\angle \phi$: Phase Angle of Z : $tan^{-1} Y/X$

- Eulers Notation:

$$e^{j\theta} \; = \; cos(\theta) \; + \; jsin(\theta) \qquad e^{-j\theta} \; = \; cos(\theta) \; - \; jsin(\theta)$$

$$cos(\omega t) \; = \; Re[e^{j\omega t}] \qquad sin(\omega t) \; = \; Im[e^{j\omega t}]$$

- Example: $2 \angle 30^o \; = \; 2e^{j\pi/6} \; = \; 2[cos(\pi/6) + jsin(\pi/6)]$
- $I_m cos(\omega t + \phi) \; = \; Re[I_m e^{j(\omega t \, + \, \phi)}] \qquad I_m sin(\omega t + \phi) \; = \; Im[I_m e^{j(\omega t \, + \, \phi)}]$