ENGR 065 Electric Circuits

Lecture: Final Review

Today's Topics

- Review the Final concepts taught the course
  - **Major Topics (Pre Midterm)**
    - Variables:
    - Three Laws:
    - Circuit Analysis Techniques:
    - Basic Equations:
    - Basic Concepts:
  - Major Topics (Post Midterm)
    - Capacitors / Inductors:
    - Operational Amplifier
    - Laplace Transform:
    - IVT / FVT
    - Circuits in s-domain
    - Transfer functions / Sinusoidal Steady State Response
- Go through sample problems as class exercise

Midterm Review (Recap)

Variables:
- Voltage
- Current
- Resistance
- Power
- Energy

Three Laws:
- Ohm's Law
- Kirchhoff's Current Law (KCL)
- Kirchhoff's Voltage Law (KVL)

Circuit Analysis Techniques:
- KCL and KVL
- Resistance combinations
- Node-voltage and mesh-current
- Source transformations
- Thévenin and Norton Theorem

Basic Equations and Concepts:
- Power and energy in resistors
- Passive sign convention
- Ideal circuit elements: passive/active
- Ideal independent sources: volt/current
- Dependent sources: (careful w/ units)
  - Voltage controlled (volt/current)
  - Current controlled (volt/current)
- Divider circuits:
  - Voltage/current
- Open circuits:
  - $R = \infty$, no loads, switch (off state)
- Short circuits:
  - $R = 0$ ($V = 0$), wires, switch (on state)
- Maximum power transfer
- Equivalent circuits
  - Series/parallel resistors
  - Series/parallel volt/current sources
  - Source transformations
  - Thévenin/Norton
- Superposition principle

Final Review

Capacitors/Inductors:

- Inductance / admittance
- Power / energy
- Series-parallel connections
- $v - i$ and $i - v$ equations
- Physical properties

The operational amplifier

1. The inverting-amplifier circuit
2. The summing-amplifier circuit
3. The noninverting-amplifier circuit
4. The difference-amplifier circuit
5. CMRR

An Inductor stores magnetic energy. It does not permit an instantaneous change in its terminal current, but permit an instantaneous change in its terminal voltage. It behaves as a short circuit in the presence of a constant terminal current.

A capacitor stores electric energy. It does not permit an instantaneous change in its terminal voltage, but permit an instantaneous change in its terminal current. It behaves as an open circuit in the presence of a constant terminal voltage.

Final Review

Definition of the Laplace Transform:
- Functional Transform
  - Step function: $\mathcal{L}\{u(t)\} = 1/s$
  - Ramp function: $\mathcal{L}\{t\} = 1/s^2$
  - Exponential function: $\mathcal{L}\{e^{-at}\} = \frac{1}{s+a}$
  - Sinusoidal function: $\mathcal{L}\{\sin \omega t\} = \frac{\omega}{s^2+\omega^2}$
- Operational Transform
  - Multiplication by constant
  - Addition / Subtraction
  - Differentiation
  - Integration
  - Translation in time domain
  - Translation in freq. domain
  - Scale changing

Inverse Laplace Transform
- Proper rational function
  - Distinct real roots of D(s)
  - Distinct complex roots of D(s)
  - Repeated roots of D(s): real or complex
- Improper rational function
  - Long division

Initial / Final Value Theorems
- IVT: $\lim_{t \to 0^+} f(t) = \lim_{s \to \infty} sF(s)$
- FVT: $\lim_{t \to \infty} f(t) = \lim_{s \to 0^+} sF(s)$

Circuit analysis in s-domain
- Redrawing circuits in s-domain
- Analyze voltage/current using t-domain techniques
- Find voltage/current in t-domain
- Apply IVT/FVT

Final Review

Second-order circuits: (understand how many different types of responses are possible)

- When $\alpha > \omega_0$, s_1 and s_2 are real and distinct, the step response of the voltage is called overdamped. $v(t) = V_f + A_1 e^{s_1 t} + A_2 e^{s_2 t}$
- When $\alpha < \omega_0$, s_1 and s_2 are distinct and complex, the step response of the voltage is called underdamped.

$$v(t) = V_f + B_1 e^{-\alpha_1 t}\cos(\omega_d t) + B_2 e^{-\alpha_2 t}\sin(\omega t)$$
$$v(t) = V_f + Be^{-\alpha t}\cos(\omega_d t + \theta) + B_2 e^{-\alpha_2 t}\sin(\omega t)$$

where $\omega_d = \sqrt{\omega_0^2 - \alpha^2}$, which is called damped radian frequency.

- When $\alpha = \omega_0$, s_1 and s_2 are repeated real roots, the step response is called critically damped. $v(t) = V_f + D_1 te^{-\alpha t} + D_1 e^{-\alpha t}$
- When $\alpha = 0$, s_1 and s_2 are repeated complex roots, the response is unstable.

Final Review

Definition of the transfer function

- H(s) = Y(s)/X(s), where Y(s) is the output and X(s) is the input

The steady state sinusoidal response of a circuit

- If the source of the circuit is $x(t) = A\cos(\omega t + \phi)$, and the transfer function is $H(s) = Y_{ss}(s)X(s)$, the steady-state response to the source is $y_{ss}(t)$, then
- $y_{ss}(t) = A|H(j\omega)|\cos[\omega t + \phi + \theta(\omega)]$.