Systems and Simulations—Lecture 4

Introduction to Electrical Systems

Systems and Computer Engineering Dept., Carleton University, Ottawa, ON, Canada

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Elements of Electrical Systems

- Resistance elements: $R = e_R / i$. Heat dissipation, no energy storage.
- Capacitance elements: $C = q / e_C$, $i = C \frac{de_C}{dt}$.
- Inductance elements: $e_L = L \frac{di_L}{dt}$.
- Voltage source
- Current source

Note: SI units assumed throughout.

Fundamentals of Electrical Circuits

- Ohm's law.
- Series and parallel circuits.
- Kirchhoff's current law.
- Kirchhoff's voltage law.
- Examples.

Modelling of Electrical Systems

- Example of RL and RC circuits.
- Example of an RLC circuit.

Transfer Functions

- Zero initial conditions.
- Nonloading versus loading cascading elements.
- Complex impedances:
  - Resistor $R \to R$.
  - Capacitor with zero initial voltage: $C \to \frac{1}{Cs}$.
  - Inductor with zero initial current: $L \to Ls$.
- Transfer functions examples.

Analogous systems

- Systems physically different by mathematically identical.
- Two mechanical-electrical analogies:
  - Force-voltage analogy: Spring-mass-damper and series RLC circuits
  - Force-current analogy: Spring-mass-damper and parallel RLC circuits

Electromechanical systems

Modelling of a dc armature-controlled servomotor.

- Motor converts electrical to mechanical.
- With constant field current:
  $T = Ki_a$—(Mechanical-electrical)
- Back-emf proportional to speed:
  $e_b = K_f\dot{\theta}$—(Mechanical-electrical)
- Motion equation: $T = J\ddot{\theta} + b\dot{\theta}$—(Electrical)

Gear train

- Ratio of radii = ratio of teeth: $\frac{r_1}{r_2} = \frac{n_1}{n_2}$.
- Equal surface speeds at point of contact: $\omega_1 r_1 = \omega_2 r_2$.
- Frictionless gears: $T_1\omega_1 = T_2\omega_2$.

Example.

The operational amplifier

- Relationship between input and output: gain K
- Negative feedback for stability.
- Ideal op-amp.

Common Op-Amp Configurations

- Inverting amplifier
- Non-inverting amplifier
- Integrator circuit.