Lab-3
Linear Control System

First Order System

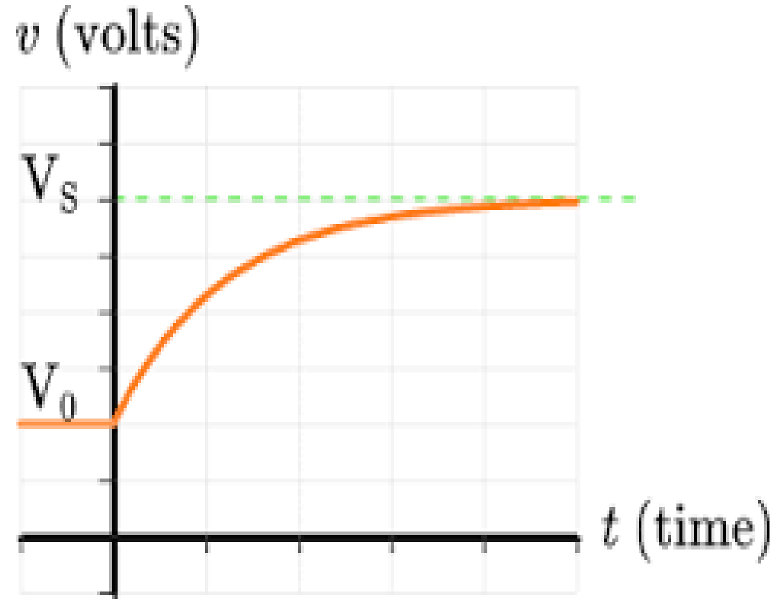
- A system whose governing equation is **first-order differential equation**.

$$G(s) = \frac{K}{\tau s + 1}$$

- K = system gain
- τ = time constant (how quickly the system responds)

Resistor and Capacitor system

- The **time constant τ** is the time it takes the capacitor voltage to reach about **63.2% of its final value** after a step input.
- After **5τ**, the capacitor is considered **fully charged/discharged (~99%)**.
- $\tau = RC$



Spring-Damping Mechanical System

- **mass is ignored** (very small inertia), leaving only **spring + damper**
- **1st-order system**, exactly like an RC circuit
- No finite zeros
- C=damping
- K= spring factor

$$\frac{X(s)}{F(s)} = \frac{1}{cs + k}$$

Seconds Order System

- A system whose governing equation is **second-order differential equation**.
- **Examples:**
  - Mass-spring-damper system
  - RLC circuit
- **Key Performance Terms:**
  - Rise Time
  - Peak Time
  - Maximum Overshoot
  - Settling Time

$$H(s) = \frac{1}{LCs^2 + RCs + 1}$$

RLC Circuits

- **RLC circuit is a second-order system**, because it has a resistor (R), an inductor (L), and a capacitor (C), leading to a **second-order differential equation**.

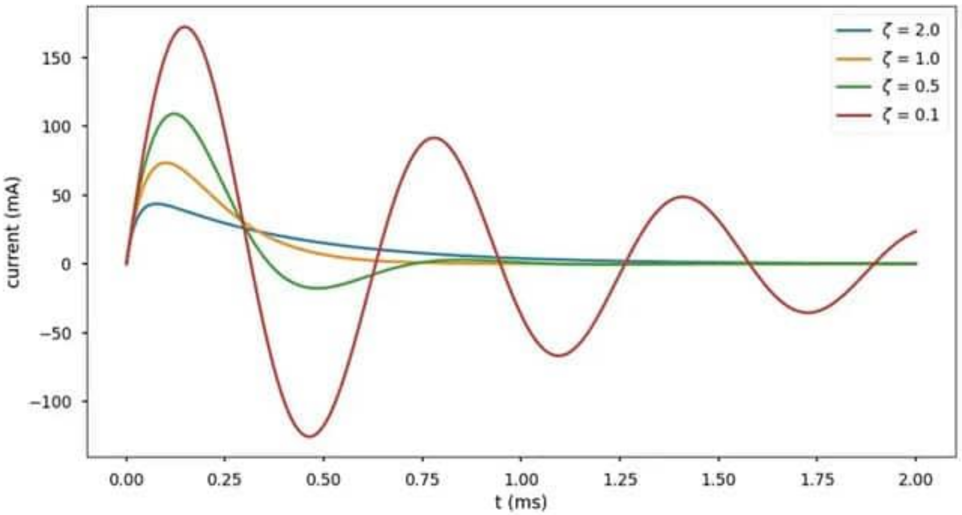
$$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}$$

If $\zeta > 1$: Overdamped (slow, no oscillations)

If $\zeta = 1$: Critically damped (fastest without oscillation)

If $0 < \zeta < 1$: Underdamped (oscillations with decay)

If $\zeta = 0$: Pure oscillation at ω_n (undamped)



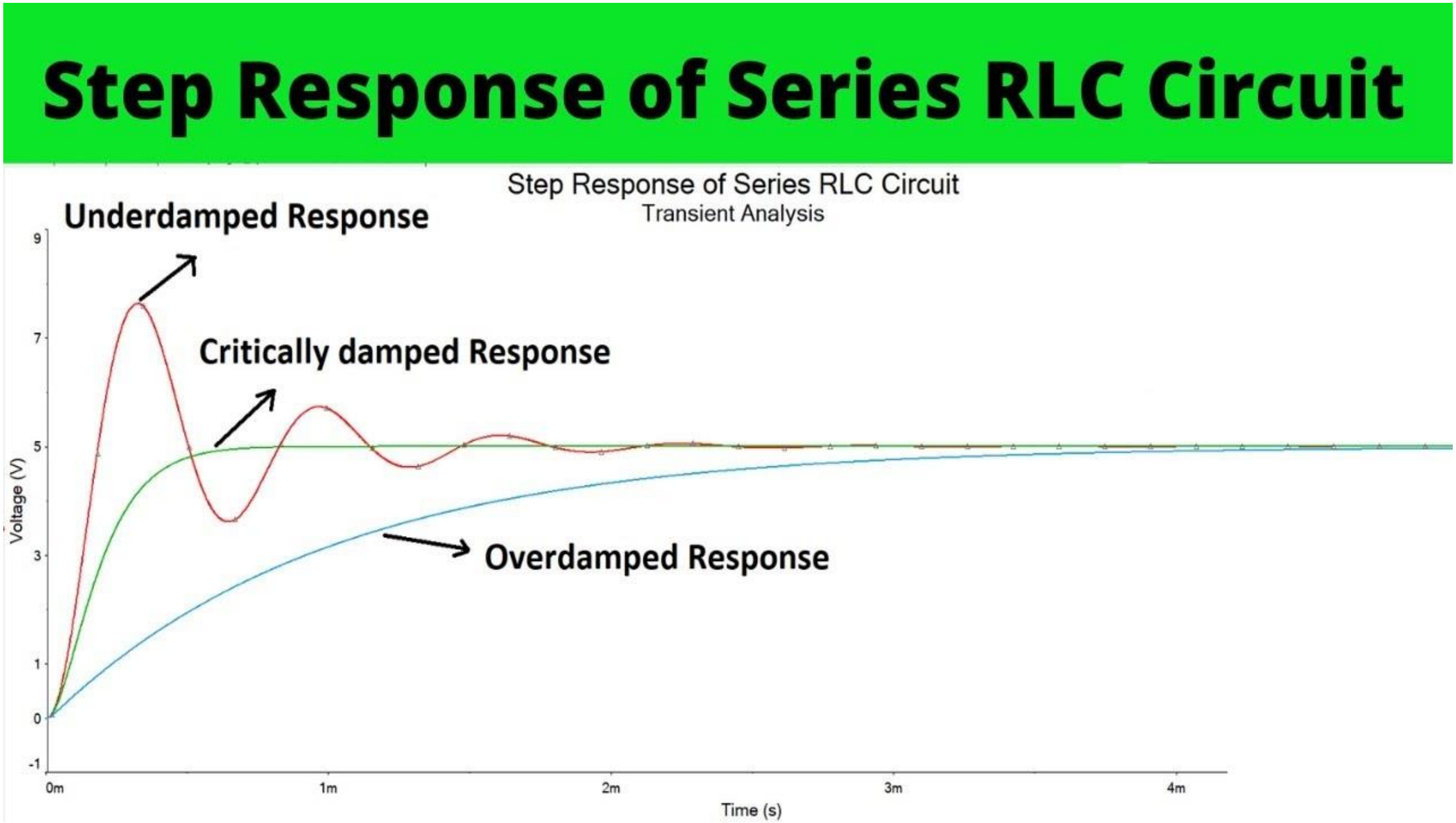
Mass–Spring–Damper

- Analogous to the **RLC circuit**
- Add mass
- Seconds polynomial
- Overshoot
- Damping Ratio

$$\frac{X(s)}{F(s)} = \frac{1}{ms^2 + cs + k}$$

$$\zeta = \frac{c}{2\sqrt{km}}$$

Damping Response of RLC



Simulink

- **Input and Signal Conversion**
- **Step Block**
  - Generates a step signal (changes from initial to final value at set time).
  - Used to analyze transient response.
- **Simulink-PS Converter**
  - Converts Simulink signal → Physical Signal (PS).
  - Allows Simulink to drive Simscape blocks.

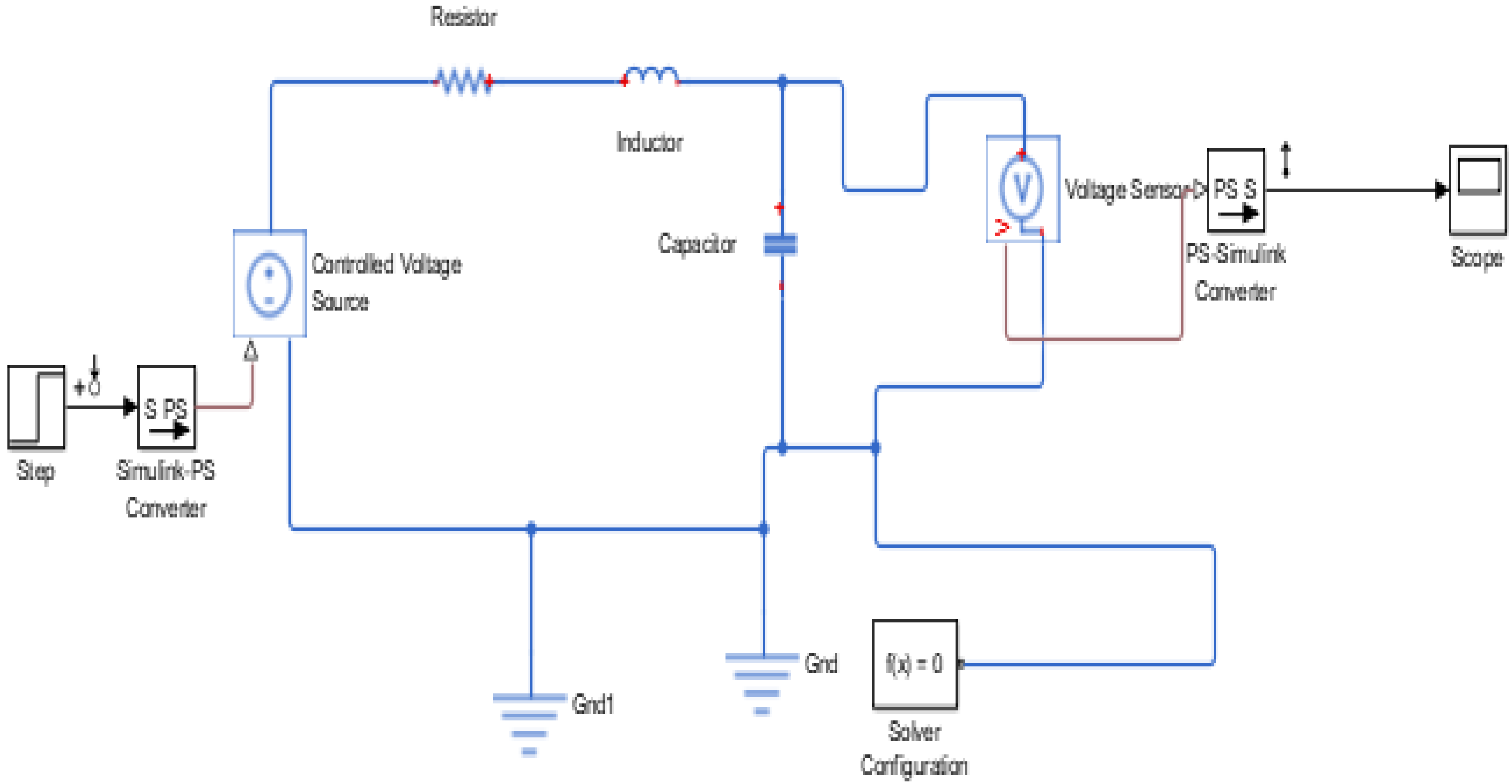
Simulink

- **Electrical Circuit (Physical System)**
- **Controlled Voltage Source**
  - Applies the converted step signal as input voltage to circuit.
- **RLC Components**
  - **Resistor (R)**
  - **Inductor (L)**
  - **Capacitor (C)**
  - Connected **in series** → same current flows through all.
- **Ground (Gnd)**
  - Defines common reference (0 V).

Simulink

- **Measurement and Output**
  - **Voltage Sensor**
    - Measures voltage across the capacitor.
  - **PS-Simulink Converter**
    - Converts physical signal → Simulink signal.
  - **Scope**
    - Displays voltage response vs time (system output).
- **Simulation Configuration**
  - **Solver Configuration**
    - Mandatory block in Simscape.
    - Defines solver type and numerical parameters.
    - Ensures accurate computation of system dynamics.

Simulink



Resistor
Inductor
Capacitor
Controlled Voltage Source
Voltage Sensor
PS S
PS-Simulink Converter
Scope
Step
S PS
Simulink-PS Converter
Gnd1
Gnd
f(x) = 0
Solver Configuration