

# Second Order System Response

## System Transfer Function

The transfer function  $H(s)$  for a second-order system is:

$$H(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

where:

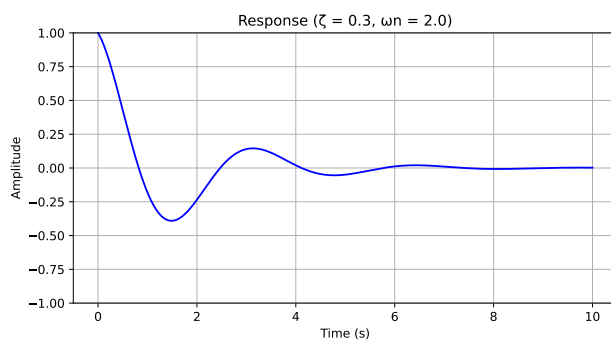
- $\zeta$  is the damping ratio
- $\omega_n$  is the natural frequency

## Response Types

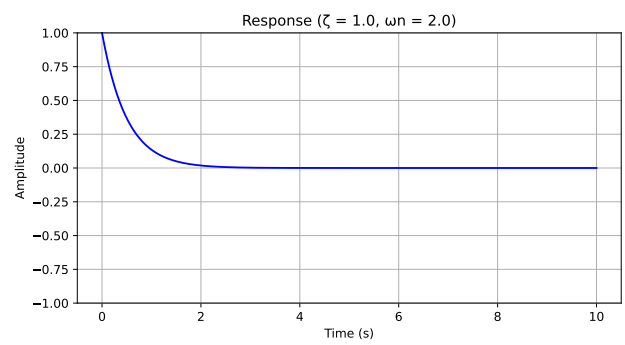
The system exhibits three characteristic behaviors:

1. **Underdamped** ( $\zeta < 1$ )
  - System oscillates with decreasing amplitude
  - Common in systems with insufficient damping
2. **Critically Damped** ( $\zeta = 1$ )
  - Fastest return to steady state without oscillation
  - Optimal for many control applications
3. **Overdamped** ( $\zeta > 1$ )
  - Returns to steady state without oscillation
  - Slower response than critically damped

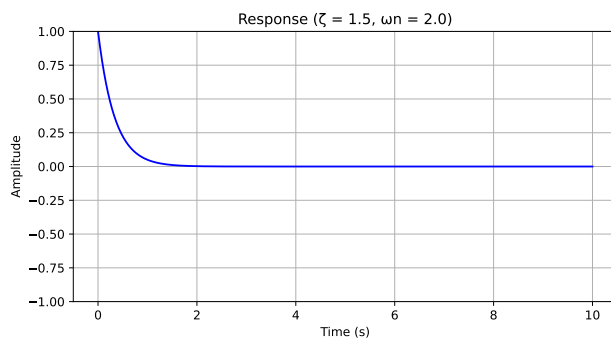
## System Response Examples



(a) Underdamped Response ( $\zeta = 0.3, n = 2.0$ )



(a) Critically Damped Response ( $\zeta = 1.0, n = 2.0$ )



(a) Overdamped Response ( $\zeta = 1.5, n = 2.0$ )