Second-Order Response

Mechanical Engineering

Natural frequency sets the speed, damping ratio sets the overshoot.

Two numbers describe it: natural frequency sets the speed and damping ratio sets the overshoot.

$$\omega_n^2 \div (s^2 + 2\,\text{zeta}\,\omega_n\,s + \omega_n^2) \cdot \text{zeta} = \text{damping ratio}$$

zeta = 0.7 A common target.	**About 5% overshoot**
zeta = 0.5 Faster, less damped.	**About 16% overshoot**
zeta = 0.7, ωn = 10 Roughly 4 ÷ zeta ωn.	**Settles in about 0.6 s**

THE COMMON MISTAKE

× **Raising the gain to make it faster**

✓ **Gain raises ωn and cuts damping**

In most loops more gain means more overshoot and less margin. Speed and damping trade against each other unless you add derivative action.

Underdamped means damping ratio below one. At exactly one the response is critically damped, the fastest with no overshoot.