Second-Order System Step Response: Overshoot and Settling Time

Percentage overshoot, peak time, rise time and settling time of an underdamped second-order system from its natural frequency and damping ratio.

Method: Standard second-order response (Ogata, Modern Control Engineering, ch. 5)

Input parameters

Unit system: SI

Parameter	Value	Unit
Natural frequency ω_n in rad/s Angular frequency in radians per second. If you have the natural frequency f_n in Hz, enter 2π f_n.	0.50000	1/s
Damping ratio	0.40000	
Settling band	2.0000	%

Calculated results

Parameter	Value	Unit
Overshoot	25.383	%
Time to the first peak	6.8555	s
Settling time (envelope)	19.996	s
Rise time 0–100 %	4.3258	s
Damped frequency ω_d in rad/s	0.45826	1/s

Notes for this case

- Natural frequency in radians per second. The settling time is from the exponential envelope, slightly longer than the exact crossing.

Formula and method

$$M_p = e^{-\zeta\pi/\sqrt{1-\zeta^2}}, \quad t_p = \frac{\pi}{\omega_d}, \quad t_s = \frac{-\ln(\epsilon\sqrt{1-\zeta^2})}{\zeta\omega_n}, \quad \omega_d = \omega_n\sqrt{1-\zeta^2}, \quad t_r = \frac{\pi - \arccos\zeta}{\omega_d}$$

Variables

ω_n	Natural (angular) frequency	rad/s
ζ	Damping ratio	-
ϵ	Settling band	-
M_p	Overshoot	-
t_p	Time to the first peak	s
t_s	Settling time (envelope)	s
t_r	Rise time 0–100 %	s
ω_d	Damped (angular) frequency	rad/s

Method and standards

Analytic step response.

Assumptions and limits

- Underdamped, no zeros.
- ω_n and ω_d are angular frequencies in rad/s (shown as 1/s); a natural frequency in Hz must be multiplied by 2π first.

References

- Standard second-order response (Ogata, Modern Control Engineering, ch. 5)

Report details

Report reference	FCC-T226-M6AW (the same inputs always give the same reference)
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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/instrumentation/control-loops/second-order-step-response

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.