

Suspension Bond Graph Cheat Sheet

Bottoming-out model: bump stop stiffness and damping

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Natural frequency	$\omega_n = \sqrt{(k / m)}$	Textbook form for the spring-mass
Damping ratio	$\zeta = b / (2 \sqrt{(k m)})$	Textbook form; post varies ζ
Barrier stiffness ratio	$k_p / k = 100, 1000, 10,000$	Barrier spring vs suspension spring
Acceptance criterion	Deformation $\leq 7 \text{ mm (0.007 m)}$	Larger was judged too large
Capacitor (C) element	$e = q / C$	Spring; bond graph effort and displacement
Inertia (I) element	$f = p / m$	Mass; flow is velocity

Key takeaways

- Bottoming out: spring fully compressed, shock hits the bump stop, as in a pothole at speed. It can severely damage the suspension.
- Model in 20sim: cosine velocity source, 0 junction to spring (C), 1 junction to mass (I), q and f sensors, barriers as k_p and b_p .
- Barrier elements get an extra port so force acts only when the mass passes the barrier position.
- $k_p/k = 100$: deflection 0.05 m, second hit about 1.75 s at half speed (0.03 m). $k_p/k = 1000$: 0.016 m. $k_p/k = 10,000$: 0.005 m.
- Only $k_p/k = 10,000$ met the 7 mm limit, and only it hit both barriers.
- Damping ratio above 1 ended repeated left-wall hits; at $\zeta = 2$ the mass stopped after the first impact (0.03, 0.02, 0.012 m).
- Author's caveat: the frequency-variation runs showed no velocity decline, so input parameters may be wrong. Values are read from graphs.
- Suggested upgrades: add a tire mass, use a one-time pothole pulse, include permanent deformation and friction.