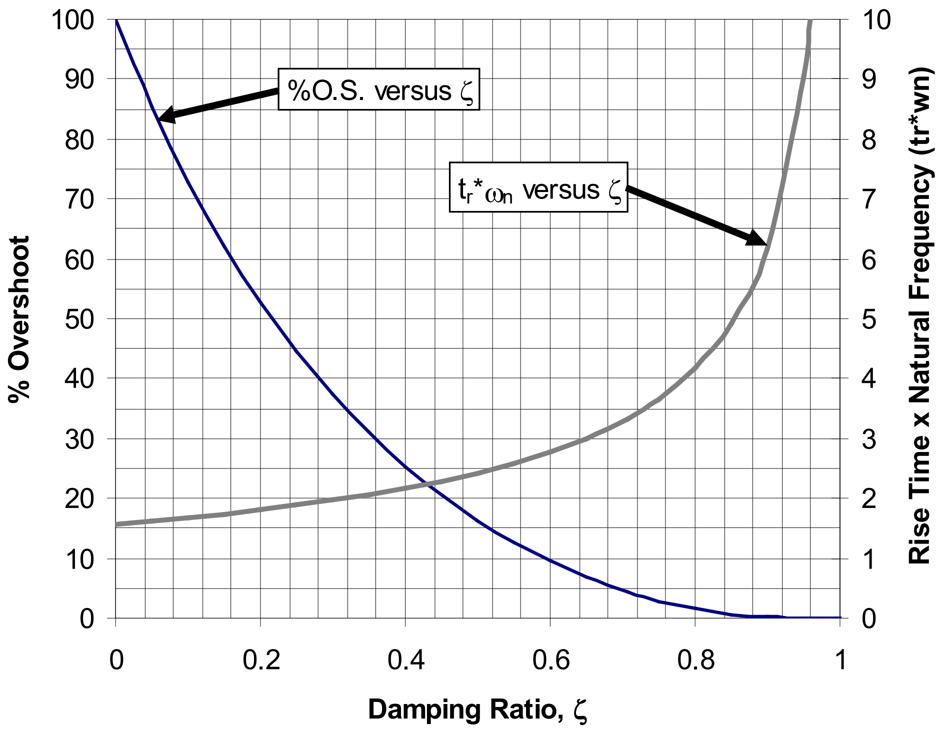

$$P.O. = 100 \cdot e^{\left(\frac{-\pi \cdot \zeta}{\sqrt{1-\zeta^2}}\right)}$$

$$t_p = \frac{\pi}{\omega_n \cdot \sqrt{1-\zeta^2}}$$

$$t_r \cdot \omega_n \approx \frac{1}{\sqrt{1-\zeta^2}} \tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{-\zeta}\right)$$

$$t_{s,2\%} = 4\tau = \frac{4}{\zeta \cdot \omega_n}$$

$$\omega_n \approx \frac{1}{t_r \cdot \sqrt{1-\zeta^2}} \tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{-\zeta}\right)$$

System Type Number n	0	1	2
Step Input R(s) = 1/s	Error = 1/(1+K)	0	0
Ramp Input R(s) = $1/s^2$	Error = ∞	Error = 1 / K	0
Acceleration Input, $1/s^3$	Error = ∞	Error = ∞	Error = 1 / K

$$q = \frac{\Delta h}{R}$$

$$q_{in} - q_{out} = C\frac{dh}{dt}$$

Common Inputs	f(t), Time Domain	F(s), Laplace Domain
Unit Step	1(t), t > 0	$\frac{1}{s}$
Unit Ramp	t	$\frac{1}{s^2}$
Common Transform Pairs	**f(t), Time Domain**	**F(s), Laplace Domain**
1st Order Step Response	$\frac{1}{a}\cdot\left(1-e^{-a\cdot t}\right)$	$\frac{1}{s\cdot(s+a)}$
2nd Order Step Response	$1-\frac{e^{-\zeta\cdot\omega_n\cdot t}}{\sqrt{1-\xi^2}}\cdot\sin(\omega_d\cdot t+\phi)$ $\omega_d = \omega_n\sqrt{1-\zeta^2}$ $\phi = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s\left(s^2+2\zeta\omega_n s+\omega_n^2\right)}$

$$\lim_{t\to\infty} f(t) = \lim_{s\to 0} s \cdot F(s)$$

Table of Physical System Relationships

System	Inductance	Capacitance	Resistance	Effort	Flow	Item
Mechanical - Translational	Mass, m	Springs, k	Damper, b	Force, F	Velocity, v	Variable
	Kg	N/m	N/m/s	N	m/s	Metric Units
	slugs	lb/in	lb/in/s	lbf	in/s	English Units
	$F = m\ dv/dt$	$F = k\ x$	$F = b\ v$	Momentum	$x = \int v\ dt$	Equation
	$E = ½\ m\ v^2$	$E = ½\ k\ x^2$	$P = b\ v^2$	$m\ v = \int F\ dt$	$P = F\ v$	Energy/Power
Mechanical - Rotational	Inertia, J	Spring, k	Damper, b	Torque, T	∠ Velocity, ω	Variable
	N-m-s^2	N-m/rad	N-m-s	N-m	rad/s	Metric Units
	lb-in-s^2	lb-in/rad	lb-in-s	lbf-in	rad/s	English Units
	$T = J\ \alpha$	$T = k\ \theta$	$T = b\ \omega$	Momentum	$\theta = \int \omega\ dt$	Equation
	$E = ½\ J\ \omega^2$	$E = ½\ k\ \theta^2$	$P = b\ \omega^2$	$J\ \omega = \int T\ dt$	$P = T\ \omega$	Energy/Power
Electrical	Inductance, L	Capacitance, C	Resistance, R	Volts	Current, I	Variable
	Henries, H	Farads, F	Ohms, Ω	V	Amps, A	Metric Units
	$V = L\ di/dt$	$V = 1/C \int i\ dt$	$V = R\ i$	Flux Linkage	$q = \int i\ dt$	Equation
	$E = ½\ L\ i^2$	$E = ½\ C\ V^2$	$P = 1/R\ V^2$	$L\ i = \int V\ dt$	$P = V\ i$	Energy/Power
Hydraulic	Fluid Inertia	Capacitance	Orifice	Pressure, p	Flow Rate, Q	Variable
Pneumatic	N s^2 / m^5	m^3/Pa (linear)	(m^3/s)/(N/m^2)^{½}	Pascal, Pa	m^3/s	Metric Units
	lbf s^2 / in^5	in^3/psi (linear)	(in^3/s)/(psi)^{½}	psi, lb/in^2	in^3/s	English Units
	$P = I\ dQ/dt$	$p = 1/C \int Q\ dt$	$Q = Kv \sqrt{P}$	Momentum	$q = \int Q\ dt$	Equation
	$E = ½\ I\ Q^2$	$E = ½\ C\ p^2$	$P = p\ Q$	$Q\ I = \int p\ dt$	Power = $p\ Q$	Energy/Power
Thermal	N/A	Capacitance	Resistance, R_f	Temperature, T	Heat flow rate, q	Variable
		J/K	K/W	Kelvin, K	Watts, W	Metric Units
		lb-in/R	R/Btu	Rankine, R	Btu/s	English Units
		$\Delta T = 1/C \int q\ dt$	$q = 1/R_f\ \Delta T$	Momentum	Heat Energy =	Equation
		$E = C\ T$	$P = 1/R_f\ \Delta T$	not used	$1/C \int q\ dt$	Energy/Power