Signal Flow

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$M \rightarrow$ Forward Path
$L \rightarrow$ Loops
$\triangle_1 \rightarrow 1 - ((\text{Loops left after} M_1 \text{ removed})$
$\triangle \rightarrow 1 - (\text{sum of loop Gains} + \text{sum of 2 non-touching})$
$\text{Gain} = \frac{C(s)}{R(s)} = \frac{M_1\triangle_1 + M_2\triangle_2 + \ldots..}{\triangle}$
Everv Deriviation Has An Initial Condition

State Space

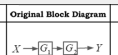
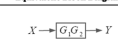
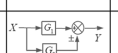
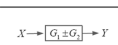
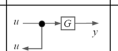
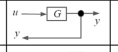
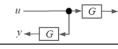
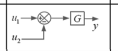
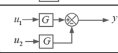
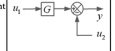
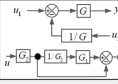
$$\frac{Y(s)}{U(s)} = \frac{b_n s^n + b_{n-1}s^{n-1} + \cdots + b_1 s + b_0}{s^n + a_{n-1}s^{n-1} + \cdots + a_1 s + a_0} \qquad (3.12)$$

Second Order System

Second Order System

Underdamped: $0 < \zeta < 1$
Critically Damped: $\zeta = 1 \rightarrow$ *Poles at same point*
Under Damped: $\zeta = 0$
Damped: $\zeta > 1$
Settling Time:
$t_s = \frac{4}{\zeta\omega_n}$
$t_{\max} = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$
$C_{\max}(t) = 1 + e^{\frac{-\pi\zeta}{\sqrt{1-\eta^2}}}$
$\%\text{Overshoot} = 100e^{\frac{-\pi\zeta}{\sqrt{1-\eta^2}}}$
Rising Time:
$t_r = \frac{1+1.1\zeta+1.4\zeta^2}{\omega_n}\ \text{sec}$
Delay Time:
$t_d = \frac{1+0.6\zeta+0.15\zeta^2}{\omega_n}\ \text{sec}$
$\#\ \text{of Oscillations} = \frac{\omega_d t_s}{2\pi}$
Where:
$\omega_d = \omega_n\sqrt{1-\zeta^2}$
Critically Damped:
$\frac{\omega_0}{s^2+2\omega_n+\omega_n^2}$

Block Diagram

	Manipulation	Original Block Diagram	Equivalent Block Diagram	Equation
1	Combining Blocks in Cascade			$Y = (G_1G_2)X$
2	Combining Blocks in Parallel; or Eliminating a Forward Loop			$Y = (G_1 \pm G_2)X$
3	Moving a pickoff point behind a block			$y = Gu$ $u = \frac{1}{G}y$
4	Moving a pickoff point ahead of a block			$y = Gu$
5	Moving a summing point behind a block			$e_2 = G(u_1 - u_2)$
6	Moving a summing point ahead of a block			$y = Gu_1 - u_2$ $y = (G_1 - G_2)u$

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