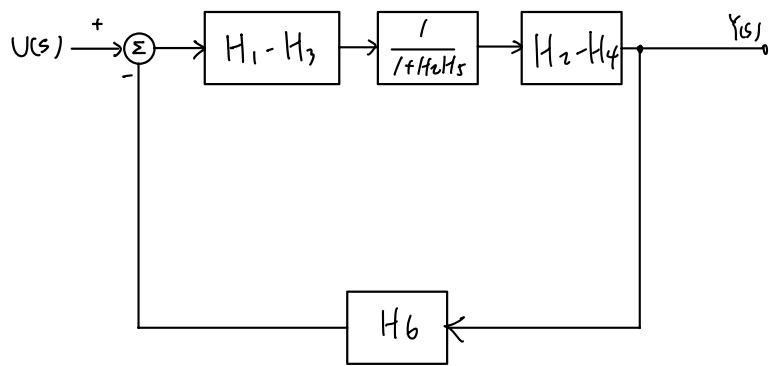


1.



$$G_1 = \frac{(H_1 - H_3)}{1 + H_2 H_5} \cdot (H_2 - H_4)$$

$$l_1 = \frac{(H_1 - H_3)(H_2 - H_4)}{1 + H_2 H_5} \cdot H_6$$

$$\Delta = \left(1 + \frac{(H_1 - H_3)(H_2 - H_4)}{1 + H_2 H_5} \right) H_6 + 0$$

$$\Delta_1 = 1 - 0 = 1$$

$$\Rightarrow G(s) = \frac{Y(s)}{U(s)} = \frac{\frac{H_1 - H_3}{1 + H_2 H_5} \cdot (H_2 - H_4)}{\left(1 + \frac{(H_1 - H_3)(H_2 - H_4)}{1 + H_2 H_5} \right) H_6} = \frac{(H_1 - H_3)(H_2 - H_4)}{1 + H_2 H_5 + (H_1 - H_3)(H_2 - H_4) H_6}$$

$$= \frac{H_1 H_2 - H_1 H_4 - H_3 H_2 + H_3 H_4}{1 + H_2 H_5 + H_1 H_2 H_6 - H_1 H_4 H_6 - H_3 H_2 H_6 + H_3 H_4 H_6}$$

2.

①

$$\omega_n = \sqrt{\frac{k_{pp} k_{vc0}}{NC}} = \sqrt{\frac{10^4 / 2\pi \cdot 2\pi \cdot 10^9}{32 \cdot \frac{1}{32(2\pi)^2 10^9}}} = \sqrt{10^5 \cdot (2\pi)^2 \cdot 10^9}$$

$$\Rightarrow 2\pi \cdot 10^7 = \sqrt{\frac{10^4}{2\pi} \cdot \frac{2\pi \cdot 10^9}{32 C}} \Rightarrow C = \frac{\frac{10^4}{2\pi} \cdot 2\pi \cdot 10^9}{(2\pi \cdot 10^7)^2 \cdot 32} = \frac{1}{(2\pi)^2 \cdot 10^9 \cdot 32}$$

$$\zeta = \frac{\omega_n}{2} RC$$

$$\Rightarrow \zeta = 1 \Rightarrow 1 = \frac{2\pi \cdot 10^7}{2} \cdot R \cdot \frac{1}{(2\pi)^2 \cdot 32 \cdot 10^9} \Rightarrow R = 1/2\pi \cdot 10^2 \Omega$$

$$\Rightarrow \zeta = 0.2 \Rightarrow 0.2 = \frac{2\pi \cdot 10^7}{2} \cdot R \cdot \frac{1}{(2\pi)^2 \cdot 32 \cdot 10^9} \Rightarrow R = 2.56\pi \cdot 10^3 \Omega$$

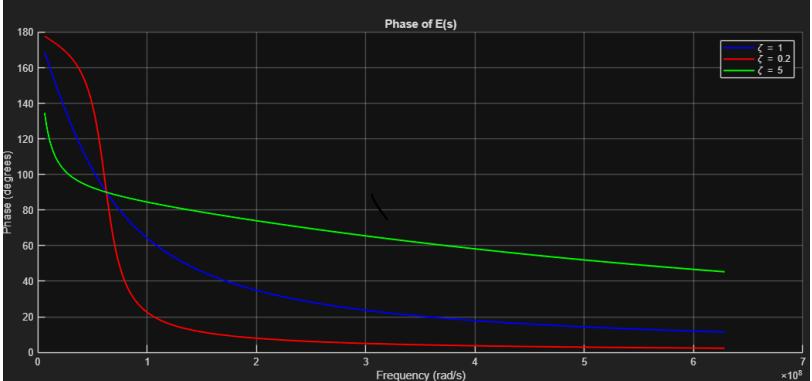
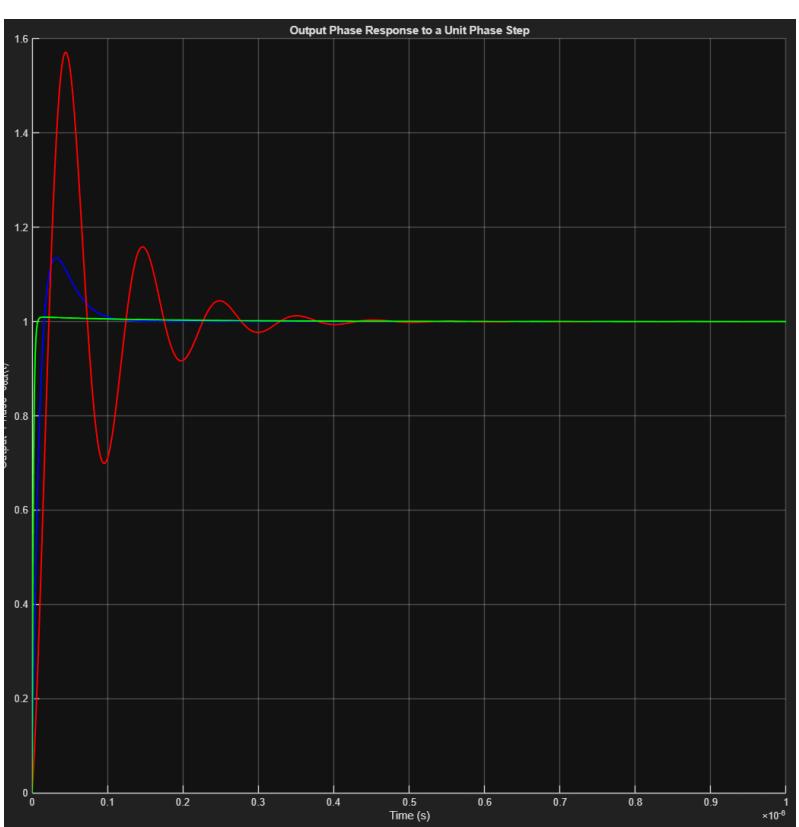
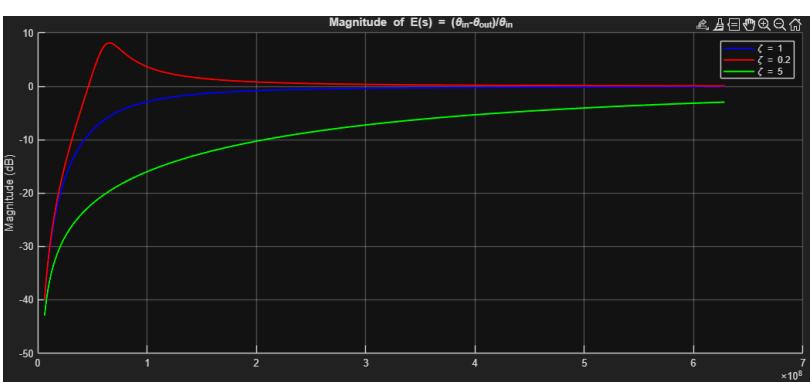
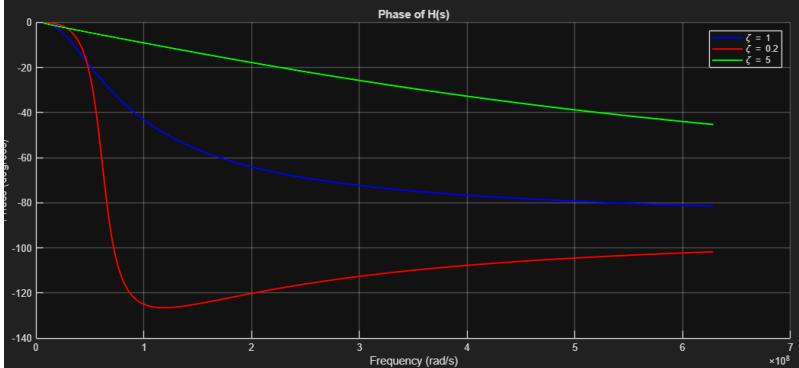
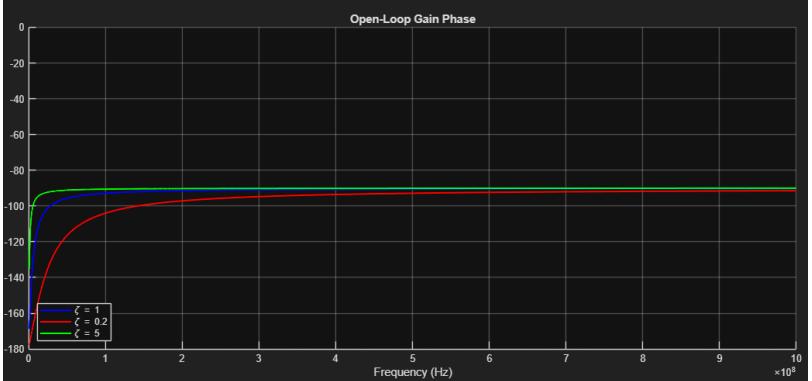
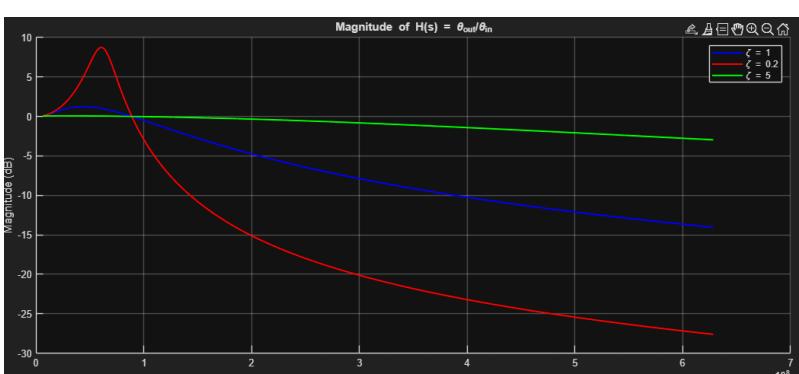
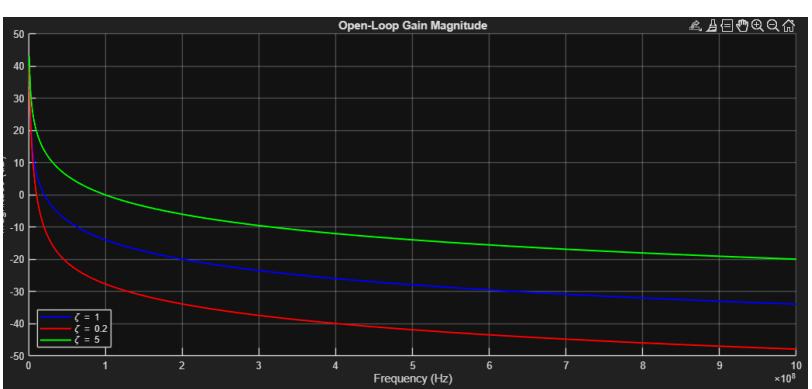
$$\Rightarrow \zeta = 5 \Rightarrow R = 6.4\pi \cdot 10^4 \Omega$$

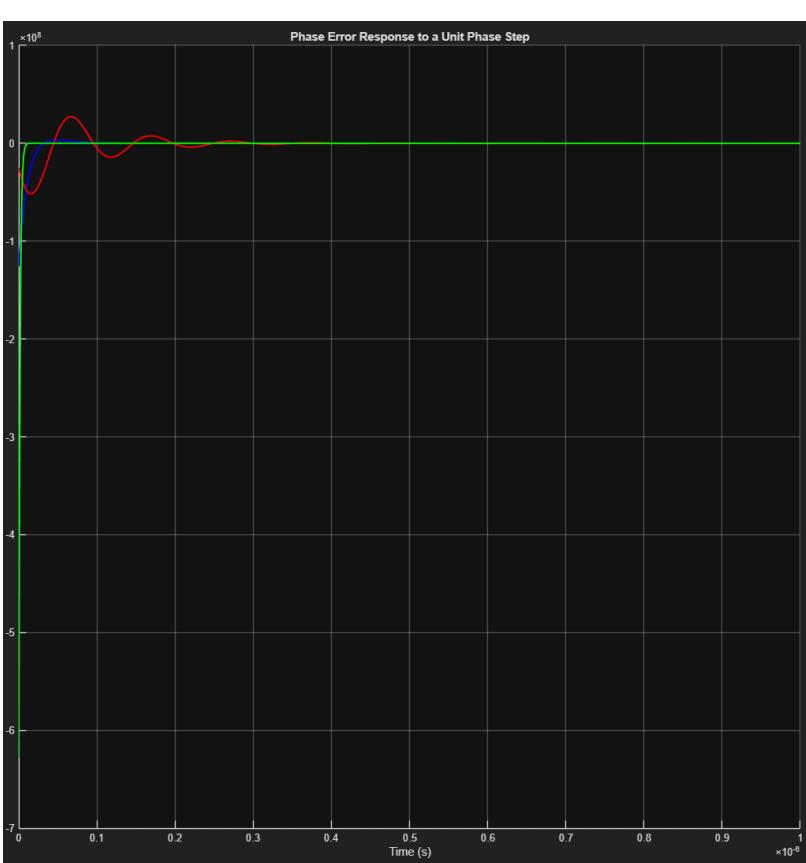
$$\text{Transfer Function: } \frac{\frac{k_{pp} k_{vc0} R (s + \frac{1}{R_C})}{s^2 + \left(\frac{k_{pp} k_{vc0} R}{NC} \right) s + \frac{k_{pp} k_{vc0}}{NC}}}{s^2 + \frac{10^5 R}{32} s + \frac{2\pi^2 \cdot 10^9 \cdot 32}{32}} = \frac{10^4 / 2\pi \cdot 2\pi \cdot 10^9 R (s + \frac{1}{R_C})}{s^2 + \frac{10^5 R}{32} s + \frac{2\pi^2 \cdot 10^9 \cdot 32}{32}}$$

$$\zeta = 1, \text{ pole } \Rightarrow -\frac{1/2\pi \cdot 10^2 \cdot \frac{10^5}{32} \pm \sqrt{(4\pi^2 \cdot 10^2)^2 - 4(2\pi \cdot 10^7)^2}}{2} = -2\pi \times 10^{-7} \text{ (critical damped)}$$

$$\zeta = 0.5, \text{ poles } \Rightarrow \zeta = -\zeta \omega_n \pm \omega_n \sqrt{\zeta^2 - 1} = -\frac{k_{pp} k_{vc0} R}{2 \cdot NC} \pm \sqrt{\frac{k_{pp} k_{vc0}}{NC} \cdot 0.04} = \frac{2.56\pi \cdot 10^8}{64} \pm \sqrt{0.96 \cdot 10^5 (2\pi)^2 \cdot 10^9} = 4\pi \cdot 10^6 \pm \sqrt{6.16 \times 10^7}$$

$$\zeta = 5, \text{ poles } \Rightarrow \zeta = \frac{-10^5 \cdot 6.4\pi \cdot 10^4}{64} \pm \sqrt{10^5 \cdot (2\pi)^2 \cdot 10^9} \cdot \sqrt{24} = -6.74 \times 10^6 \text{ or } -6.72 \times 10^6 \text{ (overdamped)}$$



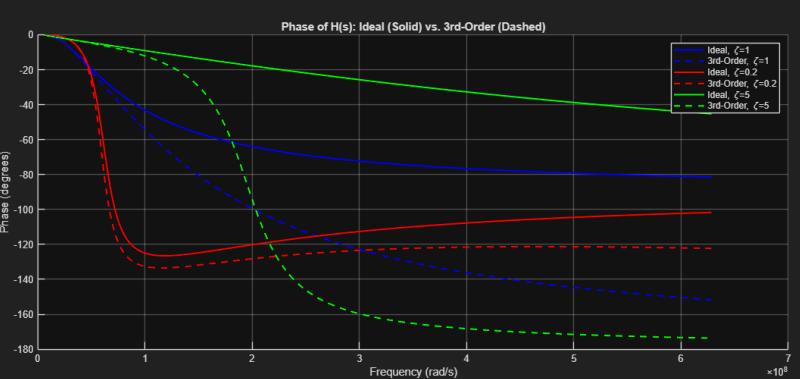
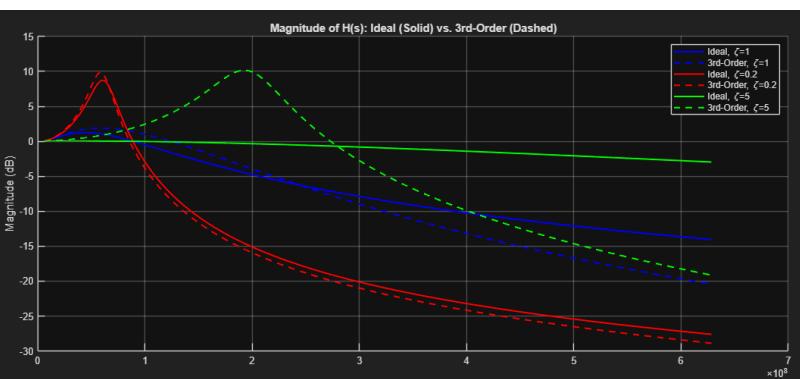


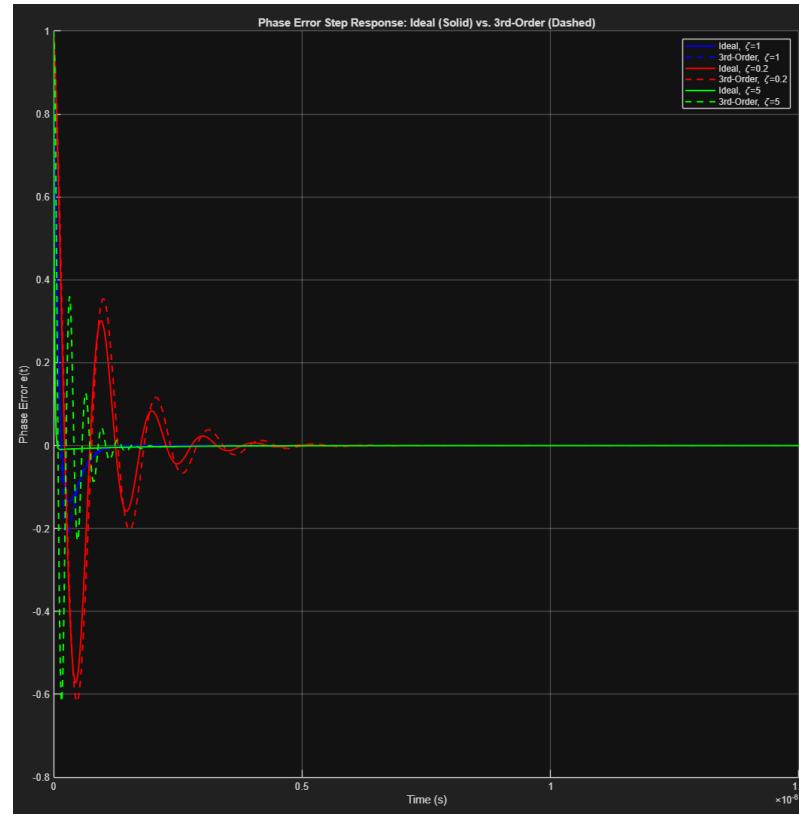
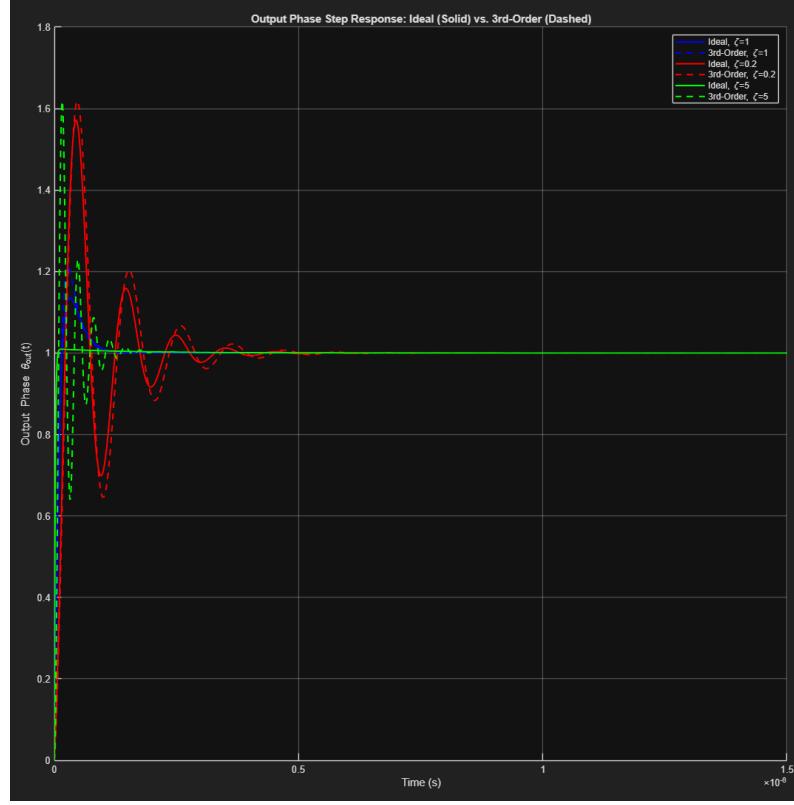
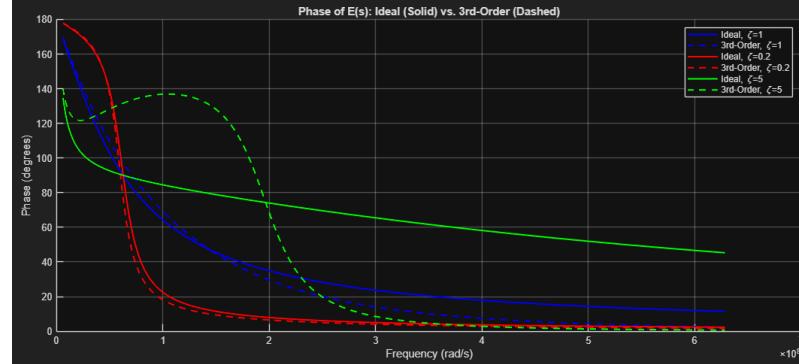
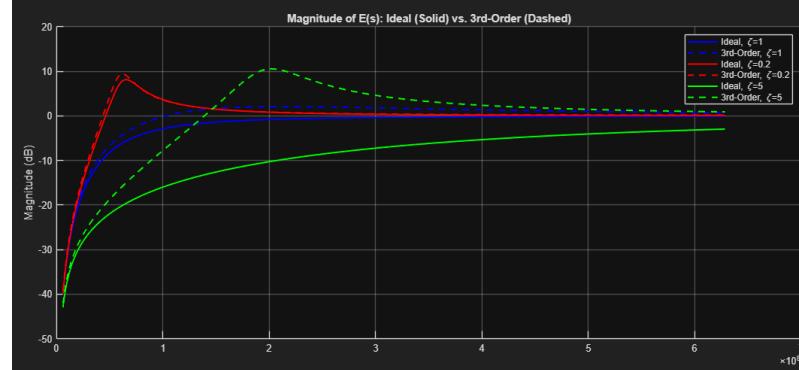
--- PART A: Open-Loop Analysis & Phase Margin ---
 For $\zeta = 1.0$, Phase Margin = 76.35 degrees
 For $\zeta = 0.2$, Phase Margin = 22.60 degrees
 For $\zeta = 5.0$, Phase Margin = 89.43 degrees

--- PART B: Closed-Loop Pole Values ---
 For $\zeta = 1.0$, Poles are: -6.283e+07 and -6.283e+07
 For $\zeta = 0.2$, Poles are: -1.257e+07 and -1.257e+07
 Imaginary part: +/- 6.156e+07 j
 For $\zeta = 5.0$, Poles are: -6.347e+06 and -6.220e+08

The under damped case ($\zeta=0.2$) shows peaking in the frequency response and overshoot in the transient response, while the critically damped ($\zeta=1$) and overdamped ($\zeta=5$) cases exhibit no peaking.

3.





--- Analyzing for ideal $\zeta = 1.0$ ---
Poles of 3rd-Order System:

$1.0e+08 *$
 $-1.4757 + 0.5307i$
 $-1.4757 - 0.5307i$
 $-0.5043 + 0.0000i$

--- Analyzing for ideal $\zeta = 0.2$ ---
Poles of 3rd-Order System:

$1.0e+09 *$
 $-1.7069 + 0.0000i$
 $-0.0105 + 0.0594i$
 $-0.0105 - 0.0594i$

--- Analyzing for ideal $\zeta = 5.0$ ---
Poles of 3rd-Order System:

$1.0e+08 *$
 $-0.3138 + 1.9518i$
 $-0.3138 - 1.9518i$
 $-0.0635 + 0.0000i$

Answer: C_2 introduces a third pole into the system. This pole directly reduces the system's phase margin. The lower phase margin makes the system less stable, especially in the transient response. For every ζ value, the third-order system has more overshoot and ringing than ideal second-order system. However, C_2 harms stability, the purpose of C_2 is provide better filtering.