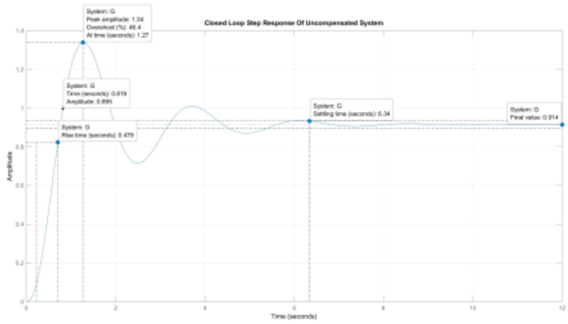
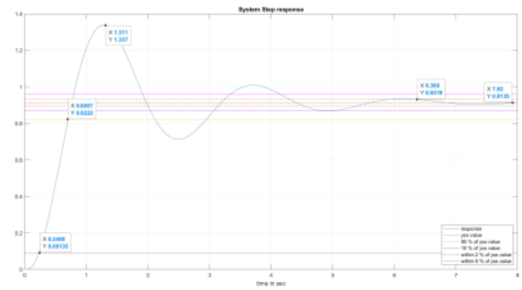
Q) $G(s) = \dfrac{100(s+0.3)}{(s+0.5)(s+1)^2(s+15)}$



1) **(2 marks)** Compute the closed loop transfer function of the uncompensated system and generate the closed loop step response of the uncompensated system. Read off the values of the **uncompensated** closed loop step response specs: Percent Overshoot, PO, Steady State Error, $e_{ss(step\%)}$, Rise Time, $T_{rise(0-100\%)}$ and Settling Time, $T_{settle(\pm 2\%)}$, and place your answers in the Table. Verify the specs values by running the Matlab "stepeval" function.



$$G_{cl}(s) = \frac{\dfrac{100(s+0.3)}{(s+0.5)(s+1)^2(s+15)}}{1 + \dfrac{100(s+0.3)}{(s+0.5)(s+1)^2(s+15)}}$$

$$= \frac{100(s+0.3)}{(s+0.5)(s+1)^2(s+15) + 100(s+0.3)}$$

$$= \frac{100s + 30}{(s^2+2s+1)(s^2+15.5s+7.5) + 100s + 30}$$

$$\frac{100s + 80}{s^4 + 15.5s^3 + 7.5s^2 + 2s^3 + 31s^2 + 15s + s^2 + 15.5s + 7.5 + 100s + 80}$$

$$\boxed{G_{cl}(s) = \frac{100s + 80}{s^4 + 17.5s^3 + 39.5s^2 + 130.5s + 87.5}}$$

$$PO = \frac{y_{max} - y_{ss}}{y_{ss}} \times 100$$

$$\frac{1.337 - 0.9135}{0.9135} \times 100$$

$$\boxed{PO = 46.36\%}$$

$$e_{ss(step\%)} = \frac{r_{ss} - y_{ss}}{r_{ss}} \times 100$$

$$= \frac{1 - 0.9135}{1} \times 100$$

$$\boxed{e_{ss(step\%)} = 8.65\%}$$

$$\boxed{T_{rise(0-100\%)} = 0.7759\,s}$$

$$\boxed{T_{settle(\pm 2\%)} = 6.3679\,s}$$

2) **(2 marks)** Now that you know what the actual specs are, **estimate these specs** by first generating a closed loop model for the uncompensated system, then calculating specs based on the relationships established for the second order dominant poles model. HINT: The most straightforward way of generating the model is from the closed loop transfer function – use the "zpk" Matlab function to factorize it, and remove the near pole-zero cancellations, and the negligible poles and zeros. Are your estimates close to the actual specs? Include calculations in your report.

$$G_{cl}(s) = \frac{100\,(s+0.8)}{(s+15.47)(s+0.7983)(s^2+1.234s+7.086)}$$

$= (s+15.47) \rightarrow$ negligible

$\dfrac{(s+0.8)}{(s+0.7983)} \rightarrow$ cancel out but not fully

$$\boxed{G_m(s) = \frac{100}{s^2+1.234s+7.086}}$$

$$G_{cl}(s) = K_{DC}\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$$

$$\boxed{\omega_n = \sqrt{7.086} = 2.66}$$

$$2\zeta\omega_n = 1.234$$

$$\boxed{\zeta = \frac{1.234}{2\times 2.66} = 0.23}$$

$\boxed{PO \approx 47\%}$ (estimation based on the graph)

$$PO = 100\cdot e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$

$$= 100\cdot e^{\frac{-0.72}{0.973}}$$

$\boxed{PO = 47.72\%}$ (using the formula)

$$e_{ss(step\%)} = 1 - K_{DC[closed]}$$

$$K_{DC\_closed(uncompensated)} = G_{cl}(0) = \frac{100\times 0.8}{(15.47)(0.7983)(7.086)}$$

$$\boxed{K_{DC\_closed(uncompensated)} = 0.9141}$$

$$\boxed{e_{ss(step\%)} = (1-K_{DC\_closed(uncompensated)})\times 100 = 8.58\%}$$

$$T_{rise(0-100\%)} = \frac{\pi-\cos^{-1}\zeta}{\omega_n\sqrt{1-\zeta^2}}$$

$$\boxed{T_{rise(0-100\%)} = 0.69\ s}$$

$$T_{settl(\ldots)} = \frac{4}{\ldots}$$

$$T_{settle\,(\pm 2\%)} = \frac{4}{\zeta\,\omega_n}$$

$$\boxed{T_{settle\,(\pm 2\%)} = 6.53}$$

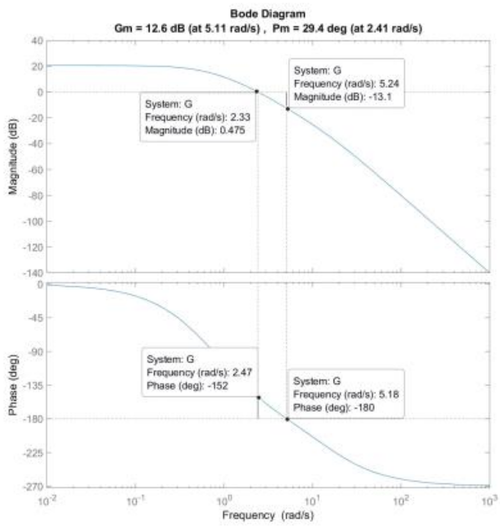
3) **(2 marks)** Generate the **uncompensated** open loop Frequency Response plot for G(s). Read off the values of the Phase Margin, Φ_m, and the Crossover Frequency, ω_{cp} are, and place your answers in the Table. Use Matlab function "margin" to verify if your read-outs were accurate. Include this plot in your report.

$$G_{m\,(db)} = x \;, \quad G_{m\,(V/V)} = 10^{\left(\frac{x}{20}\right)} = K_{crit}$$

$$G(s) = \frac{100\,(s+0.8)}{(s+0.5)(s+1)^2(s+15)}$$

$$G_{open}(s) = \frac{100 \times 0.8\,(1.25s+1)}{(0.5)\times(1)(15)(2s+1)(s+1)^2(0.066s+1)}$$

$$\boxed{G_{open}(s) = \frac{10.67 \times (1.25s+1)}{(2s+1)(s+1)^2(0.066s+1)}}$$



$$G_m = 4.27 \;\; V/V$$

$$P_m = 29.36$$

$$\omega_{cg} = 5.11$$

$$\omega_{cp} = 2.4$$