EEN1047
CONTROL SYSTEMS ANALYSIS
Exercises

Dr. Mingming Liu

School of Electronic Engineering
Dublin City University

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Lead Compensation

1. (a) Given the process $G(s) = \frac{30}{s(s+1)(s+6)}$, use MATLAB to help design a **Phase Lead** compensator that satisfy the following:
   - Overshoot = 29%.
   - Steady-state error of 3/5 for a unit ramp input.
   - A margin of safety of 6°.

   (b) Plot the uncompensated and compensated frequency responses on the same plot; save this plot.

   (c) Use SIMULINK to find the response of the compensated system to a unit step input *and* a unit ramp input; use Zero-Pole blocks for $C(s)$ and $G(s)$. Plot the step response on the same plot as the step input, save this plot. Plot the error response to the unit ramp input, save this plot.

   (d) Use MATLAB to measure the overshoot and ramp steady-state error from the simulation responses. Do these match the design criteria? Explain why they do/do not match.

Lag Compensation

2. (a) Given the process $G(s) = \frac{26}{(s+10)\left(s+2.4+j\sqrt{7}\right)\left(s+2.4-j\sqrt{7}\right)}$, use MATLAB to help design a **Phase Lag** compensator to satisfy the following requirements:
   - Overshoot = 16.3%
   - Steady-state error of 20% for a unit step input
   - A margin of safety of 3.8°

   (b) Plot the uncompensated and compensated frequency responses on the same plot, save this plot.

   (c) Use SIMULINK to find the response of the compensated system for $R(s) = 1/s$. Use a LTI block for $C(s)$ and a Zero–Pole block for $G(s)$. Plot the output response on the same plot as the step input, save this plot. Plot the step error response, save this plot.

   (d) Use MATLAB to measure the overshoot and steady-state error from the simulation responses. Do these match the design criteria? Explain why they do/do not match.

Lag-Lead Compensation

3. (a) Given the process $G(s) = \frac{30}{s(s^2/6400+s/50+1)}$, use MATLAB to help design a **Phase Lag-Lead** compensator to achieve:
   - Overshoot = 31.3%
   - Steady-state error of 1/180 for an input $r(t) = 2tu(t)$
   - A Lag phase contribution of 30.5°

   (b) Plot the uncompensated and compensated frequency responses on the same plot; save this plot.

   (c) Use SIMULINK to find the response of the compensated system to a unit step input *and* an input $r(t) = 2tu(t)$; use a transfer function block for $G(s)$. Plot the step response on the same plot as the step input, save this plot. Plot the error response to the $r(t) = 2tu(t)$ input, save this plot.

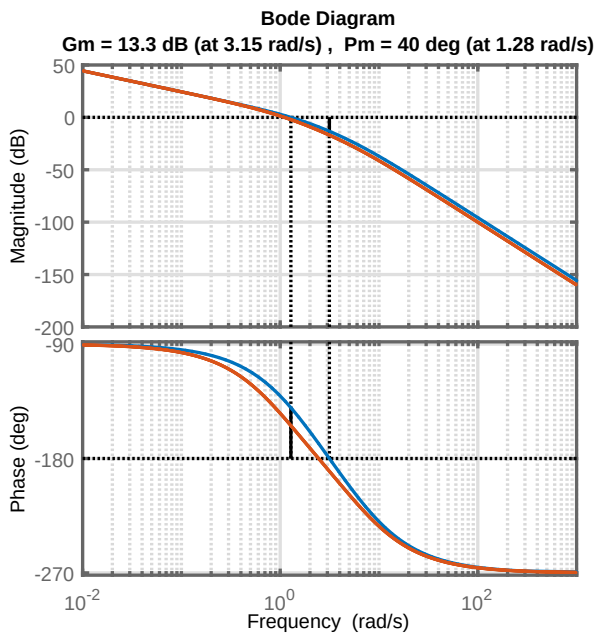
   (d) Use MATLAB to measure the overshoot and steady-state error from the simulation responses. Do these match the design criteria? Explain why they do/do not match.

Indicative Answers - Part 1

a. Key values for the different Steps:

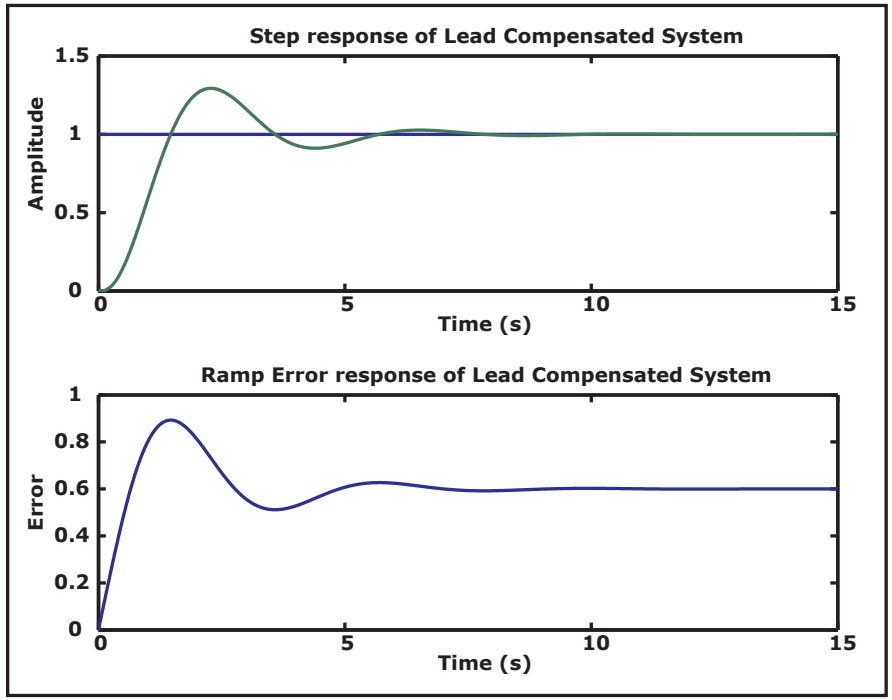
- $k = 1/3$
- Uncompensated PM $= 31.83^o$
- Desired $\zeta = 0.367$ and $PM = 39.9^o$
- Required maximum phase angle $\phi_m = 14.117^o$
- $\alpha = 1.645$
- $\omega_m = 1.29\ rad/s$
- $\tau = 0.61\ s$
- Compensated PM $= 39.97^o$

b. Plot:



Indicative Answers - Part 1 Continued

c. Response Plots:



d. Measurements:

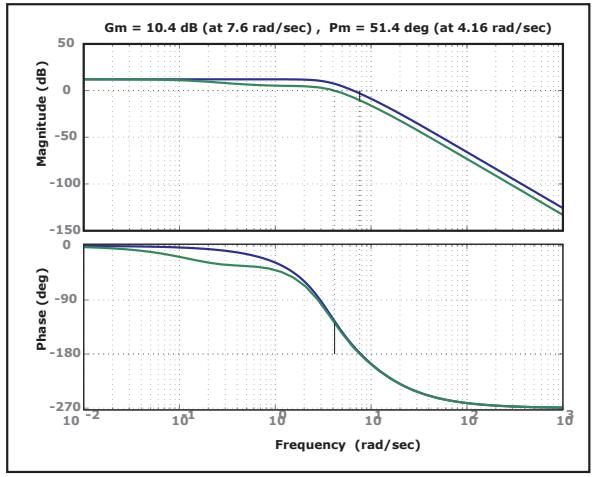
- $Ess_{ramp} = 0.6002$
- Measured overshoot: 29.3649%

Indicative Answers - Part 2

a. Key values for the different Steps:

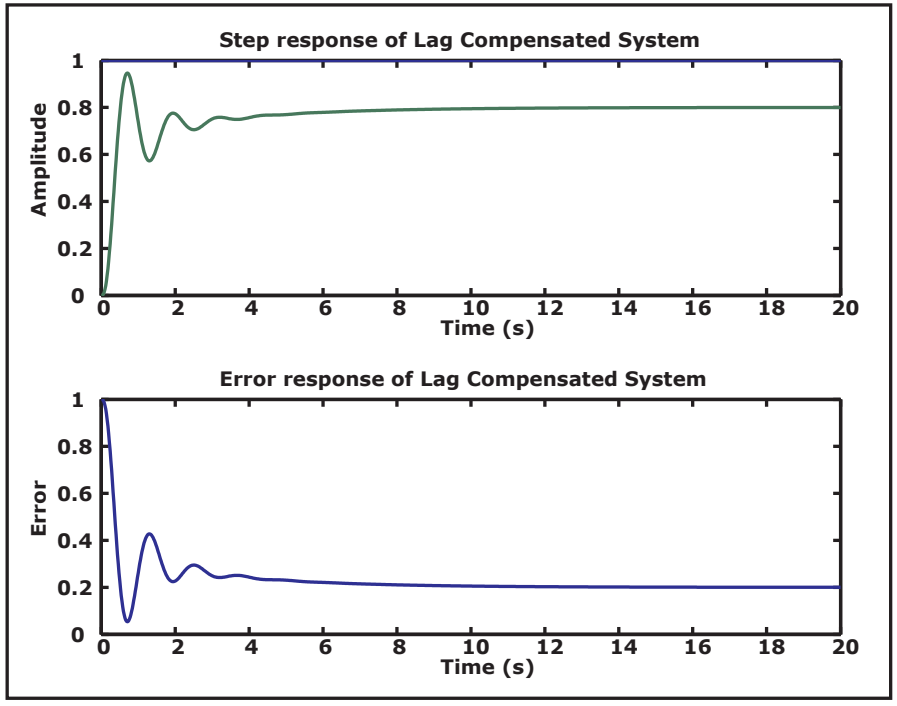
- $k = 19.63$
- Uncompensated PM $= 13.7086^o$
- Desired $\zeta = 0.5$ and $PM = 51.83^o$
- Required phase from original $= -124.37^o$
- $\omega_{cnew} = 4.15\ rad/s$
- $\beta = 0.4324$
- $\tau = 5.578\ s$
- Compensated PM $= 51.43^o$

b. Plot:



Indicative Answers - Part 2 Continued

c. Response Plots:



d. Measurements:

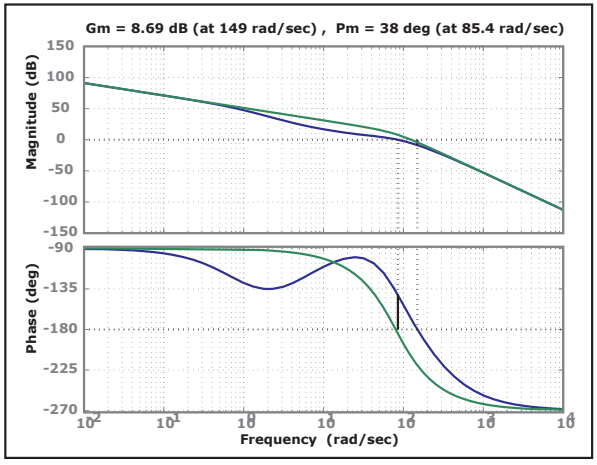
- $Ess_{ramp} = 0.2003$
- Measured overshoot: 18.3141%

Indicative Answers - Part 3 Continued

1. **Lag-Lead:** Key values for the different Steps:
   - $k = 12$
   - Uncompensated PM $= -29.9204°$
   - Desired $\zeta = 0.3468$ and $PM = 38°$
   - Desired phase angle for stability $= -149.5°$
   - $\omega_{ctemp} = 50.9\ rad/s$
   - $\beta = 0.167$
   - $\tau_2 = 1.1784\ s$
   - Phase Margin after Lag compensation $= 25.38°$
   - $\alpha = 6$
   - $\phi_m = 45.58°$
   - $\omega_m = 86.1\ rad/s$
   - $tau_1 = 0.0047\ s$
   - Compensated PM $= 38°$

Indicative Answers - Part 3

2. Frequency Plots:



3. Response Plots: