Experiment 4.2

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Objectives

To evaluate the effect of additional poles and zeros upon the time response of second-order systems.

Minimum Required Software Packages

MATLAB, Simulink, and the Control System Toolbox.

Prelab

Problem 1

1.a.

Given the transfer function $G(s) = \dfrac{25}{s^2 + 4s + 25}$*, evaluate the percent overshoot, settling time, peak time, and rise time. Also, plot the poles.*

Answer:

$$G(s) = \frac{25}{s^2+4s+25}$$

$$\omega_n = \sqrt{25} = 5$$

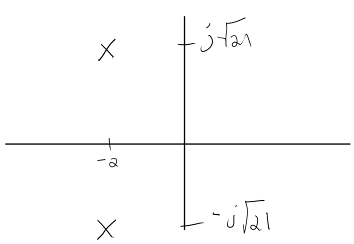
$$2\zeta\omega_n = 4 \rightarrow \zeta = \frac{4}{2\omega_n} = \frac{2}{5}$$

$$\%O.S. = e^{-(\zeta\pi/\sqrt{1-\zeta^2})} \times 100\% = e^{-\left(\frac{2}{5}\pi/\sqrt{1-\zeta^2}\right)} \times 100\% = 25.38\%$$

$$T_s = \frac{4}{\zeta\omega_n} = \frac{4}{\frac{2}{5}\cdot 5} = 2$$

$$T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} = \frac{\pi}{5\sqrt{1-(\frac{2}{5})^2}} = 0.685s$$

$$\text{Poles} = -2 \pm j\sqrt{21}$$



1.b.

Add a pole at -200 to the system of Prelab 1a. Estimate whether the transient response in Prelab 1a will be appreciably affected.

Answer:

$$G(s) = \frac{25}{s^2+4s+25}\frac{c}{(s+c)}$$

1.b) $c = 200$

if $c \geq 5\zeta\omega_n = 5 \cdot \frac{2}{5} \cdot 5 = 10$

2^{nd} order approximation ✓

Adding a pole at -200 will appreciably effect the transient response.

1.c.

Repeat Prelab 1b with the pole successively placed at -20, -10, and -2.

Answer:

1.c

$c = 20$ ✓

$c = 10$ ✓

$c = 2$ ✗

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Problem 2

A zero is added to the system of Prelab 1a at -200 and then moved to -50, -20, -10, -5, and -2. List the values of zero location in order of the greatest to the least effect upon the pure second-order transient response.

Answer:

Problem 3

Given the transfer function $G(s) = \dfrac{(25b/a)(s+1)}{(s+b)(s^2+4s+25)}$*, let* $a = 3$ *and* $b =$*3.01, 3.1, 3.3, 3.5, and 4.0. Which values of b will have minimal effect upon the pure second-order transient response?*

Answer:

Problem 4

Given the transfer function $G(s) = \dfrac{(2500b/a)(s+a)}{(s+b)(s^2+4s+25)}$*, let* $a = 30$ *and* $b =$*30.01, 30..1, 30.5, 31, 35, and 40. Which values of b will have minimal effect upon the pure second-order transient response?*

Answer:

Lab

Problem 1

Using Simulink, add a pole to the second-order system of Prelab 1a and plot the step responses of the system when the higher order pole is nonexistent, at -200, -20, -10, and -2. Make your plots on a single graph, using the Simulink LTI Viewer. Normalize all plots to a steady-state value of unity. Record percent overshoot, settling time, peak time, and rise time for each response.

For your Simulink, please provide a screenshot that clearly shows the system.

```
% Insert your code here
a = 4
```

```
a = 4
```

```
b = 25
```

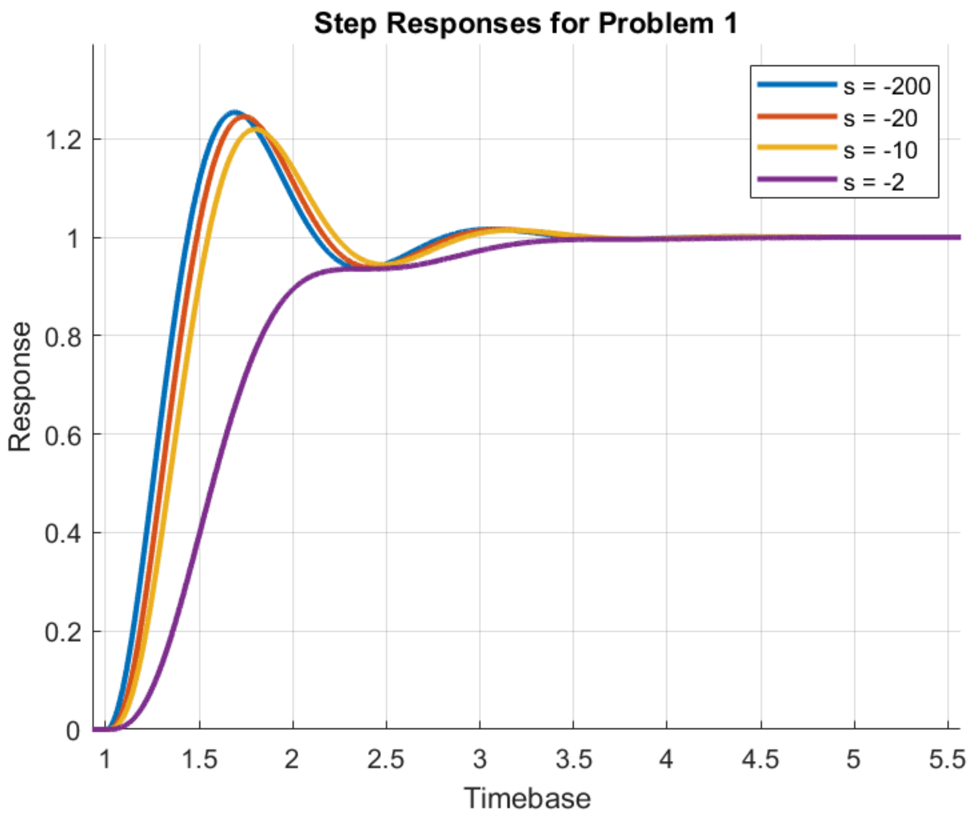
```
b = 25
```

```
c_vals = [200, 20, 10, 2];
figure(1)
hold on
for i=1:length(c_vals)
    c = c_vals(i);
    sim('Ex4_2_P1.slx');
    normData = stepResponse.data./stepResponse.data(length(stepResponse.Data));
    plot(stepResponse.time, normData, "linewidth", 2);
    disp(c_vals(i))
    stepinfo(stepResponse.data, stepResponse.time)
    stepResponses{i} = stepResponse;
end
```

```
   200
ans = struct with fields:
        RiseTime: 0.2928
    SettlingTime: 2.6869
     SettlingMin: 0.0045
     SettlingMax: 0.0063
       Overshoot: 25.3746
      Undershoot: 0
            Peak: 0.0063
        PeakTime: 1.6910
    20
ans = struct with fields:
        RiseTime: 0.3062
    SettlingTime: 2.7325
     SettlingMin: 0.0450
     SettlingMax: 0.0623
       Overshoot: 24.5136
      Undershoot: 0
            Peak: 0.0623
        PeakTime: 1.7400
    10
ans = struct with fields:
        RiseTime: 0.3356
    SettlingTime: 2.7787
     SettlingMin: 0.0900
     SettlingMax: 0.1219
       Overshoot: 21.9297
      Undershoot: 0
            Peak: 0.1219
```

```
        PeakTime: 1.7990
      2
ans = struct with fields:
        RiseTime: 0.7495
    SettlingTime: 3.0911
     SettlingMin: 0.4502
     SettlingMax: 0.5000
       Overshoot: 0
      Undershoot: 0
            Peak: 0.5000
        PeakTime: 10
```

```
hold off
title("Step Responses for Problem 1")
xlabel("Timebase")
ylabel("Response")
legend(["s = -200" "s = -20" "s = -10" "s = -2"])
grid on
```



Problem 2

Using Simulink, add a zero to the second-order system of Prelab 1a and plot the step responses of the system when the zero is nonexistent, at -200, -50, -20, -10, -5, and -2. Make your plots on a single graph, using the Simulink LTI Viewer. Normalize all plots to a steady-state value of unity. Record percent overshoot, settling time, peak time, and rise time for each response.

For your Simulink, please provide a screenshot that clearly shows the system.

```
% Insert your code here
```

Problem 3

Using Simulink and the transfer function of Prelab 3 with a = 3, plot the step responses of the system when the value of b is 3, 3.01, 3.1, 3.3, 3.5, and 4.0. Make your plots on a single graph using the Simulink LTI Viewer. Record percent overshoot, settling time, peak time, and rise time for each response.

For your Simulink, please provide a screenshot that clearly shows the system.

```
% Insert your code here
```

Problem 4

Using Simulink and the transfer function of Prelab 4 with $a = 30$, plot the step responses of the system when the value of b is 30, 30.01, 30.1, 30.5, 31, 35, and 40. Make your plots on a single graph, using the Simulink LTI Viewer. Record percent overshoot, settling time, peak time, and rise time for each response.

For your Simulink, please provide a screenshot that clearly shows the system.

```
% Insert your code here
```

Postlab

Problem 1

Discuss the effect upon the transient response of the proximity of a higher-order pole to the dominant second-order pole pair.

Problem 2

Discuss the effect upon the transient response of the proximity of a zero to the dominant second-order pole pair. Explore the relationship between the length of the vector from the zero to the dominant pole and the zero's effect upon the pure second-order step response.

Problem 3

Discuss the effect of pole-zero cancellation upon the transient response of a dominant second-order pole pair. Allude to how close the canceling pole and zero should be and the relationships of (1) the distance between them and (2) the distance between the zero and the dominant second-order poles.