Control Systems Project

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Tasks to Perform

P22 - Page 148. Perform the following:

a. Consider the state-space of Problem 22, Page 148 of Norman Nise Book Edition 5.

b. Check the stability of the system using all methods that you know.

c. Compute the controllabililty and observerability for the system. If the system is unstable design a suitable controller for it.

d. Simulate the system using the controller that you design and show all the responses.

e. Design a PID controller and show the response of the system using PID Controller. Compare the results obtained in parts d and c.

f. Compute the steady state error before and after designing controller.

g. Design a tracking controller for step tracking of amplitude $\mathbf{5u(t)}$ and ramp tracking of $\mathbf{5ut(t)}$.

State-space Model

The state-space model of Problem 22, Page 148 of Norman Nise Book Edition 5 is follows:

$$\boldsymbol{A = \begin{bmatrix} -0.435 & 0.209 & 0.02 \\ 0.268 & -0.394 & 0 \\ 0.227 & 0 & -0.02 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}} \tag{1}$$

$$\boldsymbol{C = \begin{bmatrix} 0.0003 & 0 & 0 \end{bmatrix}; D = 0} \tag{2}$$

Stability Analysis of the System

The eigen values of the system are:

$$\boldsymbol{\lambda_1 = -0.6560, \lambda_2 = -0.1889, \lambda_3 = -0.0042} \tag{3}$$

The poles of the system are:

$$\boldsymbol{p_1 = -0.6560, p_2 = -0.1889, p_3 = -0.0042,} \tag{4}$$

Cont.

Routh-Hurwitz table is shown below

s^3	1	0.127
s^2	0.849	0.000518
s^1	$-\frac{1}{0.849} \times \begin{vmatrix} 1 & 0.127 \\ 0.849 & 0.000518 \end{vmatrix} = 0.1269$	0
s^0	$-\frac{1}{0.1269} \times \begin{vmatrix} 0.849 & 0.00051 \\ 0.1269 & 0 \end{vmatrix} = 0.000518$	0

As there are no sign changes in the first column, the system is stable.

Cont.

The step response of the system is:

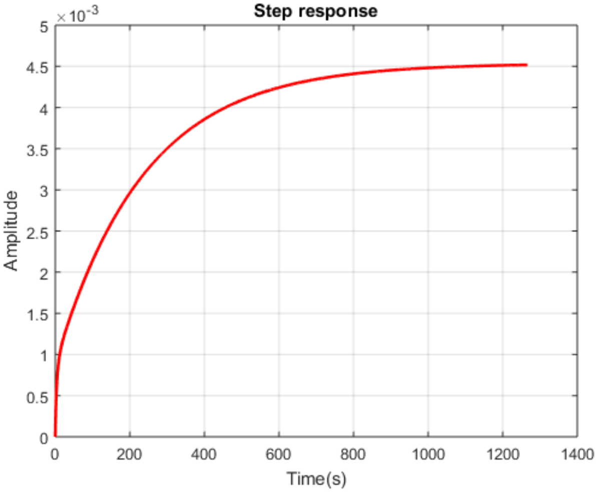

Figure: Plot of step response.

Cont.

The root locus of the system is:

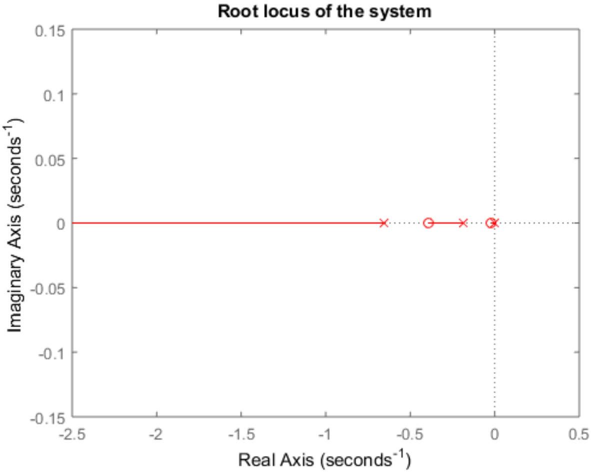

Figure: Plot of step response.

Controllability Test

Order of matrix A is: 3
P matrix is:

$$\boldsymbol{P} = \begin{bmatrix} \mathbf{1} & \mathbf{-0.435} & \mathbf{0.249} \\ \mathbf{0} & \mathbf{0.2680} & \mathbf{0.222} \\ \mathbf{0} & \mathbf{0.227} & \mathbf{-0.103} \end{bmatrix} \tag{5}$$

P echelon form is:

$$\boldsymbol{Pechelon} = \begin{bmatrix} \mathbf{1} & \mathbf{-0.435} & \mathbf{0.249} \\ \mathbf{0} & \mathbf{1} & \mathbf{-0.829} \\ \mathbf{0} & \mathbf{0} & \mathbf{1} \end{bmatrix} \tag{6}$$

The rank of P is: 3
As the rank of P is equal to order of A matrix, So the system passes controllability test.

Observerability Test

Order of matrix A is: 3 Q matrix is:

$$\boldsymbol{P = \begin{bmatrix} 0.0003 & 0 & 0 \\ -0.000130 & 0.0000627 & 0.0000060 \\ 0.000075 & -0.0000627 & -0.0000027 \end{bmatrix}} \tag{7}$$

Q echelon form is:

$$\boldsymbol{Qechelon = \begin{bmatrix} 1 & 0.694 & 0.036 \\ 0 & 1 & 0.48 \\ 0 & 0 & 1 \end{bmatrix}} \tag{8}$$

The rank of Q is: 3

As the rank of Q is equal to order of A matrix, So the system passes observerability test.

Design suitable Controller

- From above different stability checking methods it's cleared that the system is stable.
- We don't need to design a controller.

Schematic of system

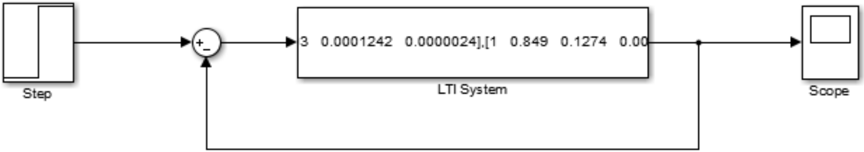

Figure: schematic of system.

Step response

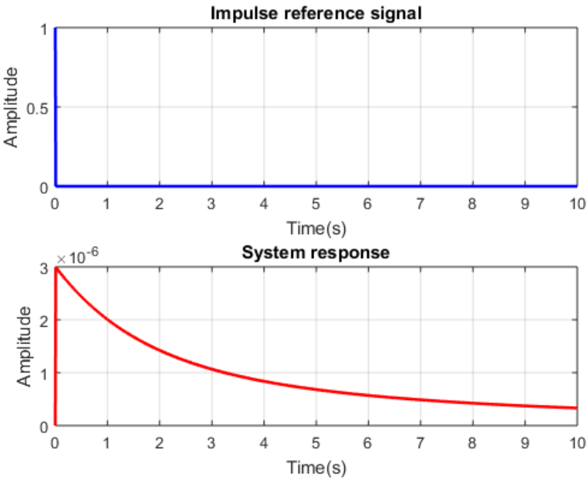

Figure: Plot of step response.

Impulse response

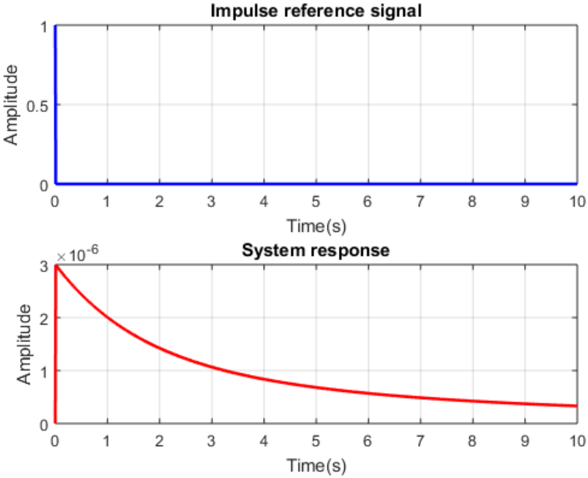

Figure: Plot of Impulse response.

Ramp response

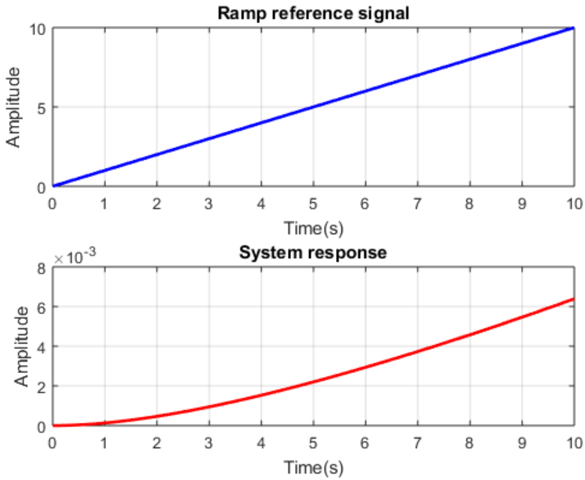

Figure: Plot of ramp response.

Parabola response

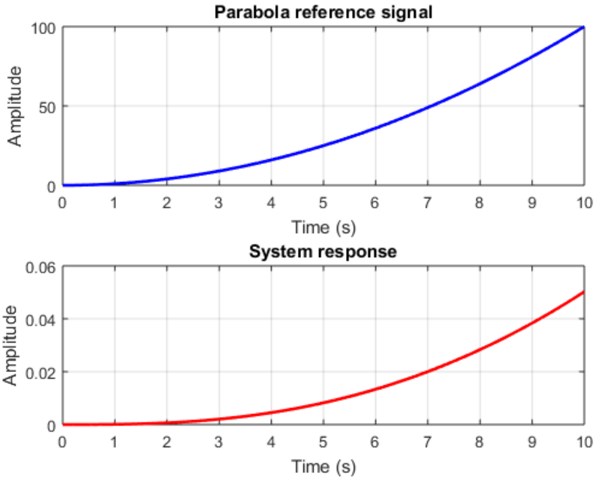

Figure: Plot of Parabola response.

PID Controller

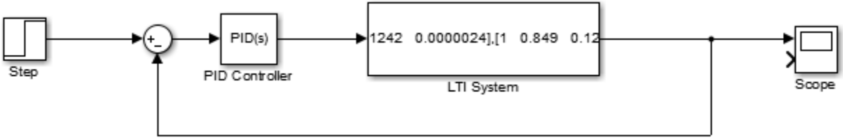

Figure: Sketch of PID Controller.

Step response after PID controller

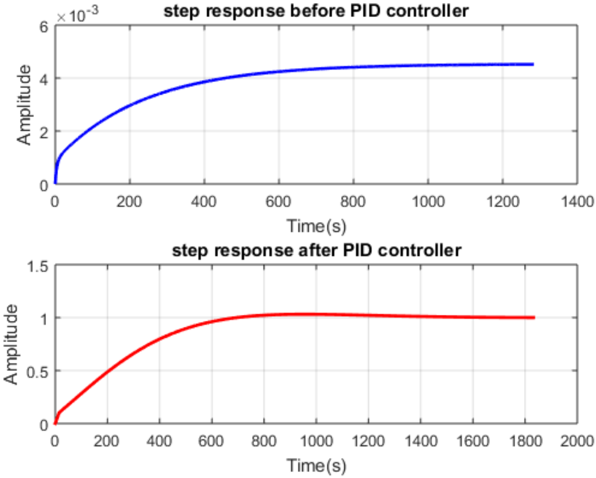

Figure: step response after PID Controller.

impulse response after PID controller

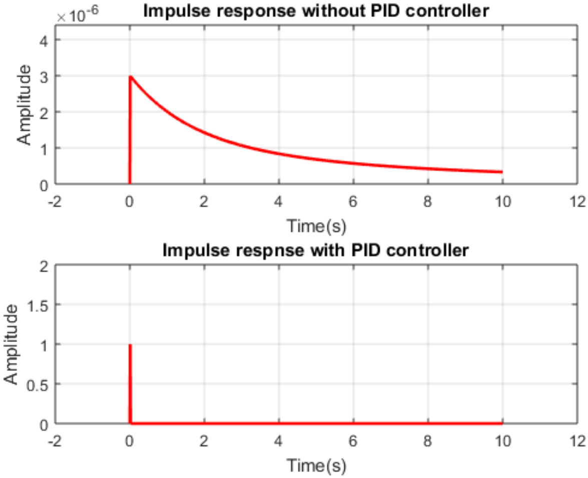

Figure: impulse response after PID Controller.

Ramp response after PID controller

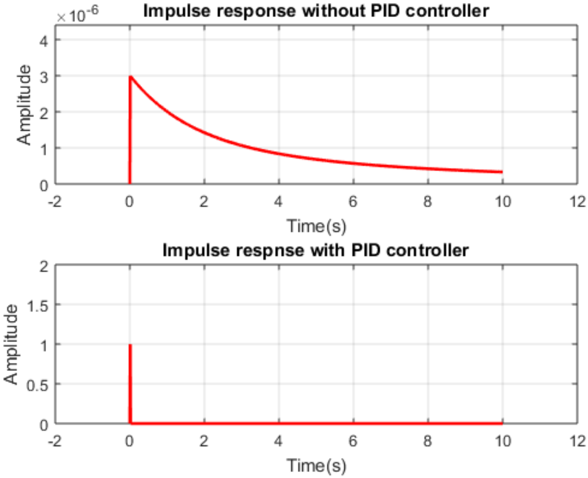

Figure: Ramp response after PID Controller.

Parabola response after PID controller

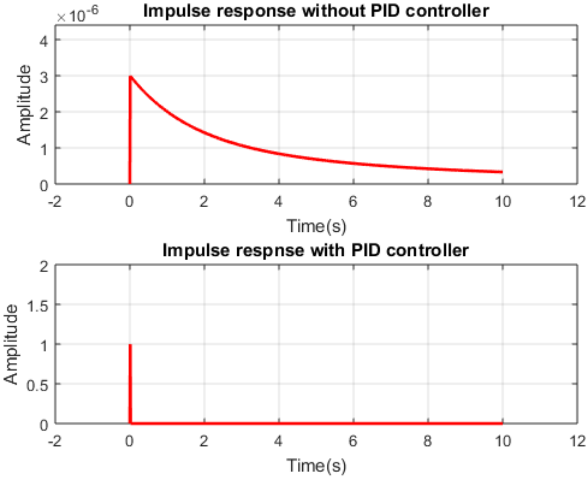

Figure: Parabola response after PID Controller.

Steady state errors

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Steady state error for step response before and after PID controller:
steady state error of step function before PID is: 0.995481
steady state error of step function after PID is: 0.000000


Steady state error for impulse response before and after PID controller:
steady state error of impulse function before PID is: 0.000000
steady state error of impulse function after PID is: 0.000009


steady state error for ramp response before and after PID controller:
steady state error of impulse function before PID is: 9.993612
steady state error of impulse function after PID is: 0.006388


Steady state error for Parabola response before and after PID controller:
steady state error of parabola function before PID is: 99.949800
steady state error of parabola function after PID is: 0.083578
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Figure: steady state errors before and after PID controller.

Tracking Controller

Tracking controller for 5u(t) is:

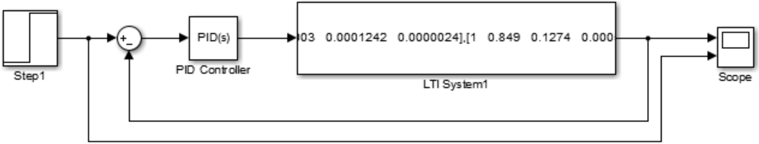

Figure: Tracking controller for 5u(t).

Cont.

Tracking controller for 5tu(t) is:

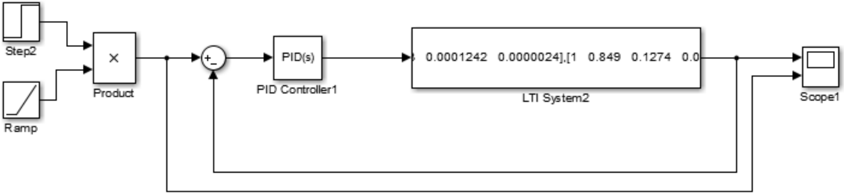

Figure: Tracking controller for 5tu(t).

Results of Tracking Controller

Result of Tracking controller for 5u(t).

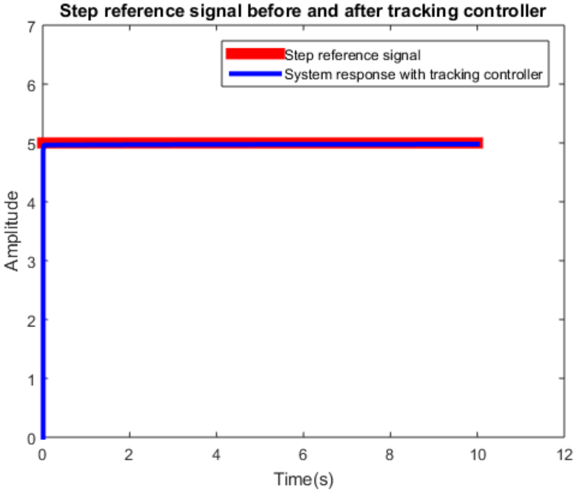

Figure: Tracking controller result for 5u(t) .

Cont.

Result of Tracking controller for 5tu(t).

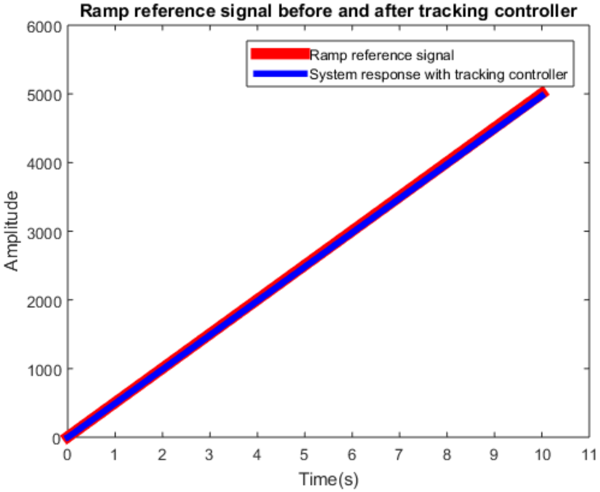

Figure: Tracking controller result for 5tu(t) .

Thank You!