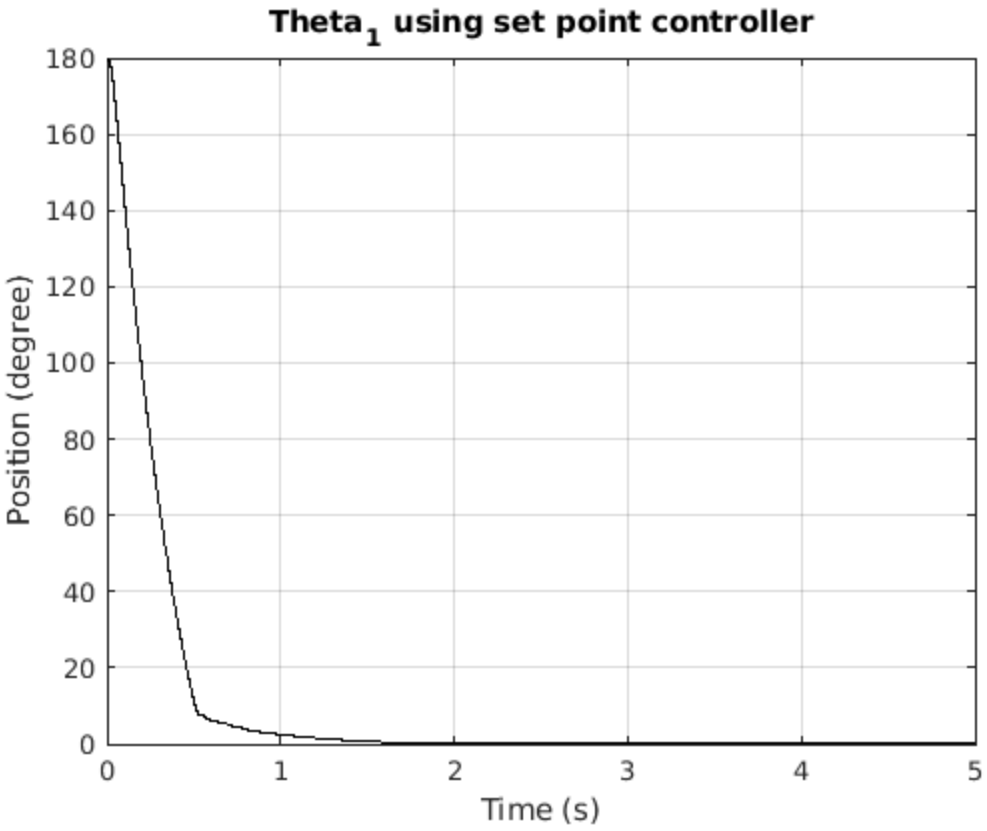
Table of Contents

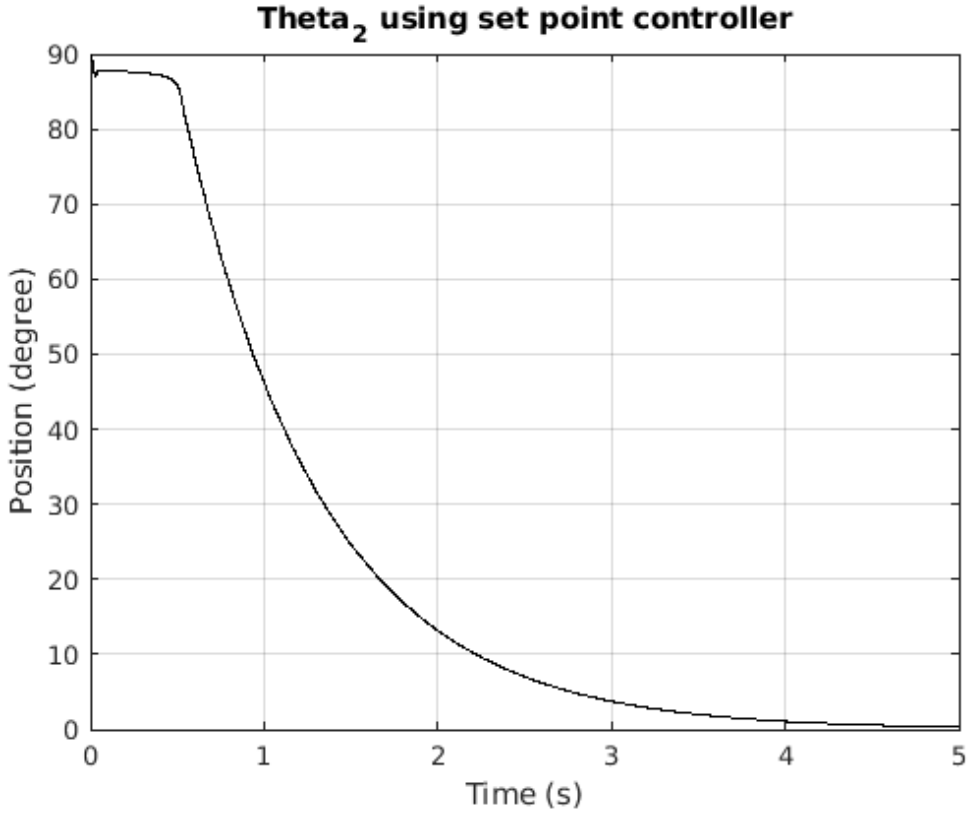

```
%%Farid Tavakkolmoghaddam
clc
clear all;
close all;
% the following parameters for the arm
I1=10;  I2 = 10; m1=5; r1=.5; m2=5; r2=.5; l1=1; l2=1;
g=9.8;

% we compute the parameters in the dynamic model
a = I1+I2+m1*r1^2+ m2*(l1^2+ r2^2);
b = m2*l1*r2;
d = I2+ m2*r2^2;
```

Problem 1

```
%initial state
tt0=0;
qq0=[pi*180/pi pi/2*180/pi 0 0];
% final state
ttf=5; % time span is 10 seconds
qqf=[0 0 0 0];
options = odeset('RelTol',1e-4,'AbsTol',[1e-4, 1e-4, 1e-4, 1e-4]);
[T0,X0] = ode45(@(t,x) feedback(t,x),[tt0 ttf],qq0, options);
figure('Name','Theta_1 using set point controller');
plot(T0, X0(:,1),'k');
title('Theta_1 using set point controller')
xlabel('Time (s)')
ylabel('Position (degree)')
grid on
hold on
figure('Name','Theta_2 using set point controller');
plot(T0, X0(:,2),'k');
title('Theta_2 using set point controller')
xlabel('Time (s)')
ylabel('Position (degree)')
grid on
hold on
```

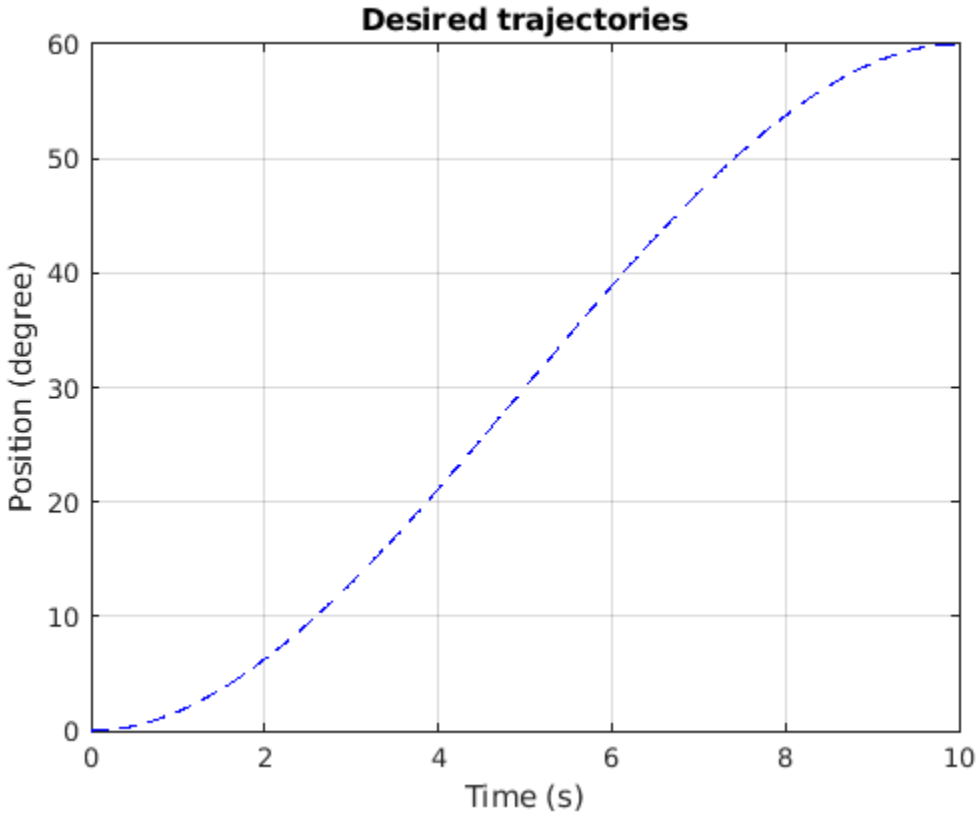

Theta1 using set point controller
Position (degree)
Time (s)
0
20
40
60
80
100
120
140
160
180
0
1
2
3
4
5

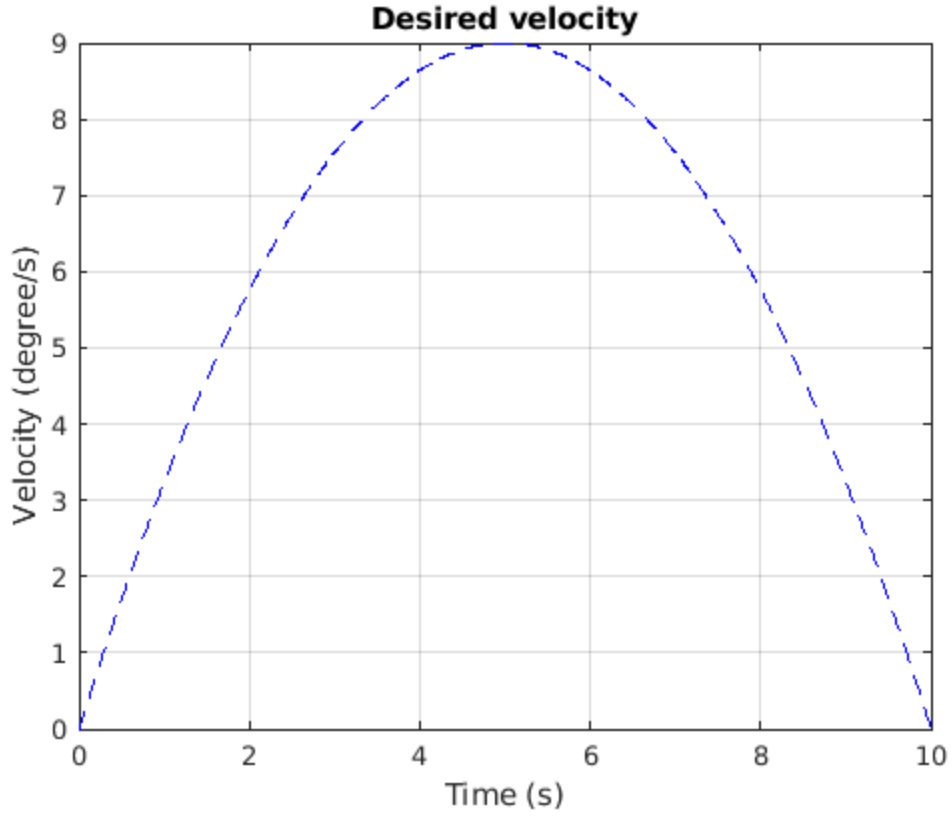

Theta2 using set point controller
Position (degree)
Time (s)
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
5

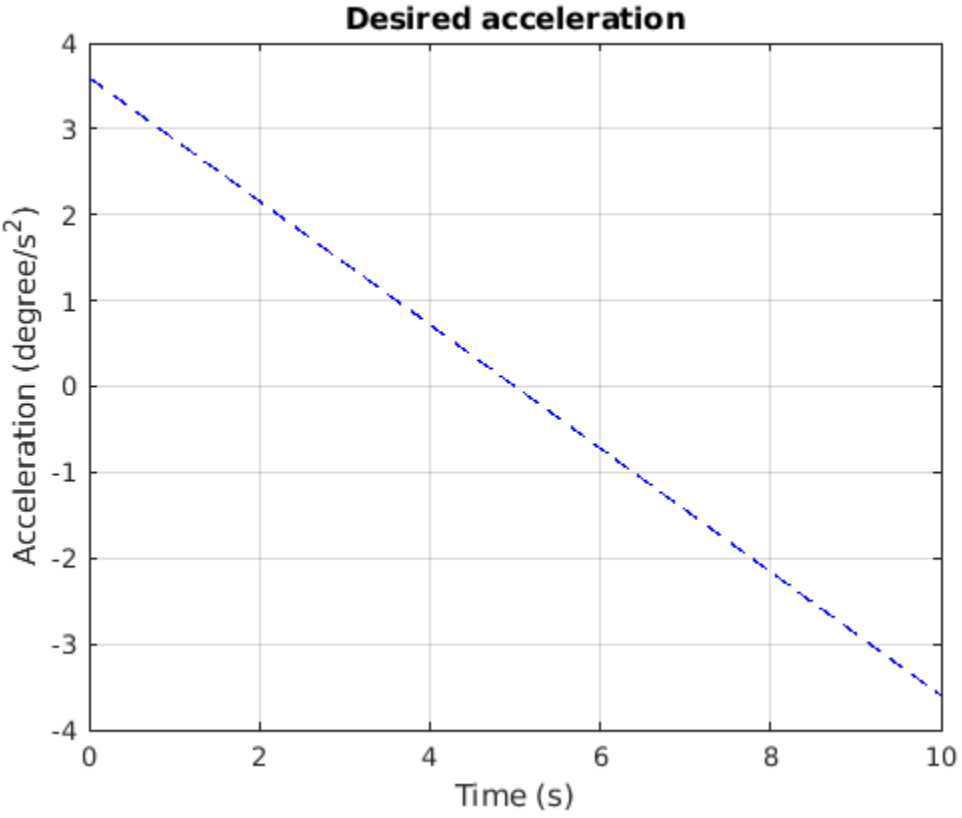
GENERATE TRAJECTORY Problem 2

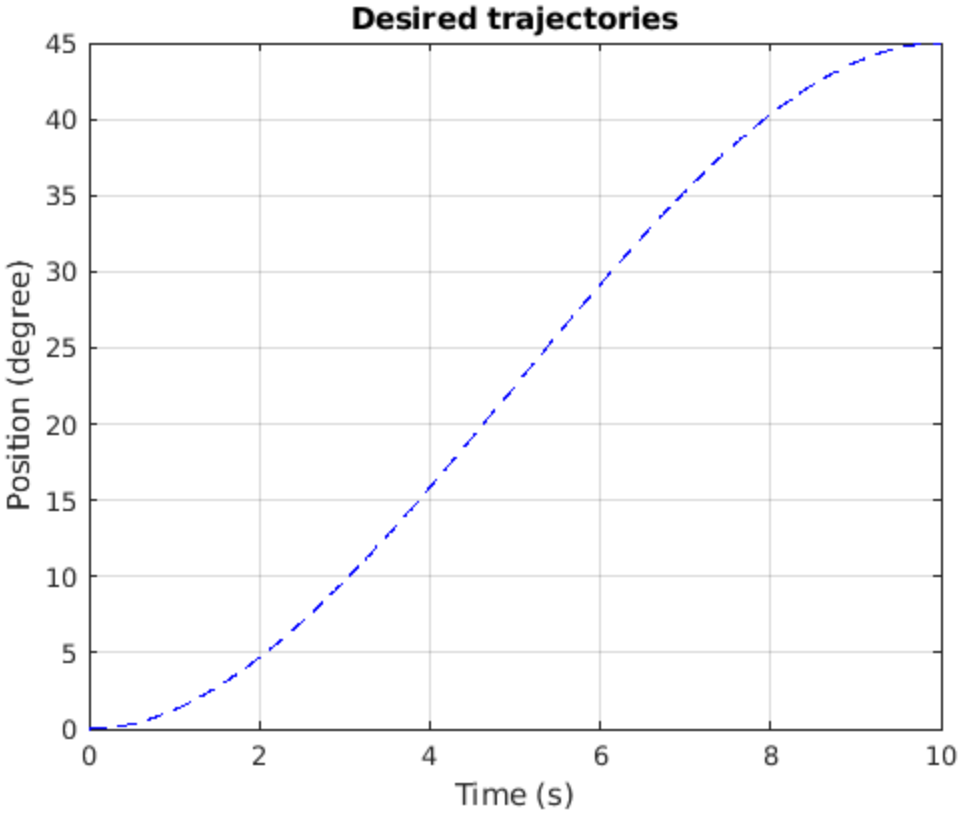
initial state

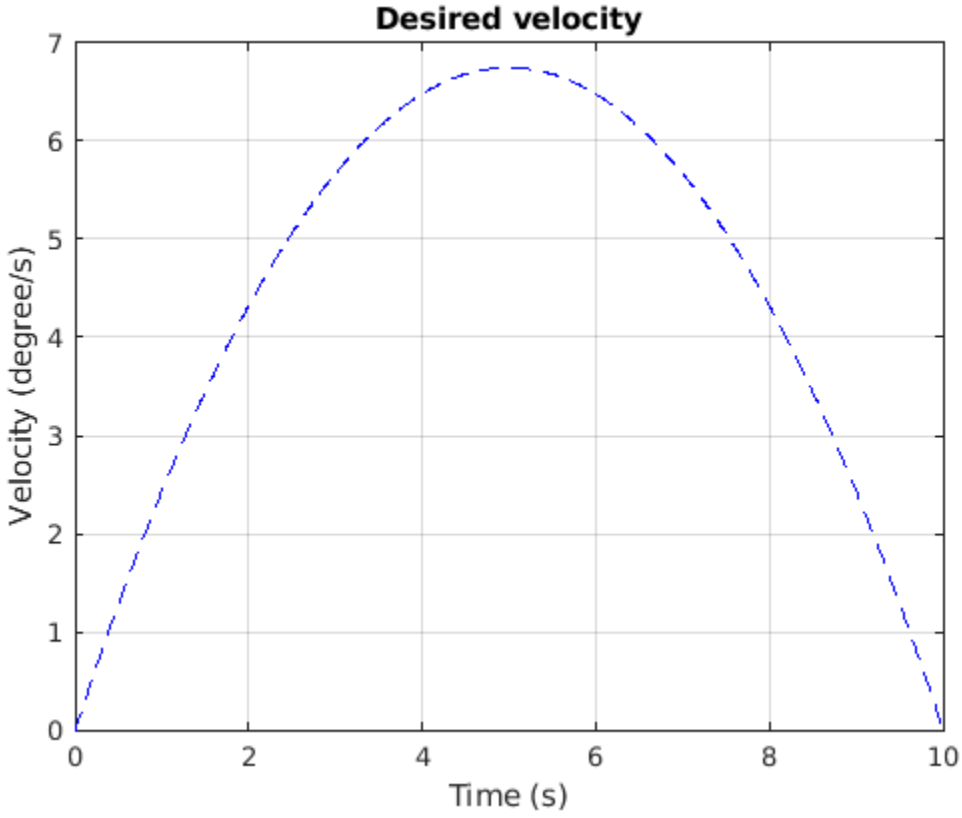
```
t0=0;
q0=[0 0 0 0];
% final state
tf=10; % time span is 10 seconds
qf=[pi/3*180/pi pi/4*180/pi 0 0];
% generating the desired trajectory based on the initial and terminal
% state conditions
[link1,position1,velocity1,t]= TajectoryGenerator( q0(1), q0(3),
 qf(1), qf(3),t0,tf);
[link2,position2,velocity2,t]= TajectoryGenerator( q0(2), q0(4),
 qf(2), qf(4),t0,tf);
```

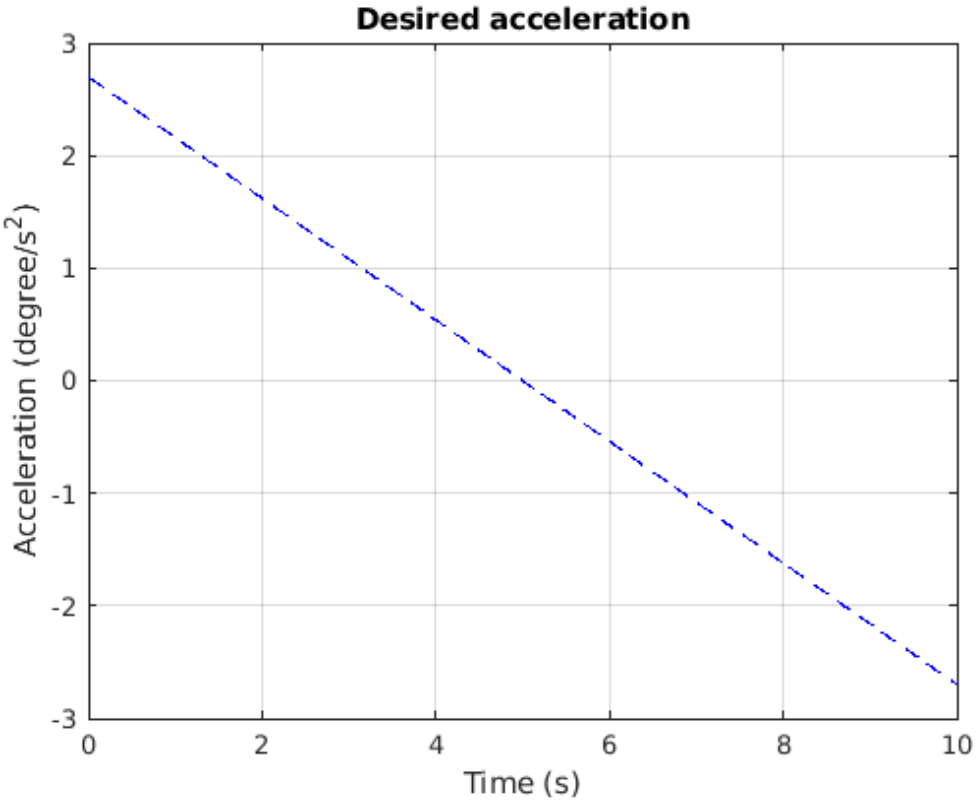



Desired velocity
Velocity (degree/s)
Time (s)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10


Desired acceleration
Acceleration (degree/s^2)
Time (s)
-4
-3
-2
-1
0
1
2
3
4
0
2
4
6
8
10


Desired trajectories
Position (degree)
Time (s)
0
5
10
15
20
25
30
35
40
45
0
2
4
6
8
10


Desired velocity
Velocity (degree/s)
Time (s)
0
1
2
3
4
5
6
7
0
2
4
6
8
10



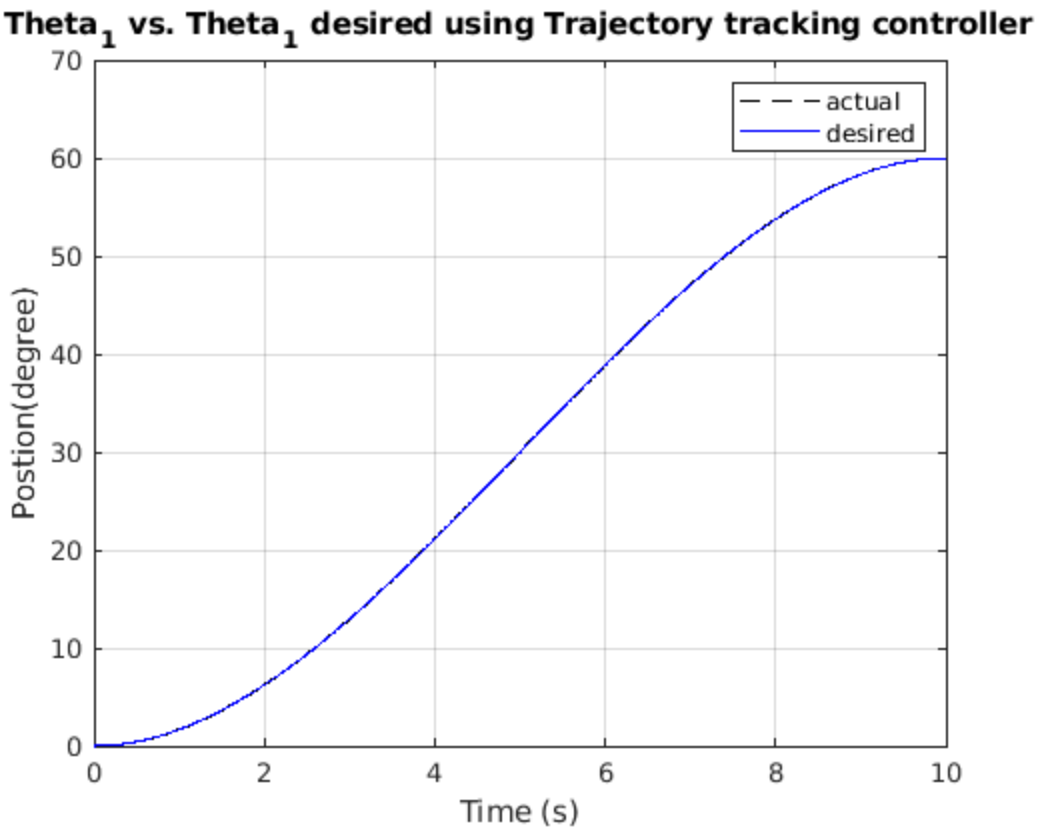
Implement the inverse dynamic control Problem 3

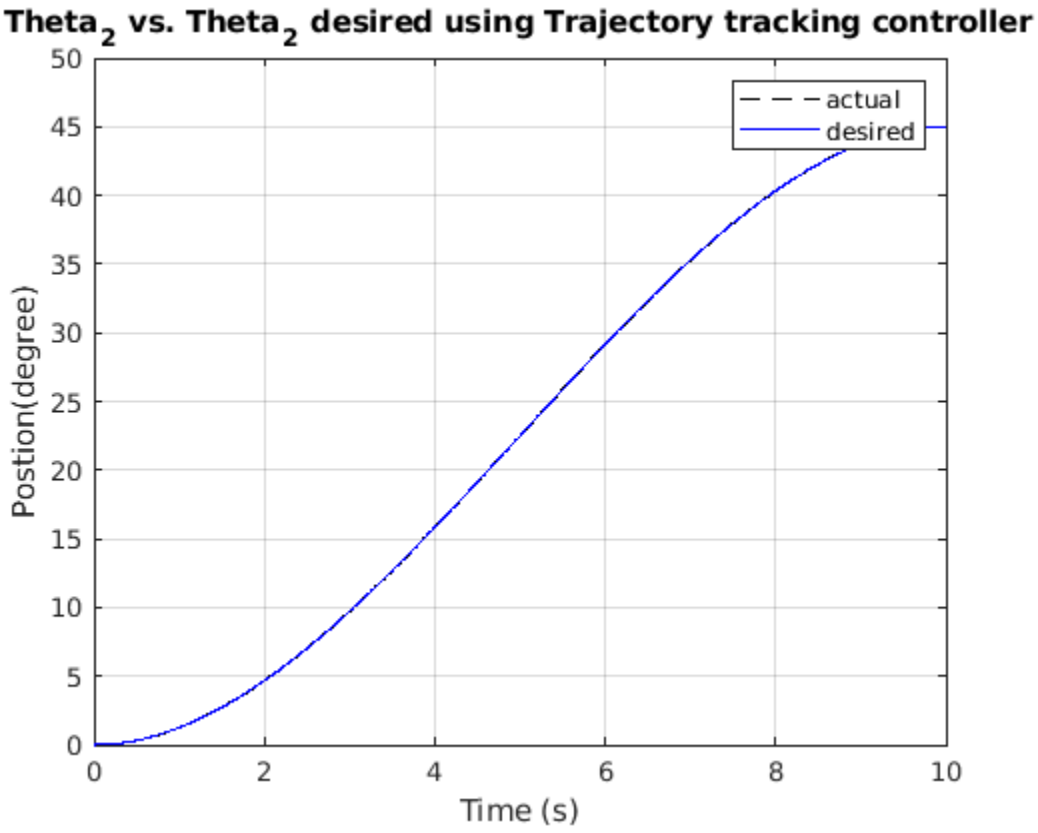
```
integral_term=false; % this is used for using the integration term for
 the controller
options = odeset('RelTol',1e-4,'AbsTol',[1e-4, 1e-4, 1e-4, 1e-4]);
[T,X] = ode45(@(t,x) inverseDC(t,x,link1,link2,integral_term),[0
 tf],q0, options);
[T1,X1] = ode45(@(t,x) inverseDC(t,x,link1,link2,integral_term),
[0 tf],[15 15 2 1.5], options);% starting with a different intial
 condition
```

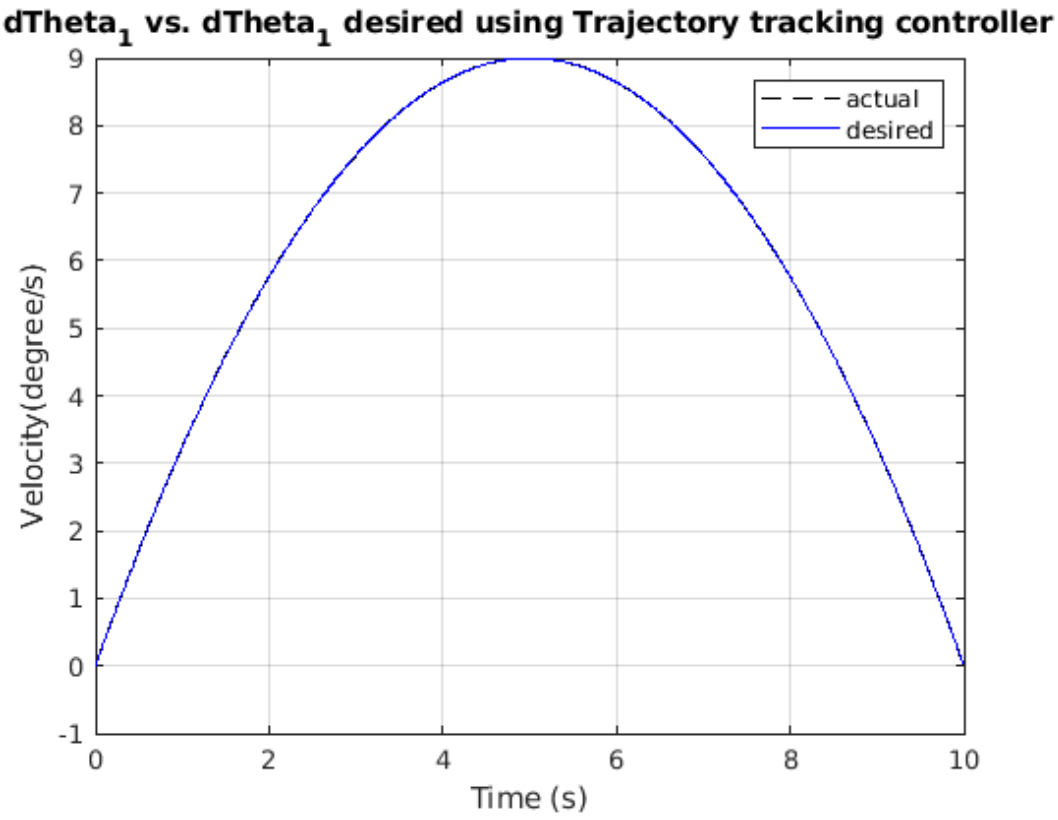
Plotting the result: please plot both the actual trajectory and the desired trajectory for the your states. example code below.

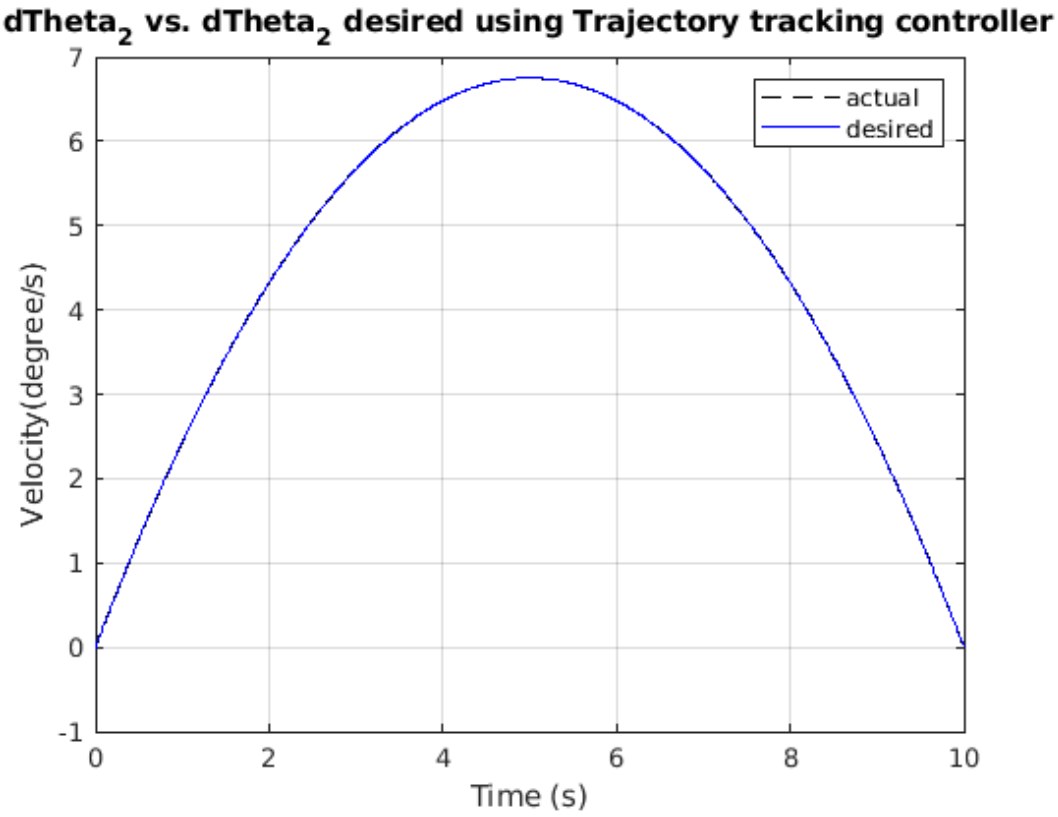
```
figure('Name','Theta_1 under inverse dynamic control');
plot(T, X(:,1),'k--',t,position1,'b');
title('Theta_1 vs. Theta_1 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Postion(degree)')
```

```
grid on
legend('actual','desired')
hold on
figure('Name','Theta_2 under inverse dynamic control');
plot(T, X(:,2),'k--',t,position2,'b');
title('Theta_2 vs. Theta_2 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Postion(degree)')
grid on
legend('actual','desired')
hold on
% Plotting the Deired velocity Vs. Actual velocity
figure('Name','dTheta_1 vs. dTheta_1 desired under inverse dynamic
 control');
plot(T, X(:,3),'k--',t,velocity1,'b');
title('dTheta_1 vs. dTheta_1 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Velocity(degree/s)')
legend('actual','desired')
grid on
hold on
figure('Name','Theta_2 under inverse dynamic control');
plot(T, X(:,4),'k--',t,velocity2,'b');
title('dTheta_2 vs. dTheta_2 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
legend('actual','desired')
ylabel('Velocity(degree/s)')
grid on
hold on
```


Theta1 vs. Theta1 desired using Trajectory tracking controller
actual
desired
Postion(degree)
Time (s)
0
10
20
30
40
50
60
70
0
2
4
6
8
10

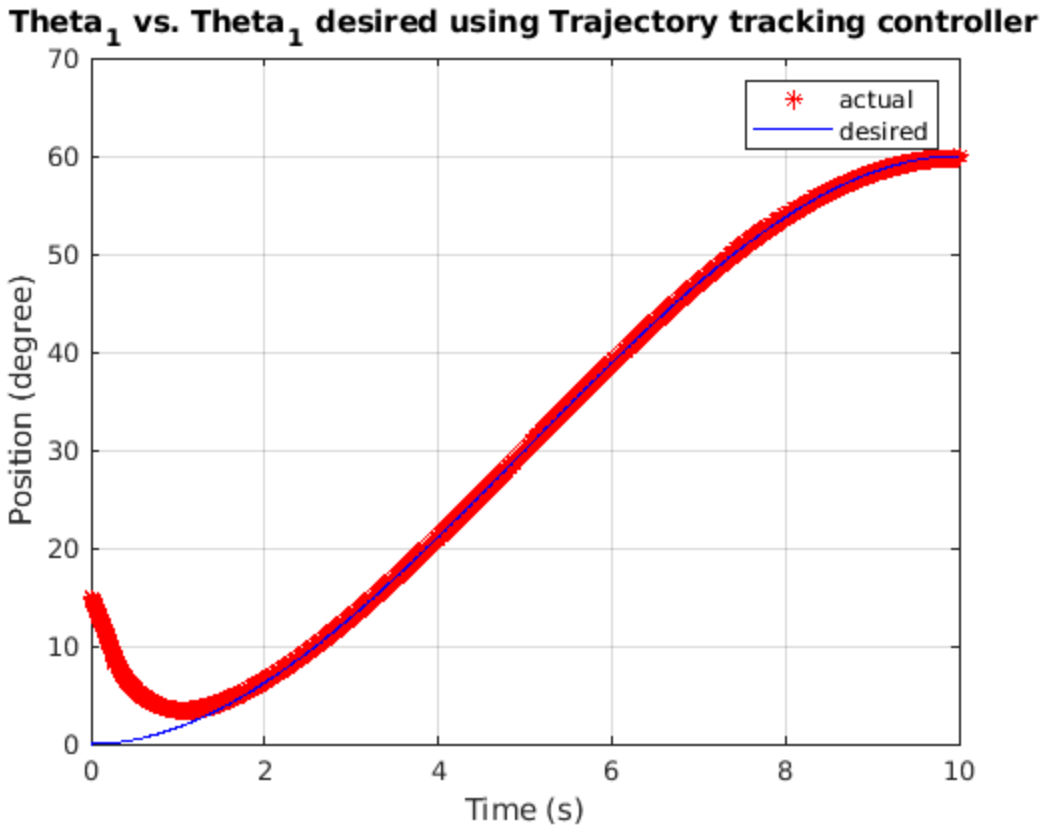

Theta2 vs. Theta2 desired using Trajectory tracking controller
actual
desired
Postion(degree)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10

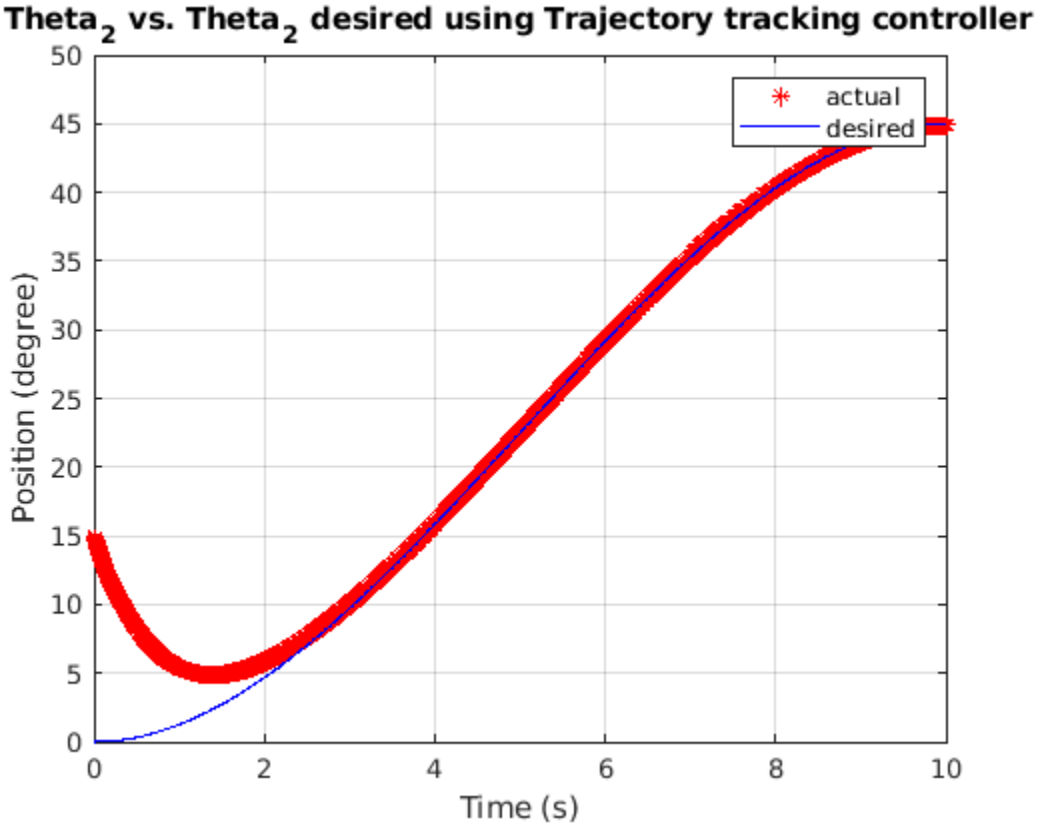

dTheta1 vs. dTheta1 desired using Trajectory tracking controller
actual
desired
Velocity(degree/s)
Time (s)
9
8
7
6
5
4
3
2
1
0
-1
0
2
4
6
8
10

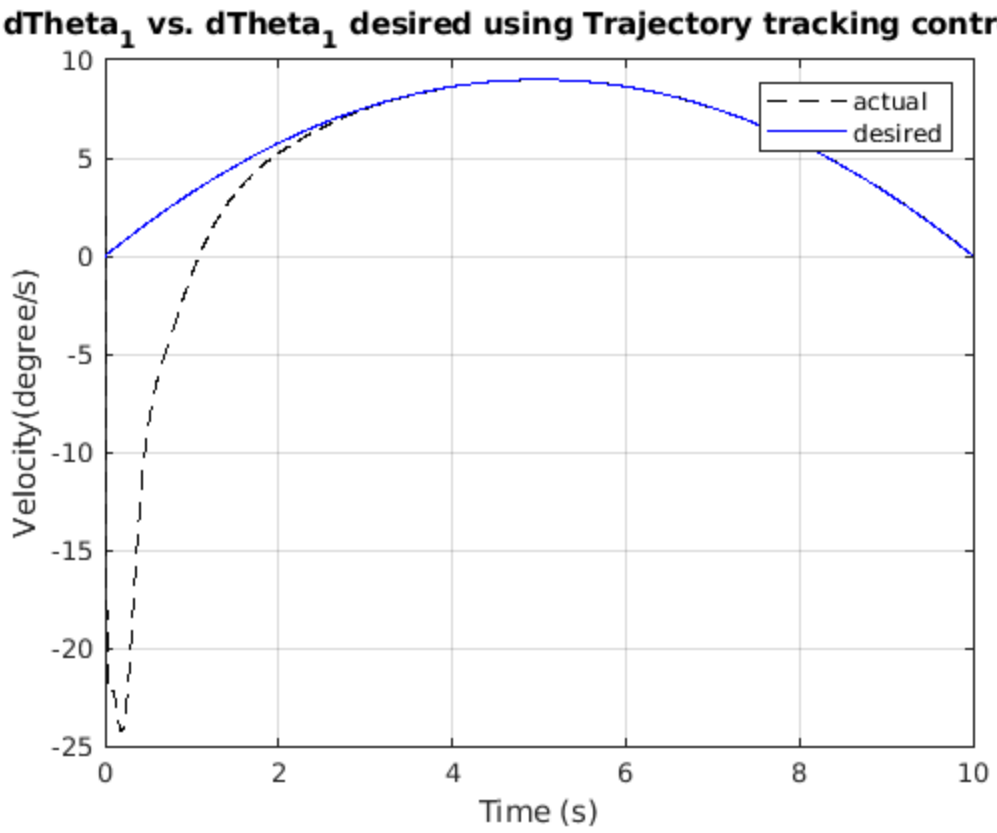

dTheta2 vs. dTheta2 desired using Trajectory tracking controller
actual
desired
Velocity(degree/s)
Time (s)
7
6
5
4
3
2
1
0
-1
0
2
4
6
8
10

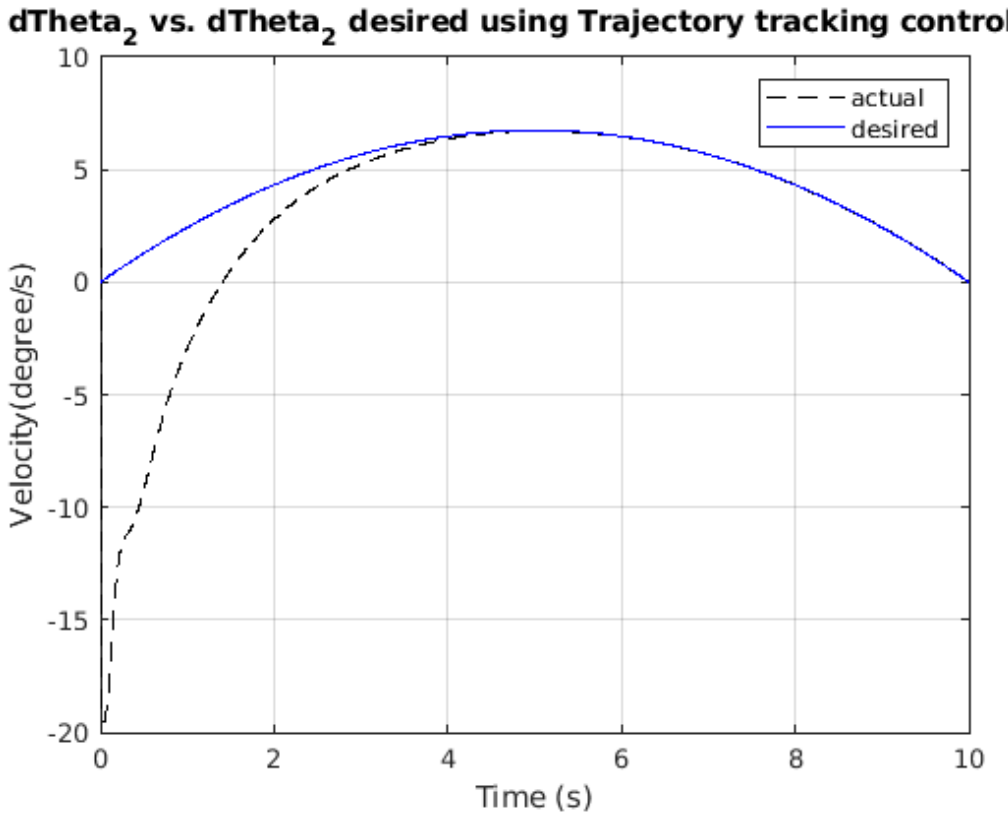
With different initial condition

```
figure('Name','Theta_1 under inverse dynamic control');
plot(T1, X1(:,1),'r*',t,position1,'b');
title('Theta_1 vs. Theta_1 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Position (degree)')
legend('actual','desired')
grid on
hold on
figure('Name','Theta_2 under inverse dynamic control');
plot(T1, X1(:,2),'r*',t,position2,'b');
title('Theta_2 vs. Theta_2 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Position (degree)')
grid on
legend('actual','desired')
hold on
%
% Plotting the Deired velocity Vs. Actual velocity
figure('Name','Theta_1 under inverse dynamic control');
plot(T1, X1(:,3),'k--',t,velocity1,'b');
title('dTheta_1 vs. dTheta_1 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Velocity(degree/s)')
legend('actual','desired')
grid on
hold on
figure('Name','Theta_2 under inverse dynamic control');
plot(T1, X1(:,4),'k--',t,velocity2,'b');
title('dTheta_2 vs. dTheta_2 desired using Trajectory tracking
 controller')
xlabel('Time (s)')
ylabel('Velocity(degree/s)')
legend('actual','desired')
grid on
hold on
```


Theta$_1$ vs. Theta$_1$ desired using Trajectory tracking controller
actual
desired
Position (degree)
Time (s)
0
10
20
30
40
50
60
70
0
2
4
6
8
10


Theta$_2$ vs. Theta$_2$ desired using Trajectory tracking controller
actual
desired
Position (degree)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10

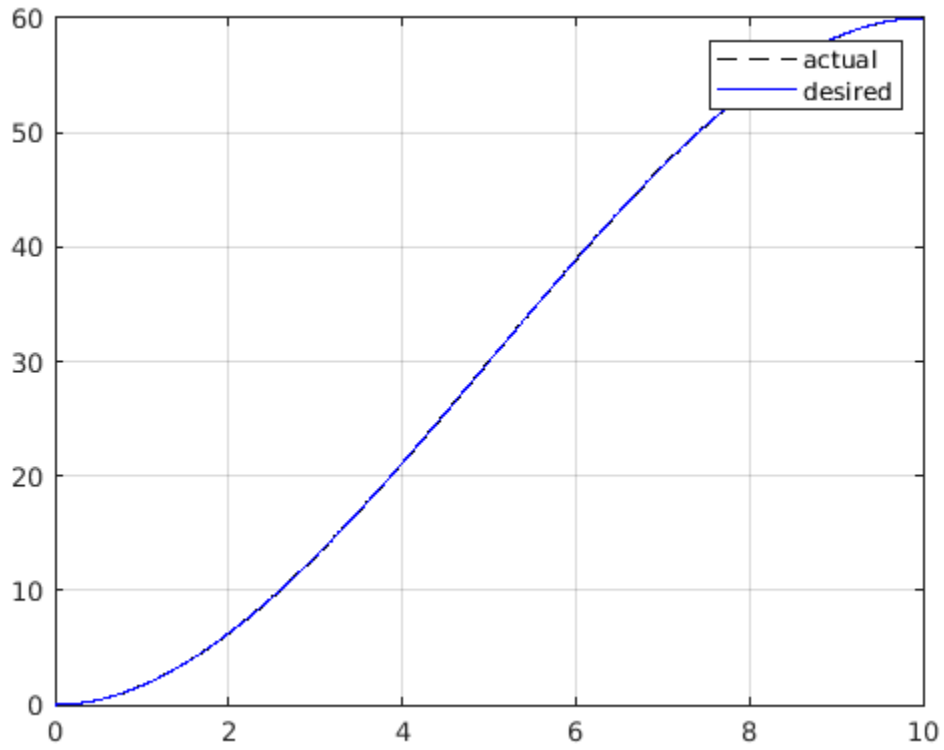

dTheta1 vs. dTheta1 desired using Trajectory tracking controller
actual
desired
Velocity(degree/s)
Time (s)
10
5
0
-5
-10
-15
-20
-25
0
2
4
6
8
10

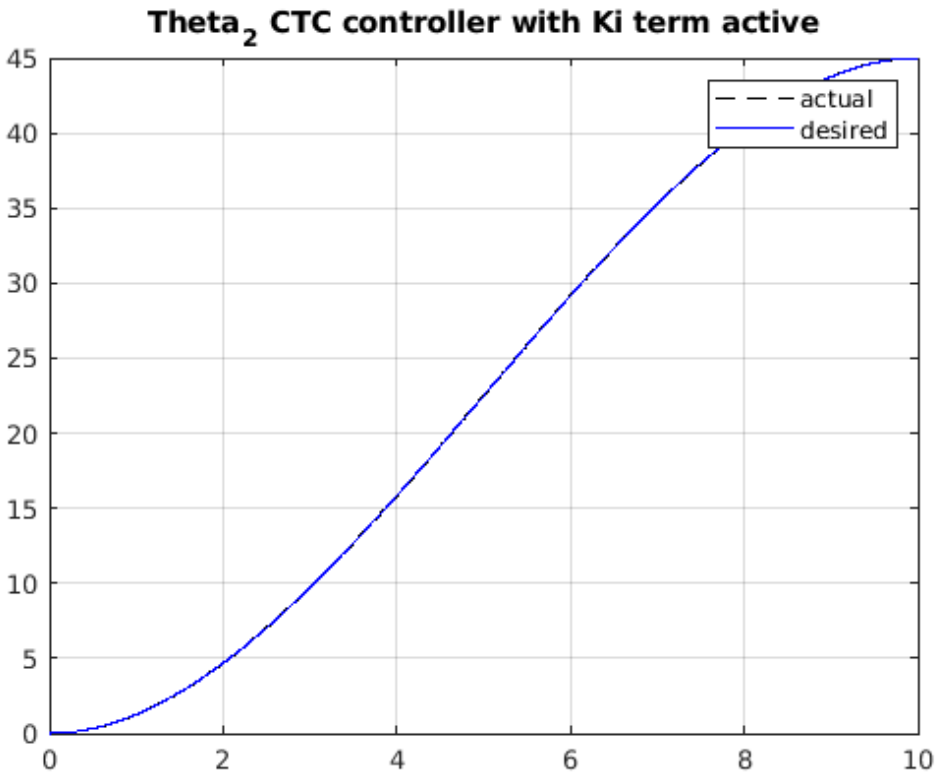

dTheta2 vs. dTheta2 desired using Trajectory tracking controller
actual
desired
Velocity(degree/s)
Time (s)
10
5
0
-5
-10
-15
-20
0
2
4
6
8
10

Bonus problem

setting the integration term to true so that we could enable the integrtion in the controller feedback.

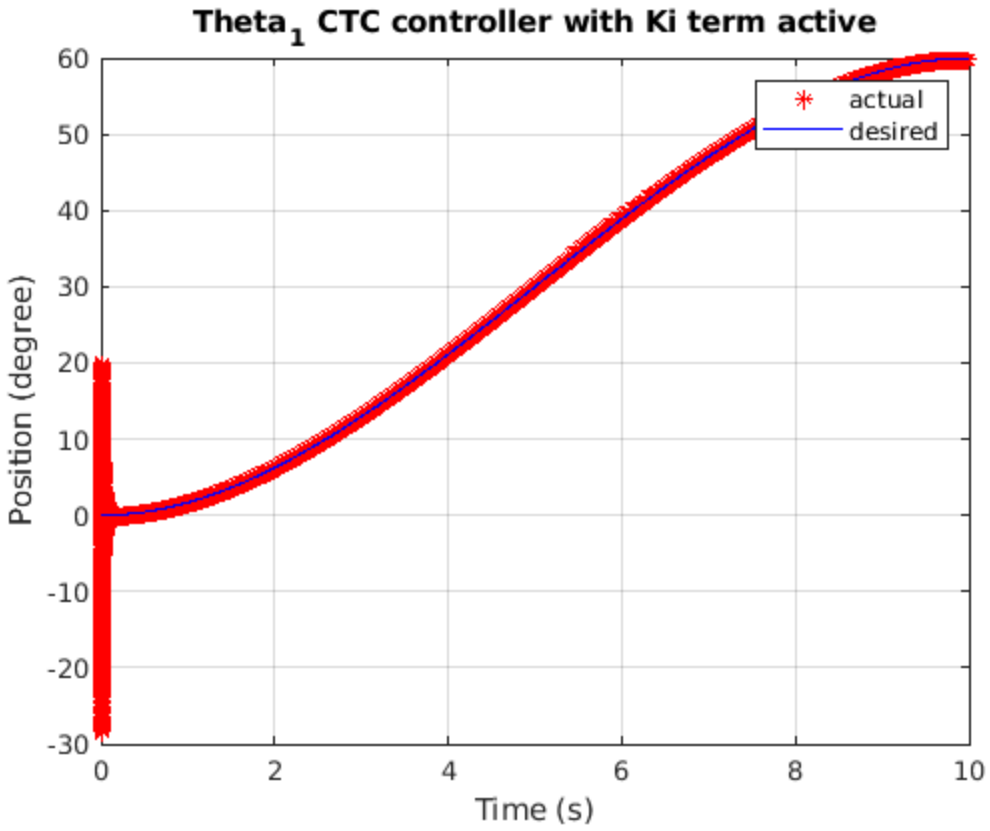
```
integral_term=true;
options = odeset('RelTol',1e-4,'AbsTol',[1e-4, 1e-4, 1e-4, 1e-4]);
[T2,X2] = ode45(@(t,x) inverseDC(t,x,link1,link2,integral_term),[0
 tf],q0, options);
figure('Name','Theta_1 under inverse dynamic control');
title('Theta_1 CTC controller with Ki term active')
plot(T2, X2(:,1),'k--',t,position1,'b');
legend('actual','desired')
grid on
hold on
figure('Name','Theta_2 under inverse dynamic control');
plot(T2, X2(:,2),'k--',t,position2,'b');
title('Theta_2 CTC controller with Ki term active')
legend('actual','desired')
grid on
hold on
```

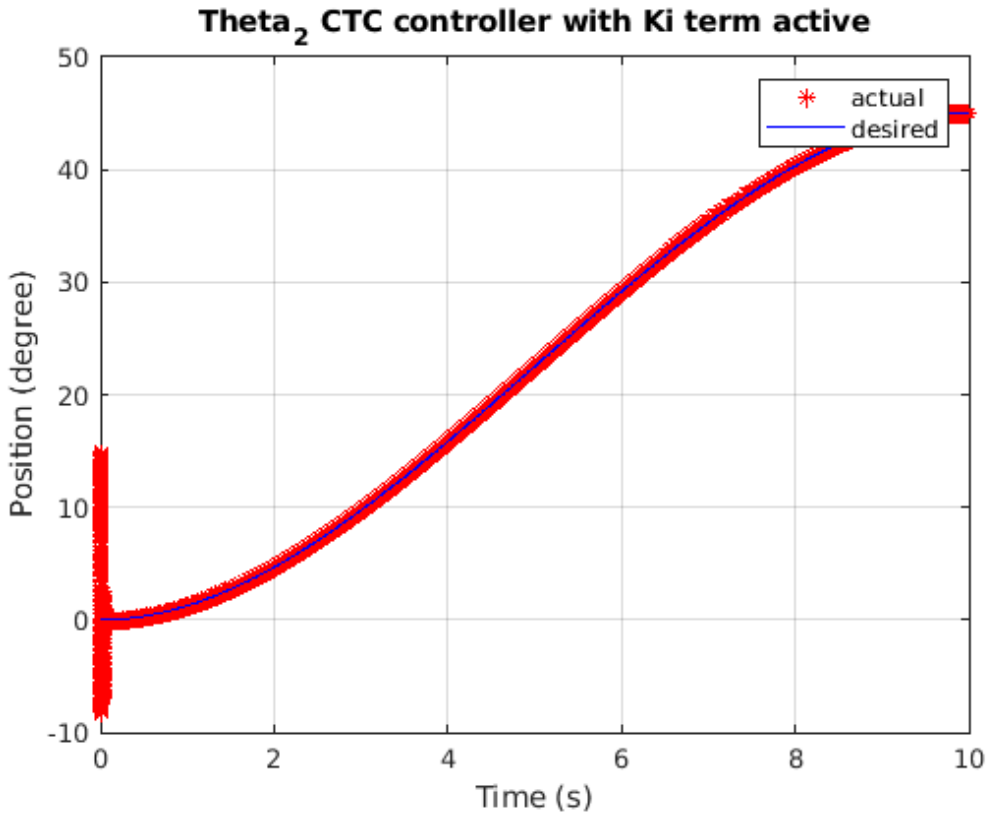




With different initial condition

```
options = odeset('RelTol',1e-4,'AbsTol',[1e-4, 1e-4, 1e-4, 1e-4]);
[T3,X3] = ode45(@(t,x) inverseDC(t,x,link1,link2,integral_term),[0
 tf],[20 15 1 5], options);
figure('Name','Theta_1 CTC controller with Ki term active');
plot(T3, X3(:,1),'r*',t,position1,'b');
title('Theta_1 CTC controller with Ki term active')
legend('actual','desired')
xlabel('Time (s)')
ylabel('Position (degree)')
grid on
hold on
figure('Name','Theta_2 CTC controller with Ki term active');
plot(T3, X3(:,2),'r*',t,position2,'b');
title('Theta_2 CTC controller with Ki term active')
legend('actual','desired')
xlabel('Time (s)')
ylabel('Position (degree)')
grid on
legend('actual','desired')
hold on
```


Theta$_1$ CTC controller with Ki term active
actual
desired
Position (degree)
Time (s)
60
50
40
30
20
10
0
-10
-20
-30
0
2
4
6
8
10


Theta$_2$ CTC controller with Ki term active
actual
desired
Position (degree)
Time (s)
50
40
30
20
10
0
-10
0
2
4
6
8
10

Published with MATLAB® R2019b