M263C. HW#3

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1\. a) $L(s) = K_p \frac{1+sT_p}{s} \cdot \frac{K_m}{1+sT_m} \cdot \frac{1}{s} = \frac{K_m K_p (1+sT_p)}{s^2(1+sT_m)}$

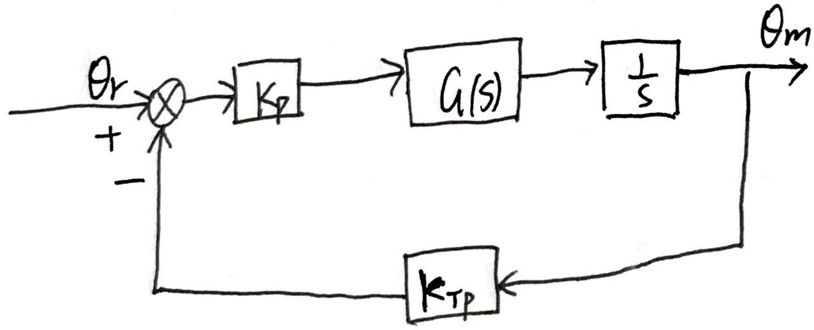
b) $H(s) = K_{Tp}$

c) $$\frac{\theta_m(s)}{\theta_r(s)} = \frac{L(s)}{1+L(s)H(s)} = \frac{\frac{K_m K_p(1+sT_p)}{s^2(1+sT_m)}}{1+\frac{K_m K_p(1+sT_p)K_{Tp}}{s^2(1+s(T_m))}}$$

$$= \frac{K_m K_p(1+sT_p)}{s^2(1+sT_m)+K_m K_{Tp} K_p(1+sT_p)}$$

d) $$\frac{\theta_m(s)}{D(s)} = \frac{-\frac{K_m}{1+sT_m}\cdot\frac{1}{s}}{1+L(s)H(s)} \cdot \frac{R_a}{K_t} = \frac{R_a K_m \cdot s}{s^2(1+sT_m)K_t + K_m K_{Tp} K_p K_t (1+s}$$

2\. a) simplify the diagram to be



$$G(s) = \frac{K_v \cdot \frac{1+sT_v}{s} \cdot \frac{K_m}{1+sT_m}}{1+\frac{K_v(1+sT_v)K_m K_{Tv}}{s(1+sT_m)}} = \frac{K_v K_m (1+sT_v)}{s(1+sT_m)+K_v K_m K_{Tv}(1+sT_v)}$$

$$\frac{\theta_m}{\theta_r} = \frac{K_P G(s)\frac{1}{s}}{1+K_P G(s)\frac{1}{s}\cdot K_{TP}}$$

$\because$ $K_m = \frac{1}{K_V} = 2\,rad/(V\cdot s)$, $T_m = \frac{K_a Z_m}{K_V K_t} = 7.2s$

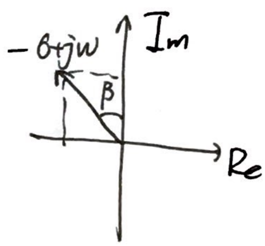
$K_{TP}=1$, $K_{TV}=1$, $\quad F_m \ll \frac{K_V K_t}{R_a}$

$$\therefore G(s) = \frac{2K_V}{S+2K_V}$$

$$\therefore \frac{\theta_m(s)}{\theta_r(s)} = \frac{\frac{2K_P K_V}{S(S+2K_V)}}{1+\frac{2K_P K_V}{S(S+2K_V)}} = \frac{2K_P K_V}{S^2+2K_V S+2K_P K_V}$$

b)

$$\begin{cases} 2K_V = 2\xi w_n \\ 2K_P K_V = w_n^2 \end{cases} \Rightarrow \begin{matrix} K_V = 8 \\ K_P = 25 \end{matrix}$$



pole: $\because \sin\beta = \xi$

$\therefore \frac{a}{w_n} = 0.4$, $a = 8$

$W = \sqrt{W_n^2 - a^2} = \sqrt{400-64} = 18.33$

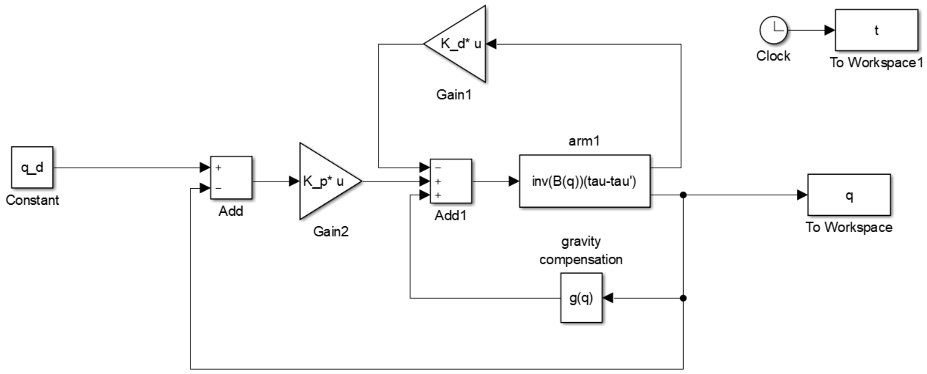
$\therefore$ poles: $-8 \pm j\,18.33$

c) $X_R = K_P K_{TP} K_V = 200$

$T_R = \max\{T_m, \frac{1}{\xi w_n}\} = 7.2s$

$\therefore$ We cannot decrease the output recovery time

3.



K_d* u
Gain1
Clock
t
To Workspace1
q_d
Constant
Add
K_p* u
Gain2
Add1
arm1
inv(B(q))(tau-tau')
q
To Workspace
gravity
compensation
g(q)

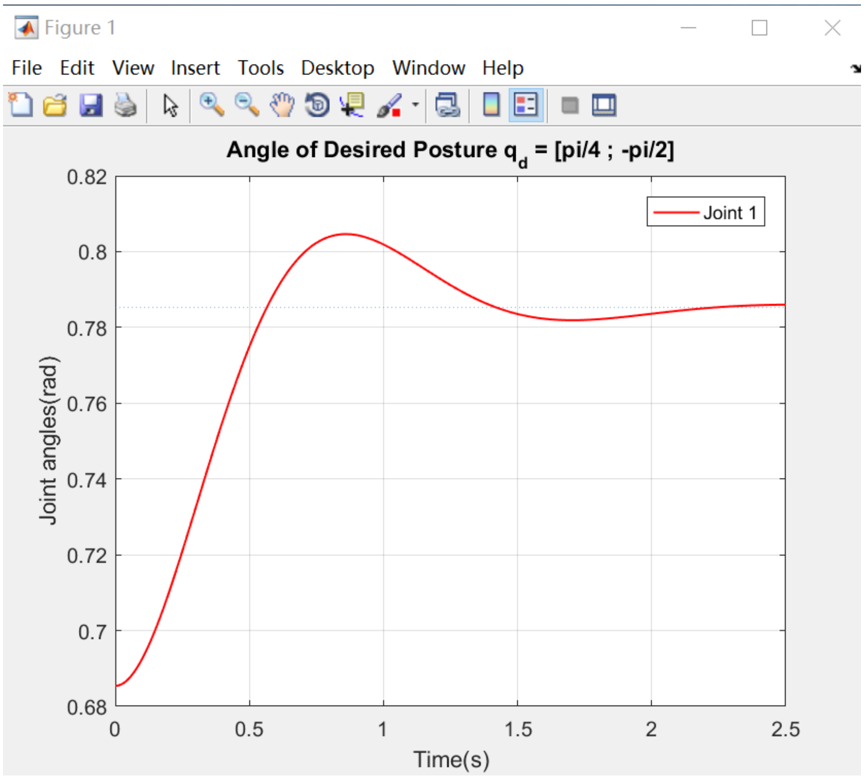


Figure 1
File Edit View Insert Tools Desktop Window Help
Angle of Desired Posture q_d = [pi/4 ; -pi/2]
Joint 1
Joint angles(rad)
Time(s)
0.82
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0
0.5
1
1.5
2
2.5

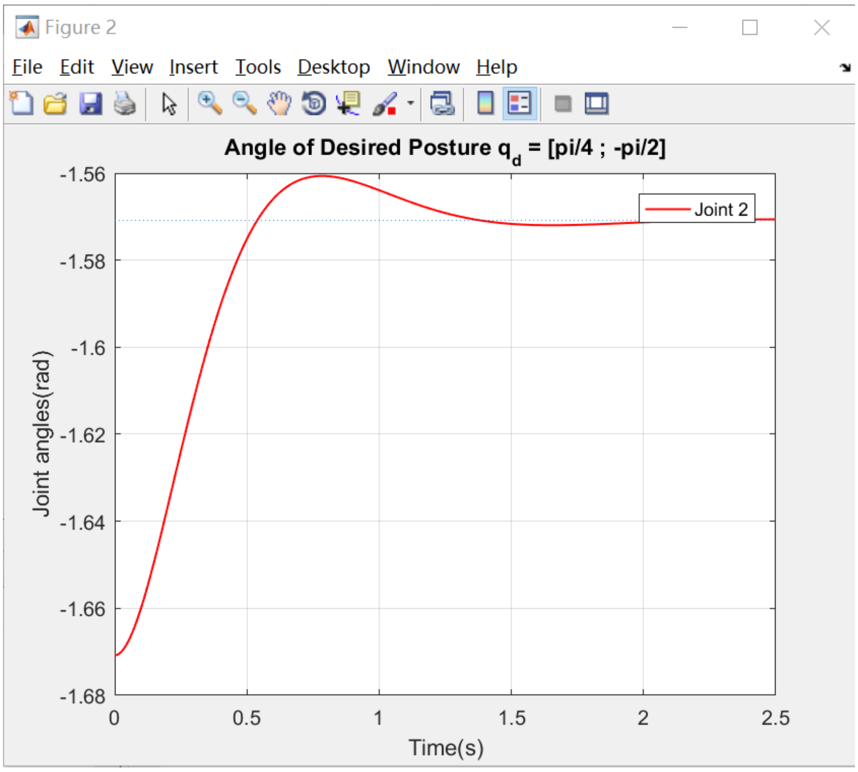


Figure 2
File Edit View Insert Tools Desktop Window Help
Angle of Desired Posture q_d = [pi/4 ; -pi/2]
Joint 2
Joint angles(rad)
-1.56
-1.58
-1.6
-1.62
-1.64
-1.66
-1.68
0
0.5
1
1.5
2
2.5
Time(s)

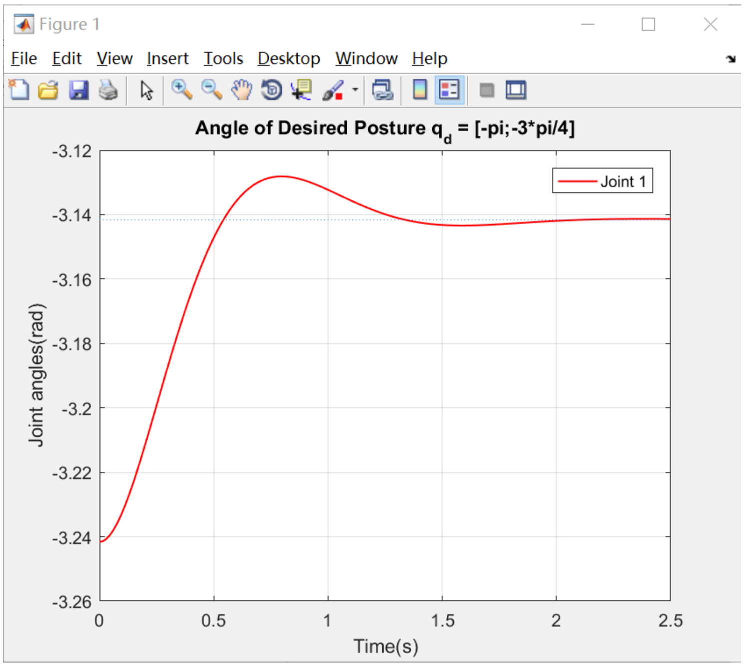
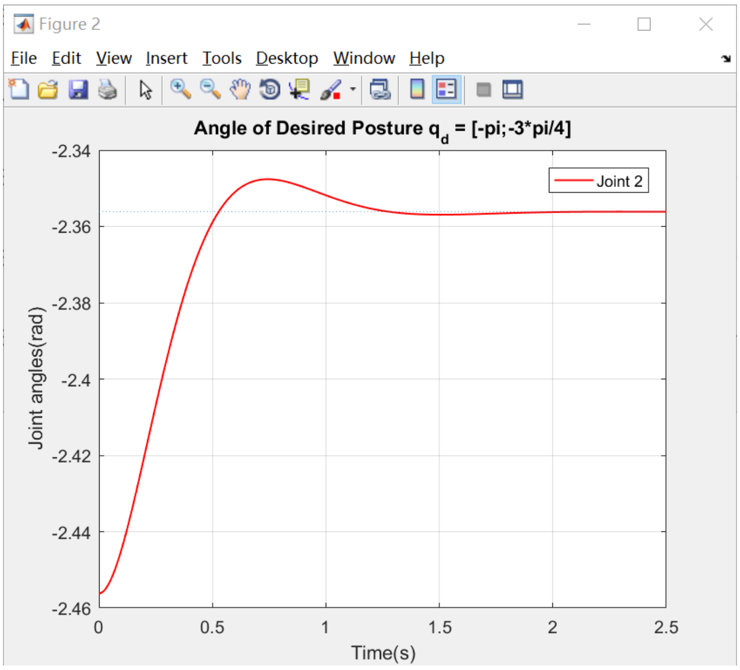


Figure 1
File Edit View Insert Tools Desktop Window Help
Angle of Desired Posture q_d = [-pi;-3*pi/4]
Joint 1
Joint angles(rad)
-3.12
-3.14
-3.16
-3.18
-3.2
-3.22
-3.24
-3.26
0
0.5
1
1.5
2
2.5
Time(s)




```
%**************************************************************************
% VERONICA J. SANTOS
% 4/20/18
% HW3_main.m
%
% This script file was originally created by L. Villani, G. Oriolo, and
% B. Siciliano in Feb. 2009.  It has been modified for MAE 263C HW #3.
%**************************************************************************

% Variable initialization
clear all;
global a k_r1 k_r2 pi_m pi_l

% load manipulator dynamic parameters without load mass
  param;
  pi_l = pi_m;

% gravity acceleration
  g = 9.81;

% friction matrix
  K_r = [k_r1,0;0,k_r2];
  F_v = K_r*[0.01,0;0,0.01]*K_r;

%
  Tc = 0.001;
```

```matlab
% controller gains
  K_p = 3700 * eye(2);
  K_d = 750 * eye(2);

% desired position
%   q_d = [pi/4;-pi/2];
  q_d = [-pi;-3*pi/4];

% initial position
  q_i = q_d-0.1;

% duration of simulation
  t_d = 2.5;

% sample time for plots
  Ts = Tc

% sim hw3
%
% figure(1)
% plot(t,q(:,1),'LineWidth',1,'Color','r'); grid on
% line([0,2.5],[q_d(1),q_d(1)],'linestyle',':');grid on
% xlabel('Time(s)');
% ylabel('Joint angles(rad)');
% title('Angle of Desired Posture q_d = [pi/4 ; -pi/2]')
% legend('Joint 1');
%
% figure(2)
% plot(t,q(:,2),'LineWidth',1,'Color','r'); grid on
% line([0,2.5],[q_d(2),q_d(2)],'linestyle',':');grid on
% xlabel('Time(s)');
% ylabel('Joint angles(rad)');
% title('Angle of Desired Posture q_d = [pi/4 ; -pi/2]')
% legend('Joint 2')

sim hw3

figure(1)
plot(t,q(:,1),'LineWidth',1,'Color','r'); grid on
line([0,2.5],[q_d(1),q_d(1)],'linestyle',':');grid on
xlabel('Time(s)');
ylabel('Joint angles(rad)');
title('Angle of Desired Posture q_d = [-pi;-3*pi/4]')
legend('Joint 1');
```

```
figure(2)
plot(t,q(:,2),'LineWidth',1,'Color','r'); grid on
line([0,2.5],[q_d(2),q_d(2)],'linestyle',':');grid on
xlabel('Time(s)');
ylabel('Joint angles(rad)');
title('Angle of Desired Posture q_d = [-pi;-3*pi/4]')
legend('Joint 2')
```