Jiyoon Park MEC Problem2

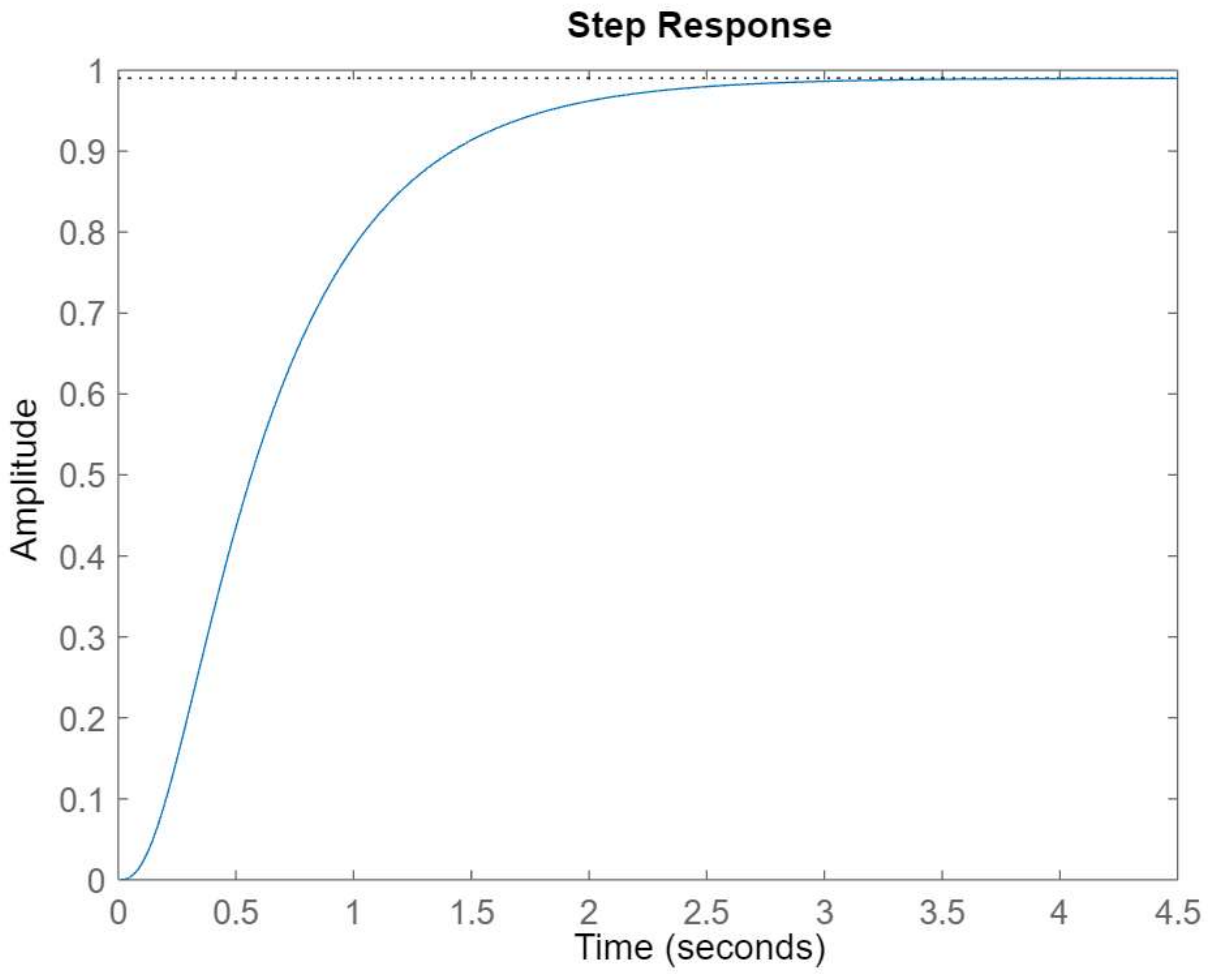
Question1

c)

```
sys = tf(200, [1 22 141 202])
```

```
sys =

             200
  -------------------------
  s^3 + 22 s^2 + 141 s + 202

Continuous-time transfer function.
```

```
step(sys)
```



Question2

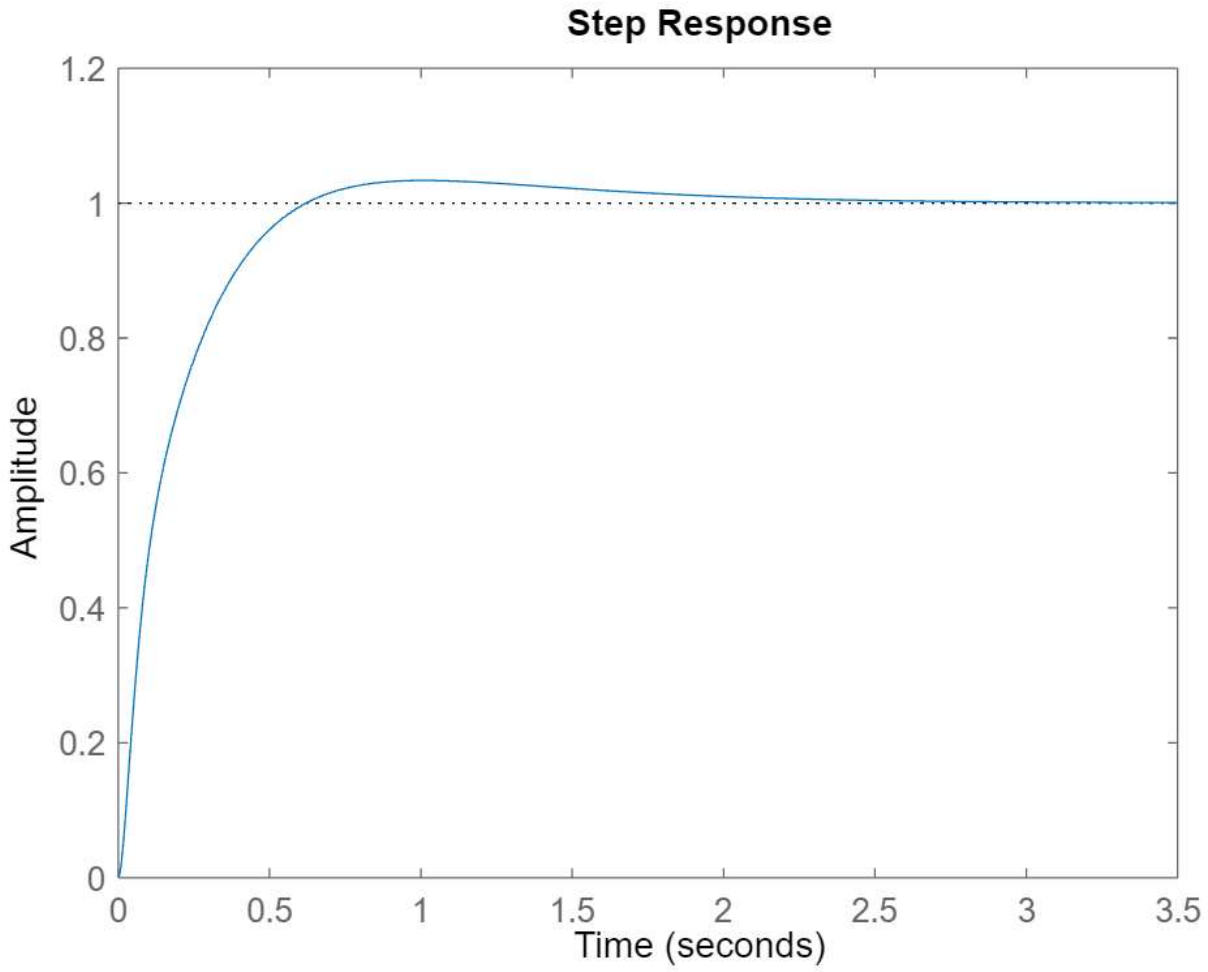
```
kp = 800;
kd=500;
ki = 1;

sys2 = tf([kd kp+10*kd ki+10*kp 10*ki],[1 71 1070+kd kp+10*kd+1000 ki+10*kp 10*ki])
```

```
sys2 =

  500 s^3 + 5800 s^2
                + 8001 s + 10
  ---------------------------
  s^5 + 71 s^4 + 1570 s^3
          + 6800 s^2
                + 8001 s + 10
```

```
[y, t] = step(sys2, 10000);
disp(y(end))
```

```
    1.0000
```

```
step(sys2)
```




```
S = stepinfo(sys2);
disp(S.RiseTime);
```

```
    0.3646
```

```
disp(S.Overshoot);
```

```
    3.3563
```

Question3

```
A = [0 0 1 0;
     0 0 0 1;
     0 1 -3 0;
     0 2 -3 0;];
B = [0;0;1;1;];

T = 0.01;
time_all = 0:T:200;
y_des = 20*square(2*pi*T*time_all);
C = [39.3700787 0 0 0];
x0=[0;0;0;0];
```

```
Obs=[C C*A C*A^2 C*A^3]'
```

```
Obs = 16×1
   39.3701
         0
         0
         0
         0
         0
   39.3701
         0
         0
   39.3701
```

```
Q_prime = [C' A'*C' (A')^2*C' (A')^3*C']
```

```
Q_prime = 4×4
   39.3701         0         0         0
         0         0   39.3701 -118.1102
         0   39.3701 -118.1102  354.3307
         0         0         0   39.3701
```

```
rank(Q_prime)
```

```
ans = 4
```

```
rank(obsv(A, C))
```

```
ans = 4
```

```
obsv(A, C)
```

```
ans = 4×4
   39.3701         0         0         0
         0         0   39.3701         0
         0   39.3701 -118.1102         0
         0 -118.1102  354.3307   39.3701
```

```
Q =[10 0 0 0;
     0 5 0 0;
     0 0 10 0;
     0 0 0 5;];
R = 8;
Kc = lqr(A, B, Q, R);
E = -inv(C*inv(A-B*Kc)*B);

eig(A-B*Kc)
```

```
ans = 4×1
   -3.5927
   -1.1134
   -0.7726
   -0.3618
```

```
poles = [-3.9 -4 -4.1 -4.2];
poles1 = [-3.6 -3.65 -3.7 -3.75];
poles2 = [-4 -5 -6 -7];
K0 = place(A',C',poles)';

x_orig_list = zeros(length(time_all), 4);
x_hat_list = zeros(length(time_all), 4);
y_list = zeros(length(time_all), 1);
y_hat_list = zeros(length(time_all), 1);
% x_hat_list(1, :) = [0.01, 0.02, 0, 0];

tic;

for i= 1:length(time_all) - 1

disp(i)
% time = (i-1)*(T):T:i*T;

[t_orig, x_orig] = ode45(@(t, x) func3(t, x, E, Kc, x_hat_list(i, :)'), [(i-1)*T, i*T], x_orig_list(i, :)');
x_orig_list(i+1, :) = x_orig(end, :);
y_list(i+1, :) = C*x_orig(end,:)';


[t_obs, x_hat] = ode45(@(t, x) func4(t, x, E, y_list(i+1, :), Kc, K0, C), [(i-1)*T, i*T], x_hat_list(i, :)');

x_hat_list(i+1, :) = x_hat(end, :);
y_hat_list(i+1, :) = C*x_hat(end, :)';


end
```

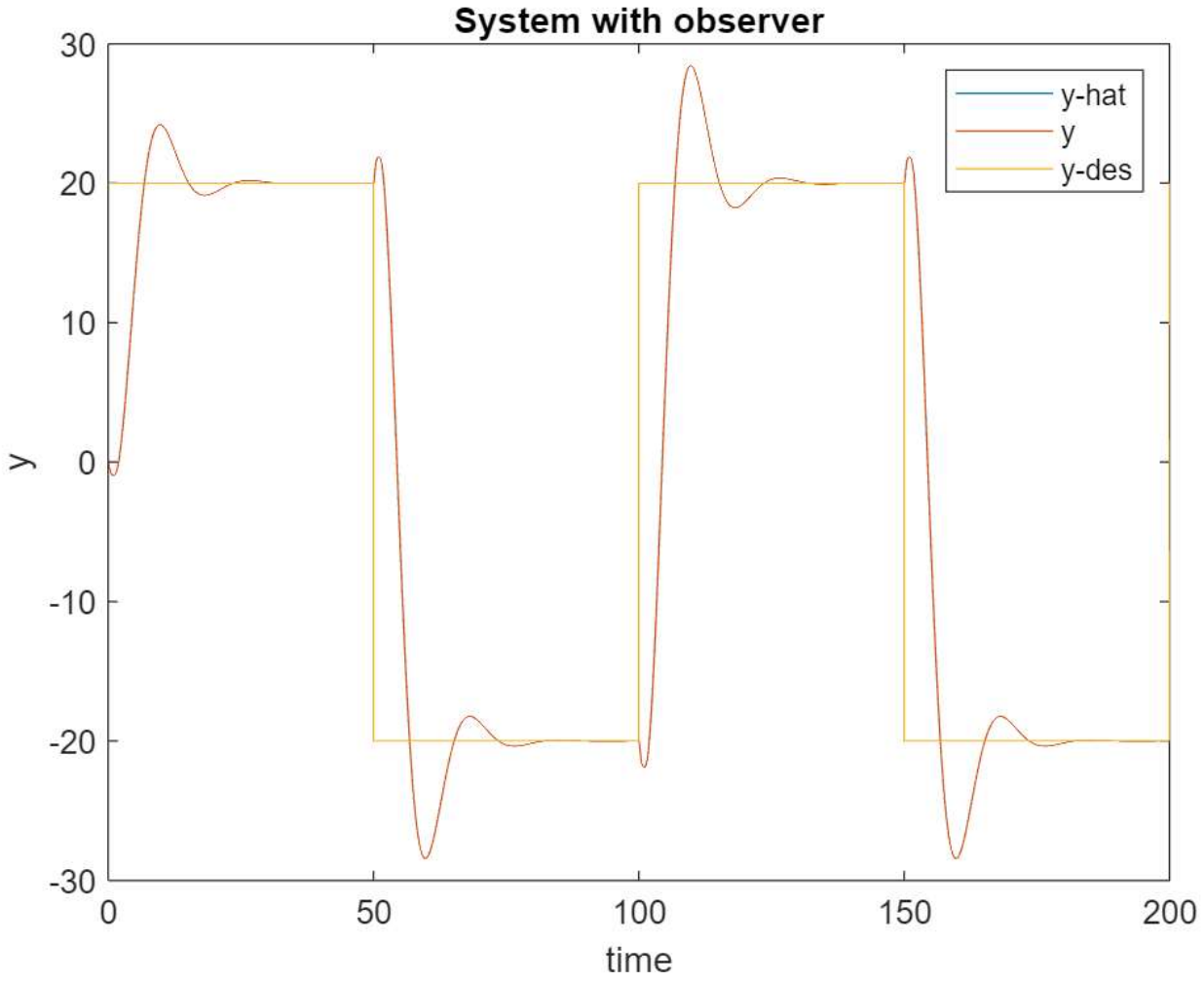
```
     1

     2

     3

     4

     5

     6

     7

     8
```

```
toc;
```

```
Elapsed time is 38.493544 seconds.
```

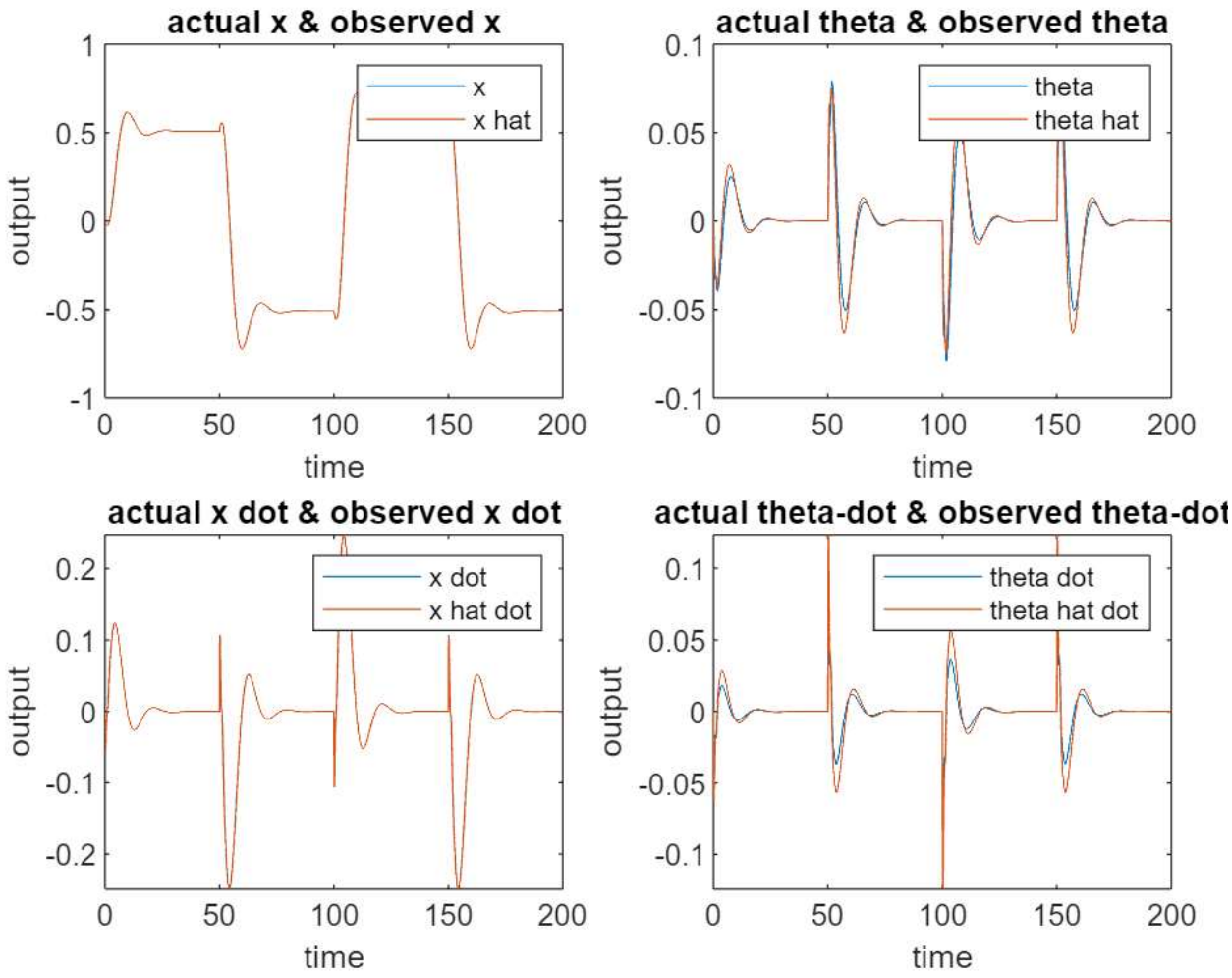
```
figure;
plot(time_all, y_hat_list)
hold on
plot(time_all, y_list)
hold on
plot(time_all, y_des)
hold on
%plot(t3(:,1), C*y3')
title('System with observer')
```

```
legend('y-hat', 'y', 'y-des')
xlabel('time')
ylabel('y')
```

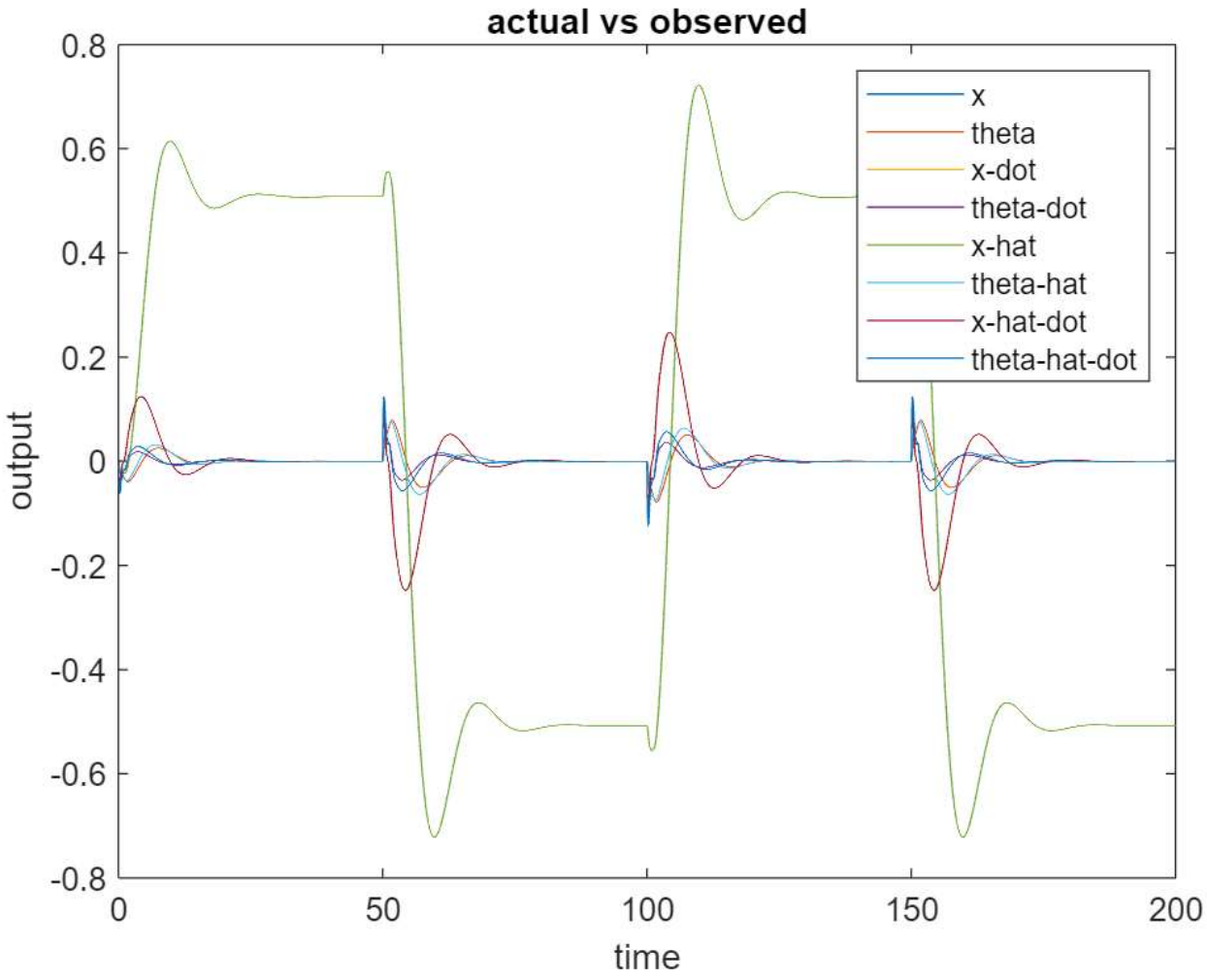



```
figure;

subplot(221);
plot(time_all, x_orig_list(:,1))
hold on
plot(time_all,x_hat_list(:,1))
legend('x','x hat')
hold on
xlabel('time')
ylabel('output')
title('actual x & observed x')


subplot(222);
plot(time_all, x_orig_list(:,2))
hold on
plot(time_all,x_hat_list(:,2))
legend('theta','theta hat')
hold on
xlabel('time')
ylabel('output')
title('actual theta & observed theta')

subplot(223);
plot(time_all, x_orig_list(:,3))
```

```
hold on
plot(time_all,x_hat_list(:,3))
legend('x dot','x hat dot')
hold on
xlabel('time')
ylabel('output')
title('actual x dot & observed x dot')

subplot(224);
plot(time_all, x_orig_list(:,4))
hold on
plot(time_all,x_hat_list(:,4))
legend('theta dot','theta hat dot')
hold on
xlabel('time')
ylabel('output')
title('actual theta-dot & observed theta-dot')
```




```
figure;

plot(time_all, x_orig_list)
hold on
plot(time_all, x_hat_list)
hold on
title('actual vs observed')
legend('x', 'theta','x-dot', 'theta-dot', 'x-hat', 'theta-hat','x-hat-dot', 'theta-hat-dot')
xlabel('time')
ylabel('output')
```




```
function out3 = func3(t, x, E, Kc, x_hat)

    y_des = 20*square(2*pi*0.01*t);
% y_des = 2;
%     disp(y_des)
    V = E*y_des;
    U = V-Kc*x_hat;
    out3 = [x(3);
            x(4);
            (U-x(4)^2*sin(x(2))-3*x(3)+cos(x(2))*sin(x(2)))/(2-cos(x(2))^2);
            (U*cos(x(2))-x(4)^2*cos(x(2))*sin(x(2))-3*x(3)*cos(x(2))+2*sin(x(2)))/(2-cos(x(2))^2)];
end

function out4 = func4(t, x, E, y, Kc, K0, C)
%     disp(t)
    y_des = 20*square(2*pi*0.01*t);
%     y_des = 2;
    V = E*y_des;
    U = V-Kc*x;
    out4 = [x(3);
            x(4);
            (U-x(4)^2*sin(x(2))-3*x(3)+cos(x(2))*sin(x(2)))/(2-cos(x(2))^2);
            (U*cos(x(2))-x(4)^2*cos(x(2))*sin(x(2))-3*x(3)*cos(x(2))+2*sin(x(2)))/(2-cos(x(2))^2)];
    out4 = out4+ K0*(y-C*x);
end
```