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ECE 463

HW # 11

05/08/2021

SATURDAY

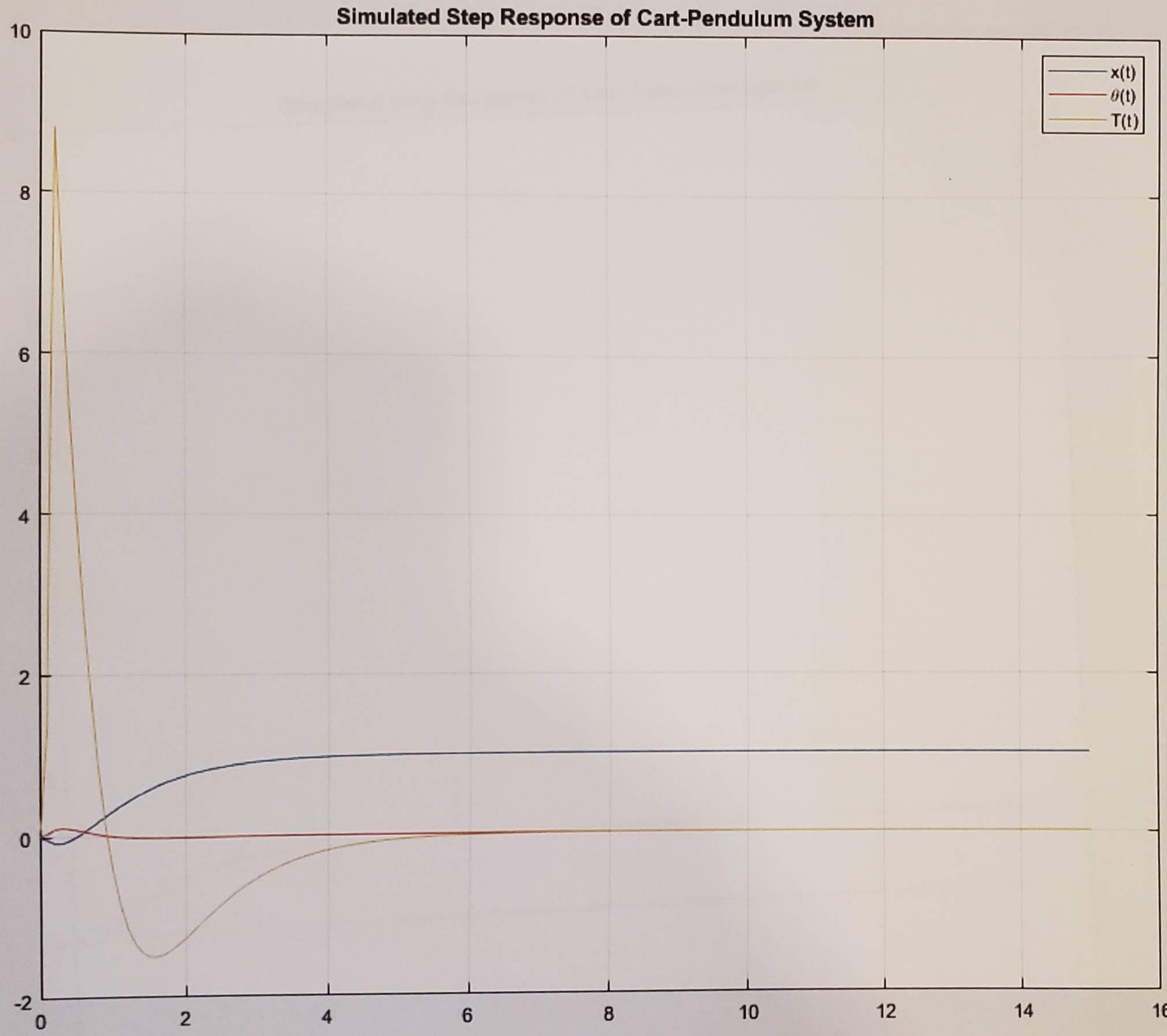
① Take the C&P of HW #6 ($m_c = 1kg$, $m_L = 4kg$, $L = 1m$) /w input disturbance $F = B$ and $n_u \sim N(0, 0.02^2)$ and sensor noise $n_y \sim N(0, 0.01^2)$.

(1) Use a servo-comp to force DC gain → 1 and observe response (a) /wo noise and (b) /w noise.

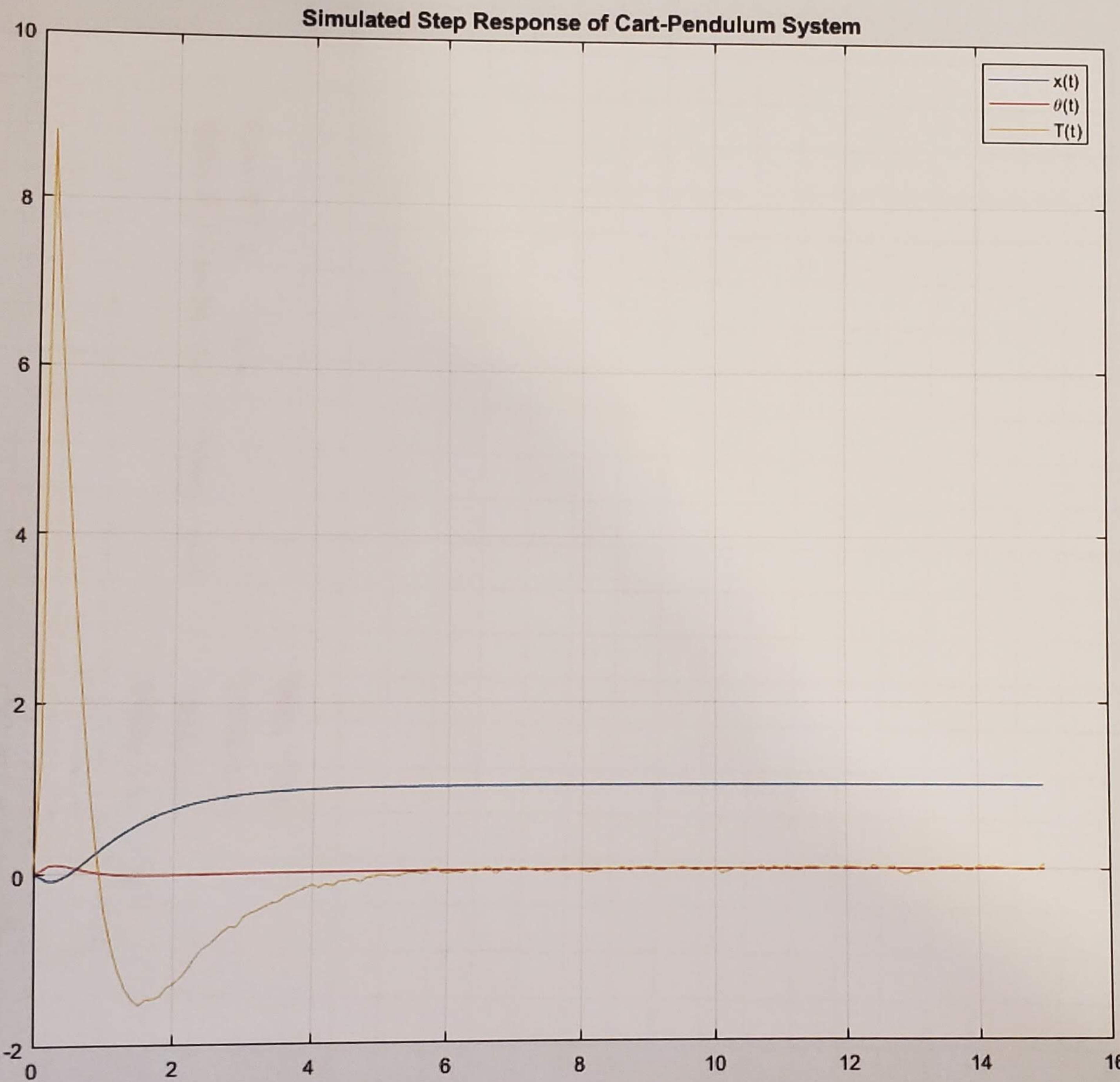
From HW 10, I got $K_x = [-1218, -2267.9, -666, -711.8]$, $K_z = -743.3707$.

(a) Now /wo noise : (next page)

(b) /w noise : (page after that)



Simulated Step Response of Cart-Pendulum System
x(t)
θ(t)
T(t)
10
8
6
4
2
0
-2
0
2
4
6
8
10
12
14
16



Simulated Step Response of Cart-Pendulum System
x(t)
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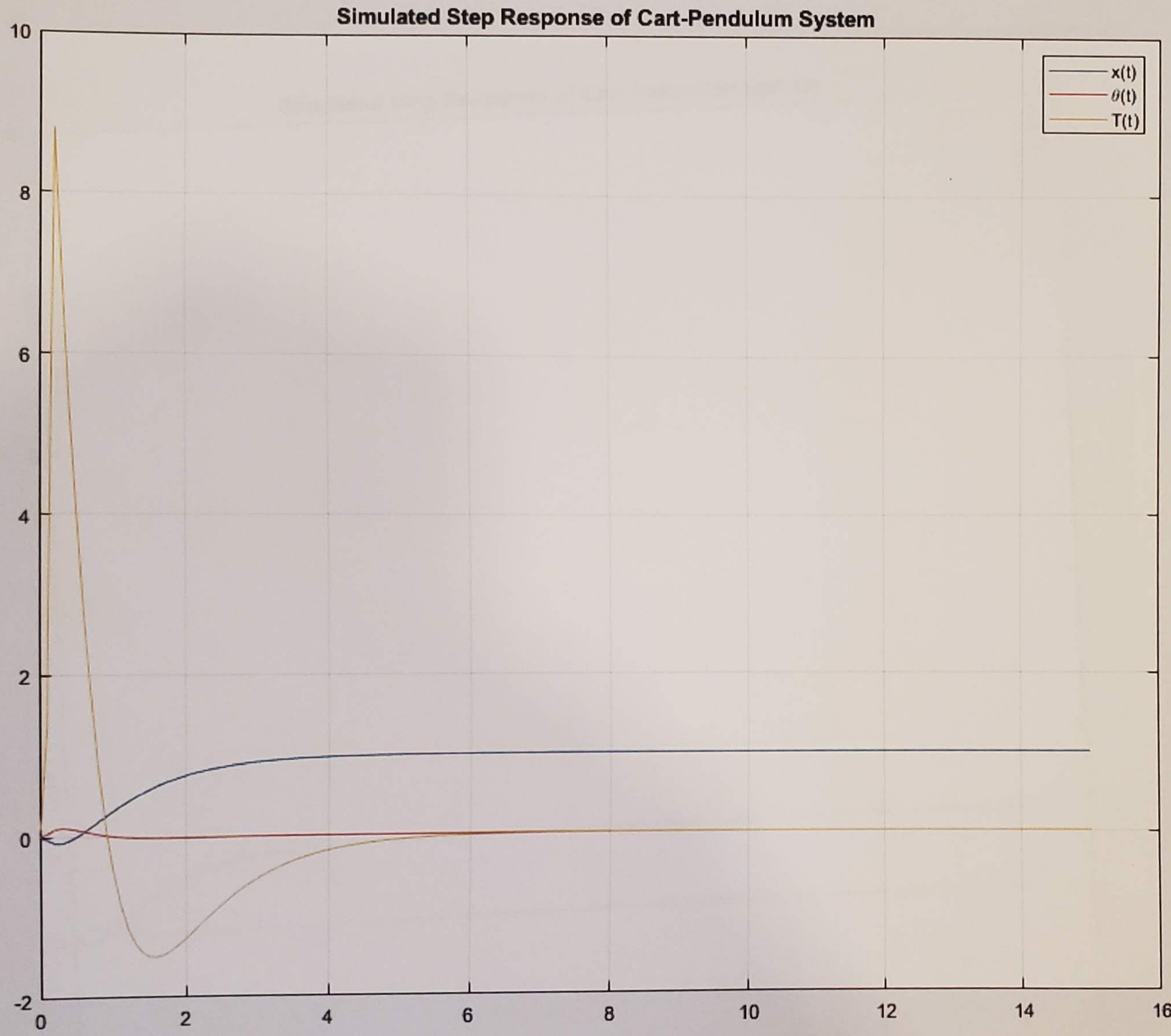
(2) Now design a full-order observer to place the observer poles at [-3, -4, -5, -6], simulate, and plot, using observer estimate.

$$H = \text{placePoles}(A', C', [-3, -4, -5, -6])' \Longrightarrow H = \begin{matrix} 18.0 \\ -31.2245 \\ 168.0 \\ -219.1837 \end{matrix}$$



Simulated Step Response of Cart-Pendulum System
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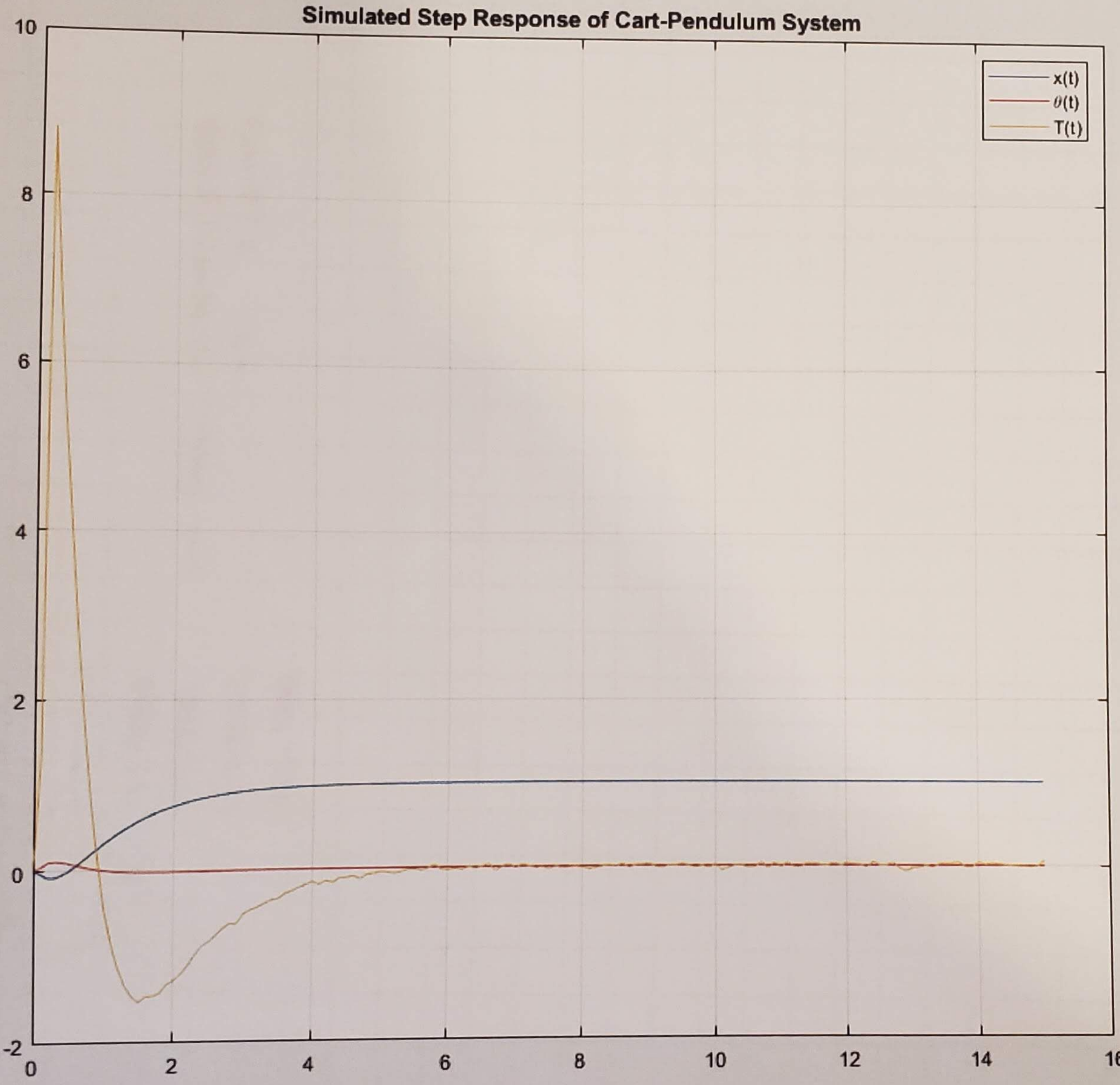
Simulated Step Response of Cart-Pendulum System
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16

3 Now Kalman.

$Q = B * B^T * 0.02^2 ; R = 0.01^2 ;$

$H = lqr(A', C', Q, R)'$

$H : \begin{matrix} 14.9088 \\ -19.9151 \\ 111.1360 \\ -139.4200 \end{matrix} \Longrightarrow$ Poles: $\begin{matrix} -0.4544 \pm j\,0.4398 \\ -7 \pm j\,0.1143 \end{matrix}$

```
% Cart and Pendulum
% EC 463 Lecture 7
% main calling routine

% System
mcart = 1; mball = 4; L = 1;
[A,B] = linearizedCartPend(mcart,mball,L);
C = [1 0 0 0];

% Noise
F = B;
nu_mu = 0; nu_sig = 0.02;
ny_mu = 0; ny_sig = 0.01;

% Feedback gains
Kx = [-1218, -2267.9, -666, -711.8];
Kz = -743.3707;

% Observer gains
% H = [18; -31.2245; 168; -219.1837];
H = [14.9088; -19.9151; 111.1360; -139.4200];

% Initial conditions
% % Trial 1
% X = zeros(4,1); Z = 0;
% dX = zeros(4,1);

% Trial 2
X = zeros(4,1); Xe = zeros(4,1); Z = 0;
dX = zeros(4,1); dXe = zeros(4,1);

% Simulation setup
Ref = 1;
t = 0; dt = 100e-6; Tend = 20;
N = (Tend / dt) + 1;

% % Trial 1
% DATA = zeros(N,3); % x, th, T
% Trial 2
DATA = zeros(N,4); % x,th,xe,the,T

i=1;
tic
while(t < Tend)

%     % Trial 1
% %     U = -Kz*Z - Kx*X;
%     U = -Kz*Z - Kx*X + normrnd(nu_mu,nu_sig);
%
%     dX = CartDynamics(X,U,mcart,mball,L);
%     dZ = C*X + normrnd(ny_mu,ny_sig) - Ref;
%
%     X = X + dX*dt;
%     Z = Z + dZ*dt;
%     t = t + dt;
```

```
%     Trial 2
    U = -Kz*Z - Kx*Xe + normrnd(nu_mu,nu_sig);

    dX = CartDynamics(X, U, mcart, mball, L);
    dXe = A*Xe + B*U + H*C*(X - Xe);
    dZ = C*X + normrnd(ny_mu,ny_sig) - Ref;

    X = X + dX*dt;
    Xe = Xe + dXe*dt;
    Z = Z + dZ*dt;
    t = t + dt;

%     DATA(i,:) = [X(1), X(2), U];
    DATA(i,:) = [X(1), X(2), Xe(1), Xe(2)];
    i = i+1;

end
toc

kk = 10;
t = [1:length(DATA)]' * dt;
DATAds = downsample(DATA,kk);
tds = downsample(t,kk);

% plot(tds,DATAds(:,1), tds,DATAds(:,2), tds,DATAds(:,3));
% legend('x(t)','\theta(t)','T(t)');
plot(tds,DATAds);
legend('x(t)','\theta(t)','x_e(t)','\theta_e(t)');
grid on;
title('Simulated Step Response of Cart-Pendulum System');
```