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EE 5322 Intelligent Control Systems
Assignment no 3

Discrete Time Simulation, Observers, Kalman Filter

1. Discrete-Time System.

Q1.a)

Solution :

```
clc;
clear all;
close all;

X=zeros(2,100);
Xn=zeros(2,100);
A=[0    1
  -0.89 1.8];
B=[0
   1];
u=ones(100,1);
t=1:100;
for i=1:99
X(:,i+1)=A*X(:,i)+B*u(i);
y(i,:) = X(:,i+1)'
hold on
end
figure(1)
plot(t,X(1,:));
hold on;
grid on;
plot(t,X(2,:),'r');
legend t X
grid on;
title('System States Without Noise')
max_overshoot = max(y(:,1))
SteadyState_value = max(y(i,:))
peak_overshoot = (max_overshoot(1) - SteadyState_value)/SteadyState_value *100
```

Solution :

y =

```
      0    1.0000
   1.0000    2.8000
   2.8000    5.1500
   5.1500    7.7780
…
  11.1361   11.1243
  11.1243   11.1126
  11.1126   11.1020
```

max_overshoot =

17.2655

SteadyState_value =

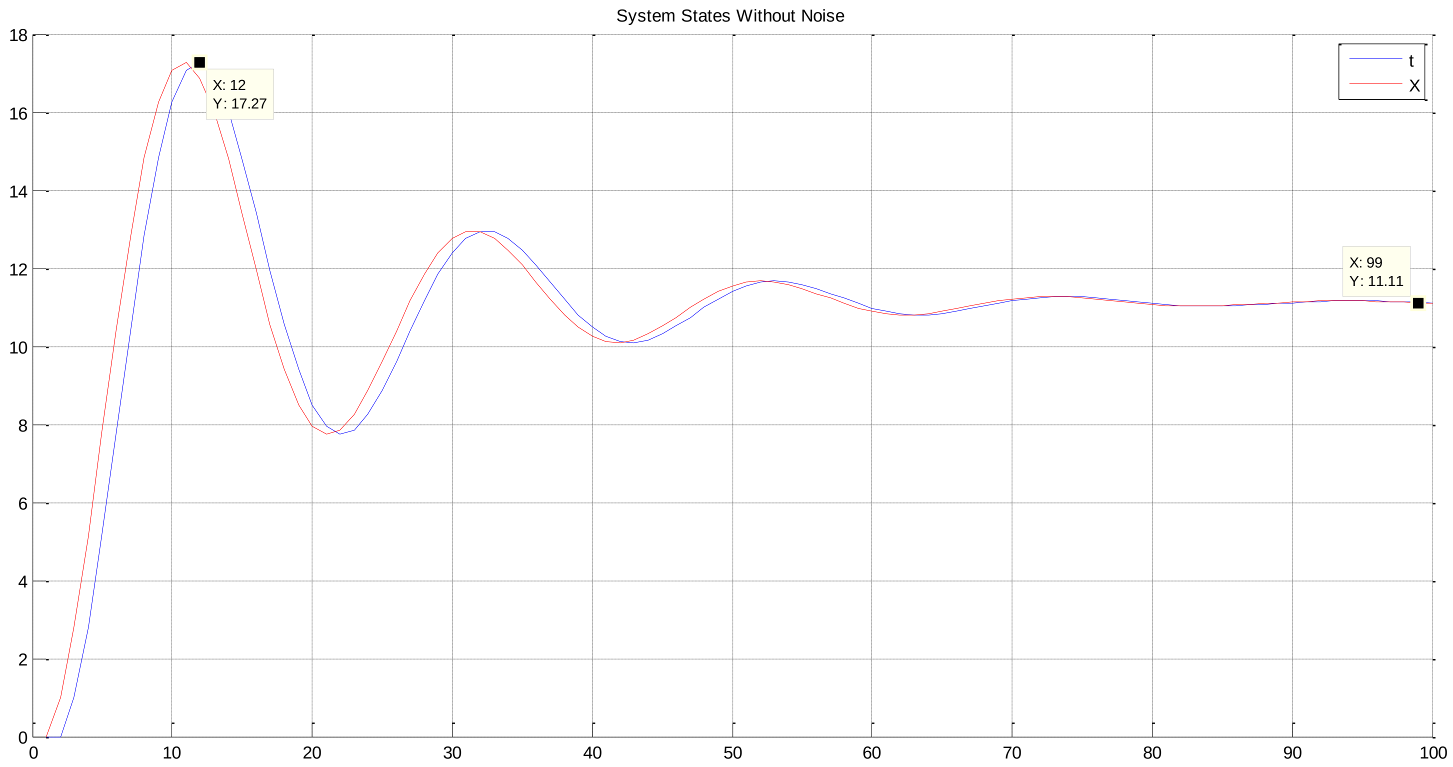
11.1126

peak_overshoot =

55.3691

Plots

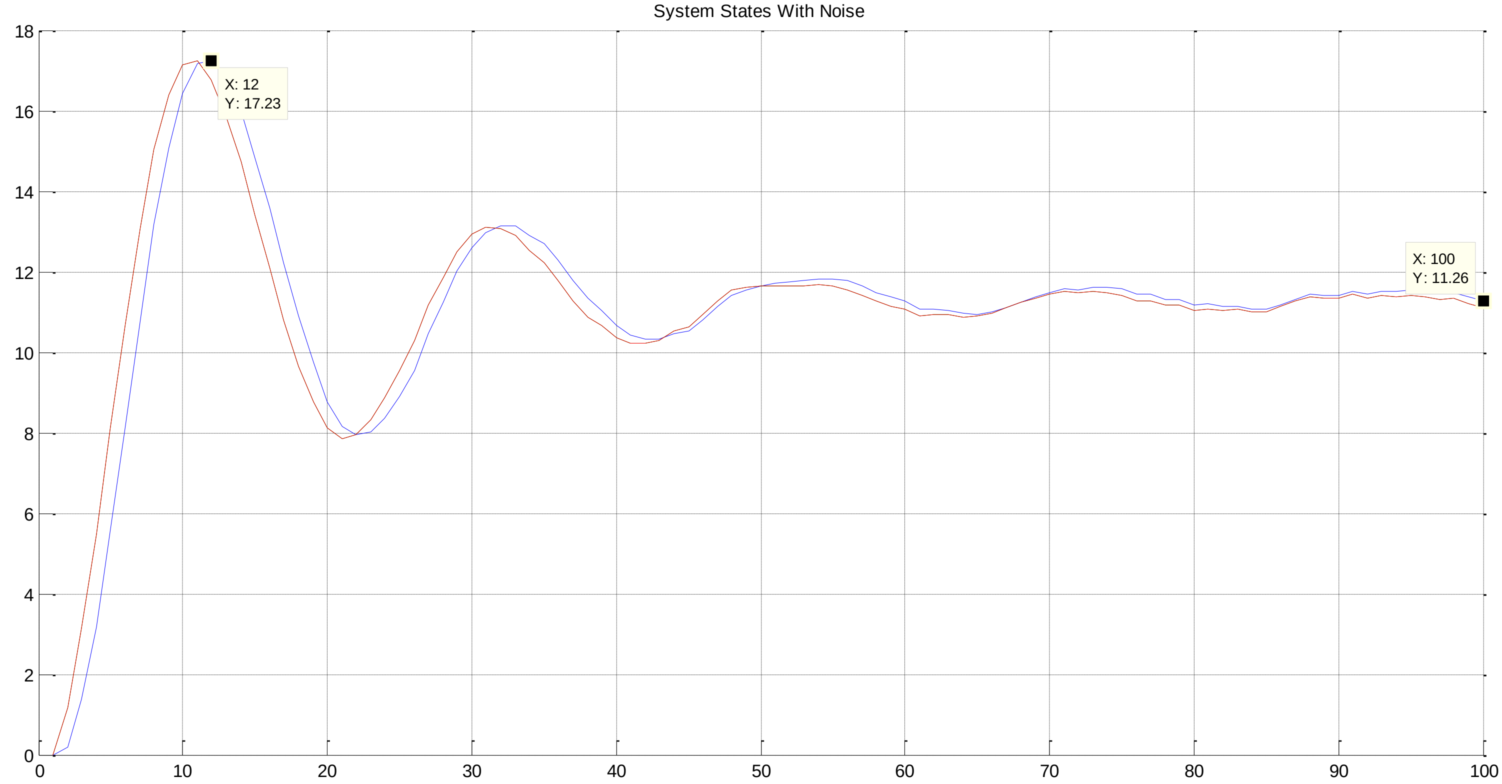
:



Q1.b)

```
Code :

clc;
clear all;
close all;

x=zeros(2,100);
xn=zeros(2,100);
A=[0    1
  -0.89 1.8];
B=[0
   1];
u=ones(100,1);
t=1:100;
w = 0.2*rand(2,100);
for i=1:99
x(:,i+1)=A*x(:,i)+B*u(i)+w(i);
y(i,:) = x(:,i+1)'
hold on
end
figure (1)
plot(t,x(1,:),t,x(2,:));
hold on;
plot(t,x(2,:),'r');
grid;
title('System States With Noise')
max_overshoot = max(y())
min_overshoot = max(y(i,:))
peak_overshoot = (max_overshoot(1) - min_overshoot)/min_overshoot *100

Solution :

y =

    0.1054    1.1054
    1.1782    2.9687
    2.9827    5.3091
    5.3588    7.9514
    7.9632   10.5551
…
   11.5183   11.3675
   11.4731   11.3158
   11.4842   11.3258
   11.3617   11.2014
   11.2566   11.1058


max_overshoot =
   17.2334

min_overshoot =
   11.2566

peak_overshoot =

   53.0955
```

Plot:

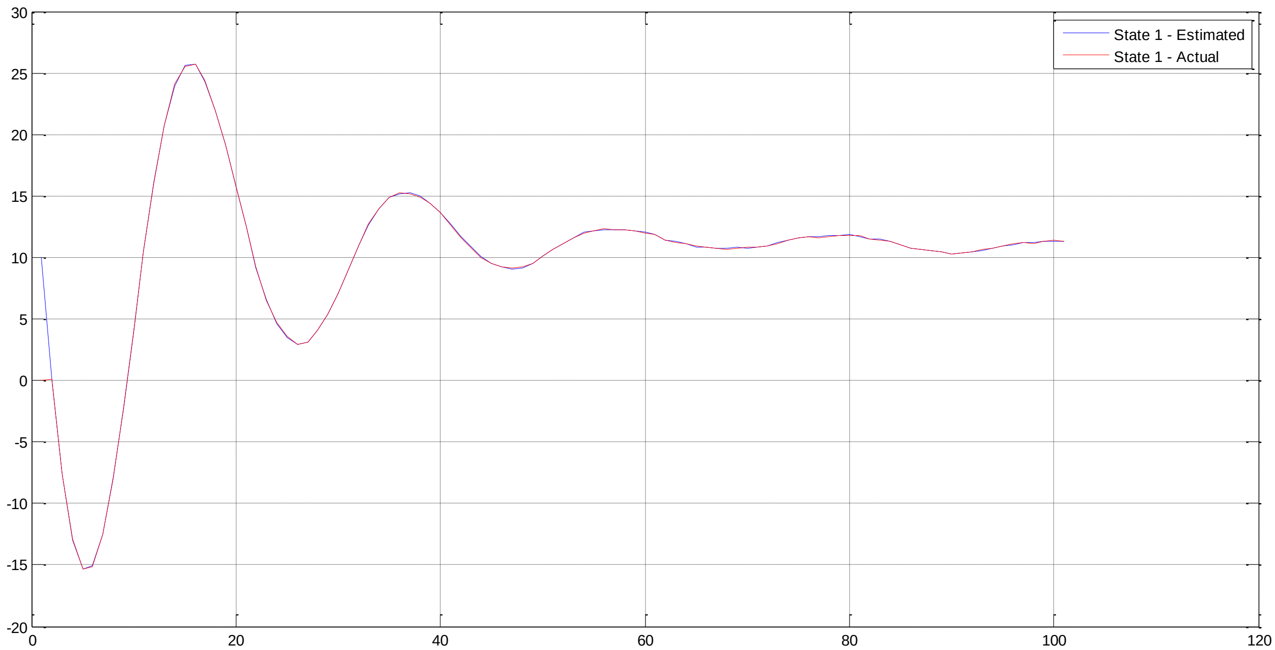

System States With Noise
X: 12
Y: 17.23
X: 100
Y: 11.26
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90
100

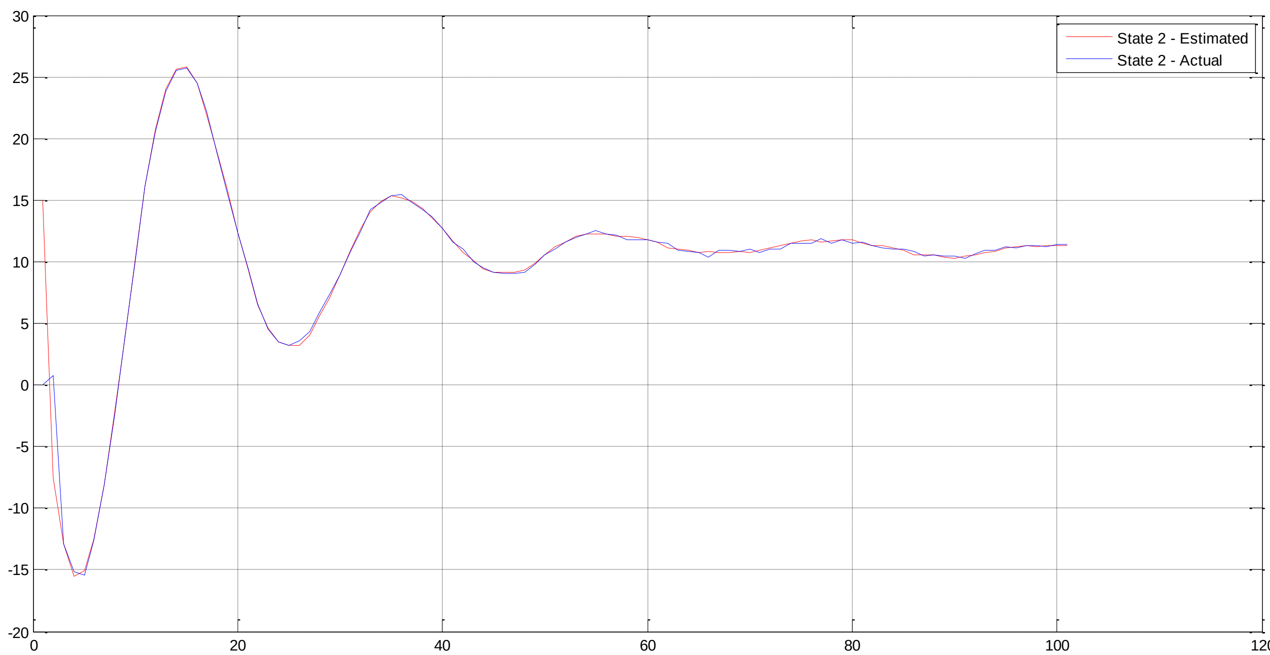
2.

CODE :

```
clc;
clear all;
close all;

A=[0     1                                                    % State space description of system
   -0.89 1.8];
B=[0
   1];
u=ones(100,1);
H=[2 0];
x(:,1)=[0;0];
X_time_mes(:,1)=[10
                 15];                                         %initial wrong estimate of states
P=100*eye(2);                                                 %initial guess of error covariance
P_cov(:,1)=diag(P);
G=eye(2);
Mean=.1*eye(2);
Var=.1;

%% Implement DT Kalman Filter
for i=1:100
    x(:,i+1) = A * x(:,i) + B * u(i) + 0.1*randn(2,1);      % system at time i+1
    z(i+1) = H * x(:,i+1) + Var * randn;                     %measurement at i+1
    x_copy(:,i+1) = x(:,i+1);

    X_time_update(:,i+1) = A * X_time_mes(:,i) + B * u(i);  %Time Update state at i+1
    P = A * P * A' + Mean * (G * G)';                        %Time Update Error Covariance
    P_error_cov(:,i+1) = diag(P);

    P = P - P * H' * 1/(H * P * H' + Var) * H * P;           %Cov Measurement Update
    P_updated_cov(:,i+1) = diag(P);                          %track time updated dovariance

    KalmanGain = P * H' * 1/(Var);                           %Kalman Gain
    Kalman_Gain_update(:,i)=KalmanGain;                      %Record kalman gain
    X_time_mes(:,i+1) = X_time_update(:,i+1) + KalmanGain * (z(i+1) - H * X_time_update(:,i+1));
%Measurement Update

    x(:,i+1)=X_time_mes(:,i+1);                              %Feedback of updated state
end
%% Plot the states Estimates and the Actual states
t=1:101;
figure (1)
plot(t,X_time_mes(1,:),'b');
hold on;
plot(t,x_copy(1,:),'r')
hold on;
grid on;
legend('State 1 - Estimated','State 1 - Actual')
figure (2)
plot(t,X_time_mes(2,:),'r');
hold on
plot(t,x_copy(2,:),'b');
grid on;
hold on;
legend('State 2 - Estimated','State 2 - Actual')
```

Plot :


State 1 - Estimated
State 1 - Actual
30
25
20
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100
120


State 2 - Estimated
State 2 - Actual
30
25
20
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100

Q3.

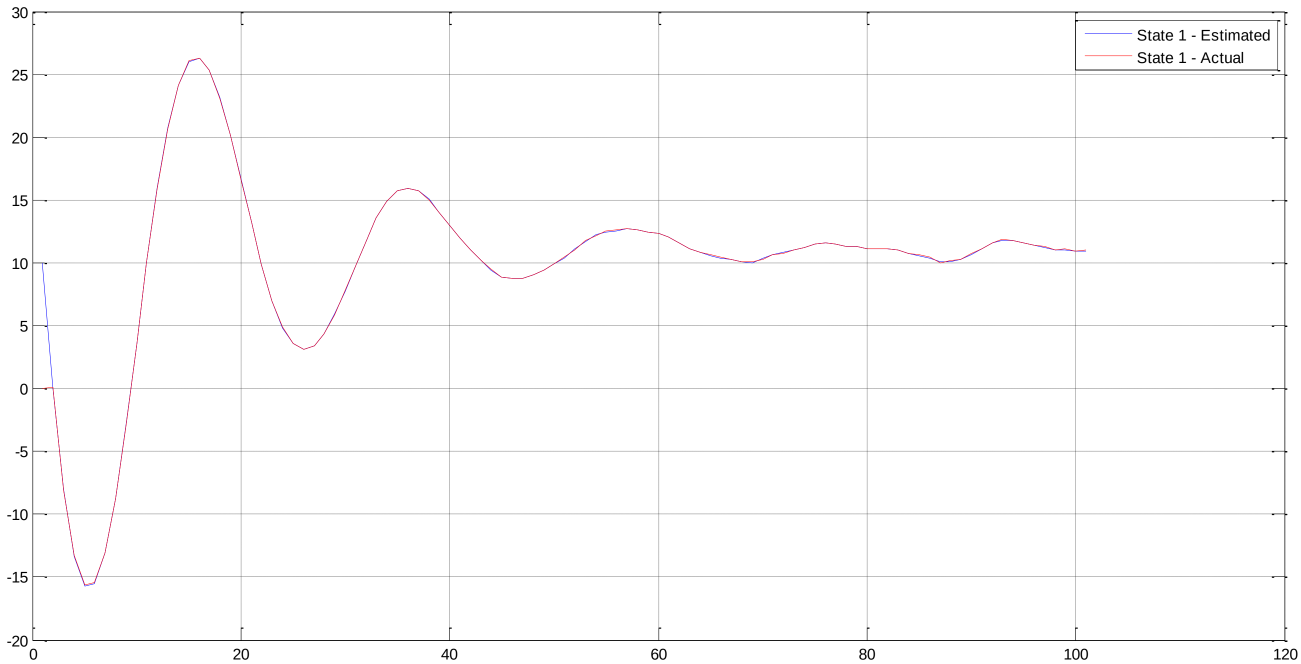
Code:

```
clc;
clear all;
close all;

A=[0     1                                          % State space description of system
  -0.89 1.8];
B=[0
  1];
u=ones(100,1);
H=[2 0];
x(:,1)=[0;0];
X_time_mes(:,1)=[10
            15];                                    %initial wrong estimate of states
P=100*eye(2);                                       %initial guess of error covariance
P_cov(:,1)=diag(P);
G=eye(2);
Mean=.1*eye(2);
Var=.1;

%% Implement DT Kalman Filter
for i=1:100
   x(:,i+1) = A * x(:,i) + B * u(i) + 0.1*randn(2,1);            % system at time i+1
   z(i+1) = H * x(:,i+1) + Var * randn;                          %measurement at i+1
   x_copy(:,i+1) = x(:,i+1);

   X_time_update(:,i+1) = A * X_time_mes(:,i) + B * u(i);         %Time Update state at i+1
   P = A * P * A' + Mean * (G * G)';                             %Time Update Error Covariance
   P_error_cov(:,i+1) = diag(P);

   P = P - P * H' * 1/(H * P * H' + Var) * H * P;                %Cov Measurement Update
   P_updated_cov(:,i+1) = diag(P);                              %track time updated dovariance

   KalmanGain = P * H' * 1/(Var);                               %Kalman Gain
   Kalman_Gain_update(:,i)=KalmanGain;                           %Record kalman gain
   X_time_mes(:,i+1) = X_time_update(:,i+1) + KalmanGain * (z(i+1) - H * X_time_update(:,i+1));    %Measurement Update

   x(:,i+1)=X_time_mes(:,i+1);                                  %Feedback of updated state
end
%% Plot the states Estimates and the Actual states
t=1:101;
figure (1)
plot(t,X_time_mes(1,:),'b');
hold on;
plot(t,x_copy(1,:),'r')
hold on;
grid on;
legend('State 1 - Estimated','State 1 - Actual')

figure (2)
plot(t,X_time_mes(2,:),'r');
hold on
plot(t,x_copy(2,:),'b');
grid on;
hold on;
legend('State 2 - Estimated','State 2 - Actual')

figure(3)
plot(t(1:100),Kalman_Gain_update(1,:),'r');
hold on;
grid on;
plot(t(1:100),Kalman_Gain_update(2,:),'g');
grid on;
hold on;
legend('Kalman Gain - State 1','Kalman Gain - State 2');
title(' Kalman Gain With Iteration')

[M,P,Z,E] = dlqe(A,G,H,Mean,Var);
```

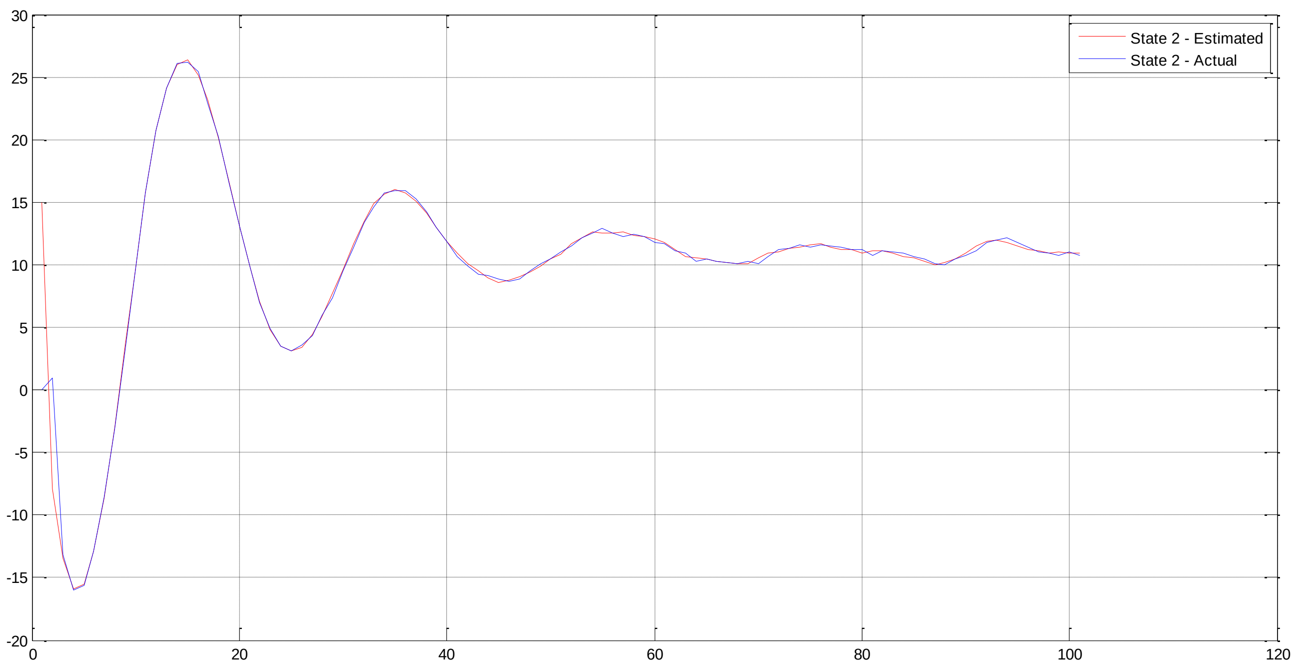
```
M = 'The value of gain by Steady State Solution is'
M
%Simulation of system
  X_time_update(:,i+1) = A * X_time_mes(:,i) + B * u(i);                    %Time Update state at i+1
  X_time_mes(:,i+1) = X_time_update(:,i+1) + M * (z(i+1) - H * X_time_update(:,i+1));    %Measurement Update end

figure (4)
plot(t,X_time_mes(1,:),'r',t,x(1,:),'b');
grid on;
hold on;
legend('State 1 - Estimated','State 1 - Actual ')
title('Fixed Kalman Gain : State 1');

Figure(5)
plot(t,X_time_mes(2,:),'r');
grid on;
hold on;
plot(t,x(2,:),'b');
grid on;
hold on;
legend('State 2 - Estimated','State 2 - Actual ')
title('Fixed Kalman Gain : State 2')

clear P
P=1000*eye(2);
for i=1:40 %some arbitrary number of Iterations to get the solution converged
P=A*P*A'+Q*G*G';
P=P-P*H'*inv(H*P*H'+Var)*H*P;
end
KG_Iteration=P*H'*inv(Var)
```

```
Kalman Gain  =

    0.8607

    1.1552

ans =

The value of gain by Steady State Solution is


M =

    0.8607

    1.1552
```

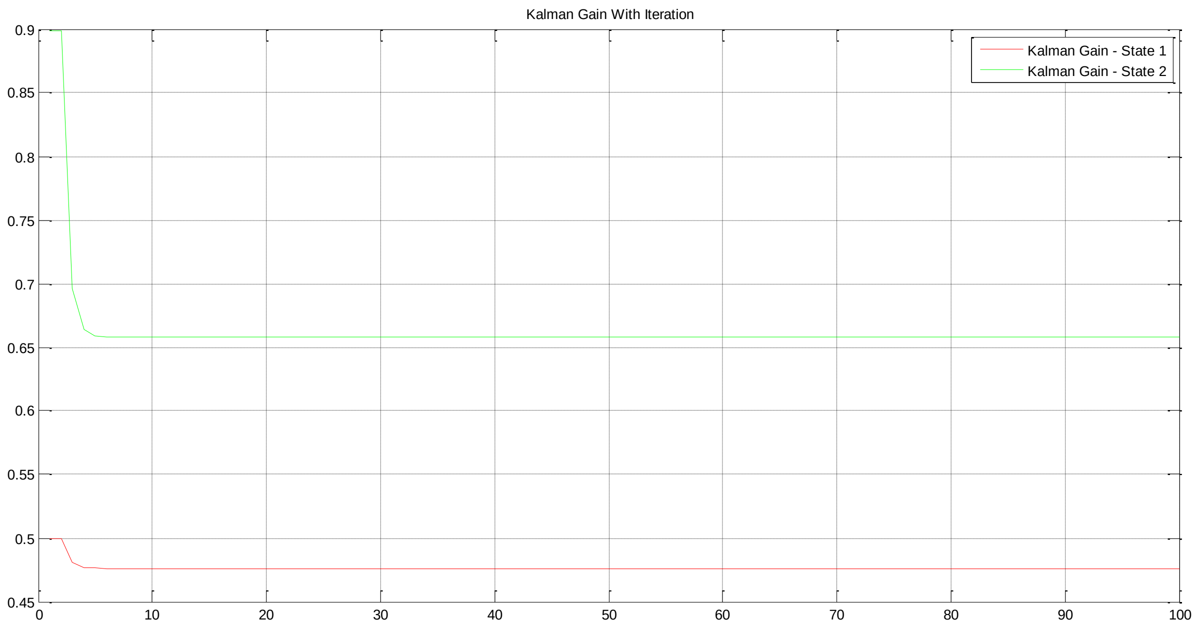
Plot:

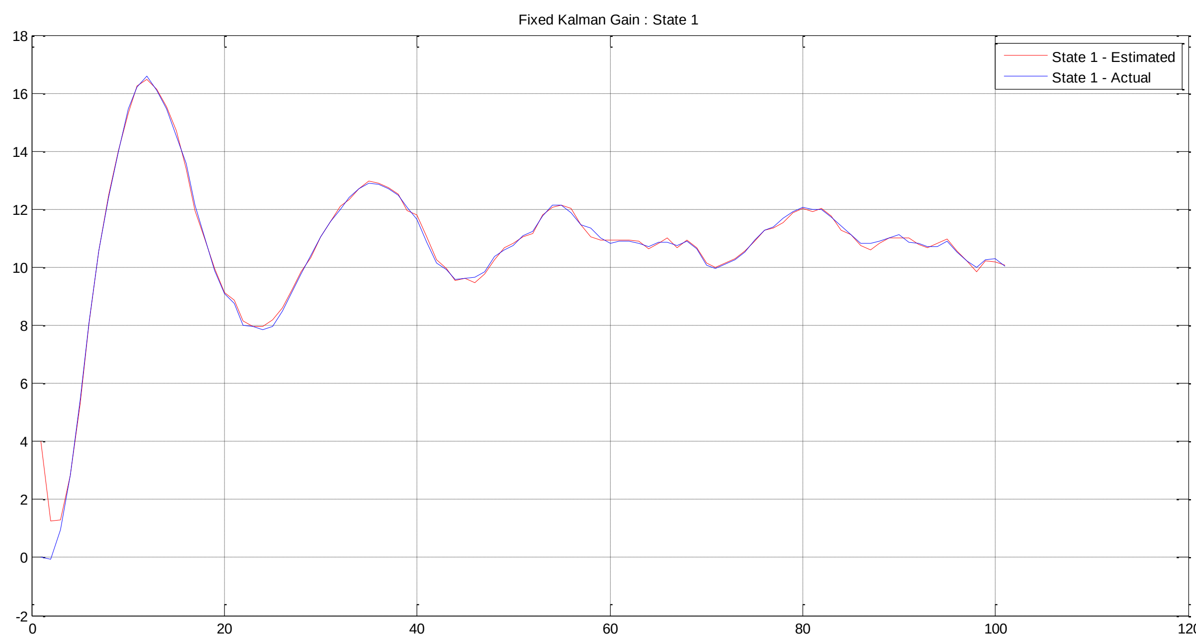


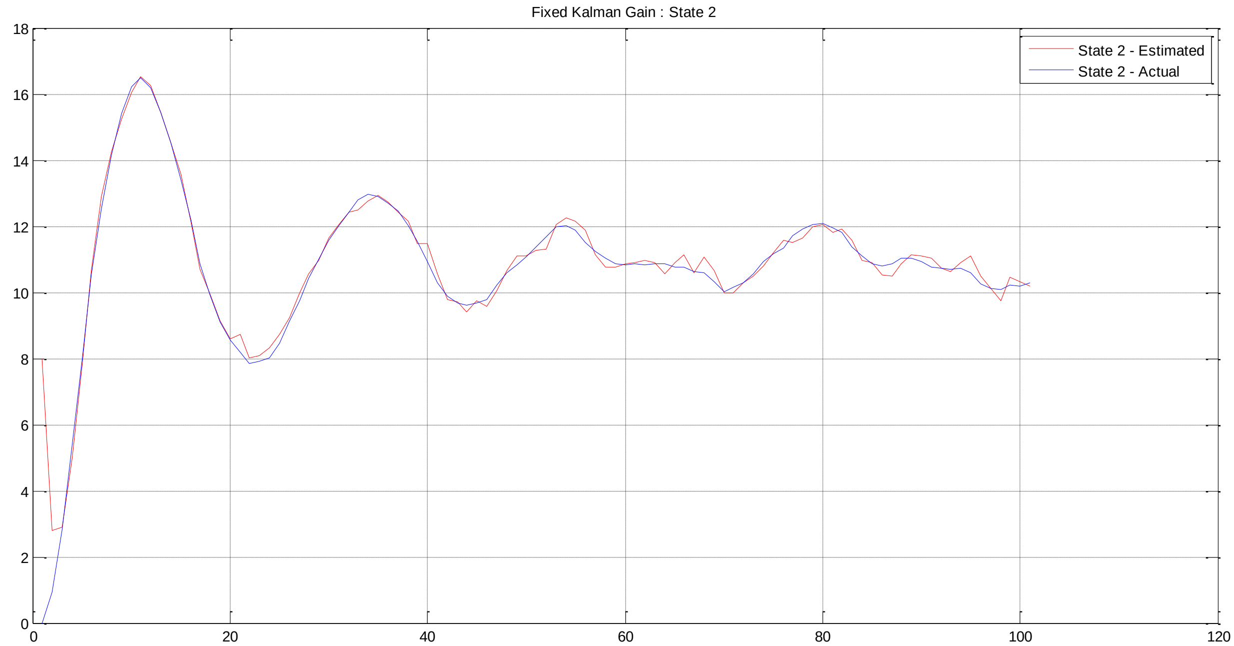
State 1 - Estimated
State 1 - Actual
30
25
20
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100
120



State 2 - Estimated
State 2 - Actual
30
25
20
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100
120


Kalman Gain With Iteration
Kalman Gain - State 1
Kalman Gain - State 2
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0
10
20
30
40
50
60
70
80
90
100


Fixed Kalman Gain : State 1
State 1 - Estimated
State 1 - Actual
18
16
14
12
10
8
6
4
2
0
-2
0
20
40
60
80
100
120



Fixed Kalman Gain : State 2
State 2 - Estimated
State 2 - Actual
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120