1.Pole Placement with Reference Tracking

```
clc;
clear;
format long;
%All constants
T=0.01;
Ts=5;
oS=0.05;%percent overshoot

m1 = 2500;
m2 = 320;
k1 = 80000;
k2 = 500000;
b1 = 350;
b2 = 15020;

A=[0                 1    0                                          0
  -(b1*b2)/(m1*m2)  0    ((b1/m1)*((b1/m1)+(b1/m2)+(b2/m2)))-(k1/m1)  -(b1/m1)
  b2/m2             0    -((b1/m1)+(b1/m2)+(b2/m2))                 1
  k2/m2             0    -((k1/m1)+(k1/m2)+(k2/m2))                 0];

B=[0                 0
   1/m1              (b1*b2)/(m1*m2)
   0                 -(b2/m2)
   (1/m1)+(1/m2)     -(k2/m2)];
C=[0 0 1 0];
D=[0 0];

sys=ss(A,B,C,D);
d_sys=c2d(sys,T,'zoh');
[G,H,I,J]=ssdata(d_sys);

%Consider a system with no Disturbance

%Controllability
H=H(:,1);
Cd=[H,G*H,(G^2)*H,(G^3)*H];
rank(Cd);

%Original Characteristic equation
a=poly(G);
r1=roots(a);
a=a(2:end);

%Desired Characteristic equation
xi=-log(oS)/sqrt(pi^2+(log(oS)^2));
wn=4/xi*Ts;
wd=wn*sqrt(1-xi^2);
ps=-wn*xi+[1;-1]*1i*wd;
pz=exp(ps*T);
p2z=0.73+[1;-1]*1i*0.27;%2 of the original roots

desired_roots=[pz;p2z];
alpha=poly(desired_roots);
alpha1=alpha(2:end);

%State feedback gain needed to obtain desired poles

Awig=[1 0 0 0;a(1) 1 0 0; a(2) a(1) 1 0; a(3) a(2) a(1) 1];
K=(alpha1-a)*(inv(Awig'))*(inv(Cd));

h=1/(I*(inv(eye(4)-G+H*K))*H);
```

```
%New system is
G_1=G-(H*K);
n_roots=roots(poly(G_1));
```

2.Integral Error Control

```
clc;
clear;
format long;
%All constants
T=0.01;
Ts=5;
oS=0.05;%percent overshoot

m1 = 2500;
m2 = 320;
k1 = 80000;
k2 = 500000;
b1 = 350;
b2 = 15020;

A=[0                 1    0                                               0
  -(b1*b2)/(m1*m2)   0    ((b1/m1)*((b1/m1)+(b1/m2)+(b2/m2)))-(k1/m1)   -(b1/m1)
  b2/m2              0    -((b1/m1)+(b1/m2)+(b2/m2))                      1
  k2/m2              0    -((k1/m1)+(k1/m2)+(k2/m2))                      0];

B=[0                 0
   1/m1              (b1*b2)/(m1*m2)
   0                 -(b2/m2)
   (1/m1)+(1/m2)     -(k2/m2)];
C=[0 0 1 0];
D=[0 0];

sys=ss(A,B,C,D);
d_sys=c2d(sys,T,'zoh');
[G,H,I,J]=ssdata(d_sys);

%Consider a system with no Disturbance
H=H(:,1);

q=-T*I;
G1=[[G;q],[zeros(size(H));1]];
H1=[H;0];

%Controllability

Cd=[H1,G1*H1,(G1^2)*H1,(G1^3)*H1,(G1^4)*H1];
rank(Cd);

%Original Characteristic equation
ax=poly(G1);
r1=roots(ax);
ax=ax(2:end);


%Roots from the transient Characteristics
xi=-log(oS)/sqrt(pi^2+(log(oS)^2));
wn=4/xi*Ts;
wd=wn*sqrt(1-xi^2);
ps=-wn*xi+[1;-1]*1i*wd;
```

```
pz=exp(ps*T);
p2z=0.73+[1;-1]*1i*0.27;%2 of the original roots

qz=0.5; %one additional root for the augmented system
desired_roots=[pz;p2z;qz];
alpha=poly(desired_roots);
alpha=alpha(2:end);

%The Toeplitz Matrix
n=length(H1);
Awig=eye(n);
for m=2:n
    for k=1:m-1
        Awig(m,k)=ax(m-k);
    end
end
K=(alpha-ax)*(inv(Awig'))*(inv(Cd));

GResultant=G1-H1*K;
roots(poly(GResultant))
```

3.Prediction State Observer

```
clc;
clear;
format long;
%All constants
T=0.01;
Ts=5;
oS=0.05;%percent overshoot

m1 = 2500;
m2 = 320;
k1 = 80000;
k2 = 500000;
b1 = 350;
b2 = 15020;

A=[0                 1    0                                              0
  -(b1*b2)/(m1*m2)   0    ((b1/m1)*((b1/m1)+(b1/m2)+(b2/m2)))-(k1/m1)   -(b1/m1)
  b2/m2              0    -((b1/m1)+(b1/m2)+(b2/m2))                     1
  k2/m2              0    -((k1/m1)+(k1/m2)+(k2/m2))                     0];

B=[0                 0
   1/m1              (b1*b2)/(m1*m2)
   0                 -(b2/m2)
   (1/m1)+(1/m2)     -(k2/m2)];
C=[0 0 1 0];
D=[0 0];

sys=ss(A,B,C,D);
d_sys=c2d(sys,T,'zoh');
[G,H,I,J]=ssdata(d_sys);

%Consider a system with no Disturbance

%Observability
H=H(:,1);
Od=[I;I*G;I*(G^2);I*(G^3)];
rank(Od);
```

```
%Original Characteristic equation
a=poly(G);
r1=roots(a);
a=a(2:end);

%Toeplitz Matrix
Awig=[1 0 0 0;a(1) 1 0 0; a(2) a(1) 1 0; a(3) a(2) a(1) 1];

%Desired Characteristic equation for deadbeat response is z^n
alpha=[0 0 0 0];

%State feedback gain needed to obtain desired error dynamics poles
Ke=(inv(Od))*(inv(Awig))*((alpha-a)');
```

Unit Step Response plot

```
clc;
clear;
format long;
%All constants
T=0.01;
Ts=5;
oS=0.05;%percent overshoot

m1 = 2500;
m2 = 320;
k1 = 80000;
k2 = 500000;
b1 = 350;
b2 = 15020;

A=[0                 1    0                                              0
  -(b1*b2)/(m1*m2)   0    ((b1/m1)*((b1/m1)+(b1/m2)+(b2/m2)))-(k1/m1)   -(b1/m1)
  b2/m2              0    -((b1/m1)+(b1/m2)+(b2/m2))                     1
  k2/m2              0    -((k1/m1)+(k1/m2)+(k2/m2))                     0];

B=[0                 0
   1/m1              (b1*b2)/(m1*m2)
   0                 -(b2/m2)
   (1/m1)+(1/m2)     -(k2/m2)];
C=[0 0 1 0];
D=[0 0];

sys=ss(A,B,C,D);
d_sys=c2d(sys,T,'zoh');
[G,H,I,J]=ssdata(d_sys);

K=  1.0e+06 *[1.991877541623324   0.101818092796048  -0.018716758887064  -
0.000856931146578];
h=2.052103543934170e+06;

G1=G-H*[1;0]*K;
H1=H*h;
new_sys=ss(G1,H,I,J,T);

step(-0.1*new_sys*[0;1],'b',3);
```