FINAL EXAM

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4 DE DICIEMBRE DE 2021

CONTROL ENGINEERING

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Exercise 1

```
A1 = 3×3
    1.9000         0   -1.0000
   -1.0000    4.7500    0.2000
    2.0000    1.0000    8.0000

B1 = 3×1
    1.0000
    0.5000
   -1.0000

C1 = 1×3
    0.2000   -1.0000    1.0000

roots_1 = 3×1
    7.7820
    2.3321
    4.5358
```

UNSTABLE

```
Control_1 = 3×3
      1.0000    2.9000   11.0100
      0.5000    1.1750    1.5812
     -1.0000   -5.5000  -37.0250

R_1 = 3
Pol_1 = 1×4
      1.0000  -14.6500   64.0250 ...

obs_1 = 3×3
      0.2000   -1.0000    1.0000
      3.3800   -3.7500    7.6000
     25.3720  -10.2125   56.6700

R1_obs = 3
```

The rank and degree match therefore is controllable

To obtain K

```
K_1=acker(A1,B1,Poles_cl_1)
```

```
K_1 = 1×3
     98.3535 -246.7089  -45.3510
```

To obtain v

```
G1_cl =

     -1.3 s^2 + 12.95 s - 30.35
   --------------------------------
   s^3 + 5.7 s^2 + 10.67 s + 6.555

Continuous-time transfer function.
k1_coup = -4.6301
```

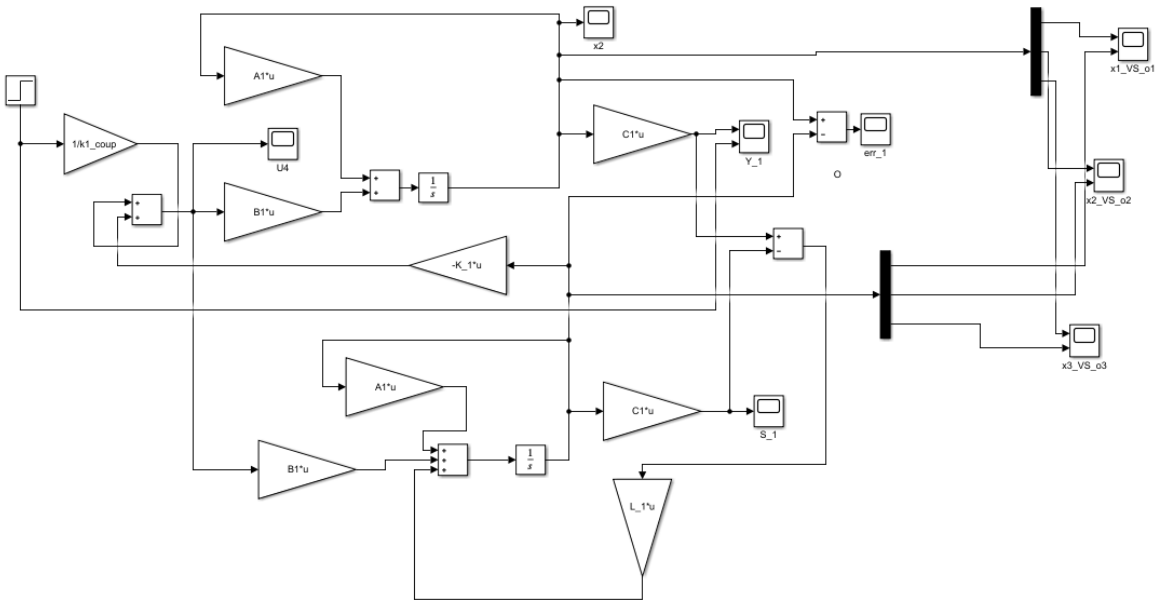
```
k1_coup=-30.35/6.555
```

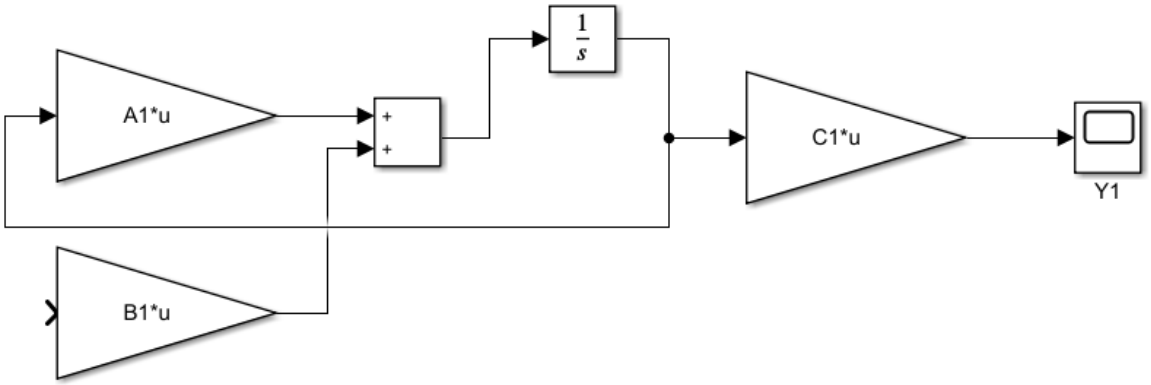
To obtain L

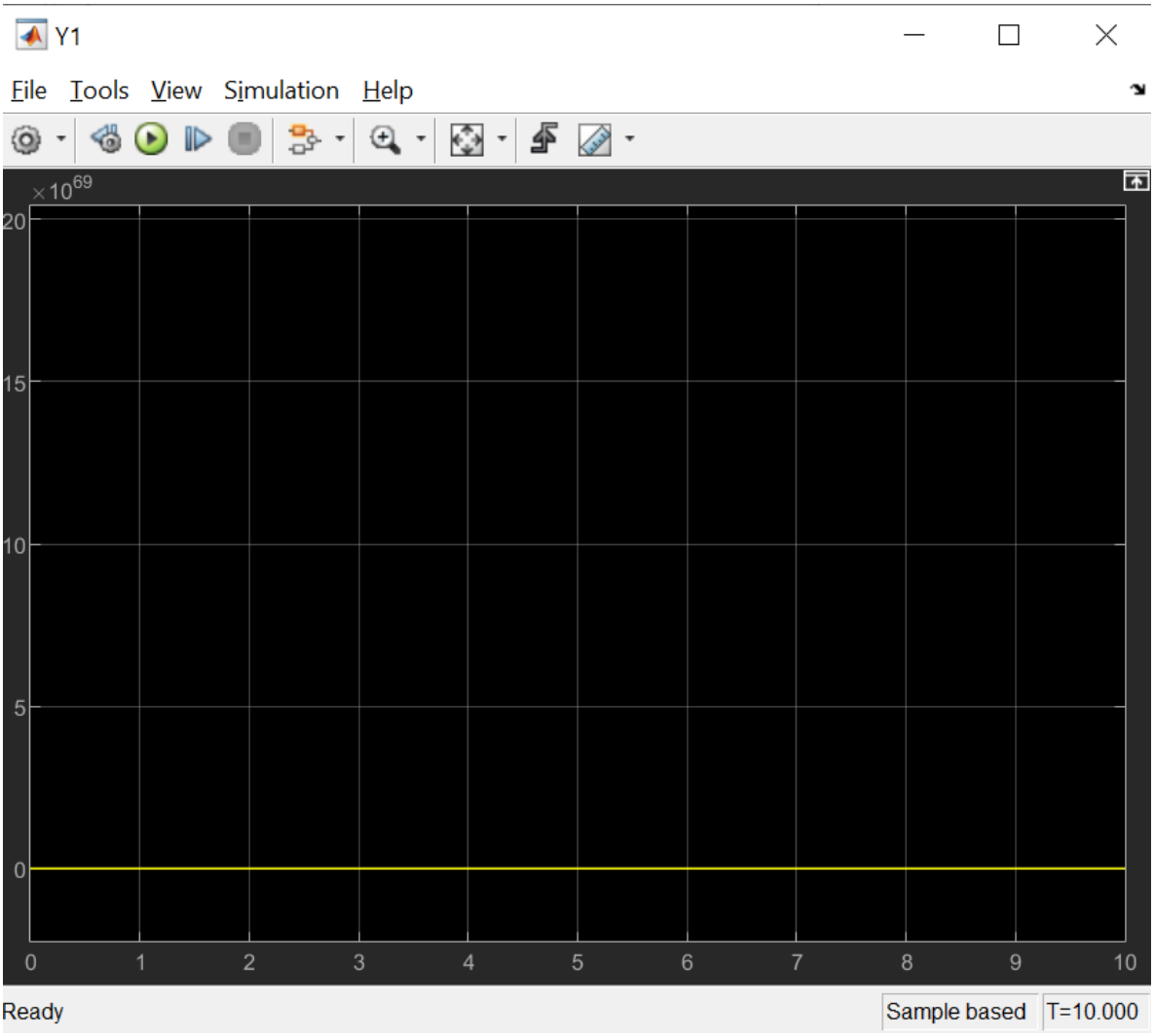
```
L_1=acker(A1',C1',[-1.5*9 -1.9*9 -2.3*9])'
```

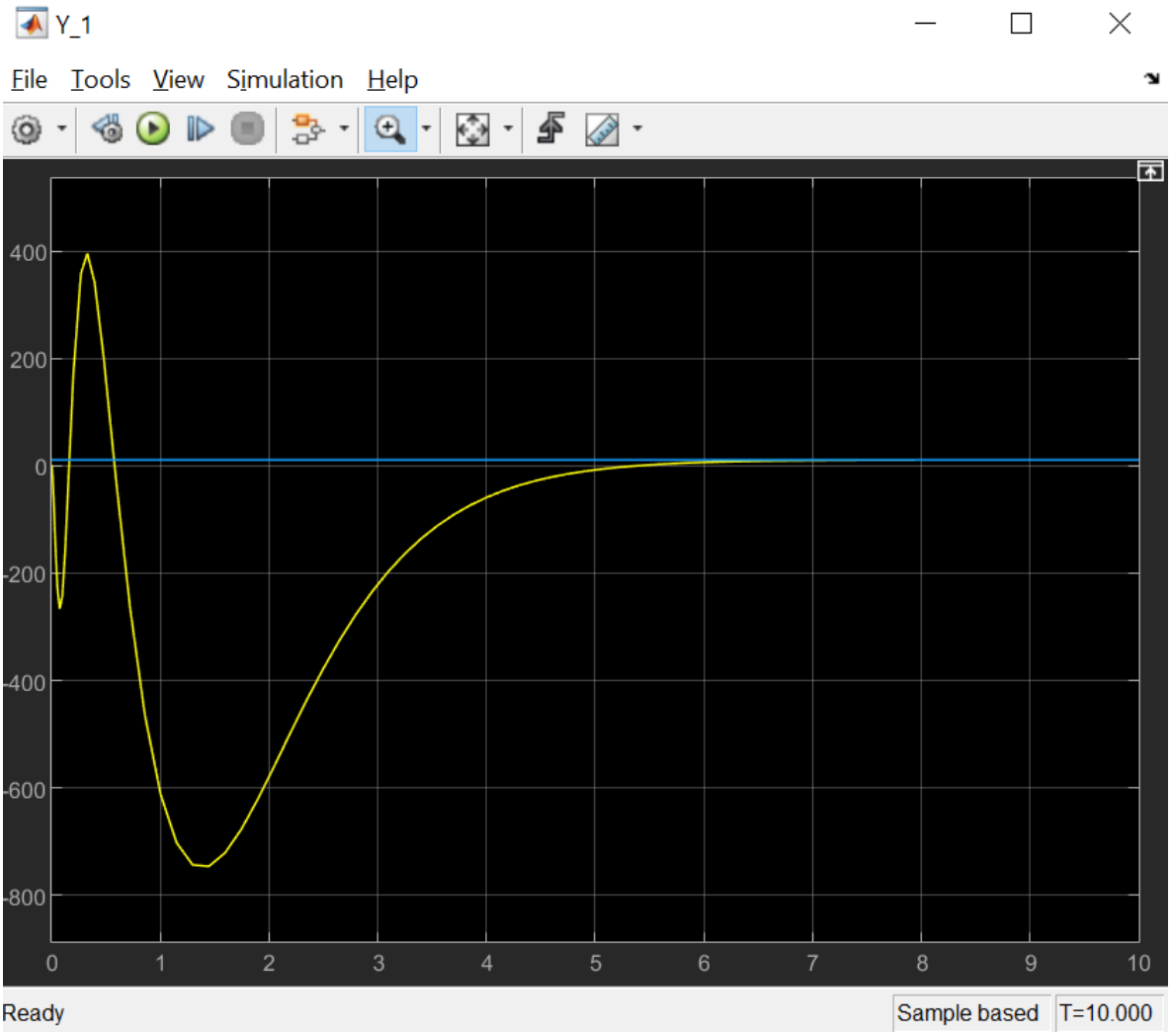
```
L_1 = 3×1
10^3  ×
     -0.8936
      0.7603
      1.0050
```

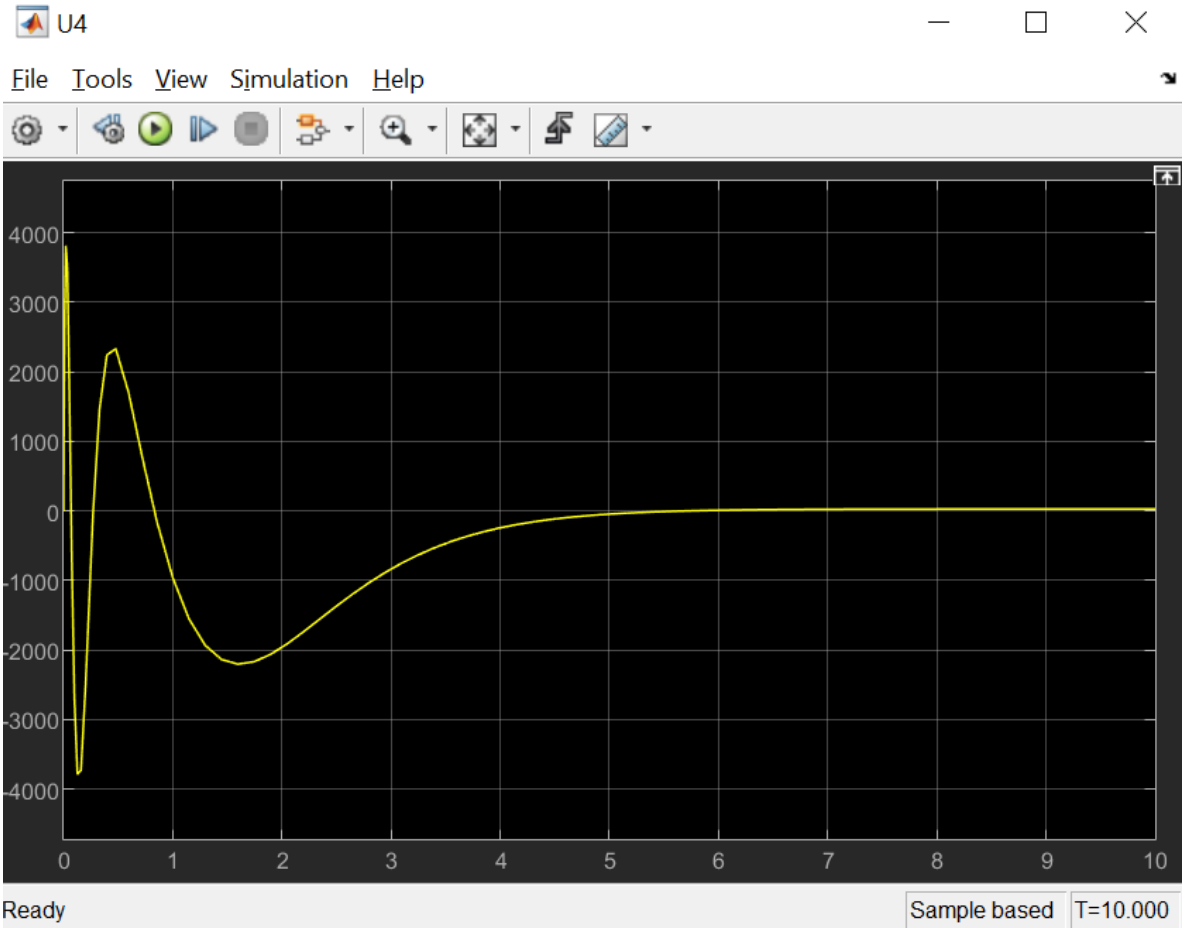
The Simulink model is the following

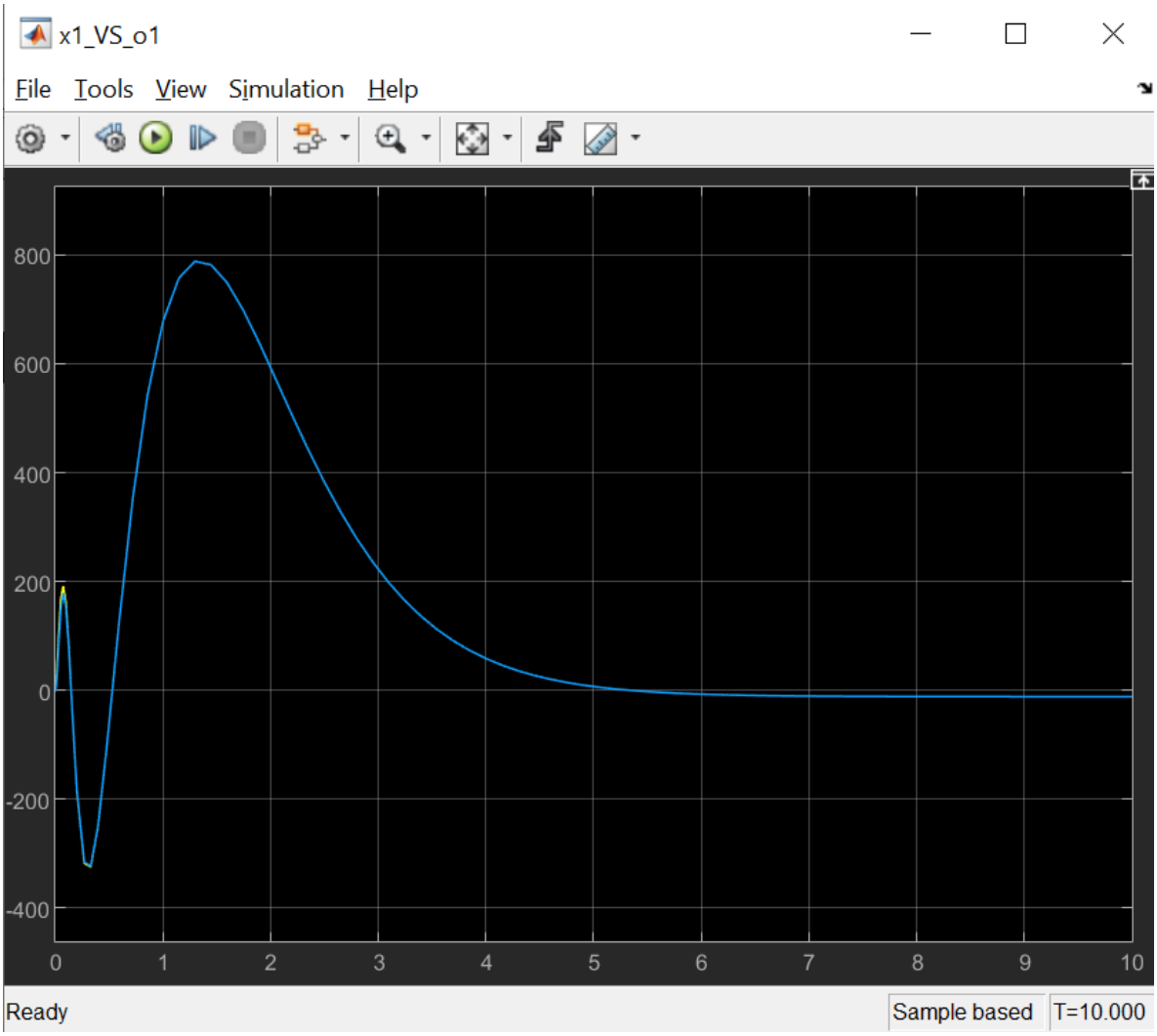

x2
A1*u
1/k1_coup
U4
B1*u
1
s
C1*u
Y_1
err_1
O
x1_VS_o1
x2_VS_o2
-K_1*u
x3_VS_o3
A1*u
C1*u
S_1
B1*u
1
s
L_1*u

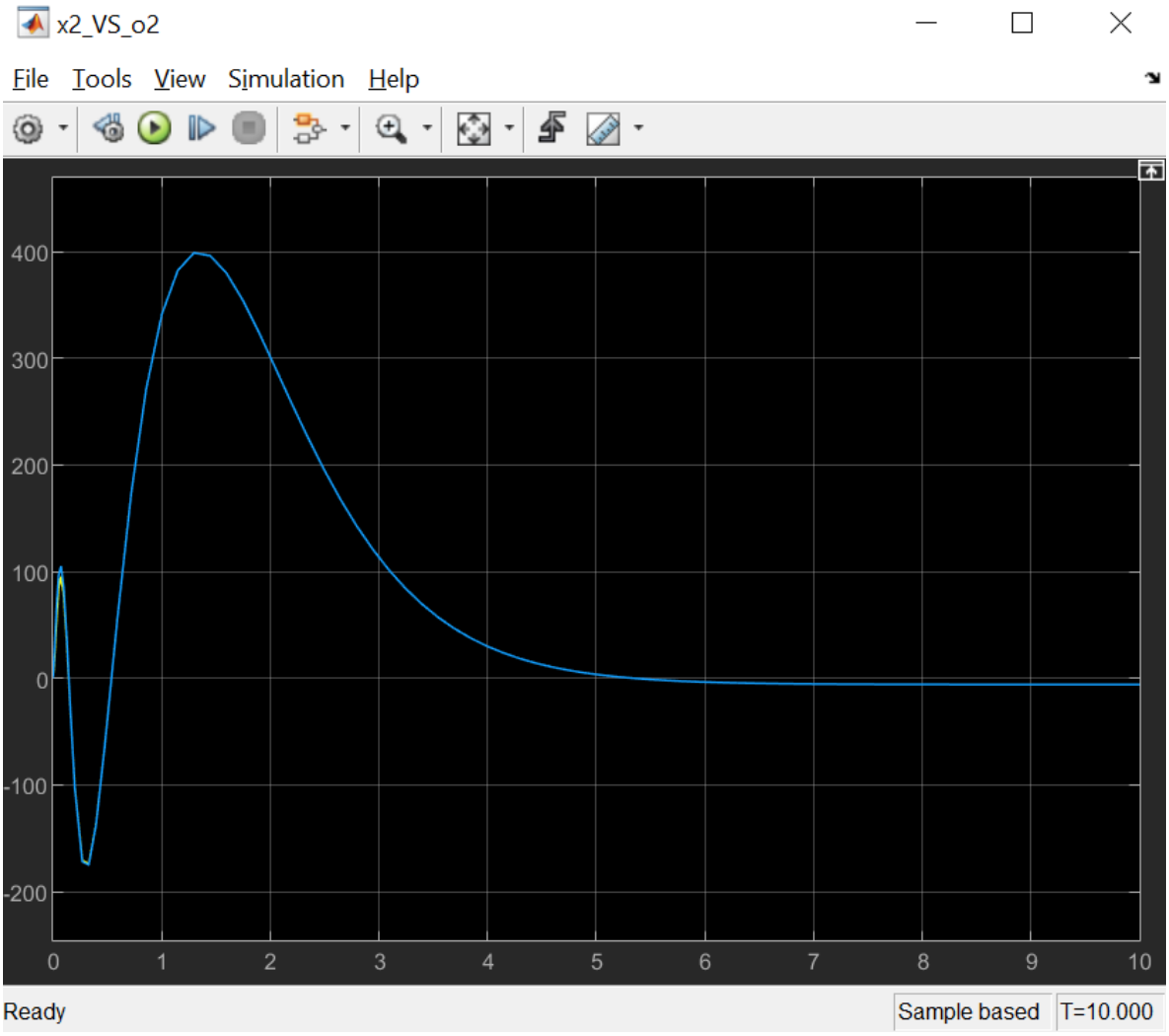

1
s
A1*u
+
+
C1*u
Y1
B1*u

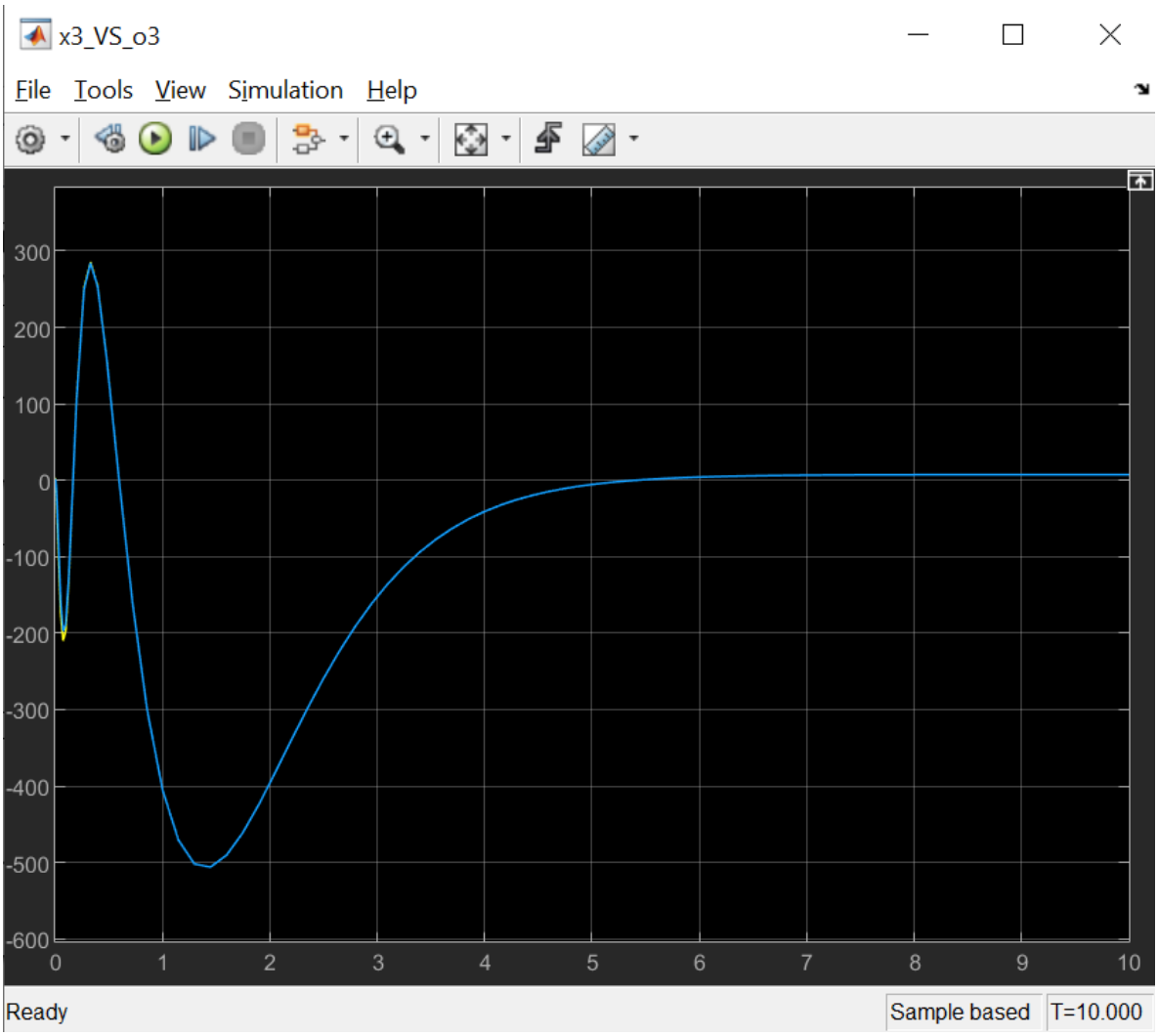

Y1
File Tools View Simulation Help
×10^69
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10
Ready
Sample based
T=10.000


Y_1
File Tools View Simulation Help
400
200
0
-200
-400
-600
-800
0 1 2 3 4 5 6 7 8 9 10
Ready
Sample based
T=10.000


U4
File Tools View Simulation Help
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
0 1 2 3 4 5 6 7 8 9 10
Ready
Sample based
T=10.000


x1_VS_o1
File Tools View Simulation Help
800
600
400
200
0
-200
-400
0 1 2 3 4 5 6 7 8 9 10
Ready
Sample based
T=10.000


x2_VS_o2
File Tools View Simulation Help
400
300
200
100
0
-100
-200
0 1 2 3 4 5 6 7 8 9 10
Ready
Sample based
T=10.000



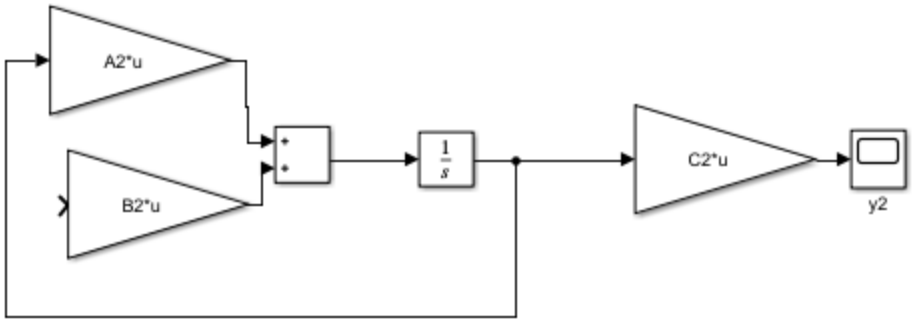
Exercise 2

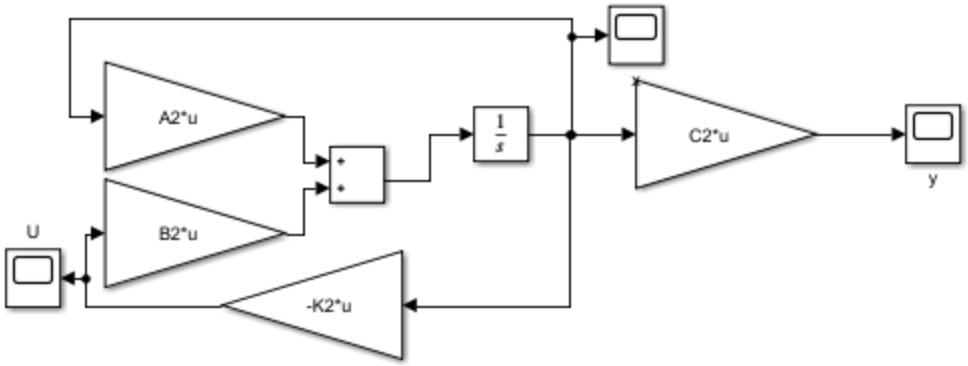
To obtain the state-space model

```
G2_opl=tf([5 23],poly([-2*b b c]))
sys2=ss(G2_opl)
```

```
sys2 =

  A =
        x1   x2   x3
   x1    2   13  -10
   x2   16    0    0
   x3    0    8    0

  B =
        u1
   x1  0.5
   x2    0
   x3    0

  C =
            x1       x2       x3
   y1        0   0.625  0.3594

  D =
       u1
   y1   0

Continuous-time state-space model.
```

Simulink Model





To obtain K

```
K2=acker(A2,B2,Poles_cl_2)
```

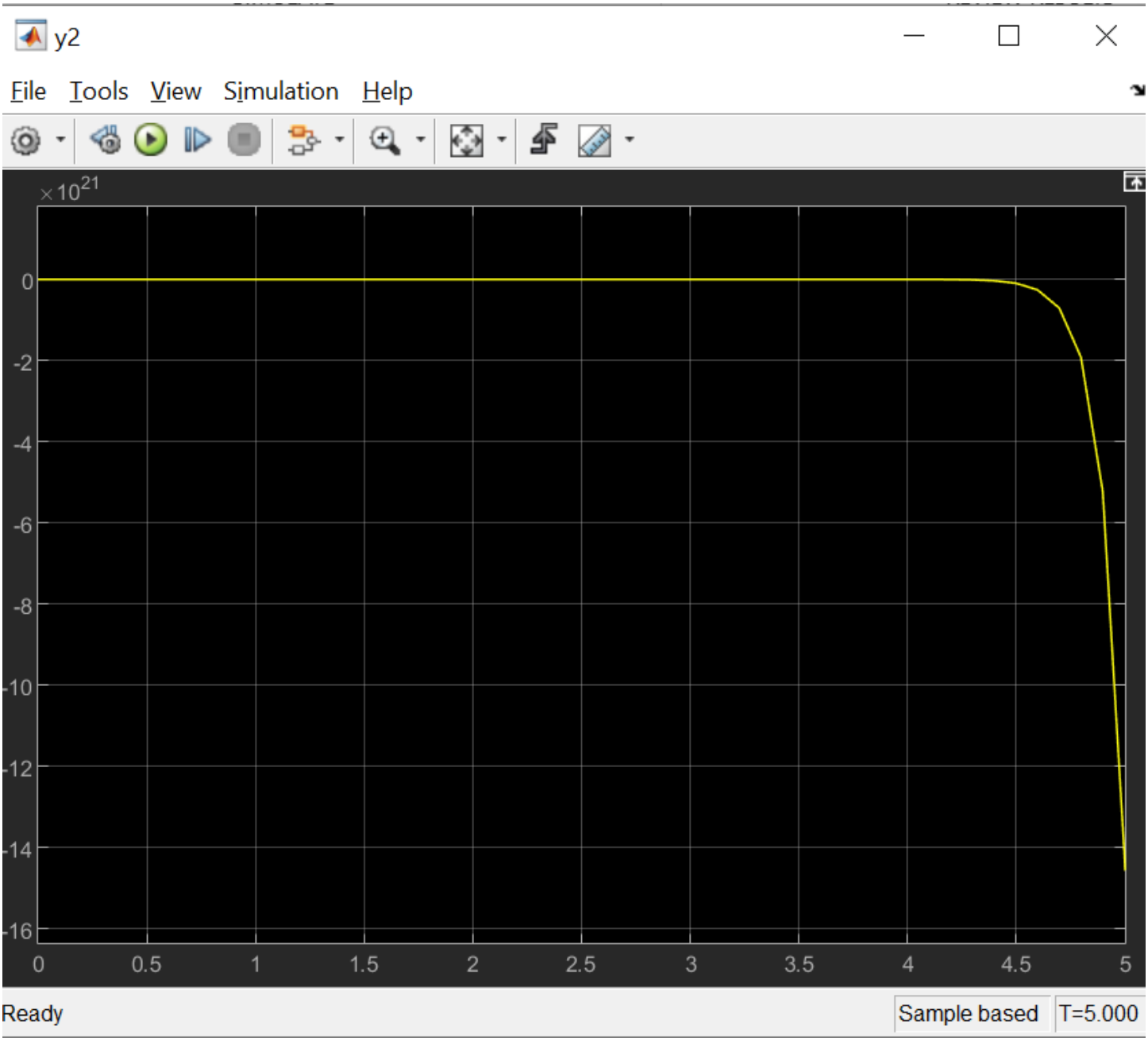
```
K2 = 1×3
      36.0000   34.1250  -19.2188
```

The transfer function

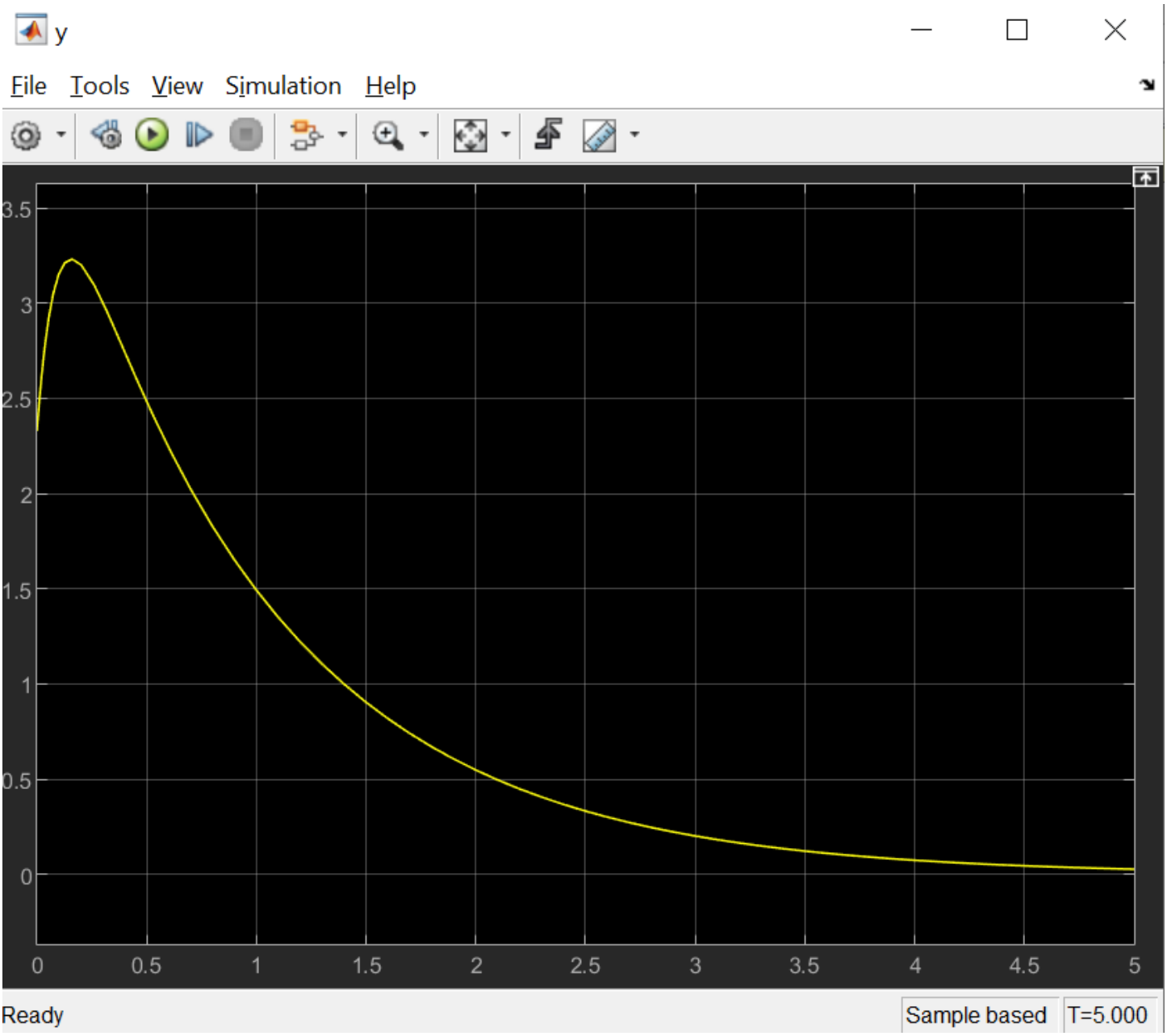
```
sys2_cl=ss(A2-B2*K2,B2,C2,0);
G2_cl=tf(sys2_cl)
```

```
G2_cl =

           5 s + 23
  -------------------------
  s^3 + 16 s^2 + 65 s + 50

Continuous-time transfer function.
```

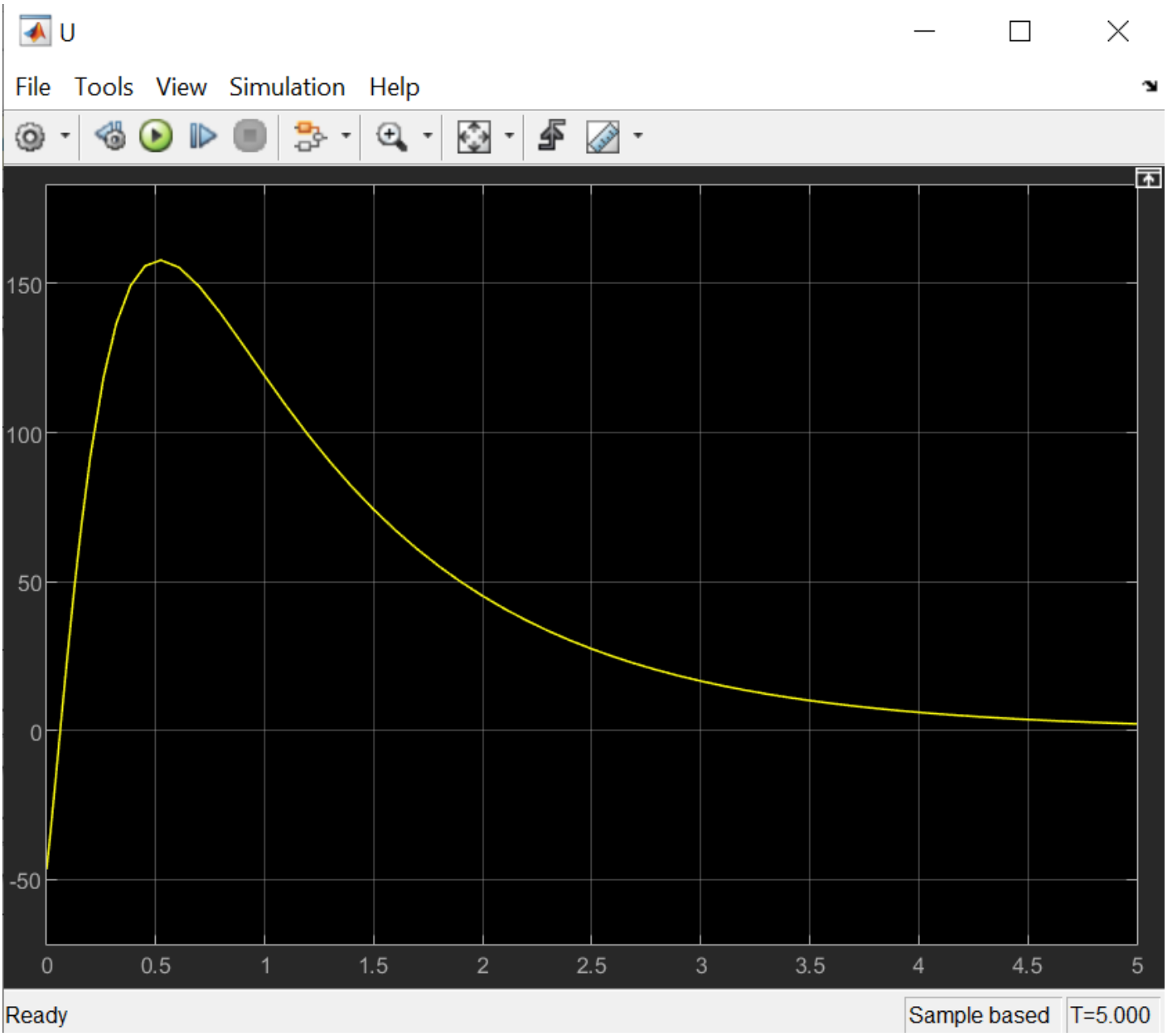
Output in open loop

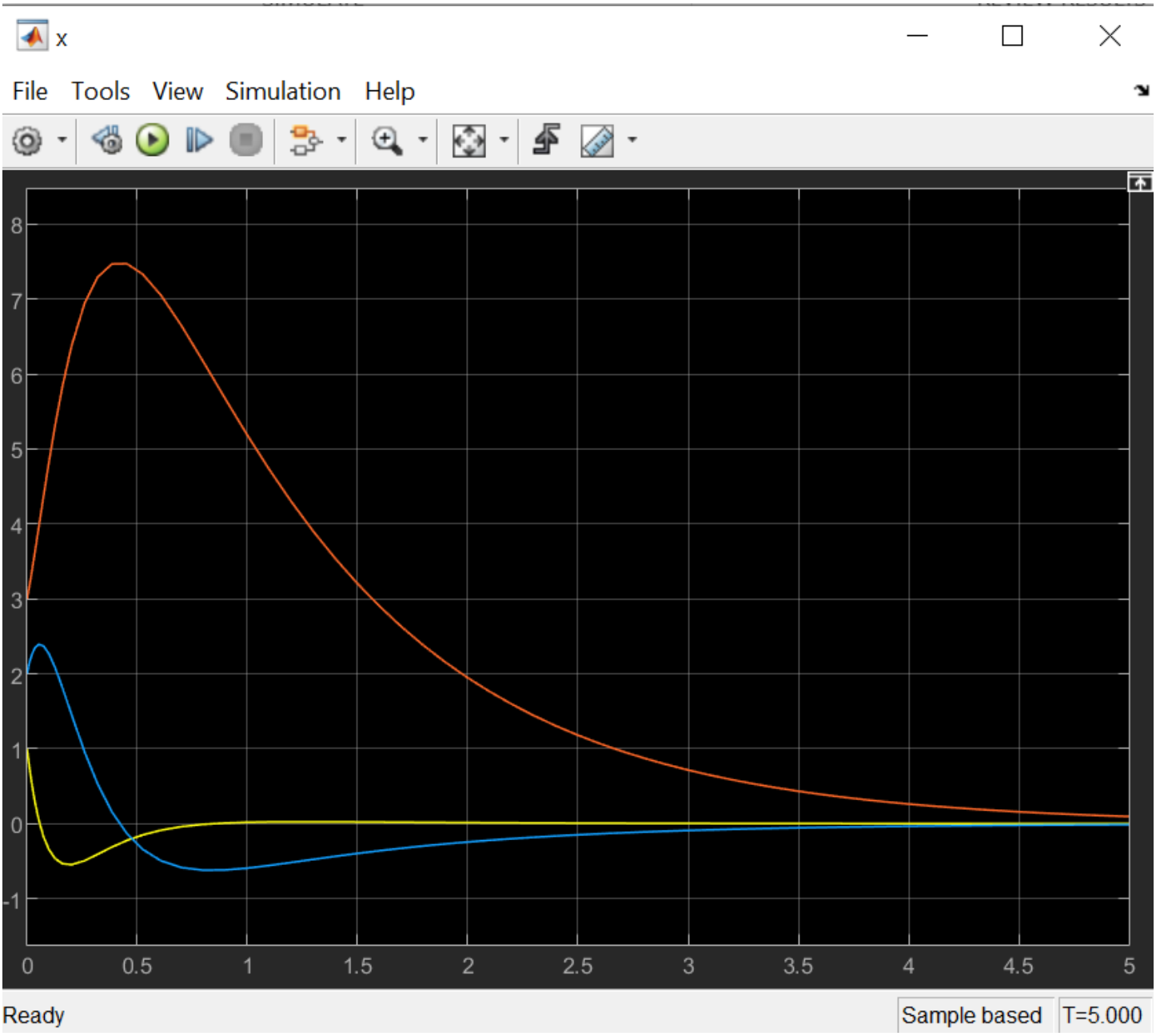


Output in close loop



Input to the plant and state variables in close loop


U
File Tools View Simulation Help
150
100
50
0
-50
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
Ready
Sample based
T=5.000



Exercise 3

To obtain state-space model

```
G3_opl=tf([3 -17.3],poly([c 2*b a]))
sys3=ss(G3_opl)
```

```
sys3 =

  A =
          x1       x2       x3
   x1       45   -20.44    11.88
   x2       32        0        0
   x3        0        8        0

  B =
       u1
   x1  0.5
   x2    0
   x3    0

  C =
            x1        x2        x3
   y1        0    0.1875   -0.1352

  D =
       u1
   y1   0

Continuous-time state-space model.
```

To obtain K

```
K_3=acker(A3,B3,Poles_cl_3)
```

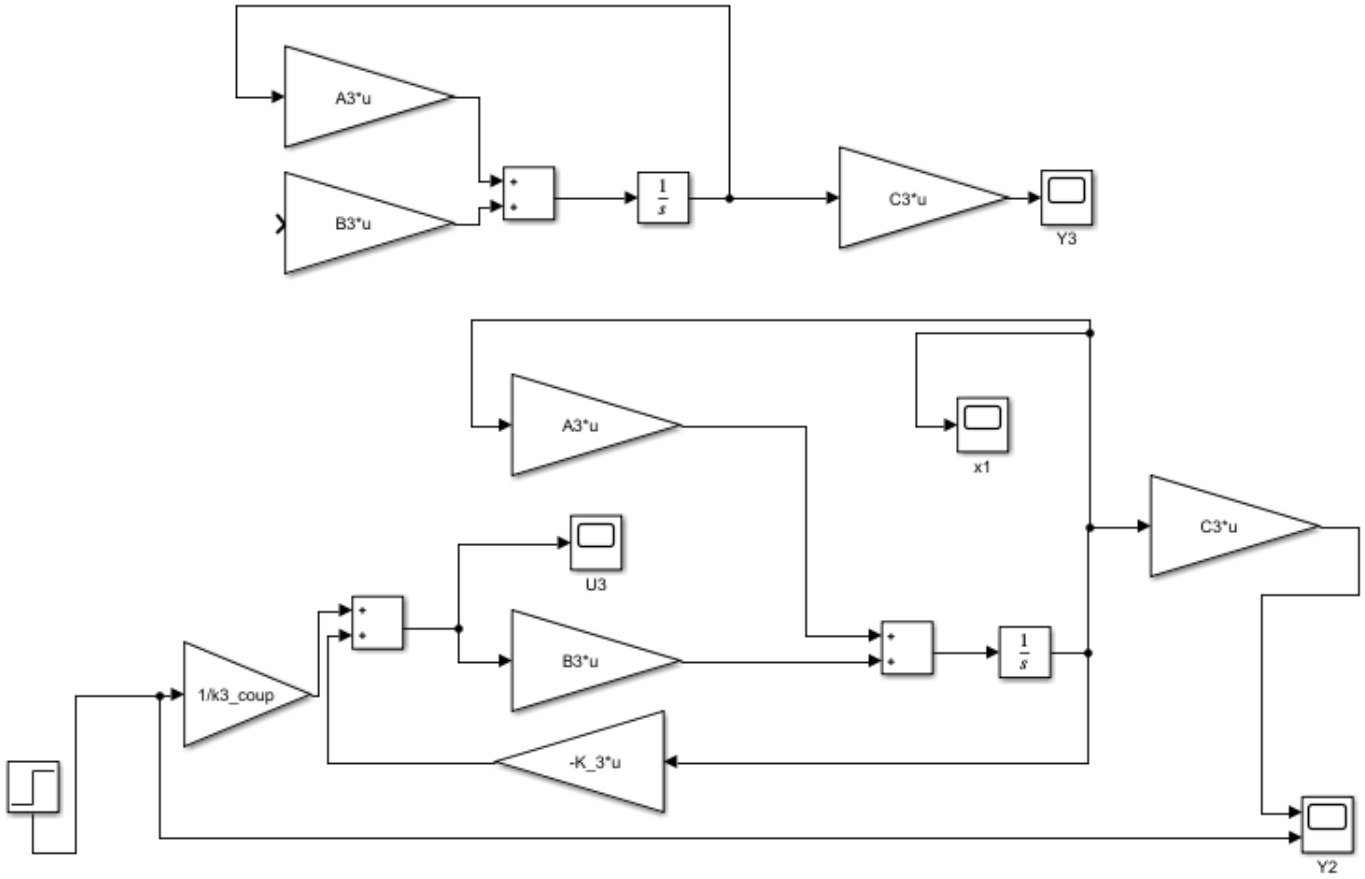
```
K_3 = 1×3
    112.0000   -38.6250   24.0313
```

To obtain v

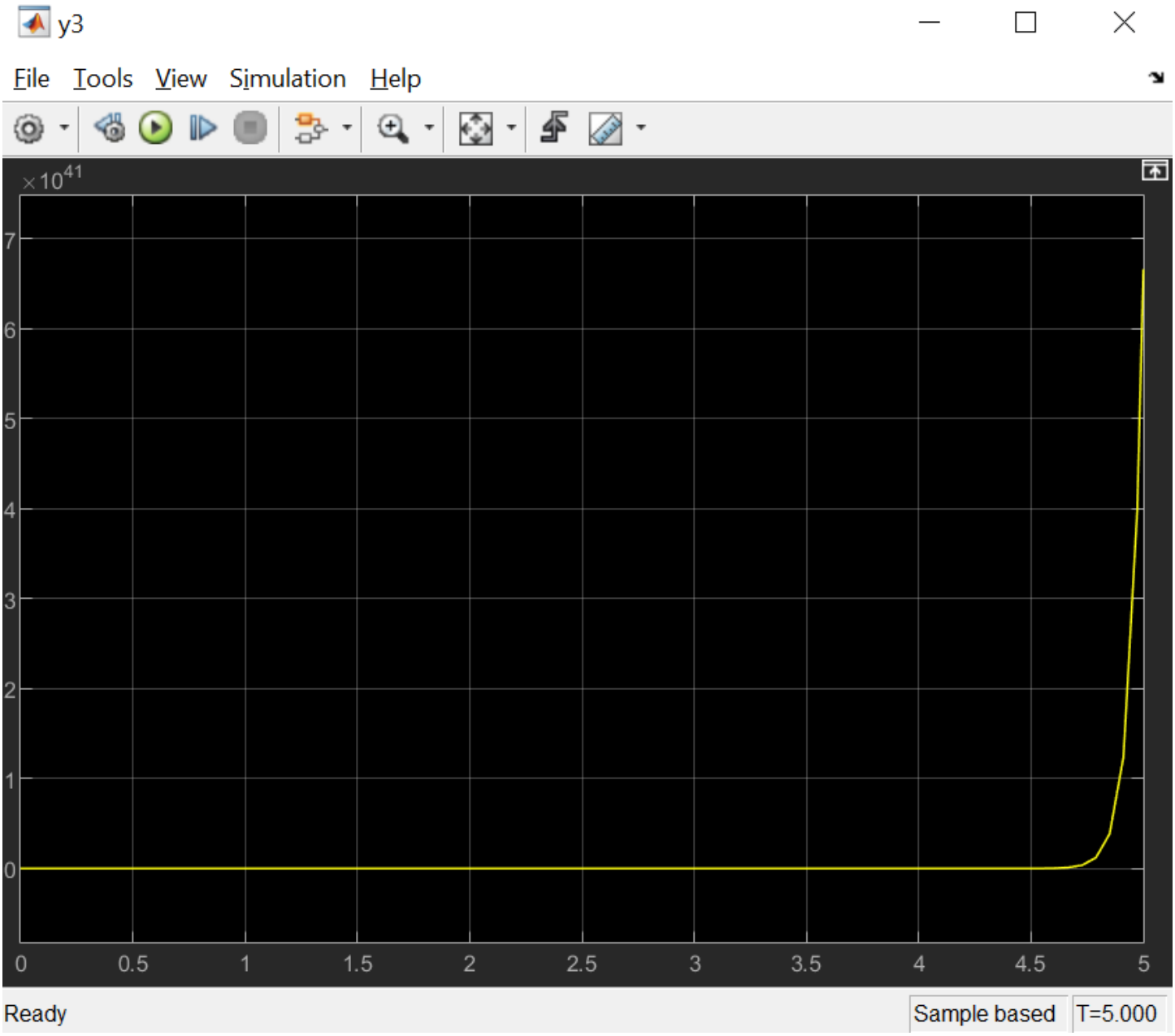
```
k3_coup=-17.3/36;
```

```
G3_cl =

          3 s - 17.3
  -------------------------
  s^3 + 11 s^2 + 36 s + 36

Continuous-time transfer function.
k3_coup = -0.4806
```

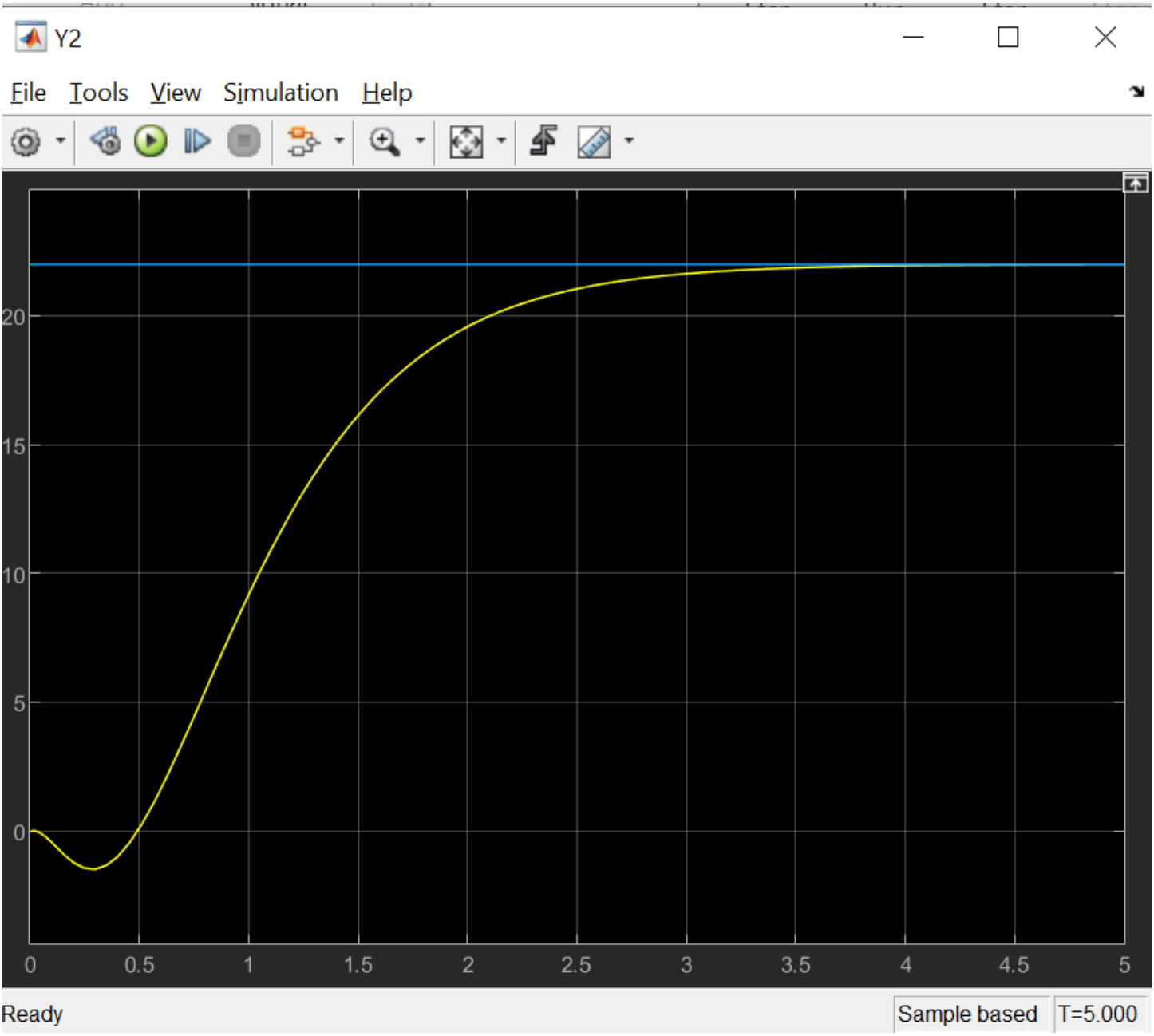
The Simulink model is the following



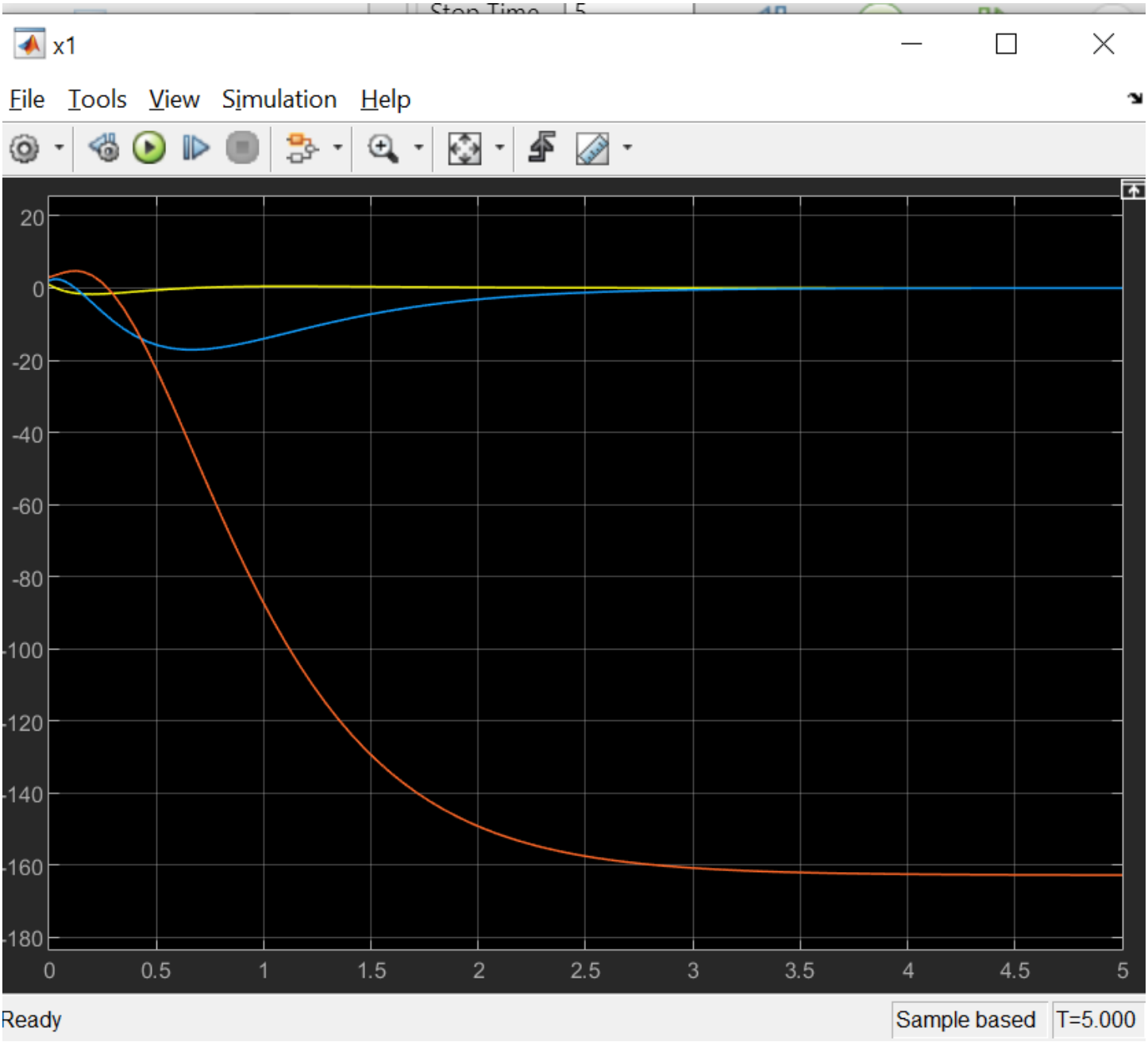
Outuput in open loop



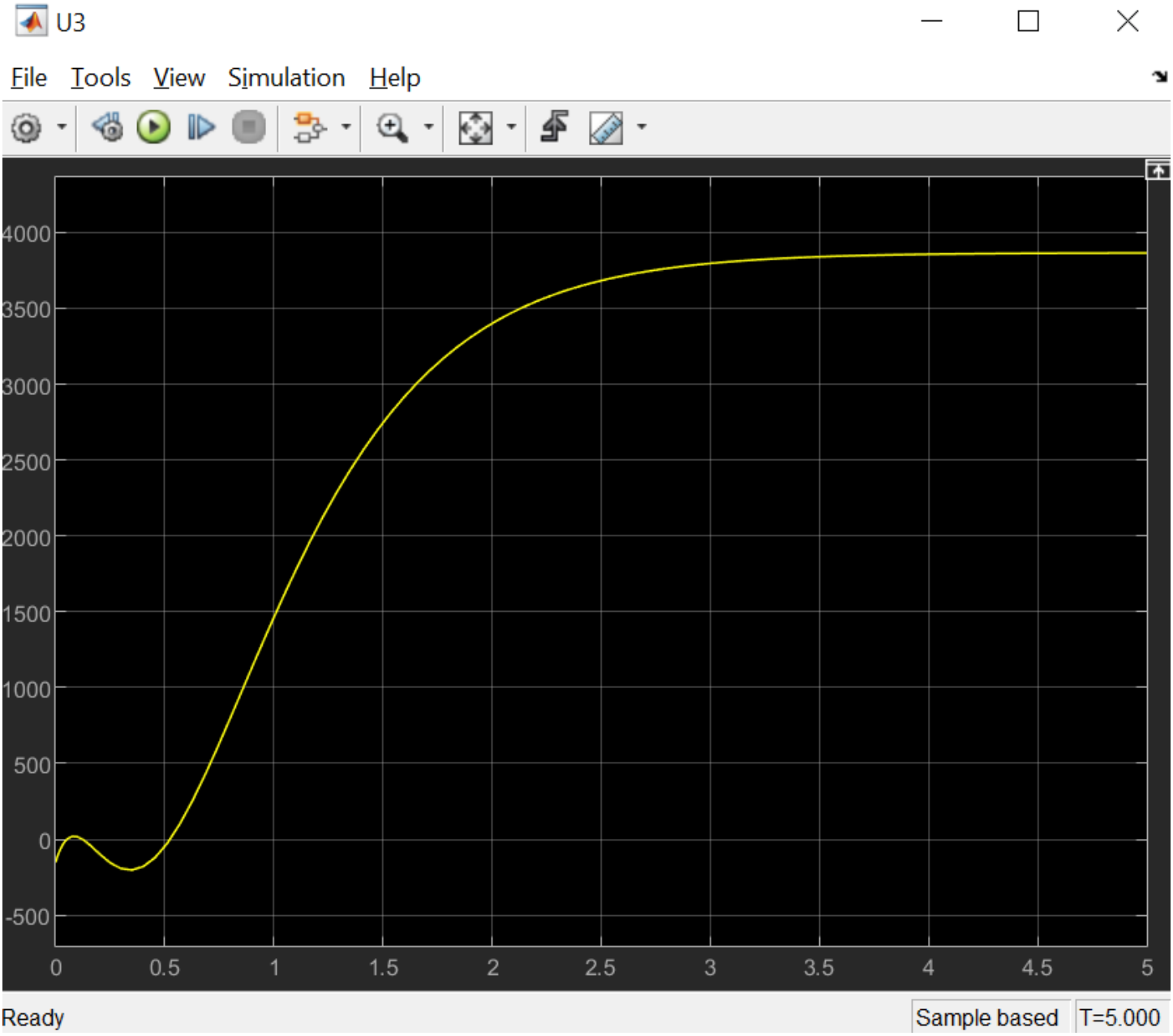
Output in close loop



Satate variables in close loop

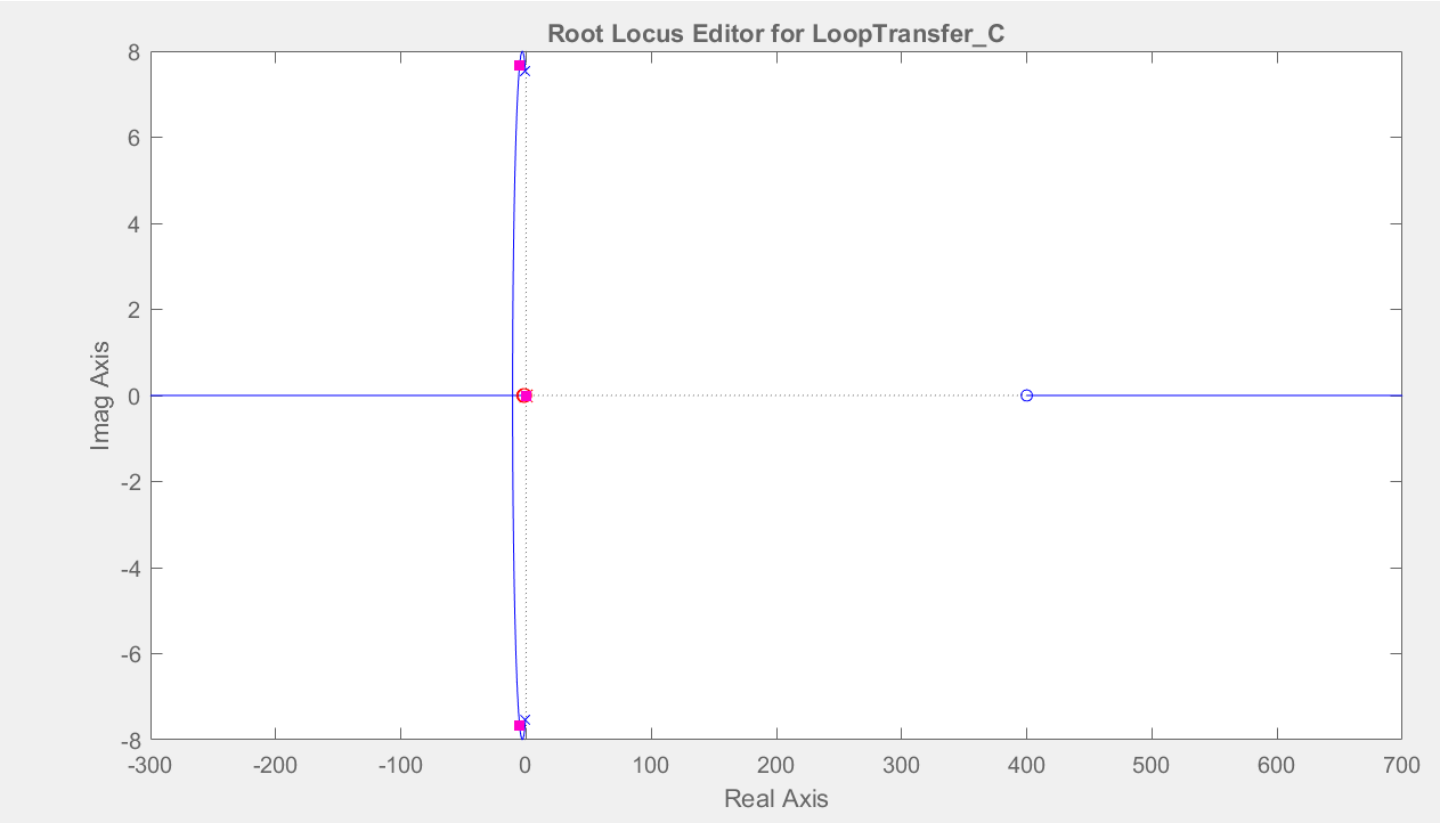

x1
File Tools View Simulation Help
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
Ready
Sample based
T=5.000

Input



Exercise 4

Using algebraic method with help of sisotool



$$\frac{0.5\ (s+1)\ (s+2)}{s}$$

```
PID4=zpk([-1 -2], [0], [0.5]);
G4_PID=tf(PID4)
kc=1.5
ki=1
kd=0.5
```

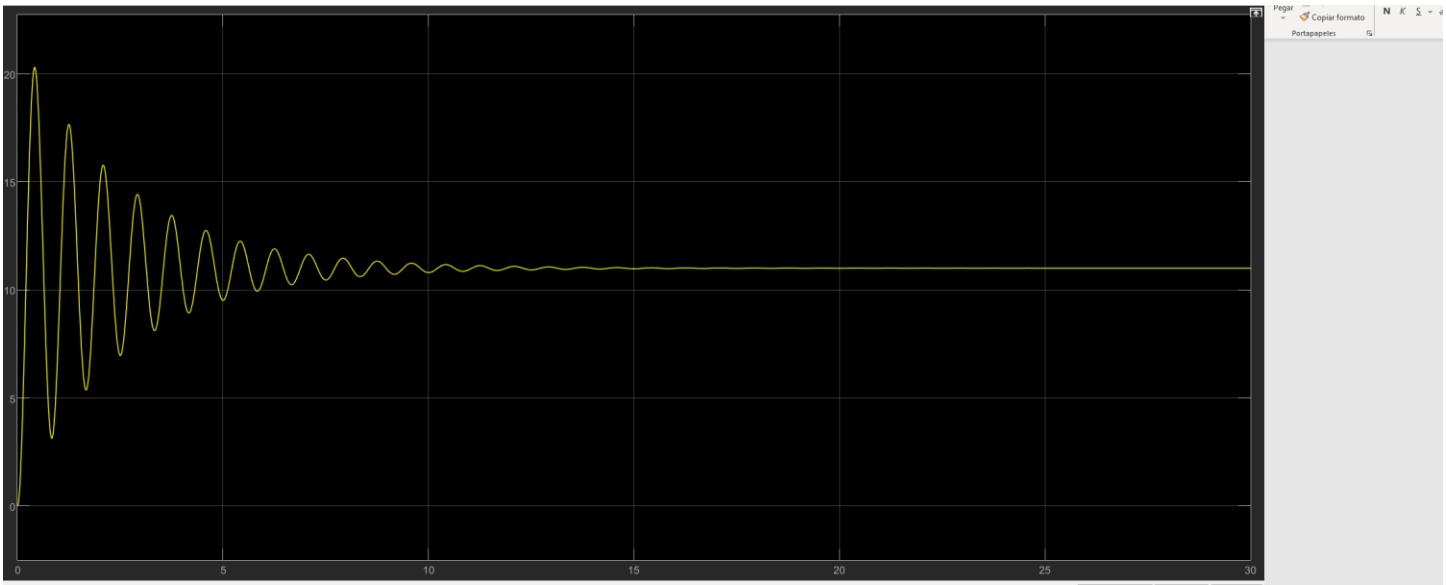
```
G4_PID =

  0.5 s^2 + 1.5 s + 1
  -------------------
          s

Continuous-time transfer function.
```

kc = 1.5000

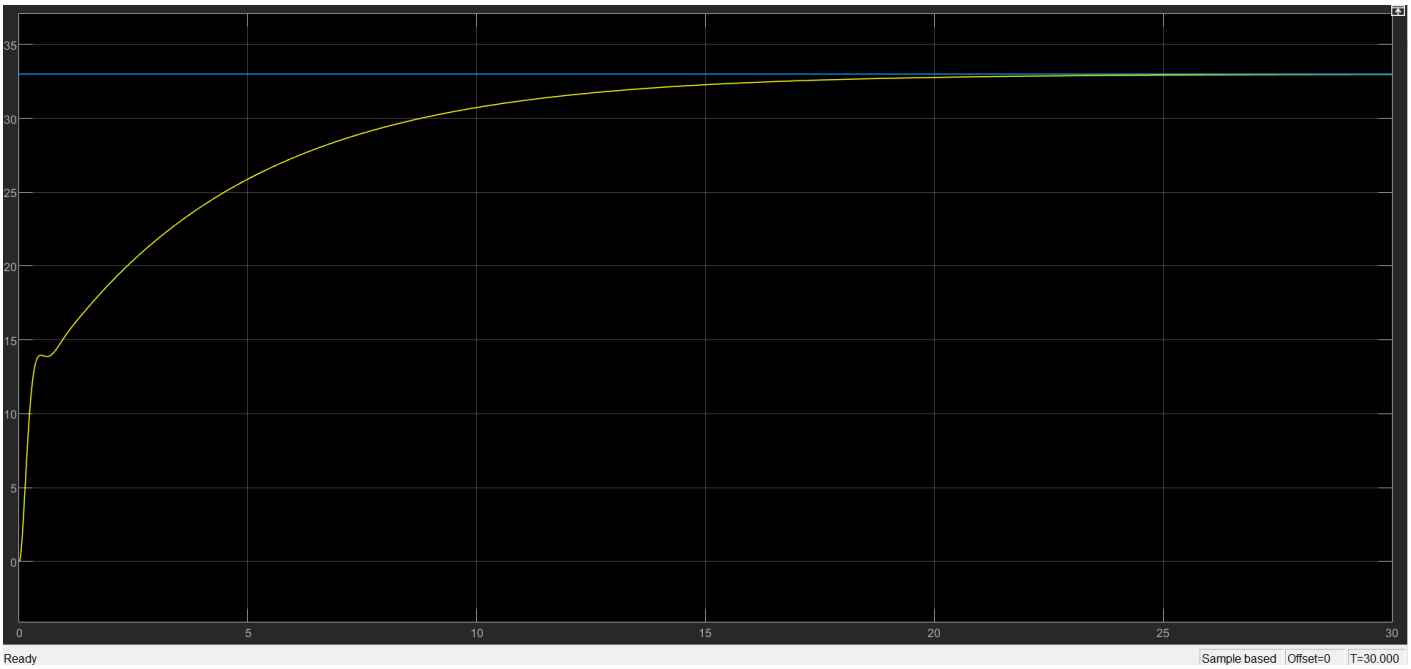
ki = 1

kd = 0.5000

Output in open loop



Output in close loop with comparison with reference



Controller signal