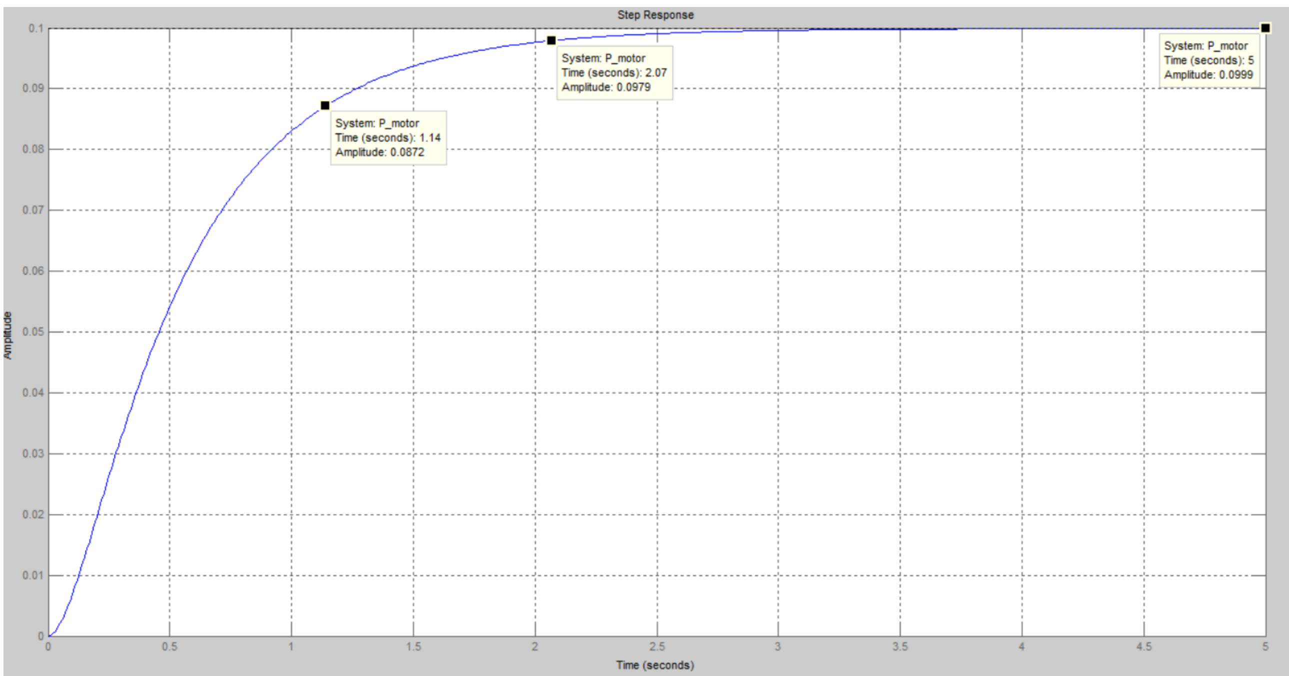
CO326: Industrial Networks
Lab 04- PID Control

E/17/297

PART I: Open-Loop Step Response



```
>> part1_open_loop
>> stepinfo(P_motor)

ans =

        RiseTime: 1.1351
    SettlingTime: 2.0652
     SettlingMin: 0.0899
     SettlingMax: 0.0998
       Overshoot: 0
      Undershoot: 0
            Peak: 0.0998
        PeakTime: 3.6758

>> |
```

Table 1: Open-loop step response

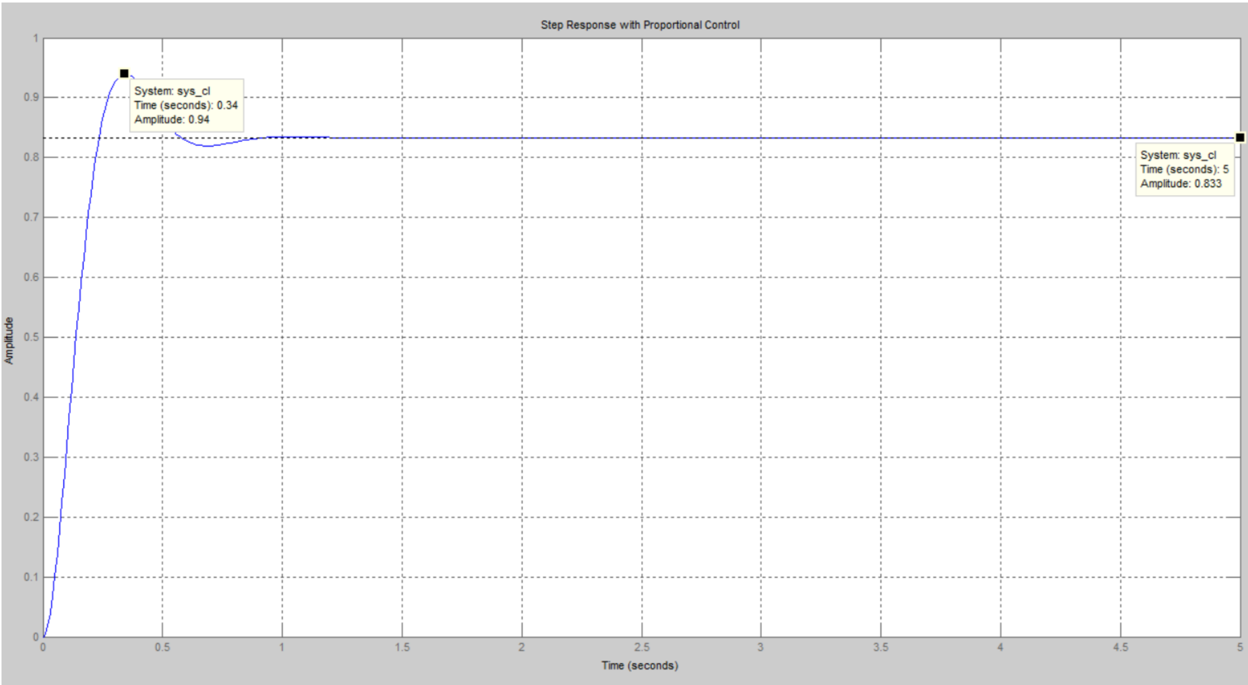
Input (Amplitude)	Output (Amplitude)	Rise Time (s)	Overshoot (Amplitude)	Settling Time (s)	Steady-state Error (Amplitude)
1.000	0.0999	1.1351	0	2.0652	0.9001

By observing the plot we can see that output has converged to 0.1 amplitude. There is a large steady state error of 0.9 Rise time and settling times are 1.14s,2s respectively.

PART II: Open-Loop Step Response

1. Proportional Control

K_p = 50



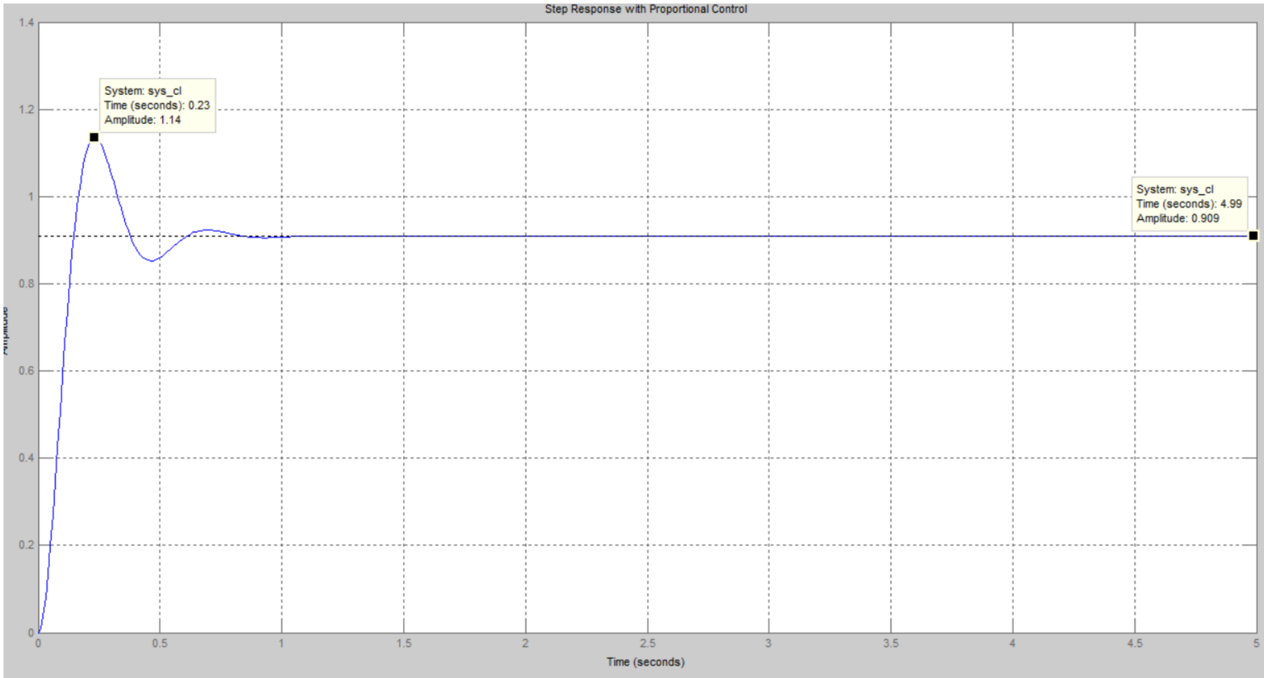

```
>> part2_close_loop
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1585
    SettlingTime: 0.5317
     SettlingMin: 0.7619
     SettlingMax: 0.9397
       Overshoot: 12.7859
      Undershoot: 0
            Peak: 0.9397
        PeakTime: 0.3454

>>
```

$\underline{K_p = 100}$



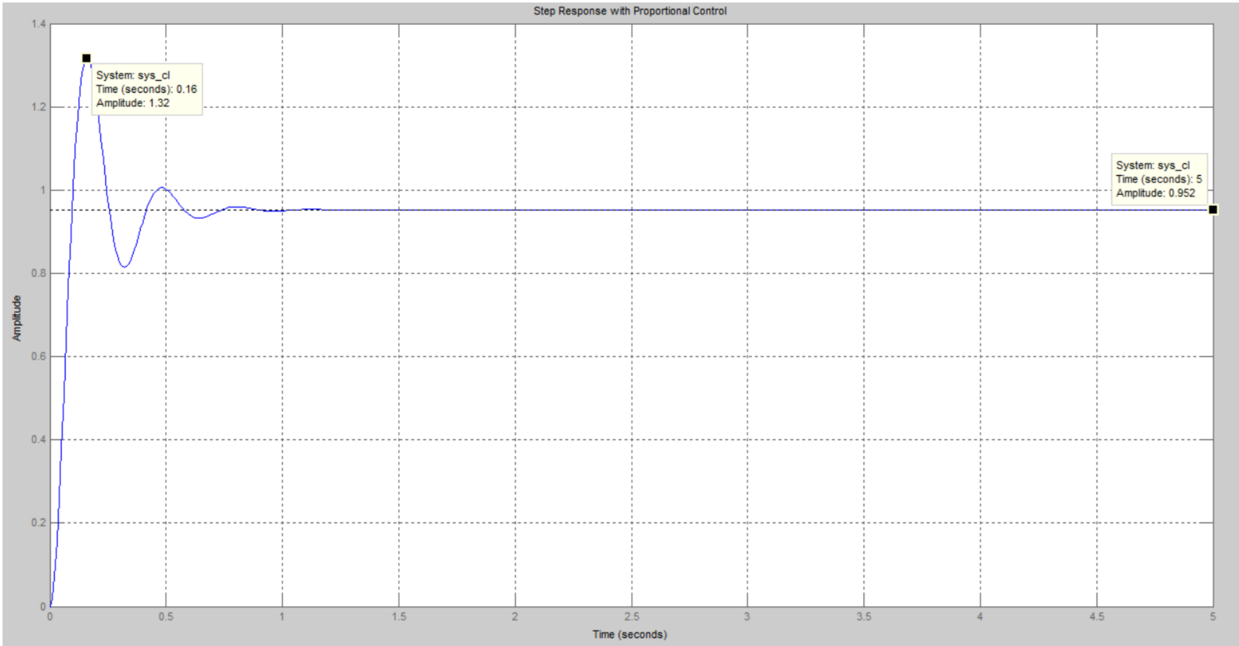

```
>> part2_close_loop
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.0993
    SettlingTime: 0.5669
     SettlingMin: 0.8526
     SettlingMax: 1.1355
       Overshoot: 24.9143
      Undershoot: 0
            Peak: 1.1355
        PeakTime: 0.2303

>> |
```

K_p = 200




```
>> part2_close_loop
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.0641
    SettlingTime: 0.6591
     SettlingMin: 0.8133
     SettlingMax: 1.3162
       Overshoot: 38.2111
      Undershoot: 0
            Peak: 1.3162
        PeakTime: 0.1612

>> |
```

Table 2: Step response with Proportional control

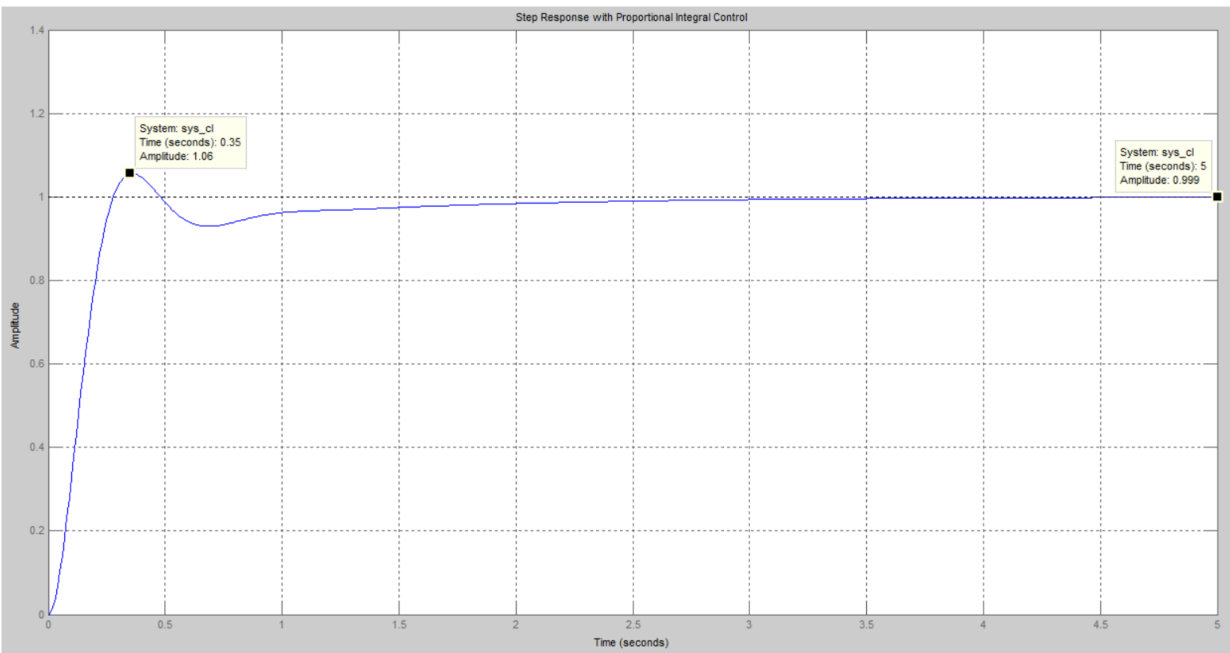
Gain	Rise Time	Overshoot	Settling Time	Steady-state Error
K_p = 50	0.1585	0.9397-0.833=0.1067	0.5317	1-0.833=0.167
K_p = 100	0.0993	1.1355-0.909=0.2265	0.5669	1-0.909=0.091

K_p = 200	0.0641	1.3162-0.952=0.3642	0.6591	1-0.952=0.048

We can observe that when we increase the K_p value the steady-state amplitude settles near to the desired output of 1. Rise time has decreased while overshoot and settling time increased with the increase of K_p value. So we can conclude that we can't achieve low overshoot and the fast converging rate at the same time by increasing K_p value.

2. Proportional –Integral Control

K_i = 50



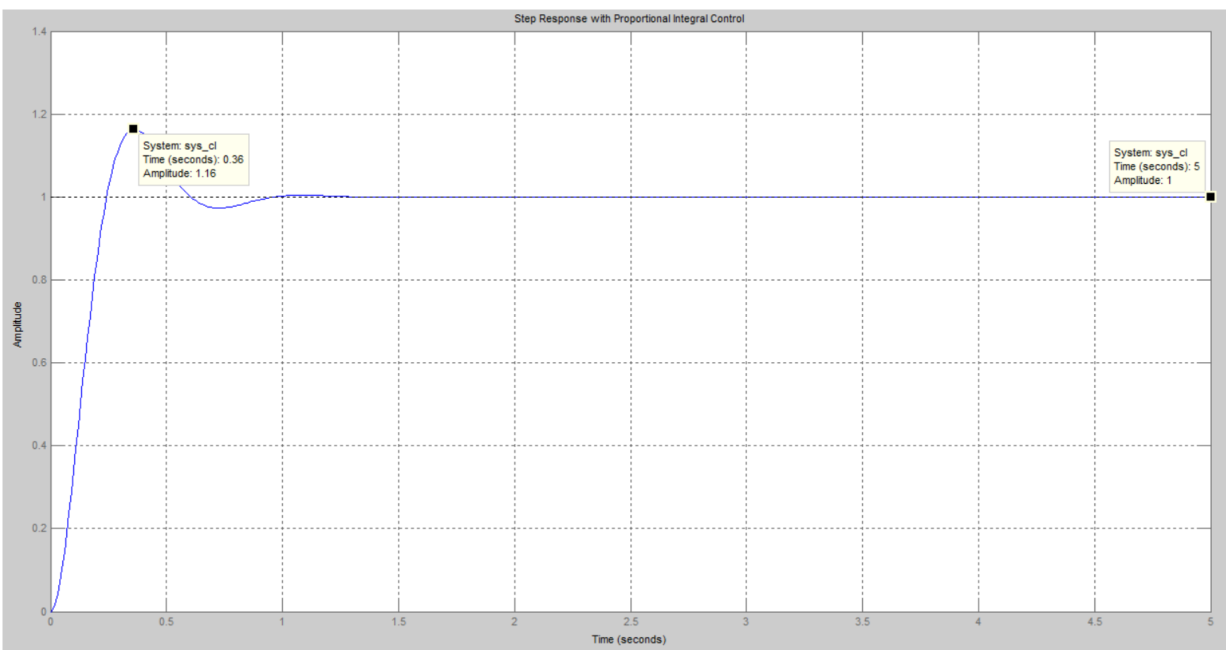
```
>> Proportional_Integral_Control
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1831
    SettlingTime: 1.7516
     SettlingMin: 0.9005
     SettlingMax: 1.0559
       Overshoot: 5.5898
      Undershoot: 0
            Peak: 1.0559
        PeakTime: 0.3571

>> |
```

$\underline{K_i = 100}$



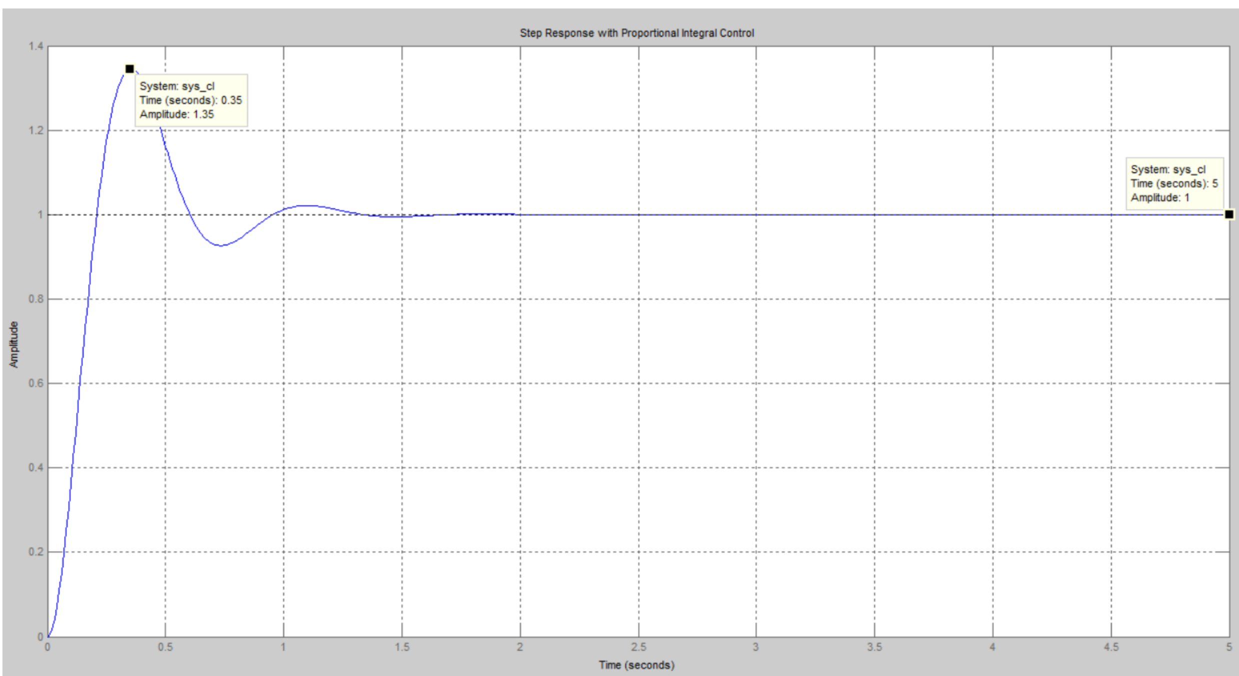
```
>> Proportional_Integral_Control
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1639
    SettlingTime: 0.8079
     SettlingMin: 0.9314
     SettlingMax: 1.1628
       Overshoot: 16.2775
      Undershoot: 0
            Peak: 1.1628
        PeakTime: 0.3592

>>
```

K_i = 200



```
>> Proportional_Integral_Control
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1416
    SettlingTime: 1.1424
     SettlingMin: 0.9269
     SettlingMax: 1.3454
       Overshoot: 34.5385
      Undershoot: 0
            Peak: 1.3454
        PeakTime: 0.3514

>> |
```

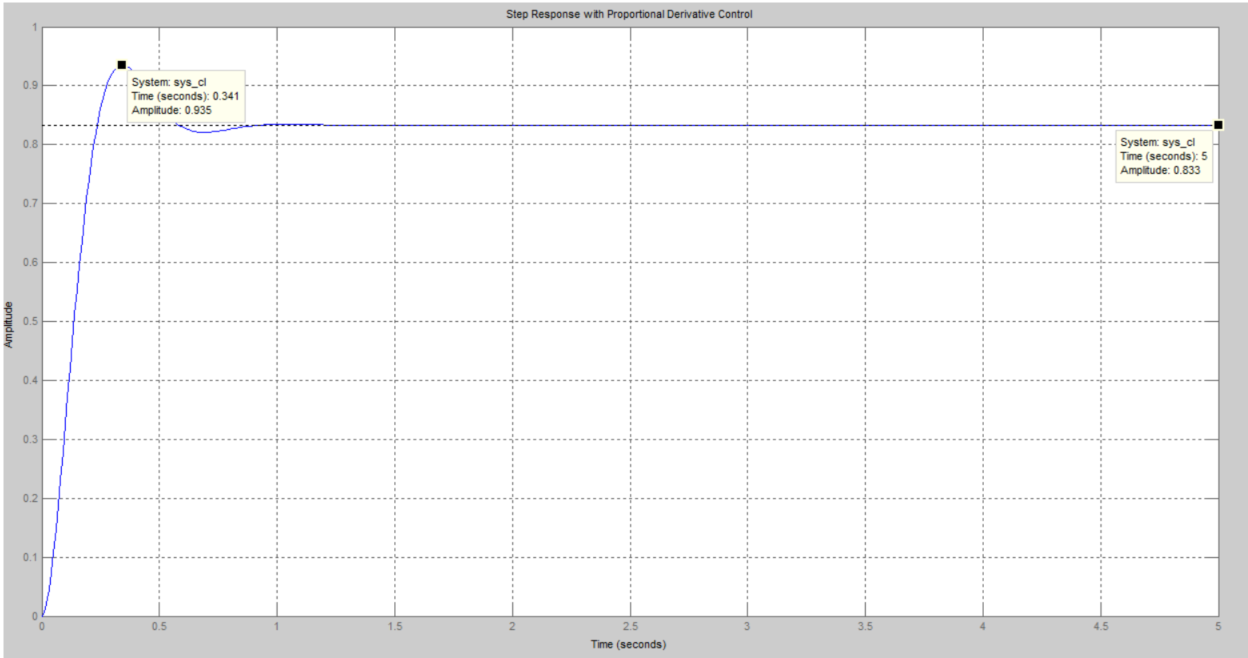
Table 3: Step response with Proportional-Integral control

Gain	Rise Time	Overshoot	Settling Time	Steady-state Error
K_p = 50 K_i = 50	0.1831	1.0559-0.999=0.0569	1.7516	0.001
K_p = 50 K_i = 100	0.1639	1.1628-1=0.1628	0.8079	0
K_p = 50 K_i = 200	0.1416	1.3454-1=0.3454	1.1424	0

We can achieve the desired output of 1 by increasing K_i value. Overshoot is increasing and rise time is decreasing with the increasing of K_i value. Settling time first decreases and then again increase with the K_i value. We can see that by using Proportional-Integral control the steady state error has eliminated.

3. Proportional –Derivative Control

K_d = 0.1



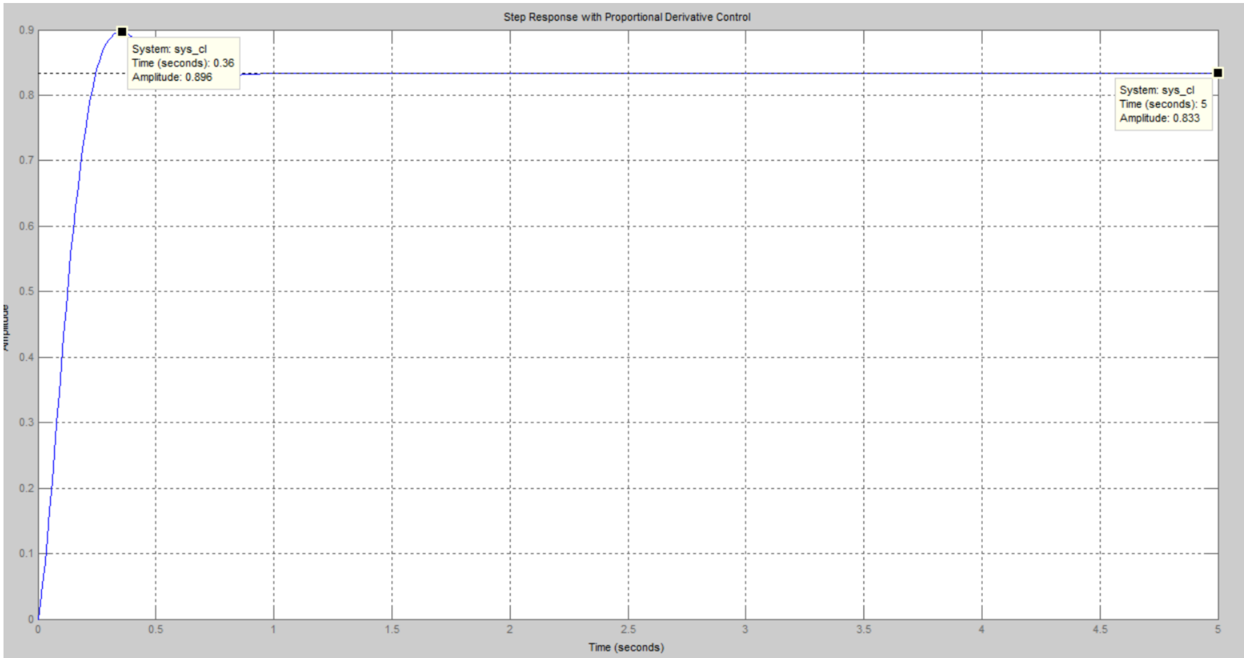

```
>> Proportional_Derivative_Control
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1602
    SettlingTime: 0.5318
     SettlingMin: 0.7520
     SettlingMax: 0.9346
       Overshoot: 12.1676
      Undershoot: 0
            Peak: 0.9346
        PeakTime: 0.3397

>>
```

<u>$K_d = 1$</u>



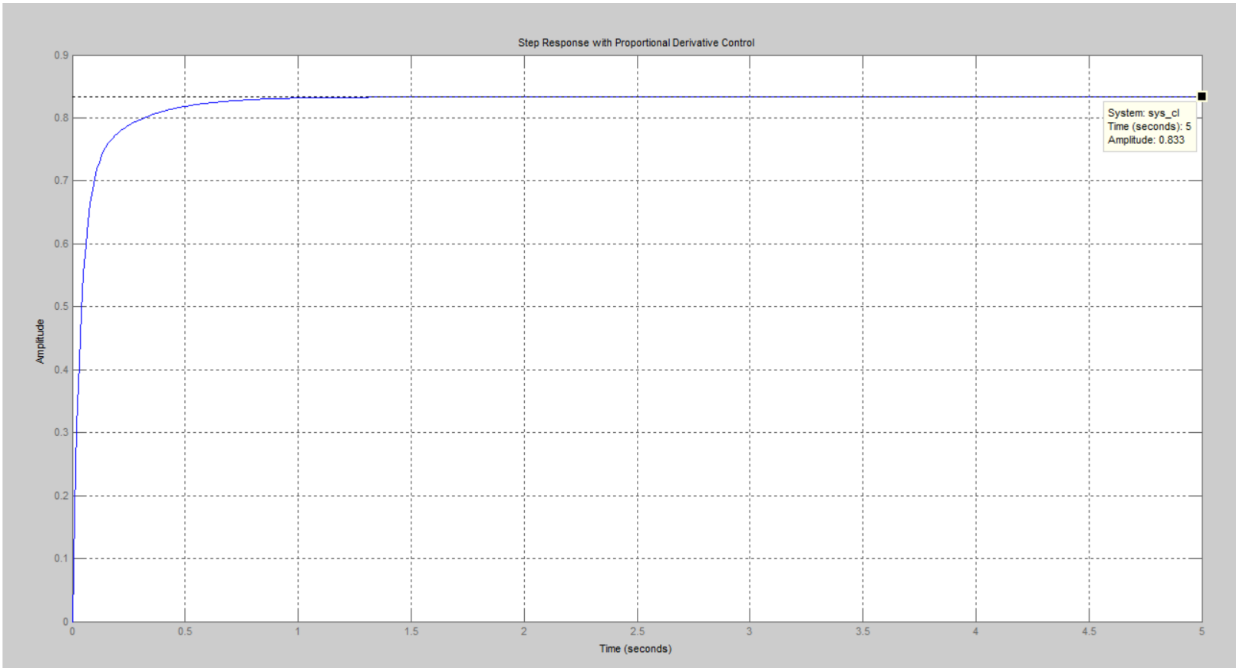

```
>> Proportional_Derivative_Control
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1730
    SettlingTime: 0.5265
     SettlingMin: 0.7548
     SettlingMax: 0.8963
       Overshoot: 7.5713
      Undershoot: 0
            Peak: 0.8963
        PeakTime: 0.3487

>> |
```

$K_d = 10$




```
>> Proportional_Derivative_Control
>> stepinfo(sys_cl)

ans =

        RiseTime: 0.1391
    SettlingTime: 0.4746
     SettlingMin: 0.7518
     SettlingMax: 0.8332
       Overshoot: 0
      Undershoot: 0
            Peak: 0.8332
        PeakTime: 2.0611

>>
```

Table 4: Step response with Proportional-Derivative control

Gain	Rise Time	Overshoot	Settling Time	Steady-state Error
K_p = 50 K_d = 0.1	0.1602	0.9346-0.833=0.1016	0.5318	1-0.833=0.167
K_p = 50	0.1730	0.8963-0.833=0.0633	0.5265	1-0.833=0.167

K_d = 1				
K_p = 50 K_d = 10	0.1391	0.8332-0.833=0.0002	0.4746	1-0.833=0.167

We can't achieve desired output of 1 by increasing K_d value. Steady-state error remain fixed for some value. Overshoot and rise time has decreased with the increase of K_d value.

4. Proportional-Integral-Derivative Control

Table 5: Step response with Proportional-Integral-Derivative control

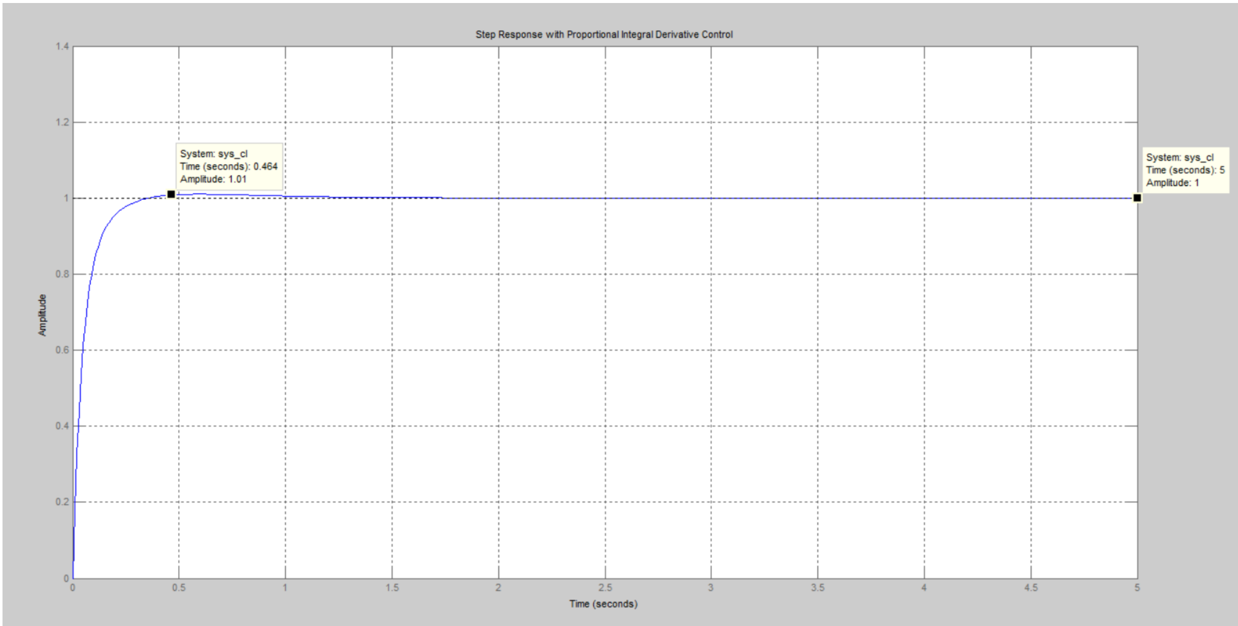
Gain	Rise Time	Overshoot	Settling Time	Steady-state Error
K_p	Decrease	Increase	Decrease	Decrease
K_i	Decrease	Increase	Decrease	Decrease
K_d	Decrease	Remain fixed	Decrease	Decrease

<u>PID Controller Design</u>

Design a PID controller to satisfy the below criteria.

For a 1-rad/s step reference,

- Settling time less than 2 seconds
- Overshoot less than 5%
- Steady-state error less than 1%




```
ans =

        RiseTime: 0.1324
    SettlingTime: 0.2570
     SettlingMin: 0.9010
     SettlingMax: 1.0103
       Overshoot: 1.0281
      Undershoot: 0
            Peak: 1.0103
        PeakTime: 0.5932
```

Input	1
Output	1
K_p	100
K_i	200
K_d	10
Rise Time	0.1324
Overshoot	1.0103-1=0.0103
Settling Time	0.2570
Steady-state Error	0