

LAB #2 PID Control using MATLAB/Simulink Simulations

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IN FULFILLMENT OF THE REQUIREMENTS FOR:
MTRE 4002L

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Contents

1. INTRODUCTION	3
2. QUESTION 1 – P Controller.....	3
3. QUESTION 2 – PI Controller	5
4. QUESTION 3 – PD Controller.....	8
5. QUESTION 4 – PID Controller	11
6. CONCLUSION	14

Figure 1	3
Figure 2	6
Figure 3	9
Figure 4	12

1. INTRODUCTION

The goal of this lab is to serve as an introduction to PID controllers. This was done by building several systems that included the different parts of the PID controller to build up to the final full PID controller. The systems built are the following, P, PI, PD, and finally the full PID controller.

2. QUESTION 1 – P Controller

In question 1 we built a basic P controller. Various parameters were given to analyze of which the results are recorded in Table 1. From looking at the trend of the graphs, it can be seen that K_p impacts how fast the response has its rise time most aggressively.

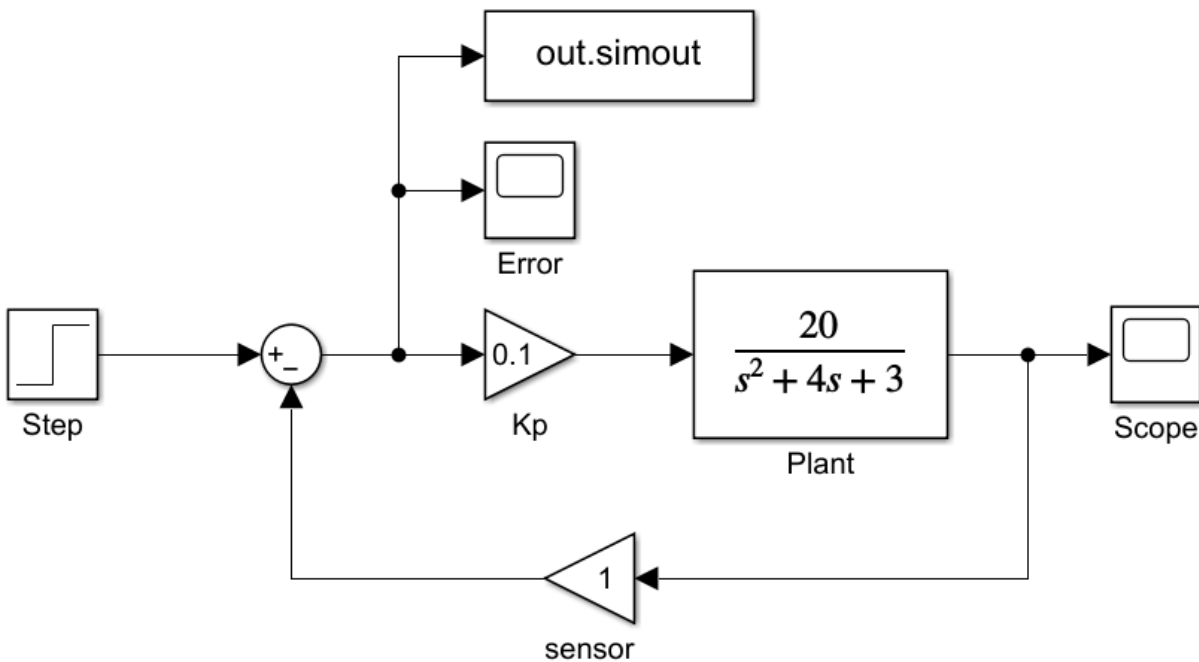
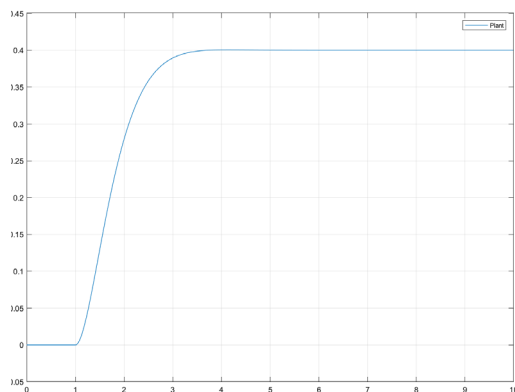
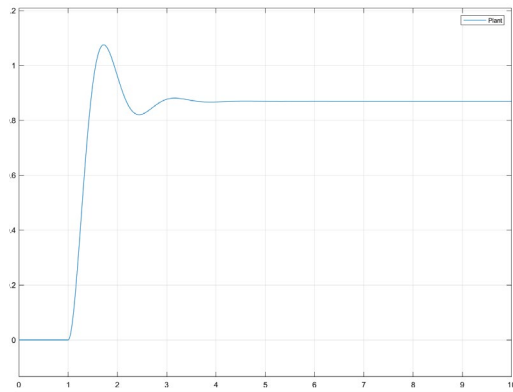


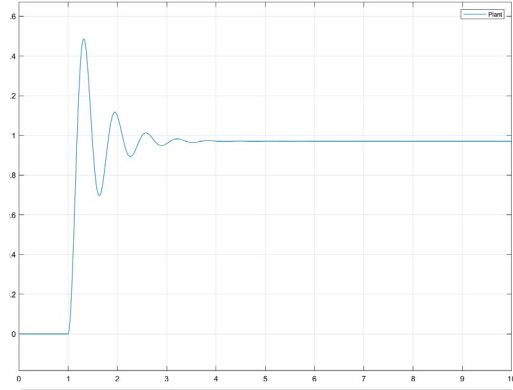
Figure 1



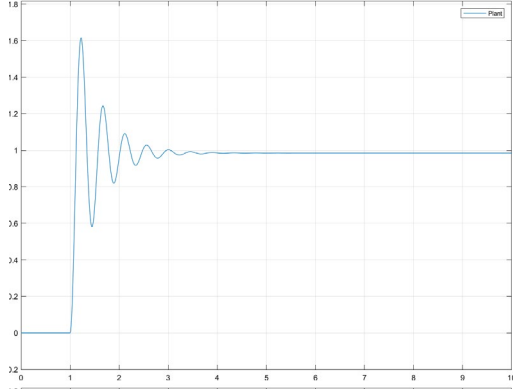
RiseTime:	1.2782
SettlingTime:	3.0749
SettlingMin:	0.3608
SettlingMax:	0.4007
Overshoot:	0.1867
Undershoot:	0
Peak:	0.4007
PeakTime:	4.1400



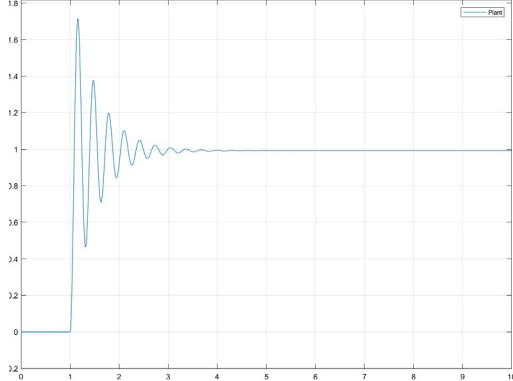
RiseTime: 0.3108
 SettlingTime: 2.7517
 SettlingMin: 0.7996
 SettlingMax: 1.0753
 Overshoot: 23.6580
 Undershoot: 0
 Peak: 1.0753
 PeakTime: 1.7200



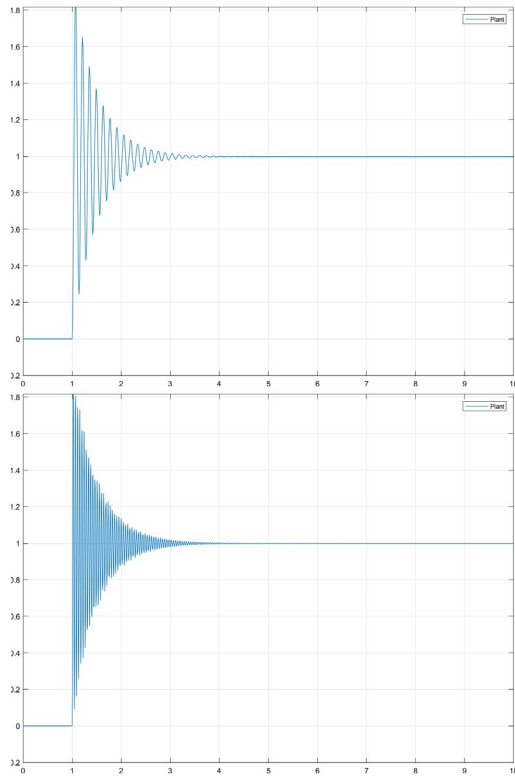
RiseTime: 0.1185
 SettlingTime: 2.9438
 SettlingMin: 0.6963
 SettlingMax: 1.4867
 Overshoot: 53.1308
 Undershoot: 0
 Peak: 1.4867
 PeakTime: 1.3200



RiseTime: 0.0804
 SettlingTime: 2.8391
 SettlingMin: 0.5817
 SettlingMax: 1.6159
 Overshoot: 64.0090
 Undershoot: 0
 Peak: 1.6159
 PeakTime: 1.2200



RiseTime: 0.0553
 SettlingTime: 2.9129
 SettlingMin: 0.4657
 SettlingMax: 1.7162
 Overshoot: 72.9028
 Undershoot: 0
 Peak: 1.7162
 PeakTime: 1.1600



RiseTime: 0.0236
 SettlingTime: 2.9069
 SettlingMin: 0.2449
 SettlingMax: 1.8660
 Overshoot: 86.8822
 Undershoot: 0
 Peak: 1.8660
 PeakTime: 1.0700

RiseTime: 0.0086
 SettlingTime: 3.0177
 SettlingMin: 0.0914
 SettlingMax: 1.9033
 Overshoot: 90.3539
 Undershoot: 0
 Peak: 1.9033
 PeakTime: 1.0246

Table 1

Proportional Gain (k_p)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
0.1	1.2782	4.1400	3.0749	0.1867	0.6000	Yes	Critically Damped
1	0.3108	1.7200	2.7517	23.6580	0.1304	Yes	Under Damped
5	0.1185	1.3200	2.9438	53.1308	0.0291	Yes	Under Damped
10	0.0804	1.2200	2.8391	64.0090	0.0148	Yes	Under Damped
20	0.0553	1.1600	2.9129	72.9028	0.0074	Yes	Under Damped
100	0.0236	1.0700	2.9069	86.8822	0.0015	Yes	Under Damped
1000	0.0086	1.0246	3.0177	90.3539	1.50e-4	Yes	Under Damped

3. QUESTION 2 – PI Controller

In question 2 we built a basic PI controller. Various parameters were given to analyze of which the results are recorded in Table 2. Please note that some responses in this set proved to go out of bounds of the graph which resulted in inaccurate results for some values. These values have been put in italics to mark their inaccuracy. These values are kept due to keeping consistently with what MATLAB outputs. It must be noted that when a response to go out of bounds of the plot it will never reach a steady state. It can be assumed that K_i is the parameter that effects the steady state error portion of the response as when that value is increased the response oscillates and may even go out of the bounds of the plot.

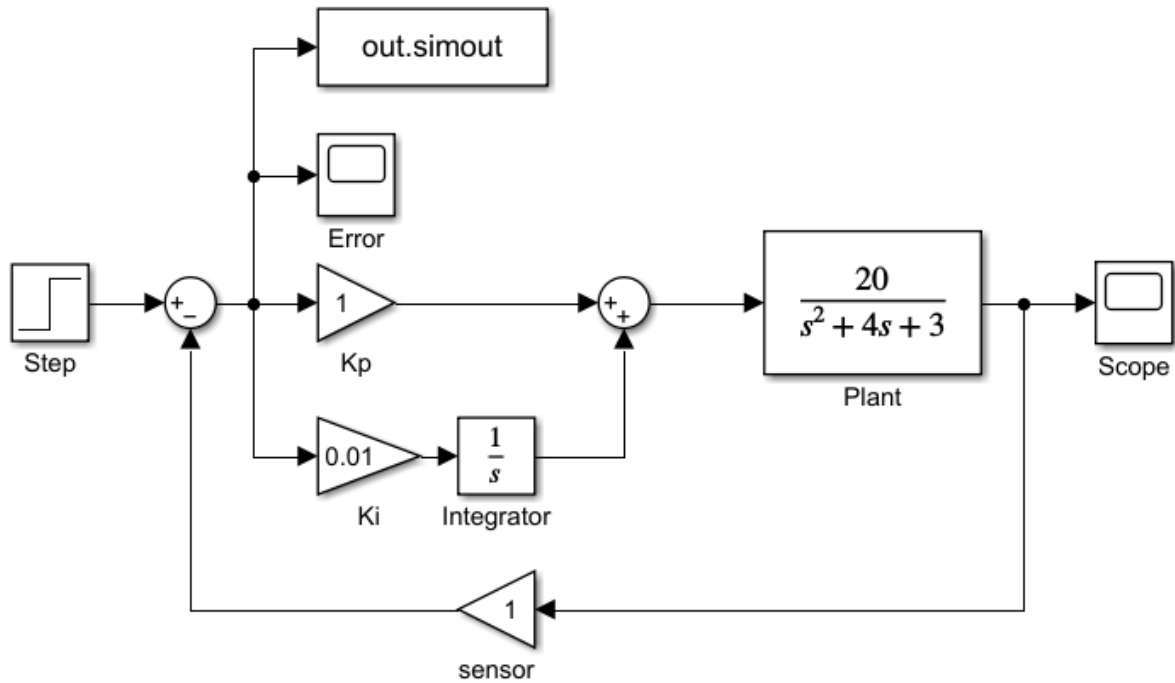
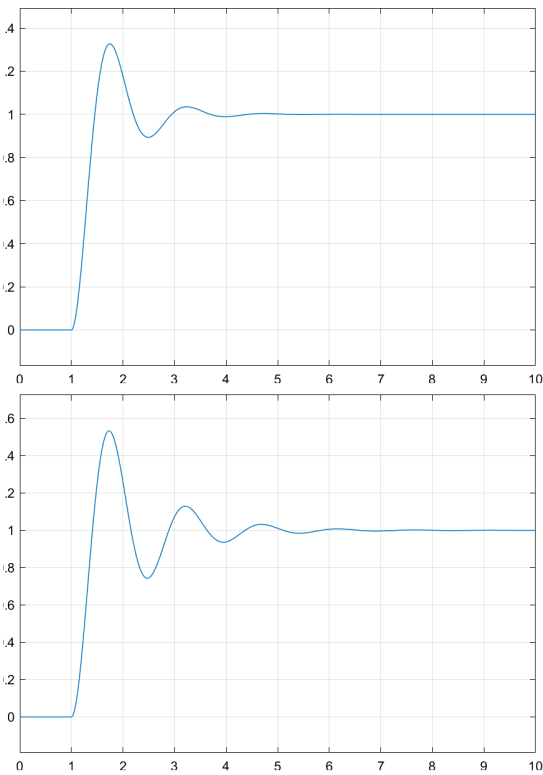
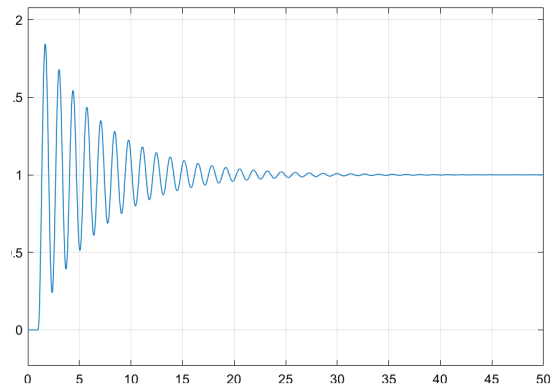


Figure 2

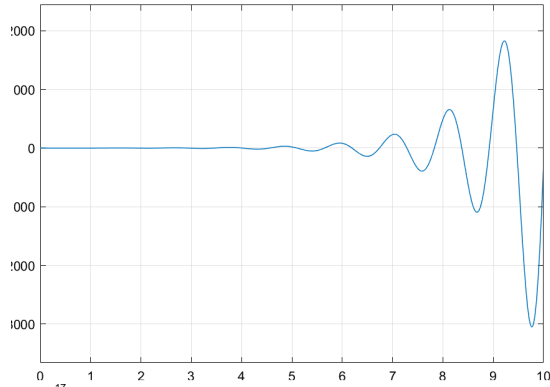


RiseTime: 0.3061
 SettlingTime: 3.4798
 SettlingMin: 0.8932
 SettlingMax: 1.3267
 Overshoot: 32.6706
 Undershoot: 0
 Peak: 1.3267
 PeakTime: 1.7500

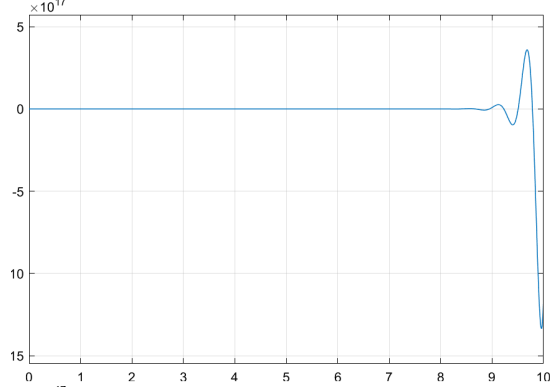
RiseTime: 0.2722
 SettlingTime: 4.9069
 SettlingMin: 0.7430
 SettlingMax: 1.5330
 Overshoot: 53.3309
 Undershoot: 0
 Peak: 1.5330
 PeakTime: 1.7300



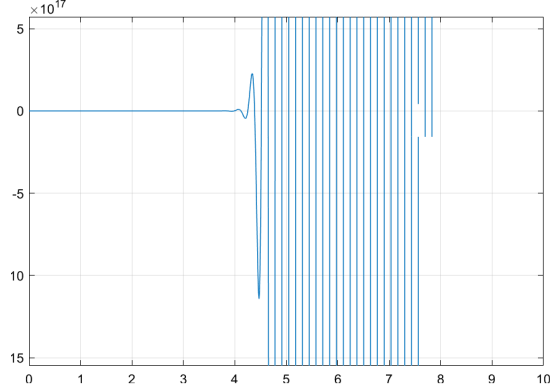
RiseTime: 0.2325
 SettlingTime: 24.0007
 SettlingMin: 0.2399
 SettlingMax: 1.8444
 Overshoot: 84.4067
 Undershoot: 0
 Peak: 1.8444
 PeakTime: 1.6800



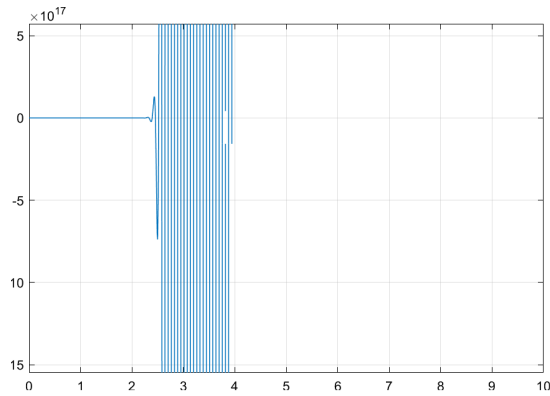
RiseTime: 2.1998
 SettlingTime: 9.9974
 SettlingMin: -3.0496e+03
 SettlingMax: 1.8290e+03
 Overshoot: 991.7894
 Undershoot: 654.8151
 Peak: 3.0496e+03
 PeakTime: 9.7700



RiseTime: 0.0983
 SettlingTime: 9.9963
 SettlingMin: -1.3361e+18
 SettlingMax: -1.0522e+18
 Overshoot: 15.7082
 Undershoot: 31.1786
 Peak: 1.3361e+18
 PeakTime: 9.9600



RiseTime: 0.0355
 SettlingTime: 9.9989
 SettlingMin: -1.4831e+47
 SettlingMax: -1.4831e+47
 Overshoot: 0
 Undershoot: 33.1838
 Peak: 1.4831e+47
 PeakTime: 10



RiseTime: 0.0223
 SettlingTime: 9.9993
 SettlingMin: 2.6651e+108
 SettlingMax: 3.3622e+108
 Overshoot: 26.1570
 Undershoot: 22.3372
 Peak: 3.3622e+108
 PeakTime: 9.9897

Table 2

Proportional Gain (k_p)	Integral Gain (k_i)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
1	1	0.3061	1.7500	3.4798	32.6706	1.44e-6	Yes	Under Damped
1	2	0.2711	1.7300	4.9069	53.3309	1.94e-4	Yes	Under Damped
1	4	0.2325	1.6800	24.0007	84.4067	-0.1041	Yes	Under Damped
1	10	2.1998	9.7700	9.9974	991.7894	280.3184	No	Under Damped
1	100	0.0983	9.9600	9.9963	15.7082	1.15e+18	No	Under Damped
1	1000	0.0355	10	9.9989	0	1.48e+47	No	Under Damped
1	10000	0.0223	9.9897	9.9993	26.1570	-2.66e+108	No	Under Damped

4. QUESTION 3 – PD Controller

In question 3 we built a basic PD controller. Various parameters were given to analyze of which the results are recorded in Table 3. K_d can be analyzed to affect the time to reach steady state. This effect can be clearly seen the further down in Table 3. As this parameter is increased the settling time becomes very large.

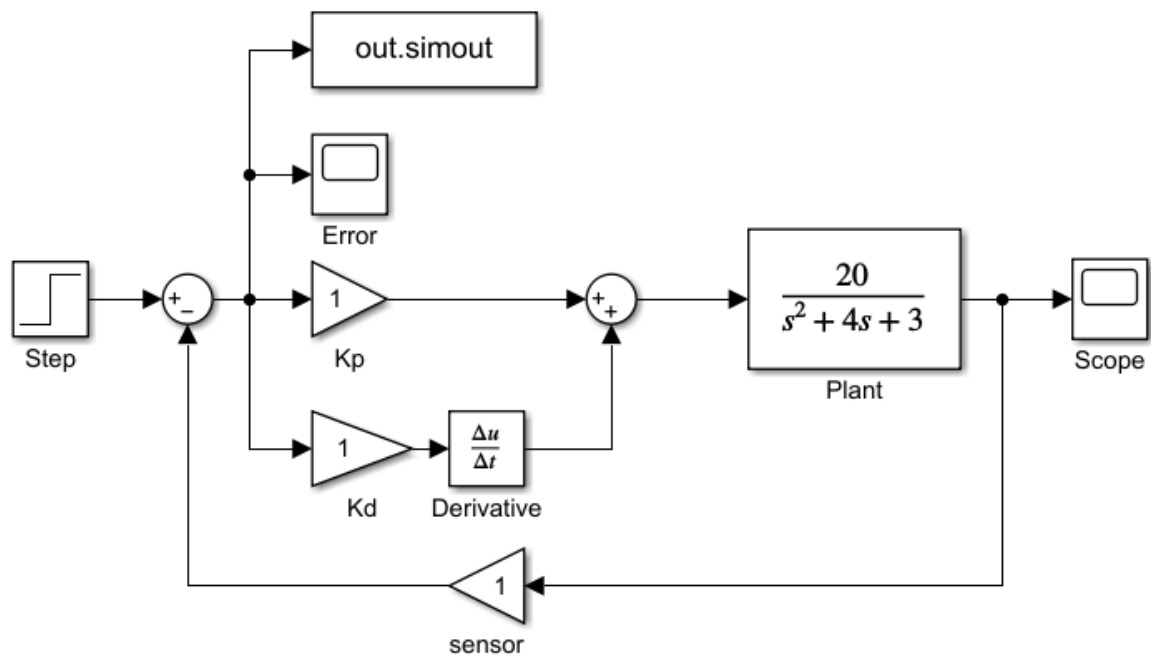
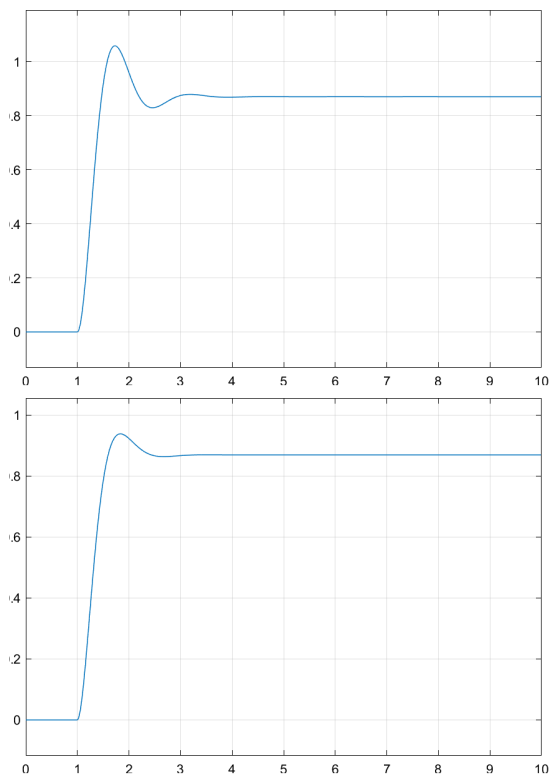
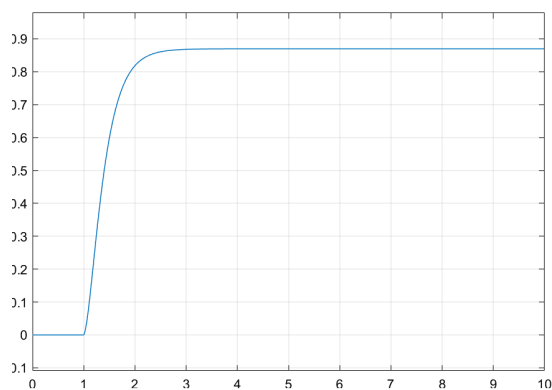


Figure 3

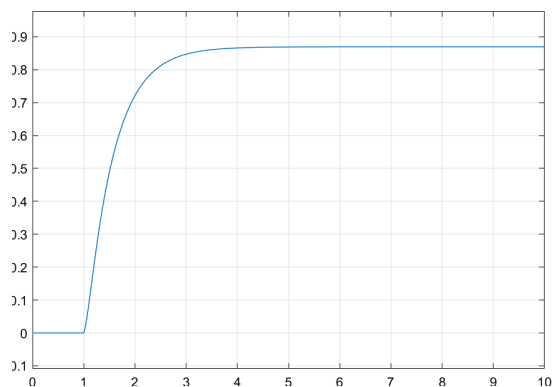


RiseTime: 0.3181
 SettlingTime: 2.7448
 SettlingMin: 0.7921
 SettlingMax: 1.0577
 Overshoot: 21.6334
 Undershoot: 0
 Peak: 1.0577
 PeakTime: 1.7234

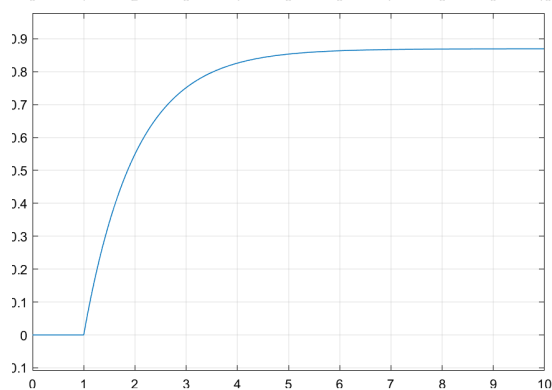
RiseTime: 0.3997
 SettlingTime: 2.2400
 SettlingMin: 0.7877
 SettlingMax: 0.9388
 Overshoot: 7.9587
 Undershoot: 0
 Peak: 0.9388
 PeakTime: 1.8334



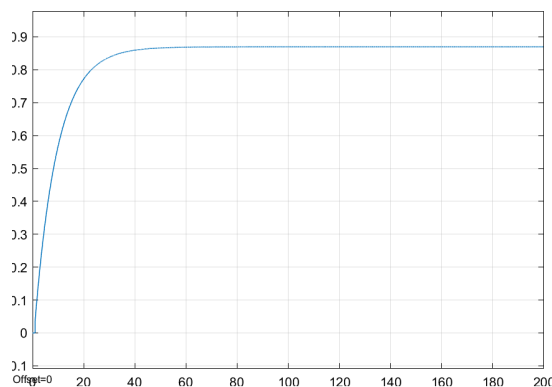
RiseTime: 0.7470
 SettlingTime: 2.3113
 SettlingMin: 0.7851
 SettlingMax: 0.8696
 Overshoot: 0
 Undershoot: 0
 Peak: 0.8696
 PeakTime: 10



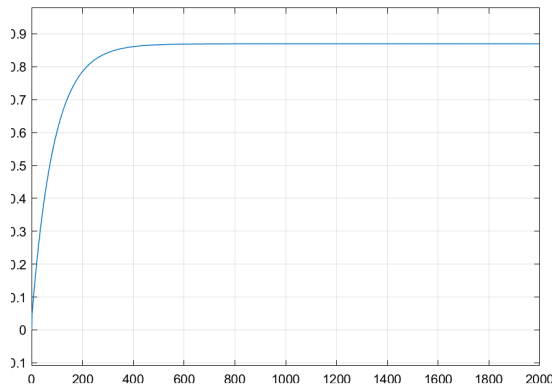
RiseTime: 1.1838
 SettlingTime: 3.1331
 SettlingMin: 0.7829
 SettlingMax: 0.8696
 Overshoot: 0
 Undershoot: 0
 Peak: 0.8696
 PeakTime: 10



RiseTime: 2.2018
 SettlingTime: 4.9141
 SettlingMin: 0.7832
 SettlingMax: 0.8695
 Overshoot: 0
 Undershoot: 0
 Peak: 0.8695
 PeakTime: 10



RiseTime: 19.4910
 SettlingTime: 35.2625
 SettlingMin: 0.7829
 SettlingMax: 0.8696
 Overshoot: 0.0105
 Undershoot: 0
 Peak: 0.8696
 PeakTime: 199.9646



RiseTime: 191.4564
 SettlingTime: 337.9327
 SettlingMin: 0.7826
 SettlingMax: 0.8696
 Overshoot: 0
 Undershoot: 0
 Peak: 0.8696
 PeakTime: 2000

Table 3

Proportional Gain (k_p)	Derivative Gain (k_d)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
1	0.01	0.3181	1.0577	2.7448	21.6334	0.1304	Yes	Under Damped
1	0.1	0.3997	1.8334	2.2400	7.9587	0.1304	Yes	Under Damped
1	0.3	0.7470	10	2.3113	0	0.1304	Yes	Critically Damped
1	0.5	1.1838	10	3.1331	0	0.1304	Yes	Over Damped
1	1	2.2018	10	4.9141	0	0.1306	Yes	Over Damped
1	10	19.4910	199.9646	35.2625	0.0105	0.1305	No	Over Damped
1	100	191.4564	2000	337.9327	0	0.1304	Yes	Over Damped

5. QUESTION 4 – PID Controller

In question 4 we built a basic PID controller. Various parameters were given to analyze of which the results are recorded in Table 4. Incorporating all three of these parameters we are given a highly tunable controller. With the responses given one can see that we have a plethora of different characteristics that might be desirable in many different applications.

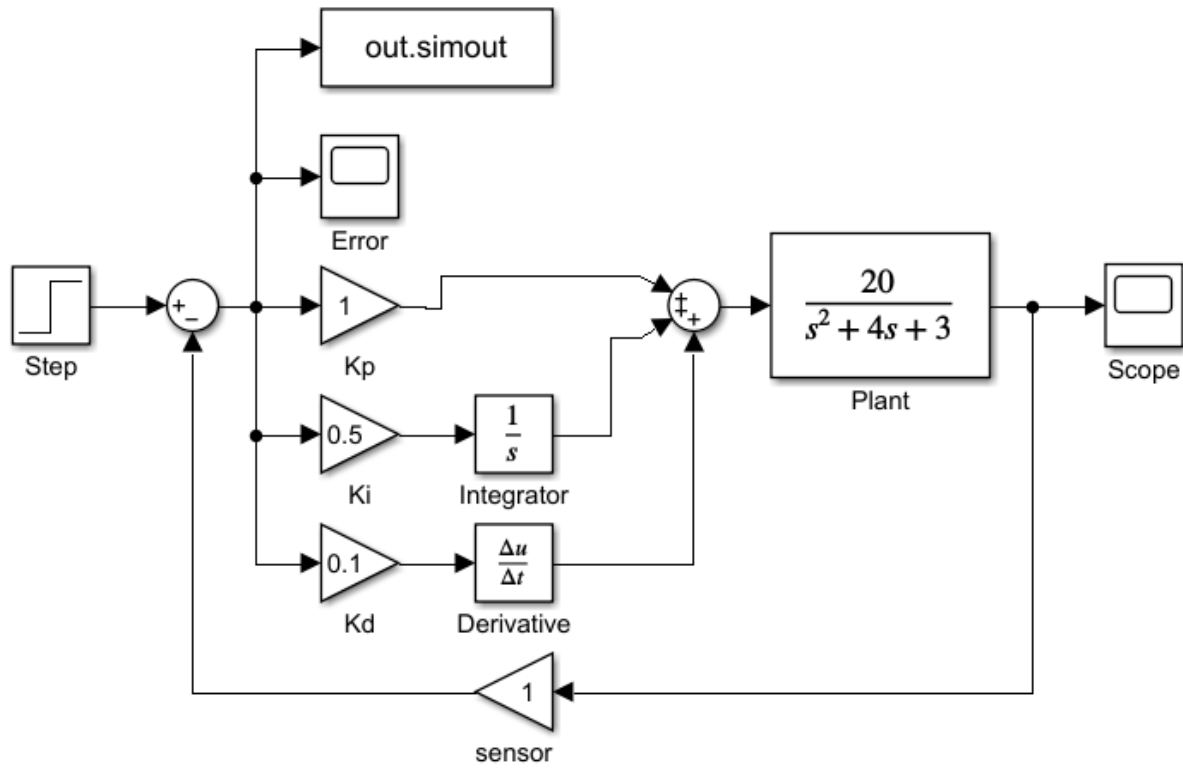
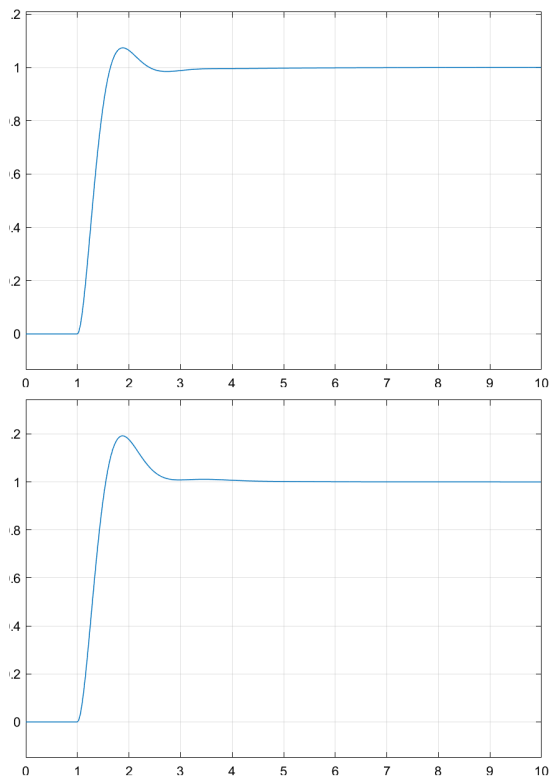
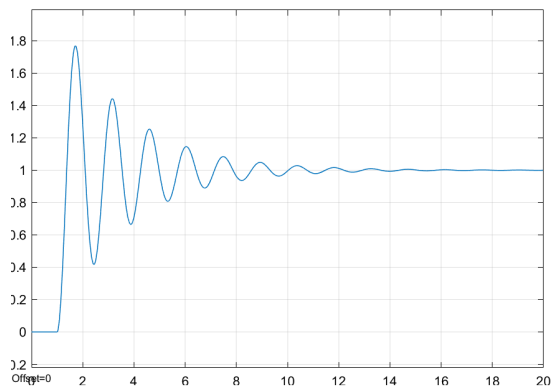


Figure 4

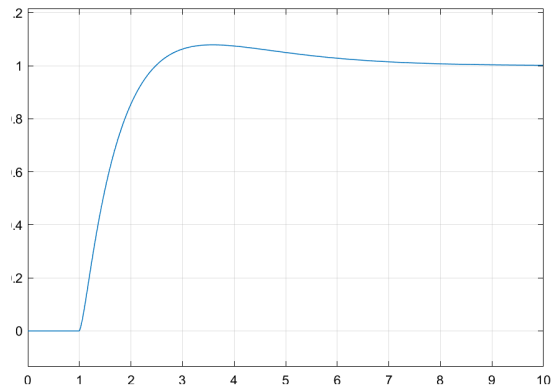


RiseTime: 0.4272
 SettlingTime: 2.2524
 SettlingMin: 0.9110
 SettlingMax: 1.0735
 Overshoot: 7.3782
 Undershoot: 0
 Peak: 1.0735
 PeakTime: 1.8834

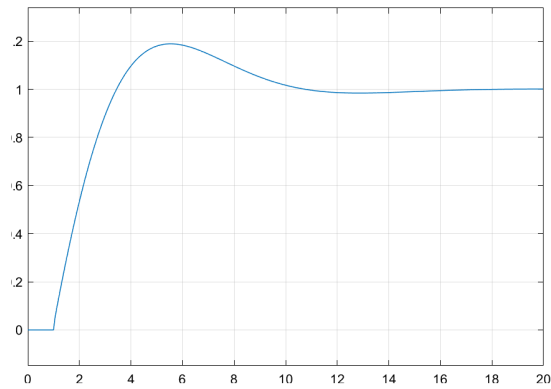
RiseTime: 0.3775
 SettlingTime: 2.6532
 SettlingMin: 0.9005
 SettlingMax: 1.1919
 Overshoot: 19.1920
 Undershoot: 0
 Peak: 1.1919
 PeakTime: 1.8734



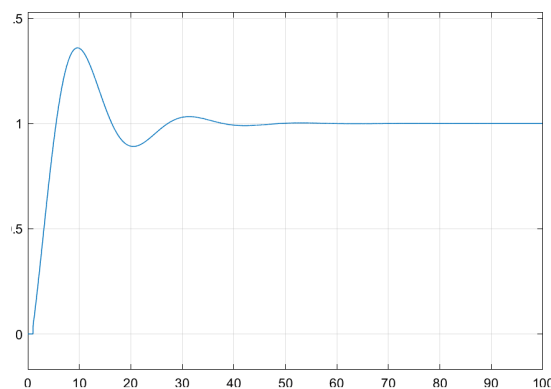
RiseTime: 0.2477
 SettlingTime: 11.1522
 SettlingMin: 0.4175
 SettlingMax: 1.7686
 Overshoot: 76.9313
 Undershoot: 0
 Peak: 1.7686
 PeakTime: 1.7134



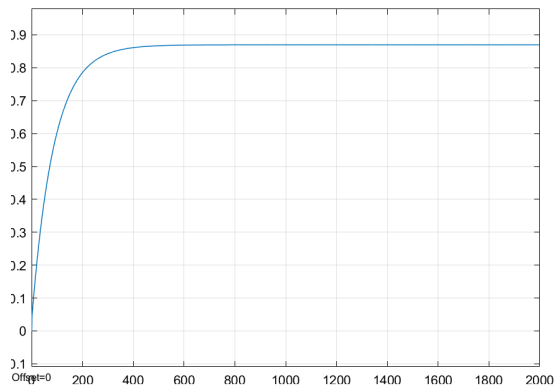
RiseTime: 1.0070
 SettlingTime: 6.4249
 SettlingMin: 0.9044
 SettlingMax: 1.0789
 Overshoot: 7.7073
 Undershoot: 0
 Peak: 1.0789
 PeakTime: 3.5834



RiseTime: 1.8912
 SettlingTime: 9.8503
 SettlingMin: 0.9023
 SettlingMax: 1.1890
 Overshoot: 18.7495
 Undershoot: 0
 Peak: 1.1890
 PeakTime: 5.5334



RiseTime: 3.6157
 SettlingTime: 34.6526
 SettlingMin: 0.8912
 SettlingMax: 1.3599
 Overshoot: 35.9871
 Undershoot: 0
 Peak: 1.3599
 PeakTime: 9.6497



RiseTime: 191.4194
 SettlingTime: 337.7783
 SettlingMin: 0.7826
 SettlingMax: 0.8696
 Overshoot: 0.0036
 Undershoot: 0
 Peak: 0.8696
 PeakTime: 1.9999e+03

Table 4

Proportional Gain (k_p)	Integral Gain (k_i)	Derivative Gain (k_d)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
1	0.5	0.1	0.4272	1.8834	2.2524	7.3782	1.57e-6	Yes	Under Damped
1	1	0.1	0.3775	1.8734	2.6432	19.1920	-6.34e-11	Yes	Under Damped
1	5	0.1	0.2477	1.7134	11.1522	76.9313	3.91e-4	Yes	Under Damped
1	0.5	0.5	1.0070	3.5834	6.4249	7.7073	-5.69e-7	Yes	Under Damped
1	0.5	1.5	1.8912	5.5334	9.8503	18.7495	-0.013	Yes	Under Damped
1	0.5	5	3.6157	9.6497	0.8912	35.9871	-1.36e-5	Yes	Under Damped
1	0	100	191.4194	1.9999e+03	337.7783	0.0036	0.1305	Yes	Critically Damped

6. CONCLUSION

In conclusion, this lab was a very helpful exercise in visualizing what each component does in a PID controller. Understanding each component on their own was enlightening and will certainly aid in designing controllers. Additionally, this has shown to show the power of MATLAB in analyzing PID controllers.