PID tuning procedure

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Step 1: Tuning K_p

Setting K_i and K_d to 0, I had to find the value of K_p for which the system executed stable oscillations about the setpoint. Starting with $K_p = 1$, here is the visual process of how I tuned the proportional gain.

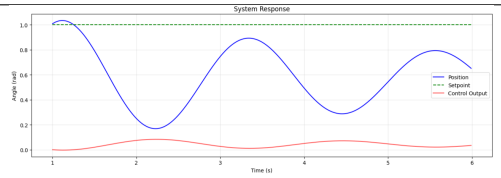
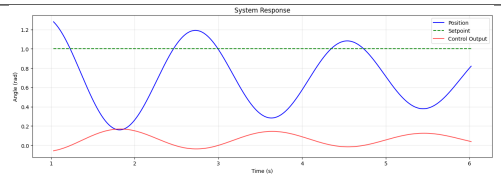
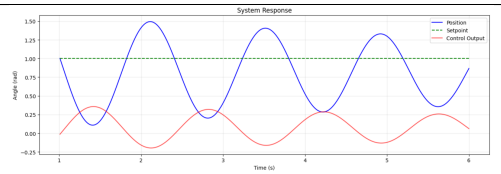
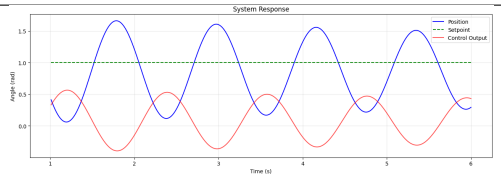
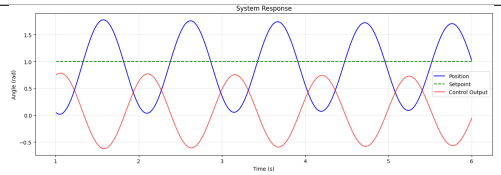
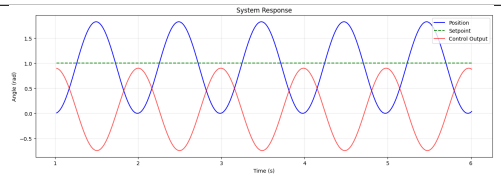
Value of K_p	Observation	System Response Image
1.0	Output always stays below the setpoint	
2.0	Output mostly below setpoint, no oscillating nature	
4.0	System oscillates mildly, but eventually settles	
6.0	Stronger oscillations, but still decaying nature	
8.0	Clear oscillations, but amplitude gradually decreases	
9.0	Clear oscillations with constant amplitude	

Table 1: Effect of Proportional Gain (K_p) on System Response

Conclusion : The value of $K_p \approx 60\%\ of\ 9.0 \approx 5.4$

Step 2: Tuning K_i

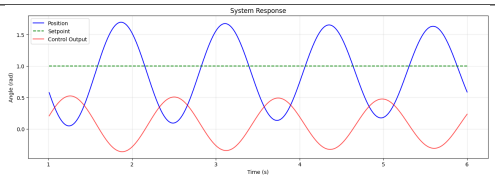
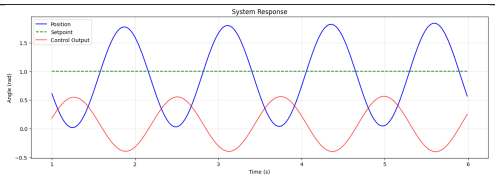
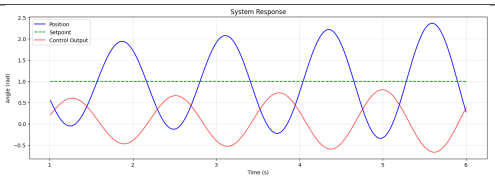
Value of K_i	Observation	System Response Image
0.5	System oscillates a lot	
1.0	System oscillates	
2.0	Oscillations grow	

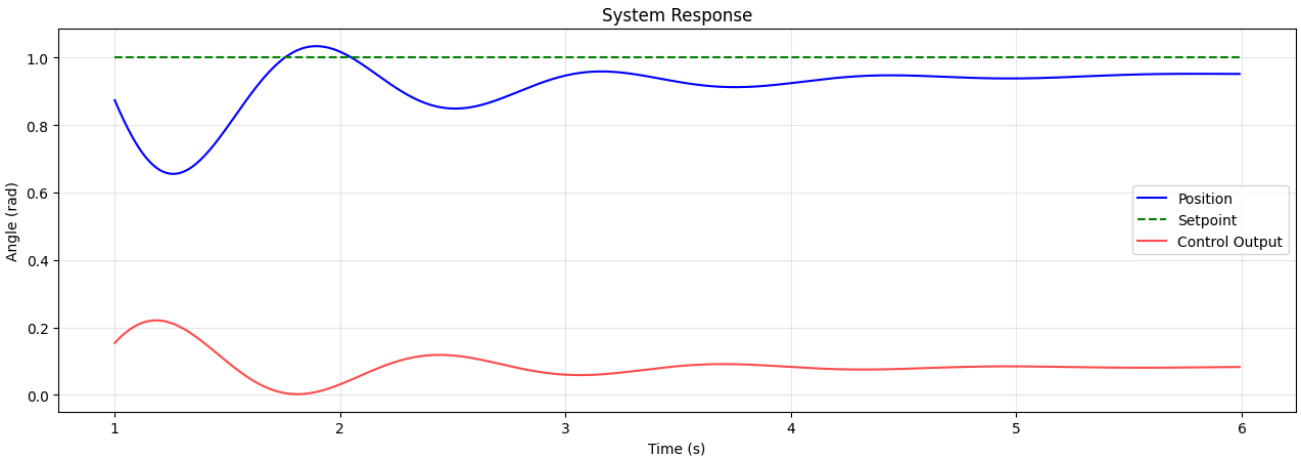
Table 2: Effect of Integral Gain (K_i) on System Response

Conclusion : The value of $K_i \approx 1.0$

Step 3: Tuning K_d + fine-tuning of other gains

Step 3.1

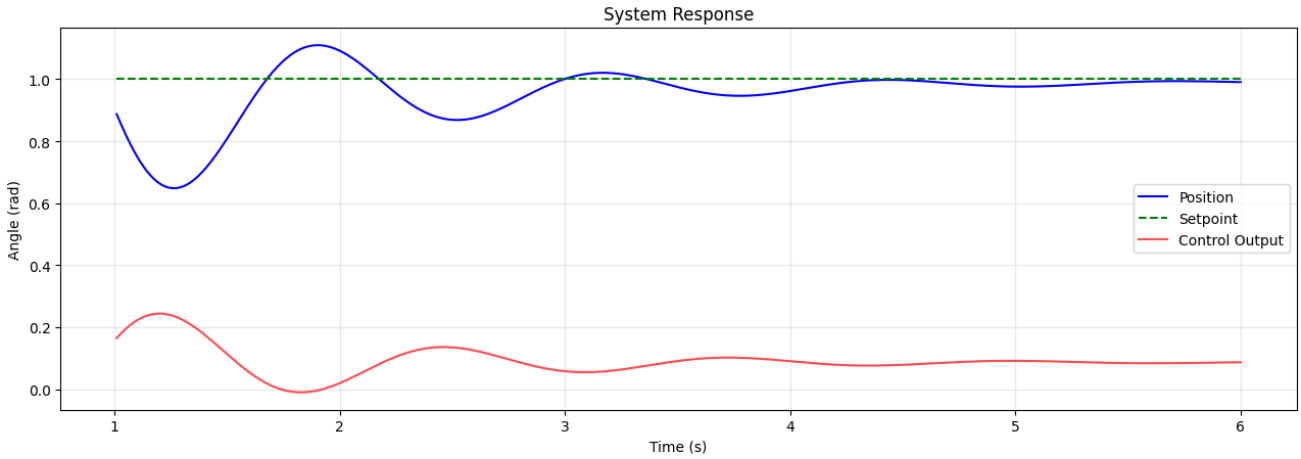
K_p	K_i	K_d
5.4	1.0	0.5



Conclusion : Large steady state error $\rightarrow$ increase K_i

Step 3.2

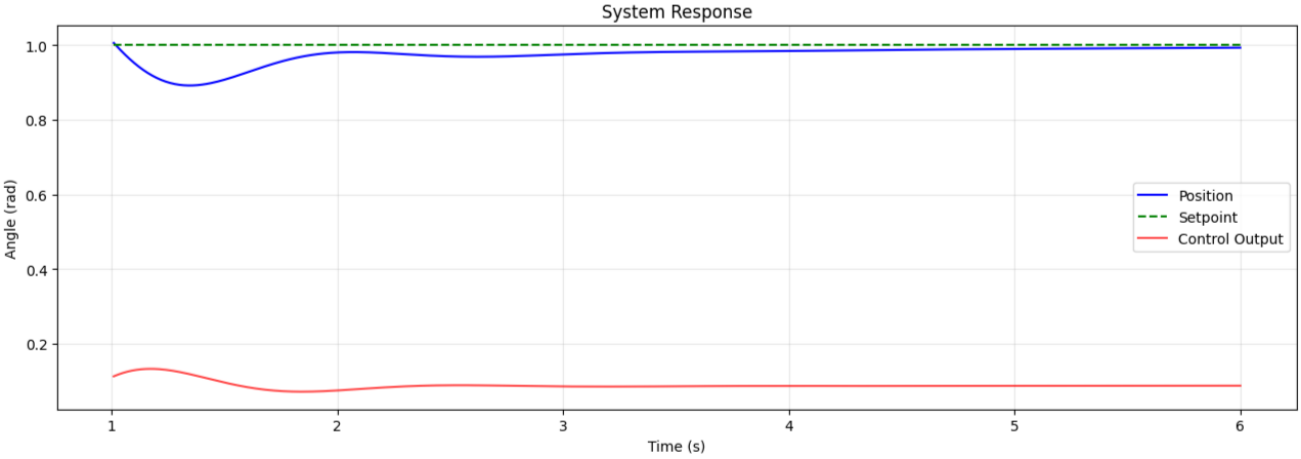
K_p	K_i	K_d
5.4	1.5	0.5



Conclusion : Steady state error decreased → increase K_i more

Step 3.3

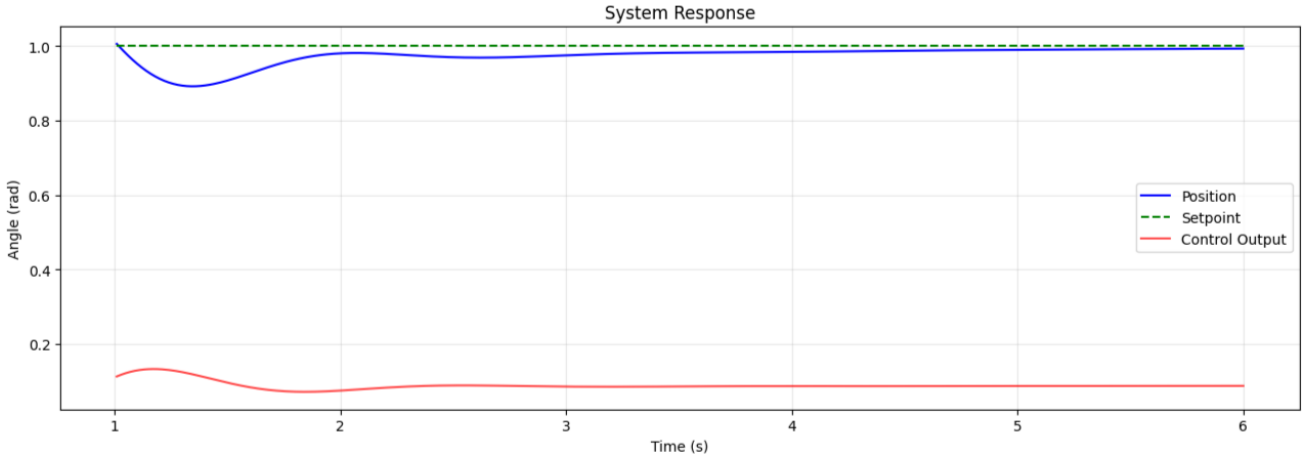
K_p	K_i	K_d
5.4	2.5	0.5



Conclusion : Steady state error negligible, but settling time large → increase K_d

Step 3.4

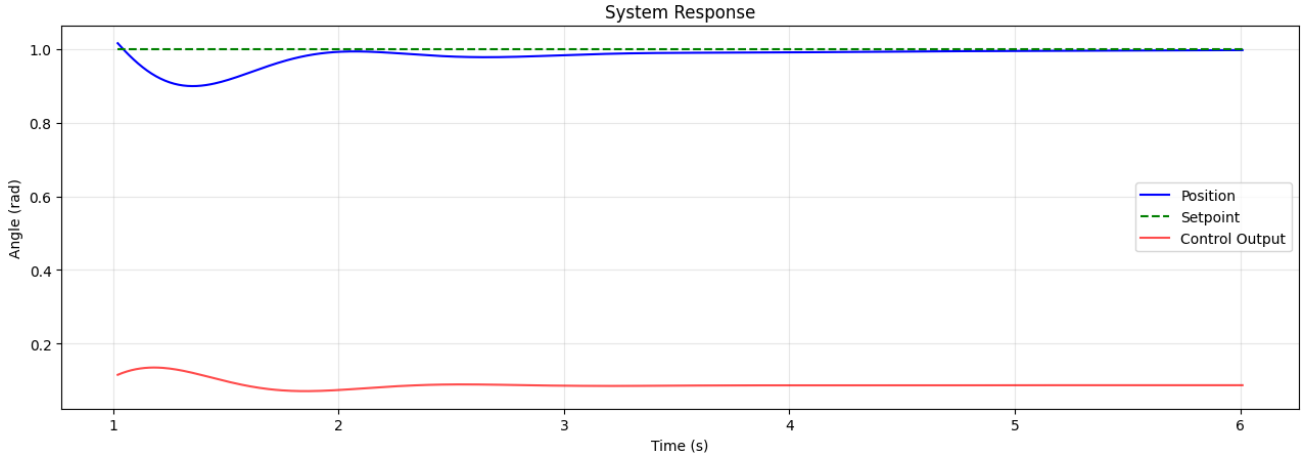
K_p	K_i	K_d
5.4	2.5	1.0



Conclusion : Settling time reduced, however small steady state error present → increase K_i

Step 3.5

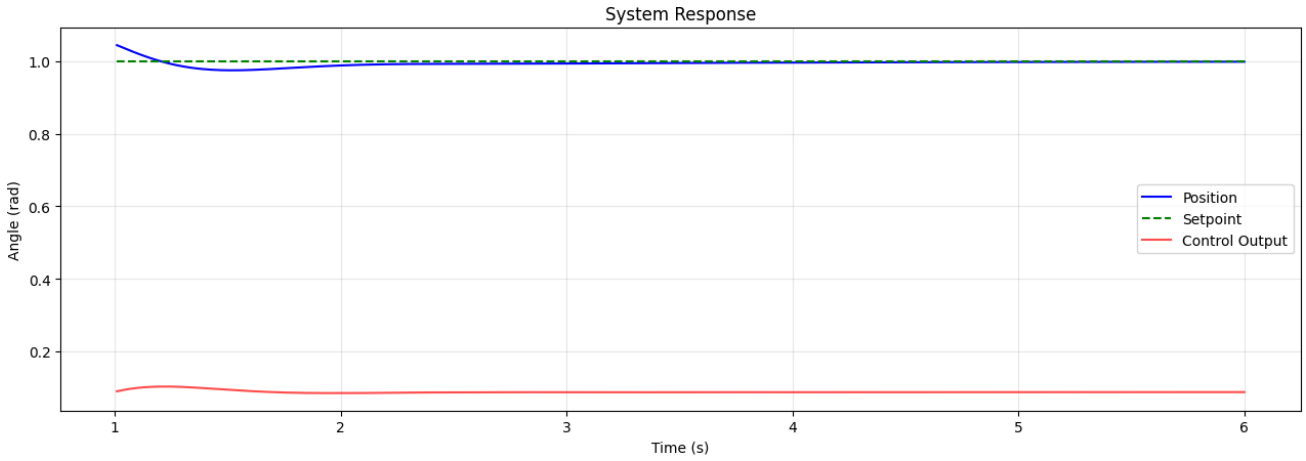
K_p	K_i	K_d
5.4	3.0	1.0



Conclusion : Steady state error reduced; scope to improve settling time → increase K_d

Step 3.6

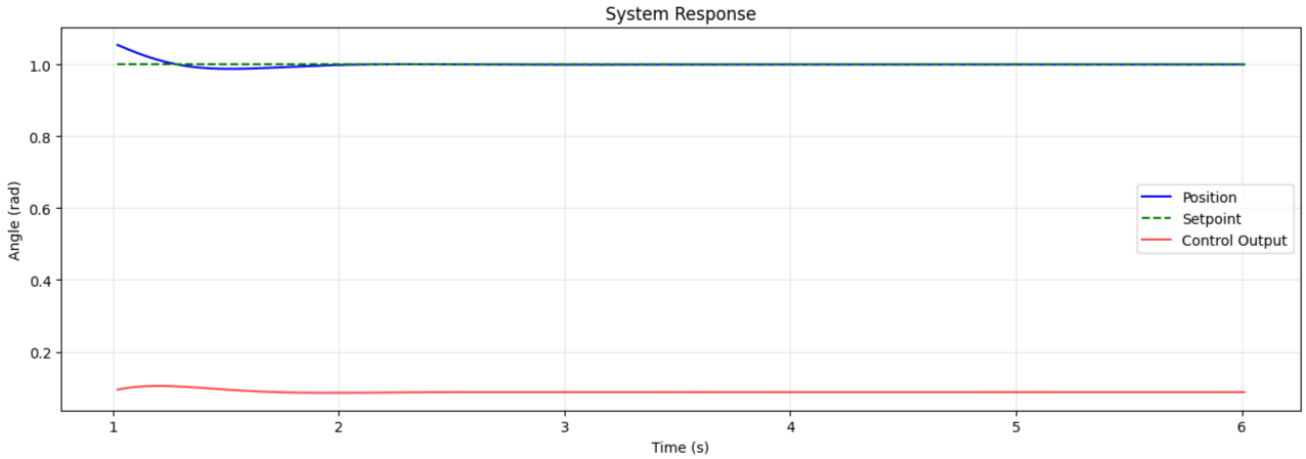
K_p	K_i	K_d
5.4	3.0	1.4



Conclusion : Settling time reduced

Step 4 - Final gain parameters

K_p	K_i	K_d
5.7	3.6	1.45



Conclusion : The gain parameters K_p, K_i and K_d affect the system in the following way :

TABLE 1 Effects of independent P, I, and D tuning on closed-loop response. For example, while K_I and K_D are fixed, increasing K_P alone can decrease rise time, increase overshoot, slightly increase settling time, decrease the steady-state error, and decrease stability margins.

	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
Increasing K_P	Decrease	Increase	Small Increase	Decrease	Degrade
Increasing K_I	Small Decrease	Increase	Increase	Large Decrease	Degrade
Increasing K_D	Small Decrease	Decrease	Decrease	Minor Change	Improve

(*Taken from IEEE Control Systems magazine (Feb 2006 edition)*)