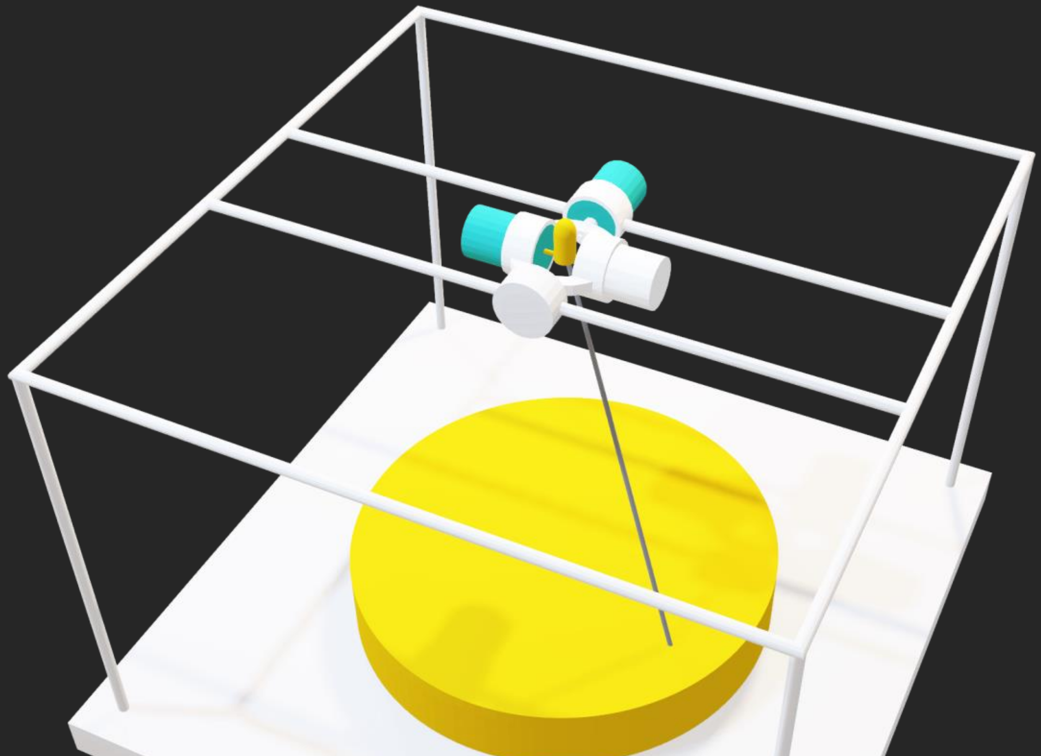
ELEC 341 Design Project

Selective Laser Sintering 3D Printer



Part 2

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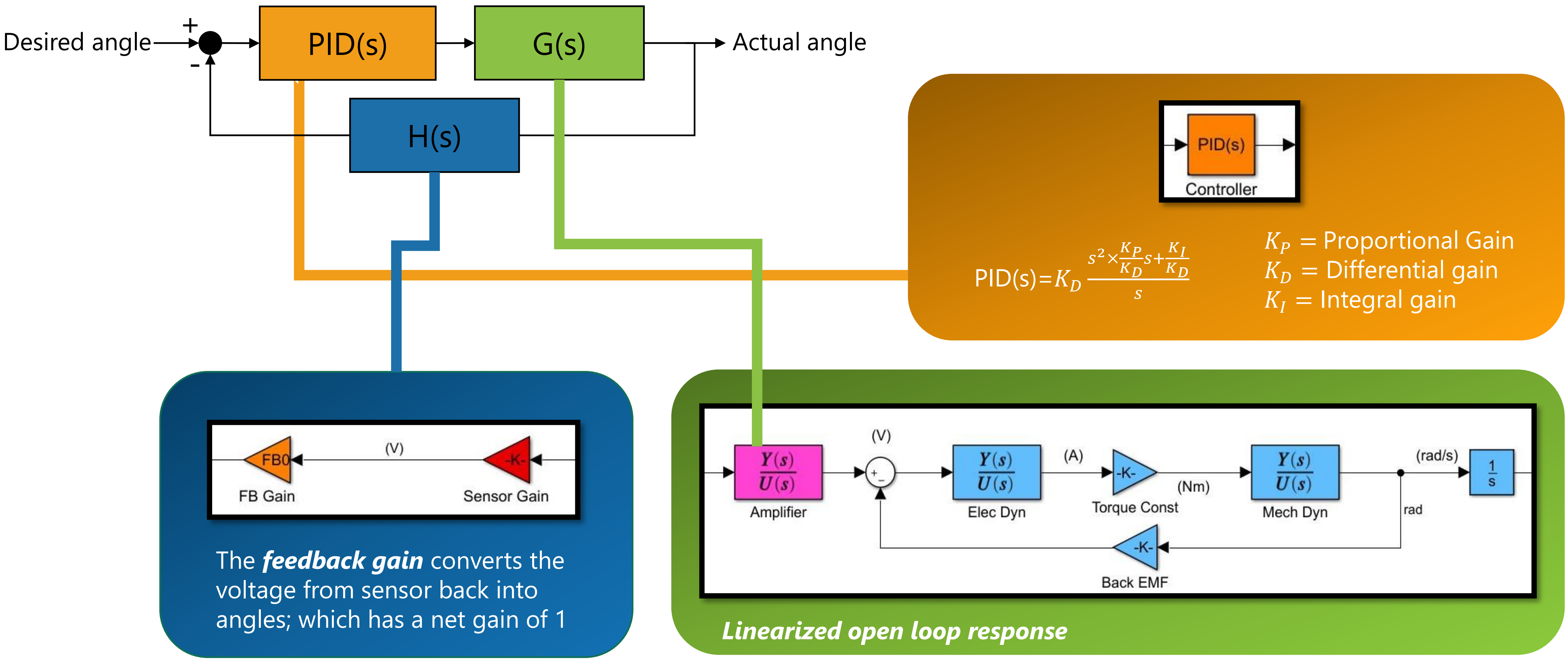
System & Controller Overview



Strategy

To successfully tune our PID to a minimum value, these are the steps we took

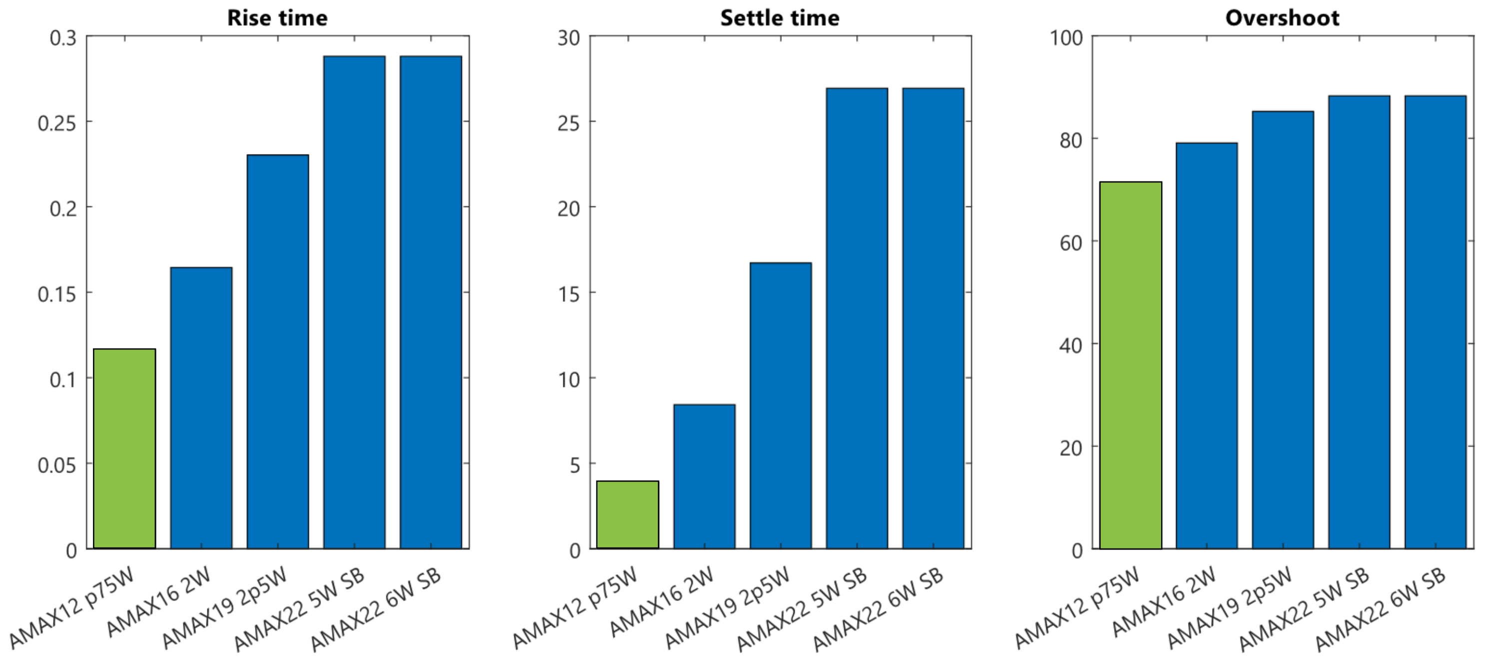
For the gain K, start with K that yields a critical damping

1. **1.** Obtain open-loop transfer function
2. **2.** Choose poles to eliminate
3. **3.** Root locus
4. **4.** Choose K=KD
5. **5.** Obtain KP, KI from KD
6. **6.** Fine tune PID based on system response
7. **7.** Check stability

Motor Selection

Keeping Q0 at default and changing Q1

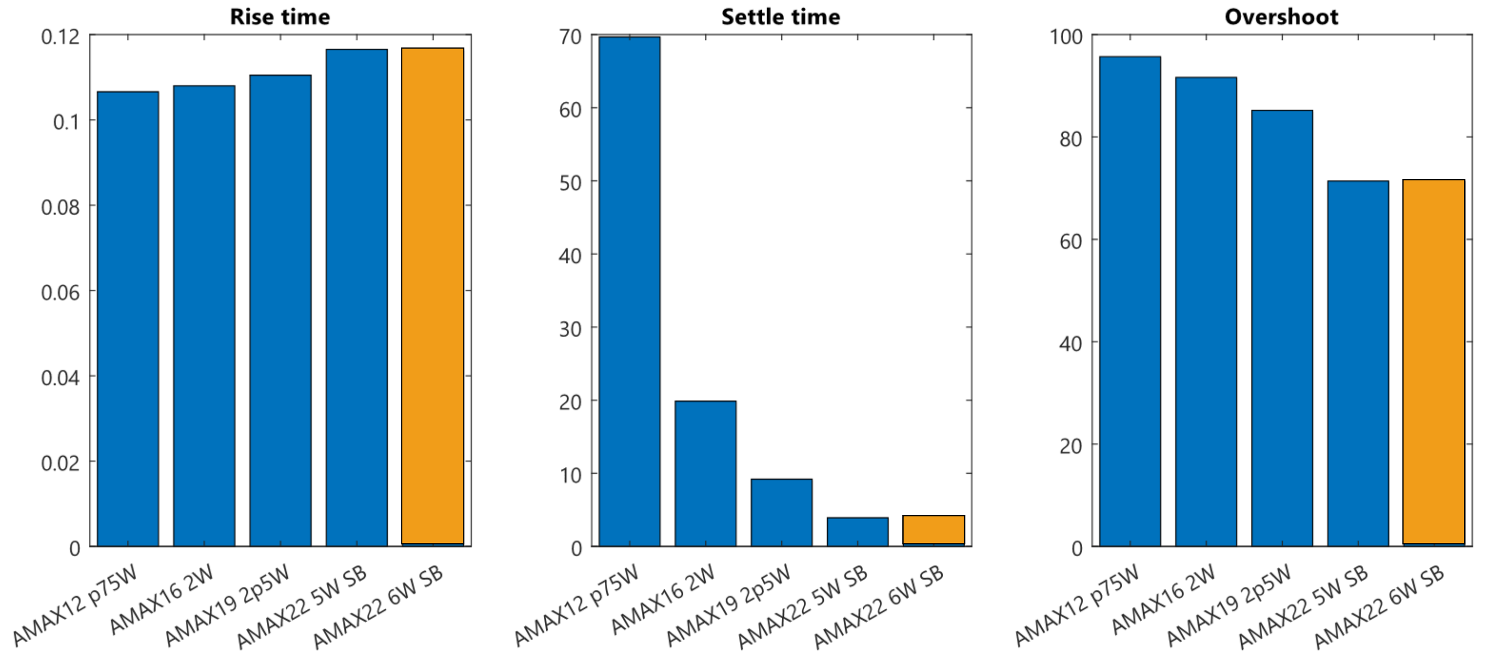
We chose ***AMAX16 p75W SB*** motor as it outperforms all other motor and it's lightweight – reducing load for the outer motor



Keeping Q1 as *AMAX16 p75W SB* motor and changing Q0:

The 6W motor has highest risetime, but performs much better in other criteria

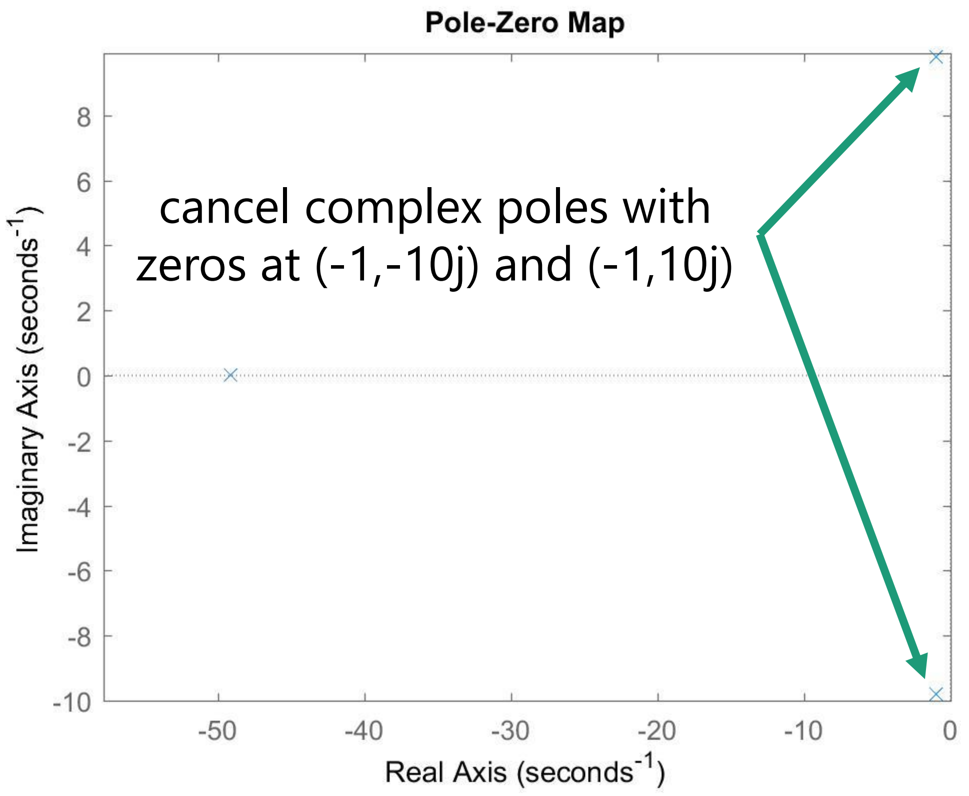
Ultimately, we chose ***AMAX22 6W SB*** motor as it provided maximum power and torque – good for heavier loads



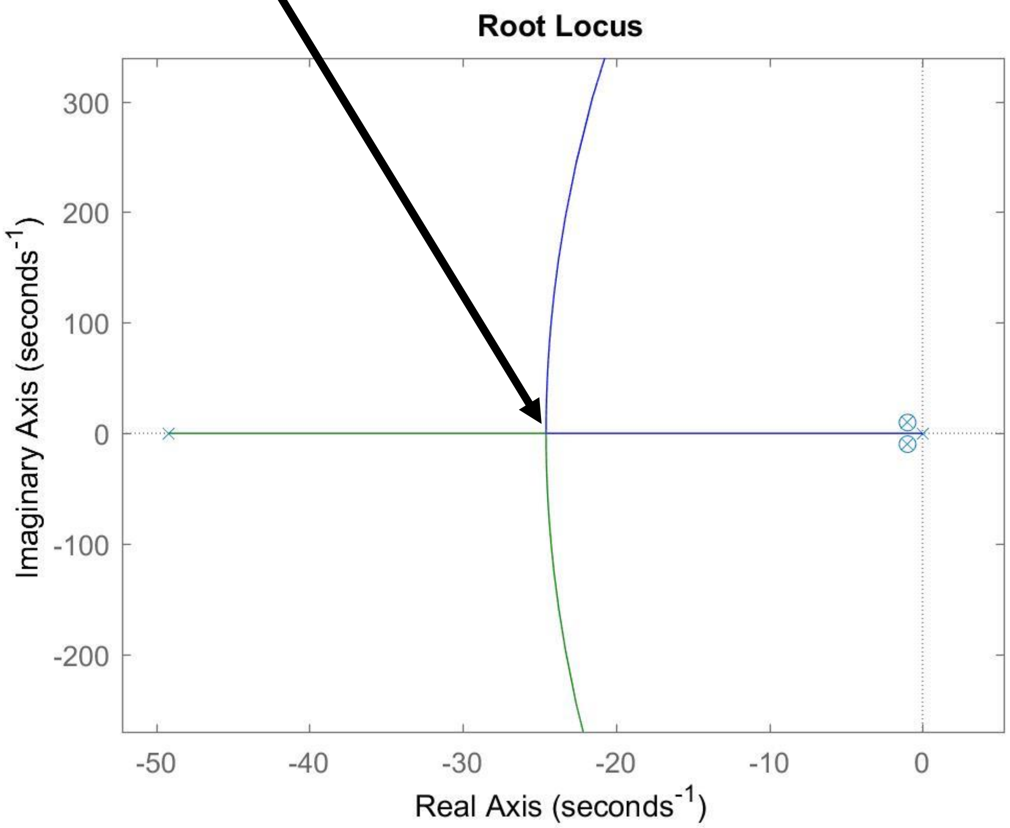
System Review (q0)

Open Loop Transfer function (q0)

$$\frac{1.2815 \times 10^{8}}{(s + 1.523 \times 10^{4})(s + 49.17)(s^{2} + 1.95s + 96.77)}$$



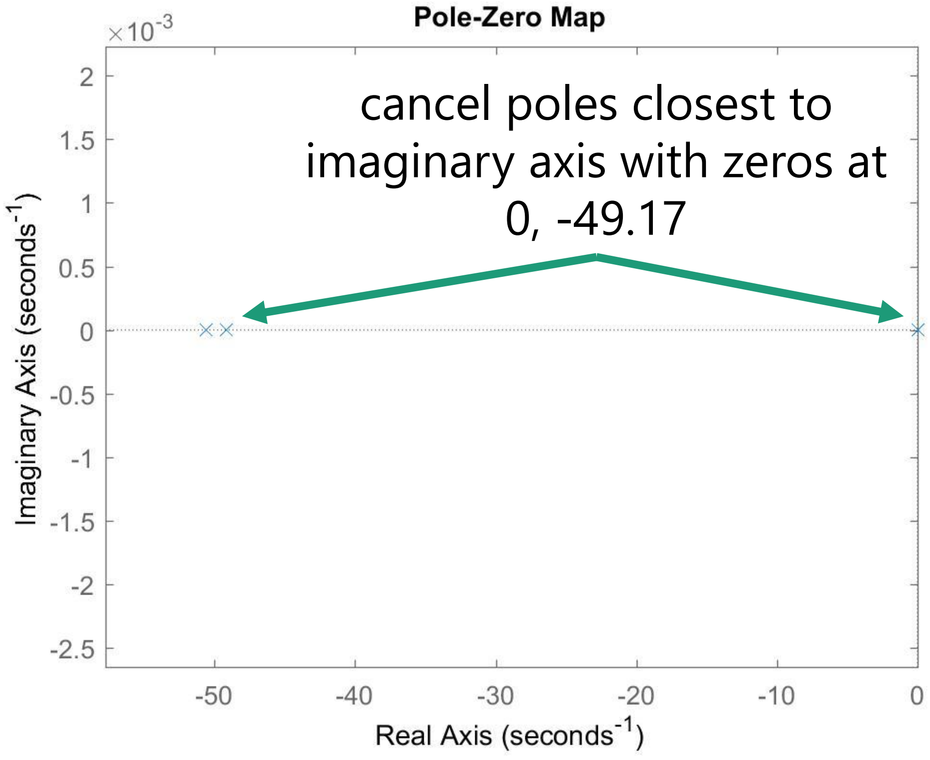
Choose K=0.0648
for critical damping



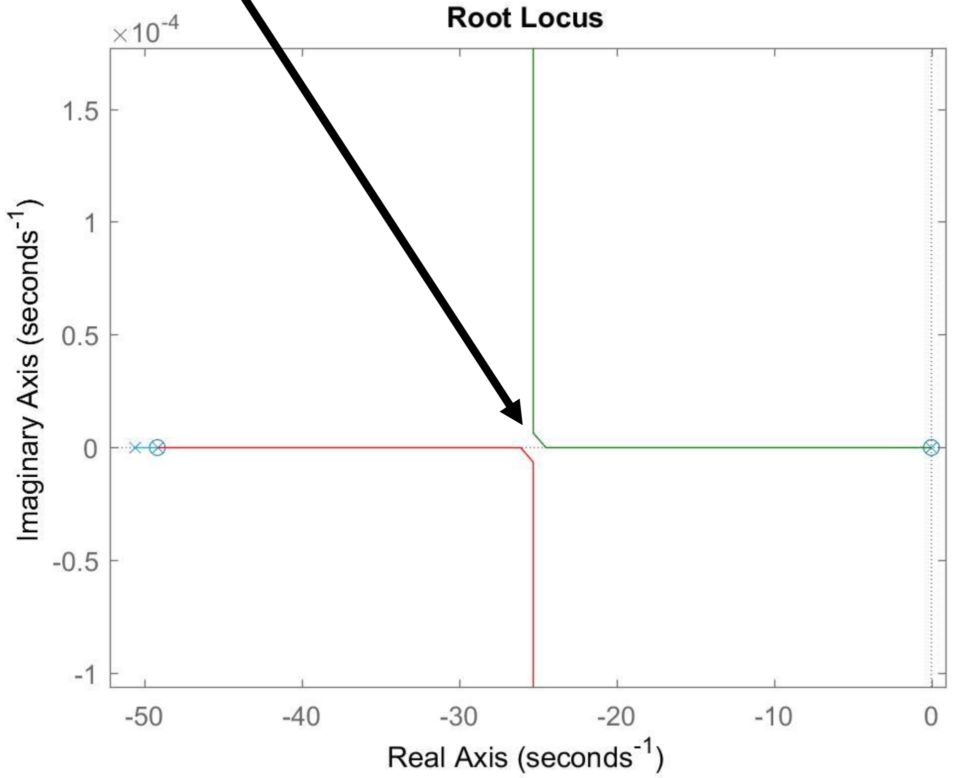
System Review (q1)

Open Loop Transfer function (q1)

$$\frac{1.4146 \times 10^{10}}{s(s + 4.045 \times 10^{4})(s + 50.6)(s + 49.17)}$$



Choose K=0.0028 for critical damping



PID Tuning

The PID for Q0 is adequate from the starting values, but the risetime is too long, so we increased D-gain and I-gain. This caused more overshoot so we decreased P gain

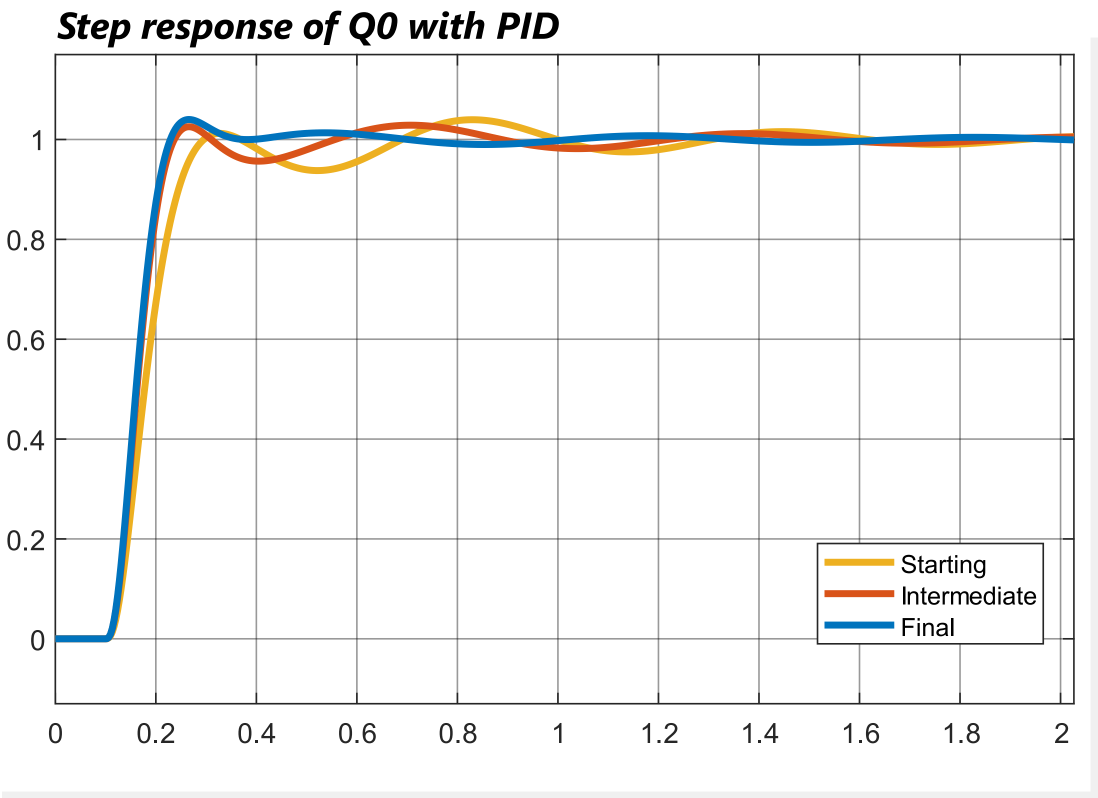
	Rise Time	***Overshoot***	***Settle Time***	***Steady State Error***
K_P	↓	↑	↑	↓
K_I	↓	↑	↑	Eliminate
K_D	↑	↓	↓	No effect

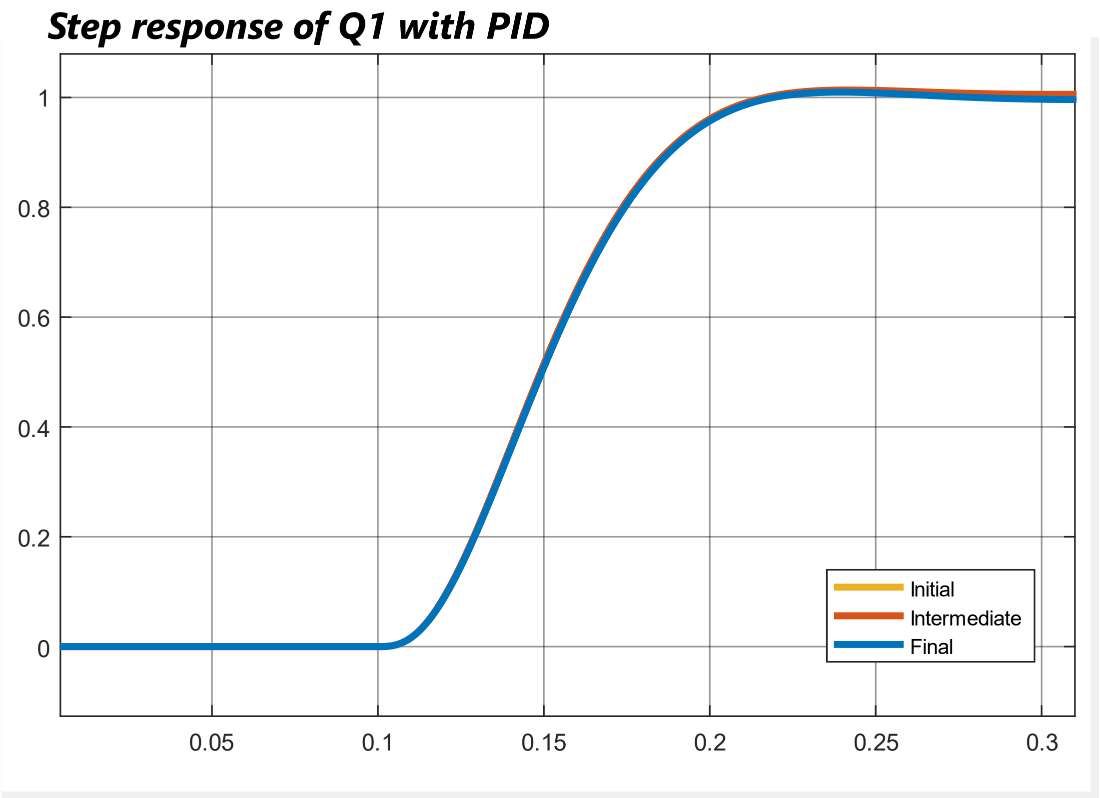
	Q0			***Q1***		
	P-gain	I-gain	D-gain	P-gain	I-gain	D-gain
Starting	0.1464	6.2707	0.0648	0.1377	0.00	0.0028
Intermediate	0.123	8.470	0.0940	0.1360	0.03	0.0029
Final	0.070	9.650	0.100	0.1366	0.00	0.0028

Progression of PID Tuning

Risetime and settling time for Q0 improved drastically after fine tuning. Overshoot is decreased as well

Motor Q1 had a good starting point as it is easier to control. Fine tuning reduced overshoot

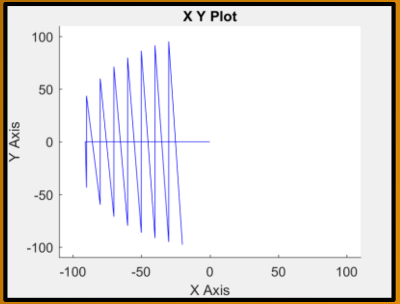


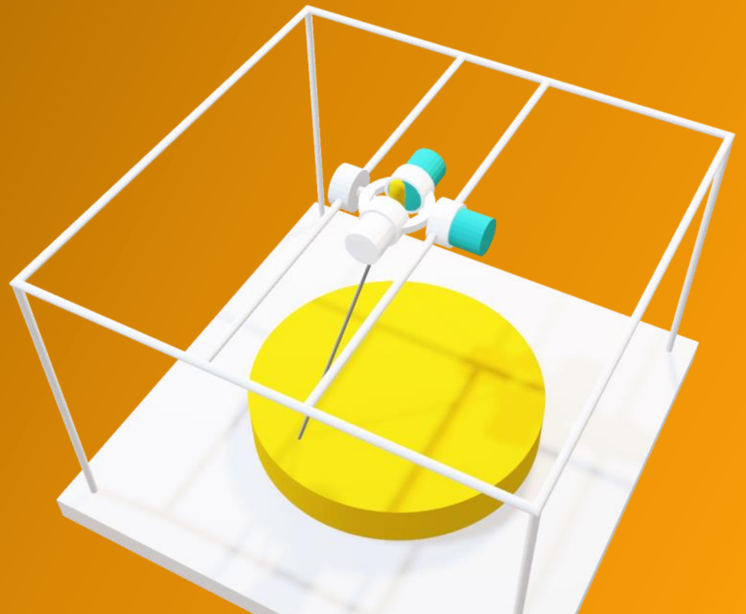


Simulation Results

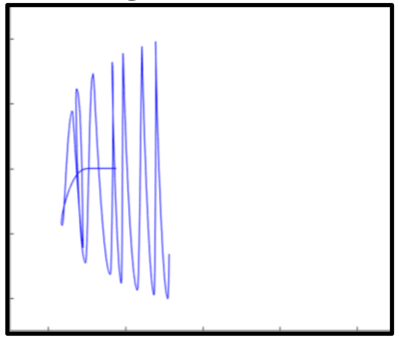
Simulation is ran with PID tuned at different stages: start, intermediate, and final. The maximum position error is reduced drastically

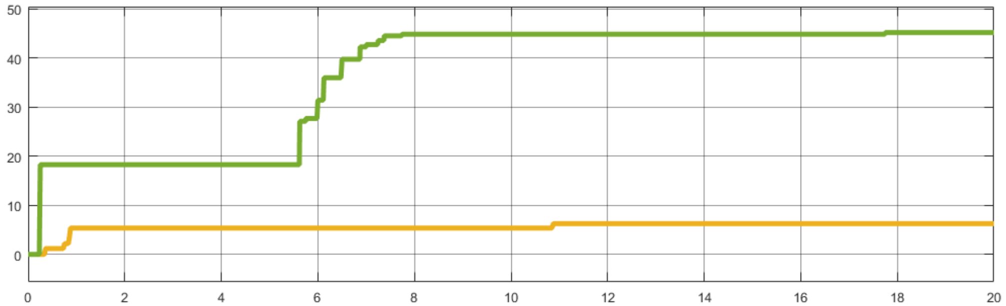
Desired position





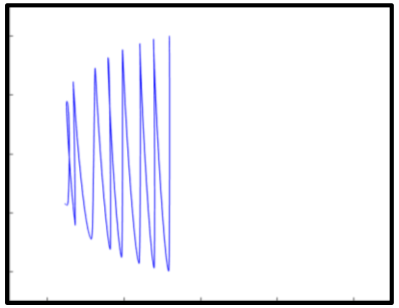
Starting

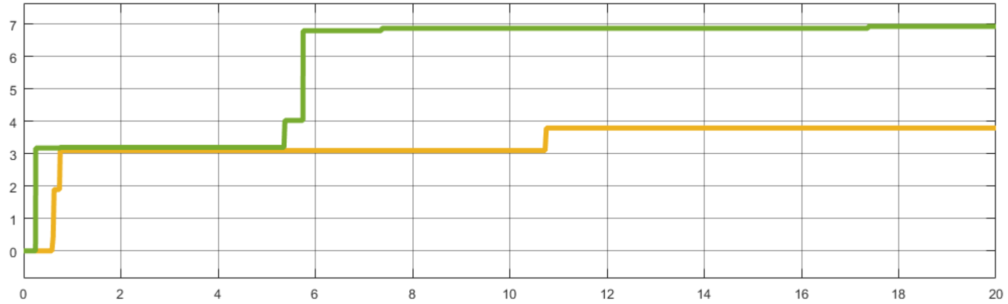




Max. position error: 45.2

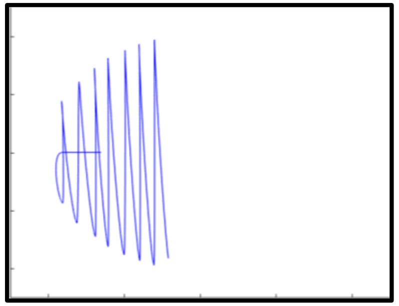
Intermediate

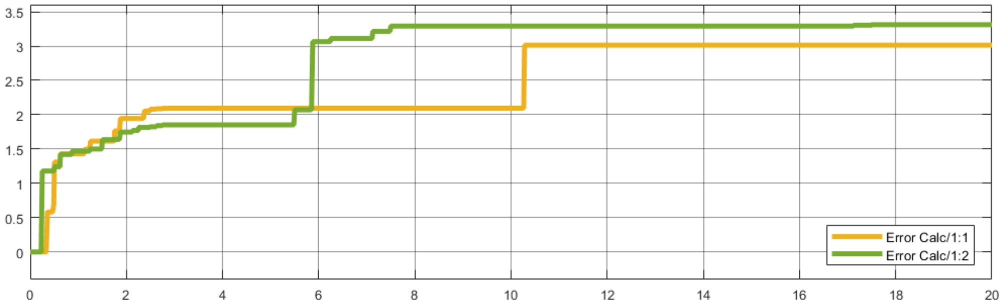




Max. position error: 6.98

Final





Max. position error: 3.29

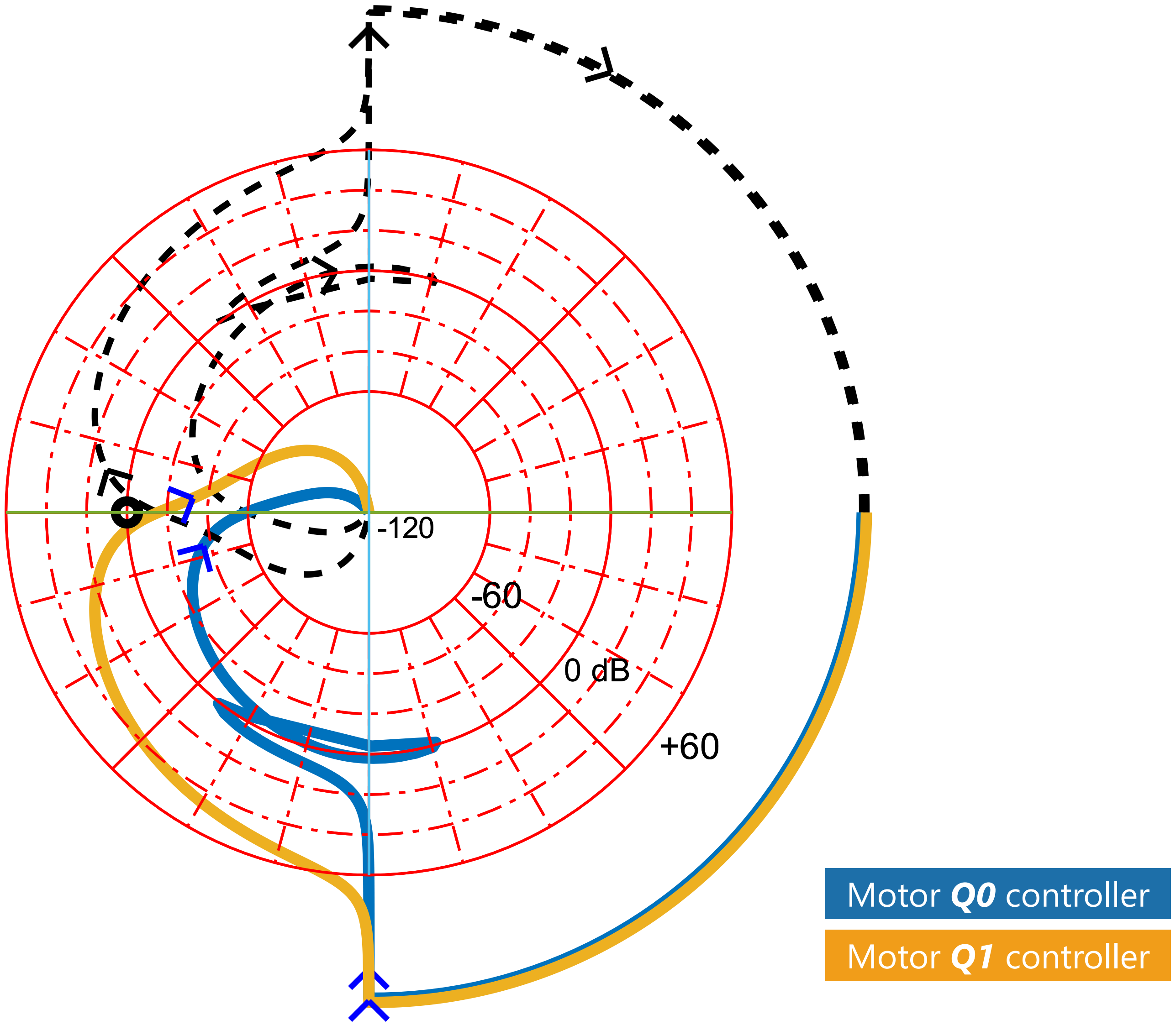
Nyquist Stability Criteria

The Nyquist stability criterion plot is used to determine how close our system with PID is to unstable

The system with finalized PID values is ***stable*** as seen in the Nyquist plot

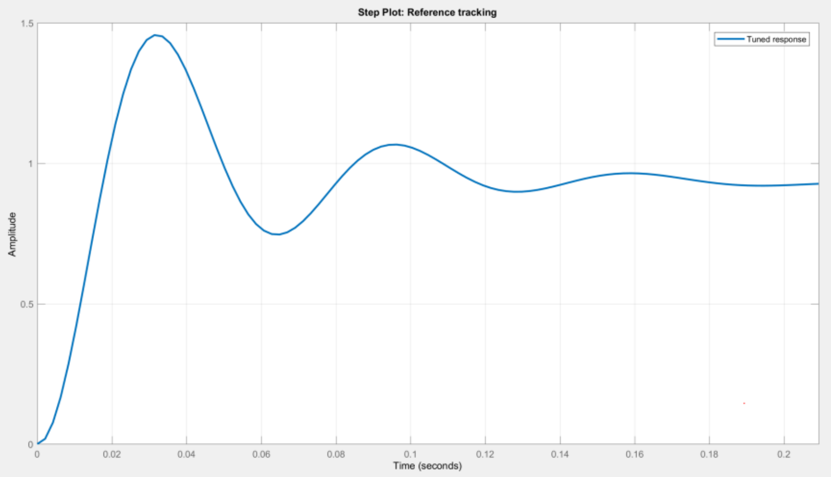
Q0
Gain margin: ***59.2 dB***
Phase margin: ***52 degrees***

Q1
Gain margin: ***15.4 dB***
Phase margin: ***4.1 degrees***

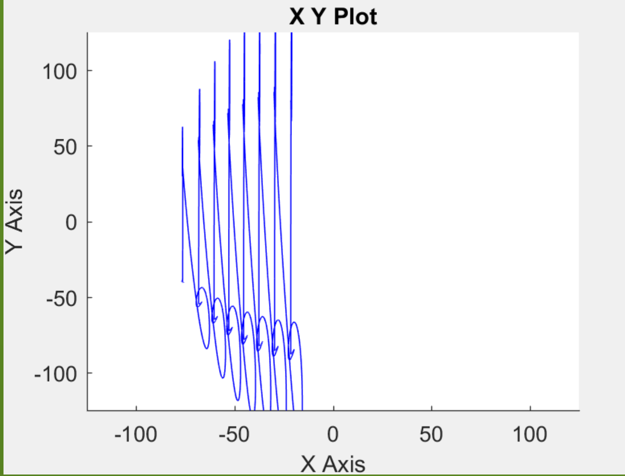


Result of PID Auto Tuner

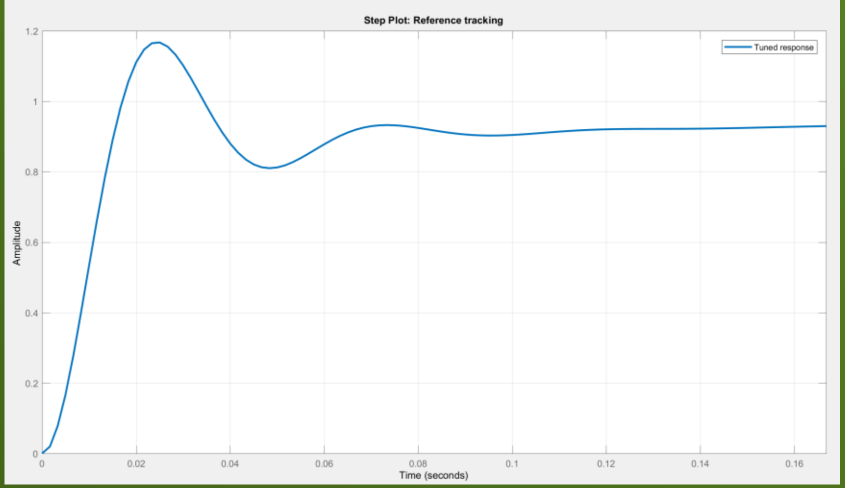
Step response of Q0 with PID tuner



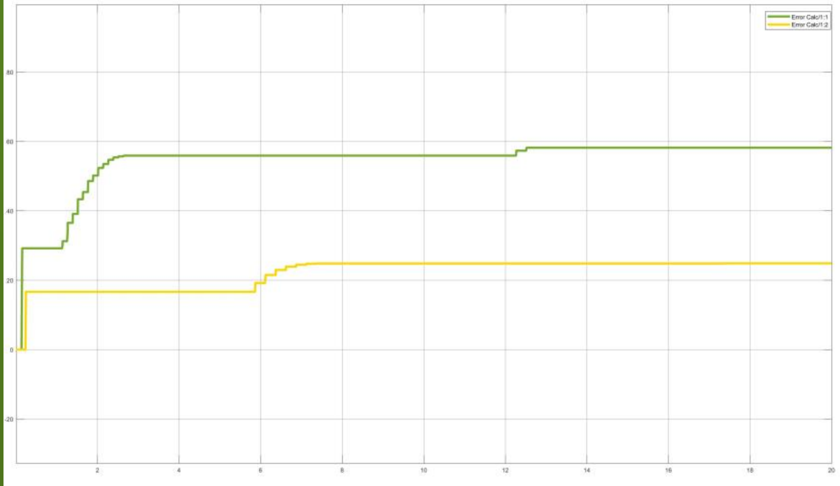
Actual position



Step response of Q1 with PID tuner



Position error



Max. position error: 58.18

Less control over steady state error

Greater instability

Tuning by hand is the better method

Q0 auto tune PID

Proportional (P):	3.03054287543802
Integral (I):	1.68965274804233
Derivative (D):	1.20771477017914
Filter coefficient (N):	10921.863844033

Q1 auto tune PID

Proportional (P):	0.151813497662589
Integral (I):	0.106208839744898
Derivative (D):	0.0482148787737828
Filter coefficient (N):	13704.7150537379