AERO Lab 5

Submitters:

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1. Pre Lab

Part 1 – Qualitative PID Control

Preparation questions

Q1) The unit step response in Laplace plain is given by

$res(s) = u(s) \cdot H(s)$, where u(s) is the step function and H(s) is the transfer function

$res(s) = \frac{1}{s} \cdot H(s)$. So, for deriving the transfer function of a linear system from its unit step response res(t) we can use Laplace transform $Laplace\ \{res(t)\} = res(s) = \frac{1}{s} \cdot H(s)$.

Therefore,

H(s)=s· $res(s)$ and therefore, h(t)= Inverse Laplace {H(s)} =

Inverse Laplace {s· $res(s)$}

Q2)

$$Y_{step} = 1 - \frac{e^{\xi w_n t}}{\sqrt{1-\zeta^2}} \cdot Sin(\sqrt{1-\zeta^2} \cdot w_n t + \emptyset)$$

(I) $\sigma = e^{-\frac{\xi\pi}{\sqrt{1-\zeta^2}}}$

(II) $t_s = \frac{3}{\xi w_n}$

From the plot we can find the overshoot and the settling time. So, by using these values and both equations we can find w_n and ξ.

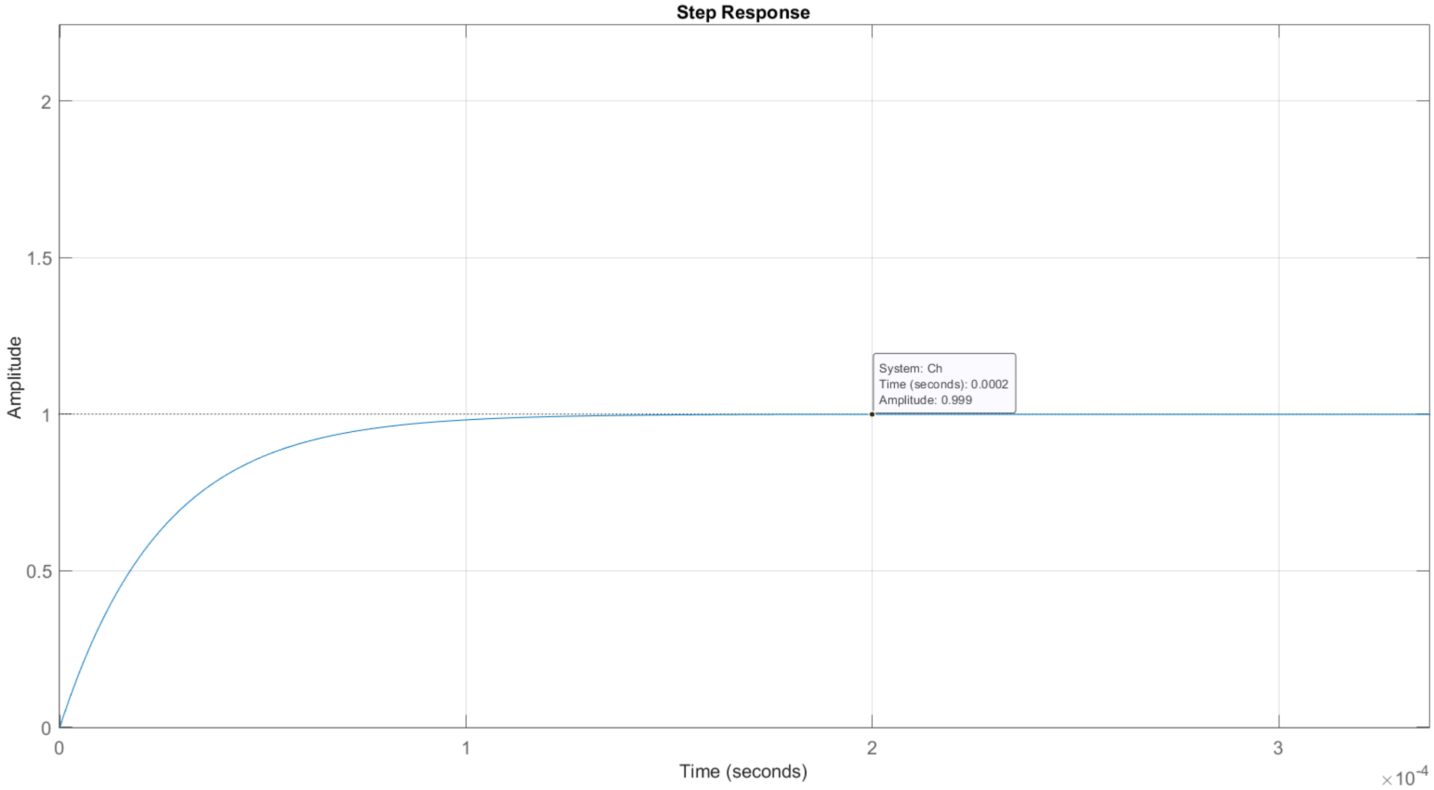
Q3)

we want to find a PID controller that will satisfy:

Overshoot = 0, $e_{ss} = 0$, S.t<0.25

For: $C(s) = K_p + \frac{Ki}{s} + K_D \cdot s\ and\ G(s) = \frac{1}{s^2+5s+10}$ in a closed loop for

a step response.



The specifications were satisfied with $K_D = 40{,}000, K_p = 25, K_s = 20.34$

A very large K_D was needed for the chosen $K_p and\ K_s$ in order to reduce the steady state error to zero.

Part 2 – Aero Simulation

Preparation questions

1. The state variables for the Aero simulation can be identified from the output of the Flight Dynamics/Visualization block. Based on the diagram, the state variables appear to be:
   X: Horizontal position or sway
   Z: Vertical position or altitude
   Pitch: The angular position around the lateral axis
   These variables represent the dynamic state of the simulated vehicle.

2. Each PID controller has two main inputs and one output: Input r (reference input): This represents the desired command or setpoint. Input y (measured output): This represents the current state of the system. Output u: This represents the control signal that is sent to the actuator to minimize the error (difference between the reference input and the measured output). Based on the diagram:

- Sway PID Controller:

  Input r: Target X

  Input y: X (current horizontal position)

  Output u: Control signal for sway adjustment

- Pitch PID Controller:

  Input r: Target Z

  Input y: Pitch (current angular position)

  Output u: Control signal for pitch adjustment

- Throttle PID Controller:

  Input r: Target Z

  Input y: Z (current vertical position)

  Output u: Control signal for throttle adjustment

3. To create a simplified block diagram, we need to outline the state variables, command variables, and indicate which controller is in parallel and which is in a cascade configuration.

- State Variables:

  X (Horizontal position)

  Z (Vertical position)

  Pitch (Angular position)

- Command Variables:

  Target X (desired horizontal position)

  Target Z (desired vertical position)

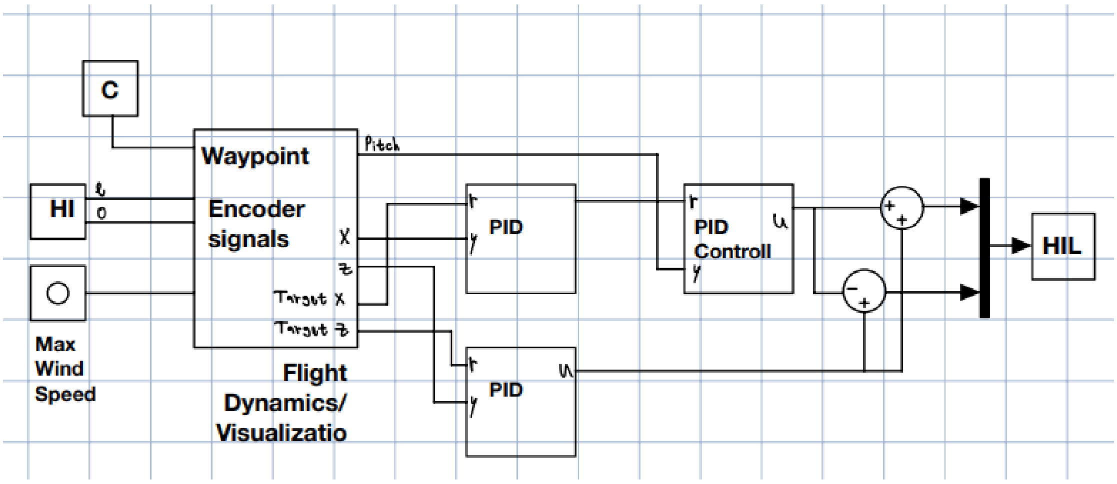
Pitch (desired pitch angle)

- Parallel and Cascade Configurations:

  Parallel Configuration: Sway PID Controller and Throttle PID Controller both receive their respective setpoints and control their specific state variables independently.

  Cascade Configuration: The output of the Pitch PID Controller feeds into the Throttle PID Controller, indicating a cascade configuration where pitch adjustment influences throttle control.

  Simplified block diagram:



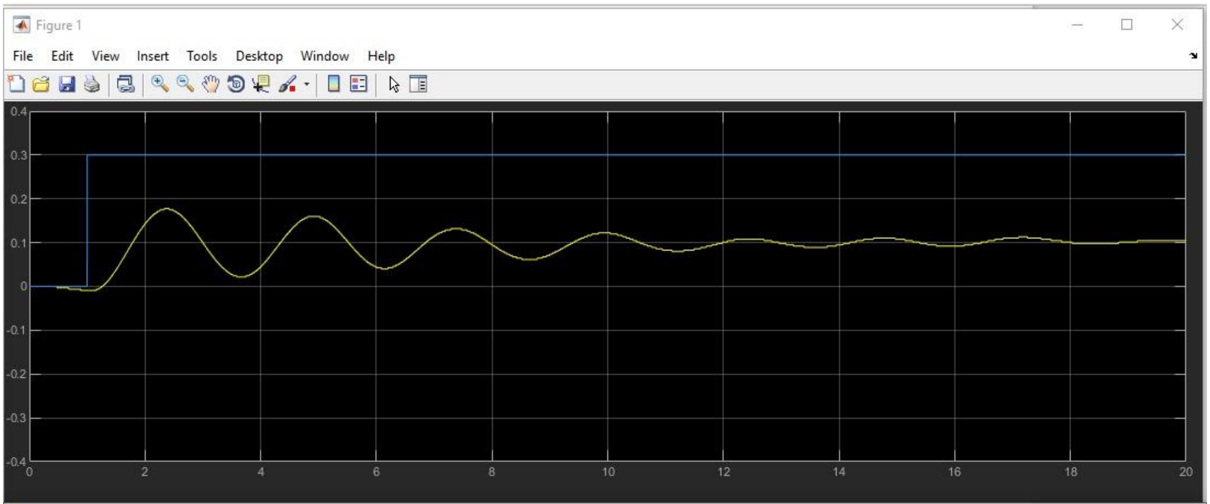
Part 1 – Qualitative PID Control

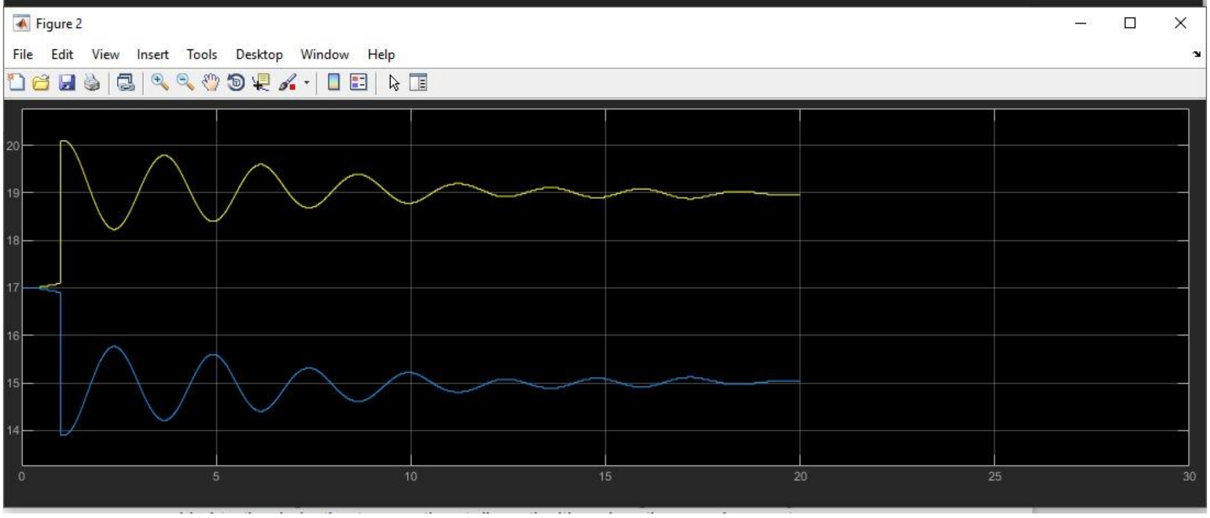
In lab questions

2. In Lab

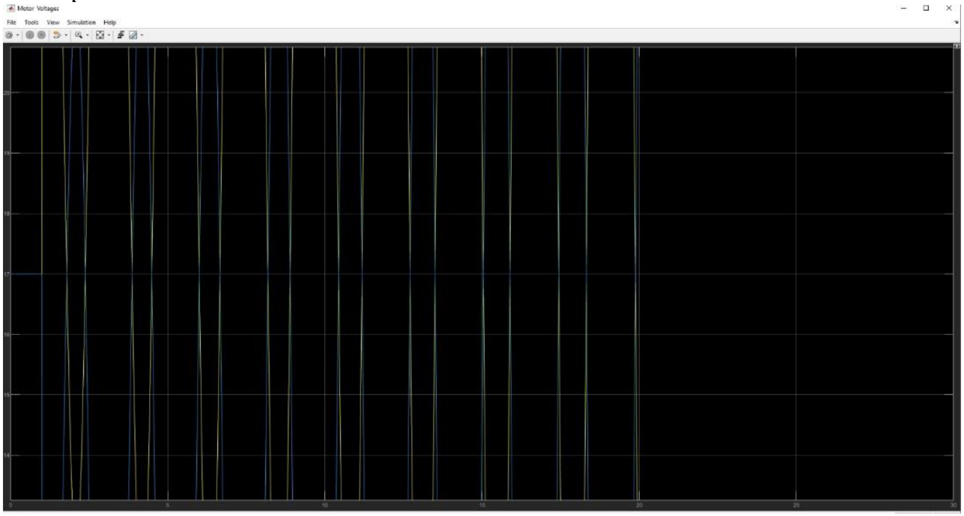
2.1 Proportional Control

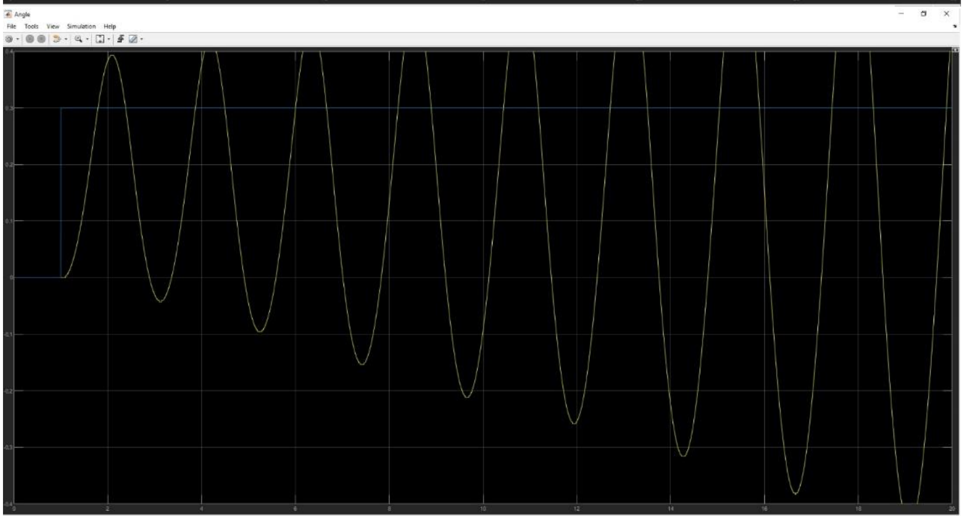
2. Build and run the QUARC® controller:



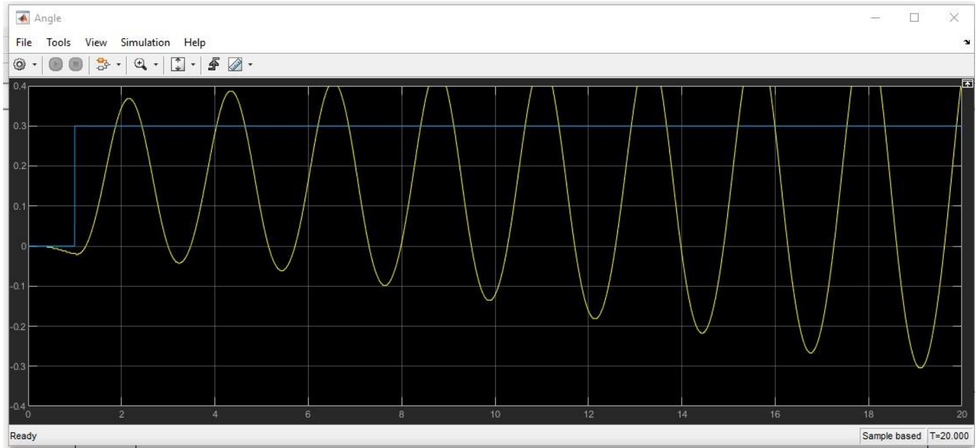


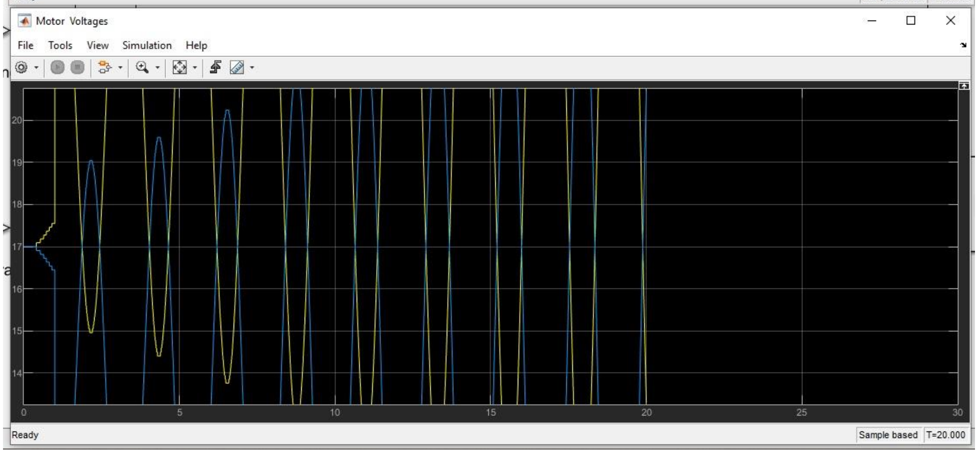
3. For $k_p = 50$:


Motor Voltages
File Tools View Simulation Help


Angle
File Tools View Simulation Help

For $k_p = 30$:





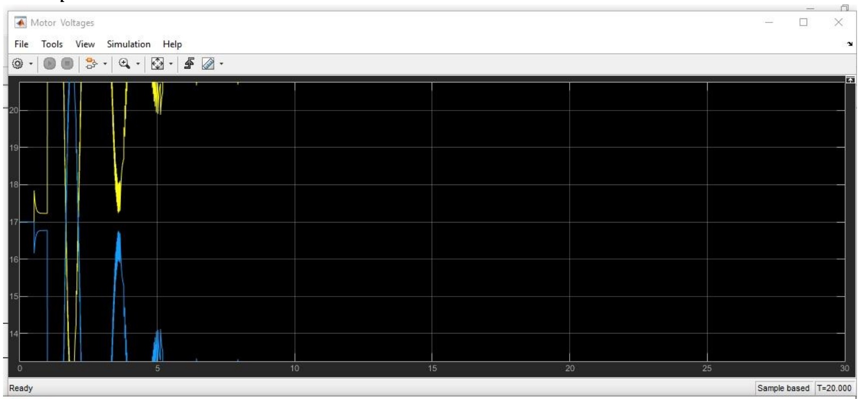
Overall, we can see that as the Kp gets larger, the system become less stable. large proportional gains lead to a system with large overshoot, which oscillate for a long time.

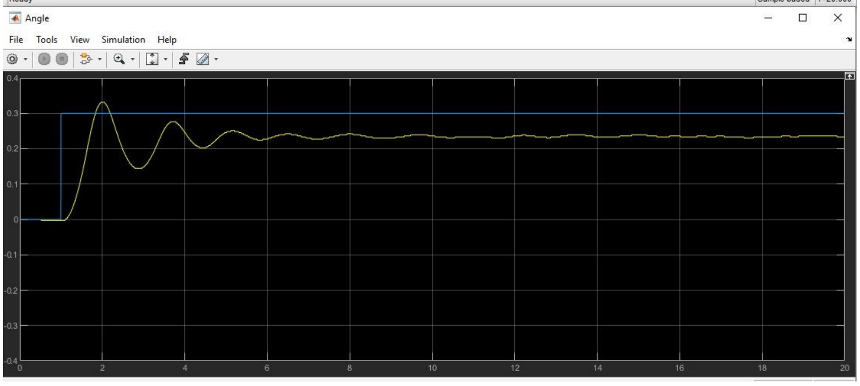
4. No. Although greater proportional gain will result in a system with a shorter rise time, it will also lead to a system with large overshoot, which oscillate for a long time. Our goal is to have stable system, it is not practical to use purely proportional control for shorter rise time if the system will not be stable.

2.2 Derivative Control

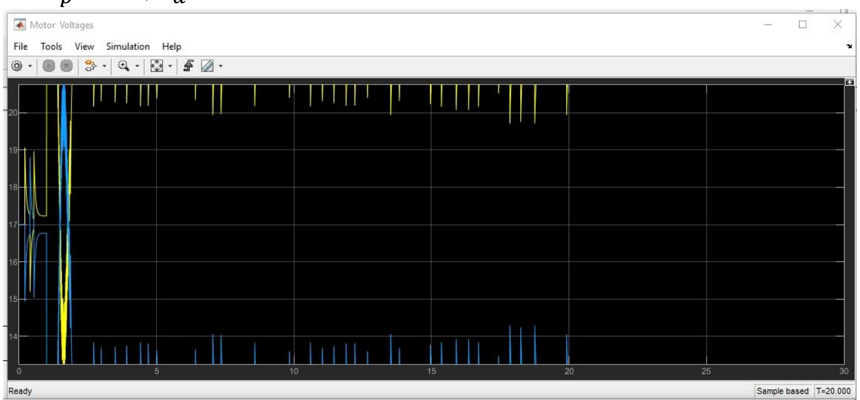
2.

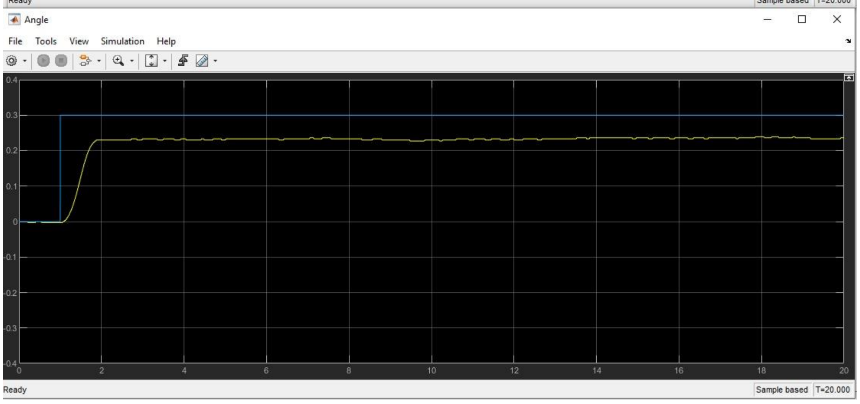
for $k_p = 75, k_d = 10$:



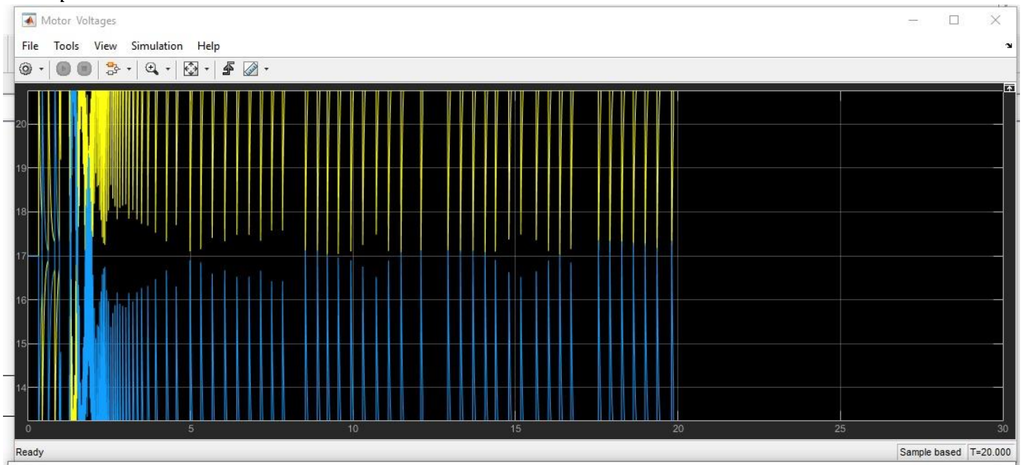


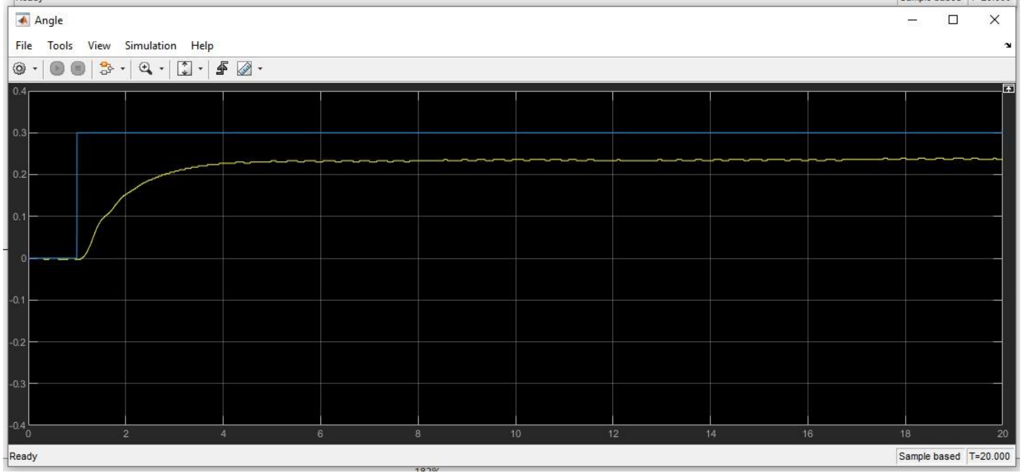
for $k_p = 75, k_d = 30$:



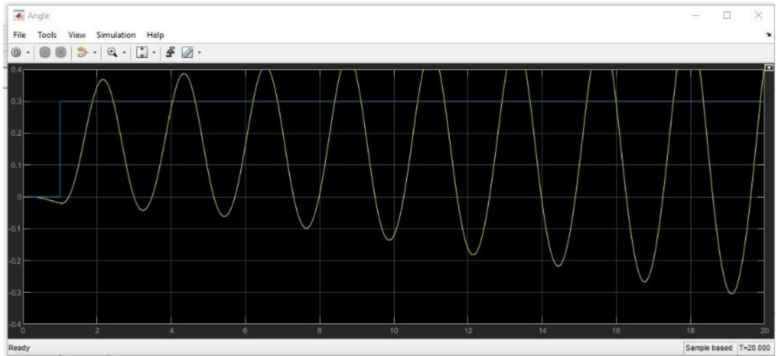


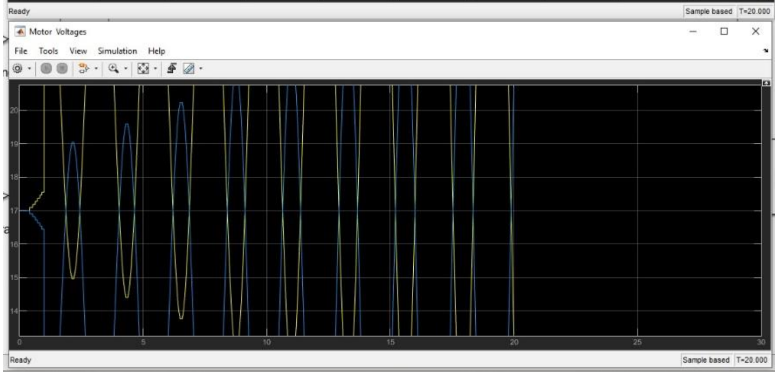
for $k_p = 75, k_d = 80$:





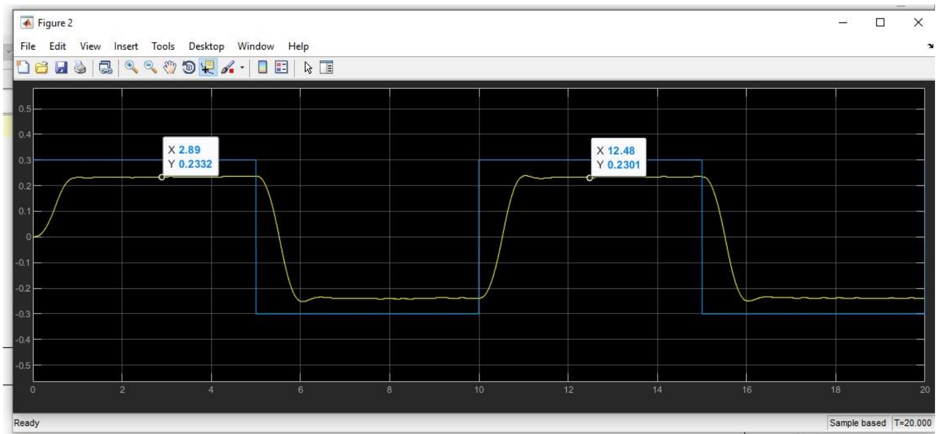
for $k_p = 75, k_d = 0.5$(very small):

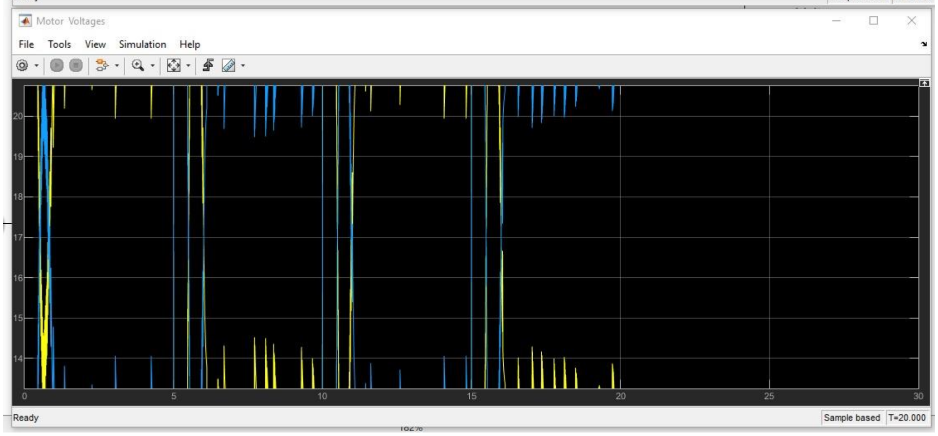




As the Kd gets larger, the system become more stable and with less (up to without) overshoot. Small value of Kd will give us the opposite the system become not stable

4. for $k_d = 30$ we got the acceptable OS :

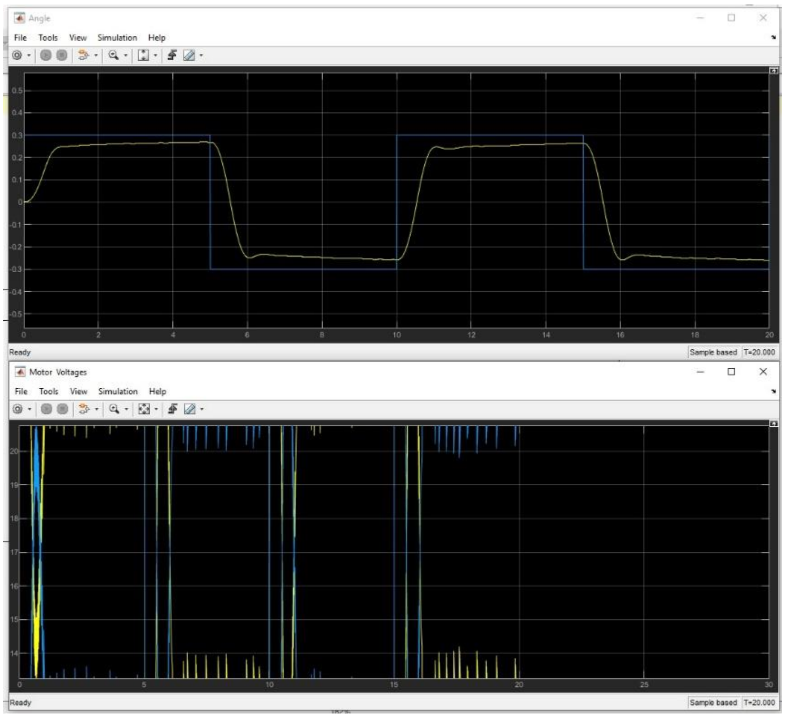




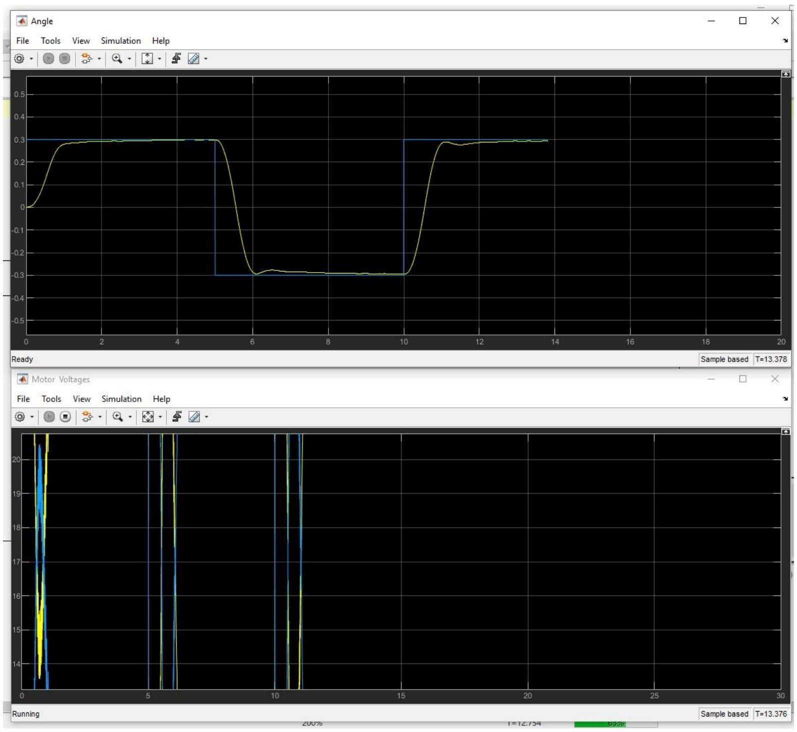
2.3 Integral Control

2. There is a range of Ki (up to about 50) that the integral control changes the system response to be closer to the input value (with the previous Kp and Kd) – increasing the magnitude and without overshoot. If the Ki increasing too much we will get an overshoot in the system.

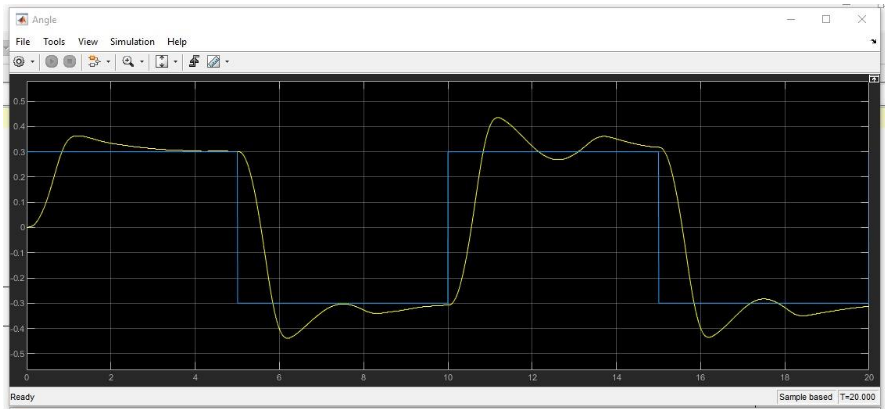
For $k_i = 10$:

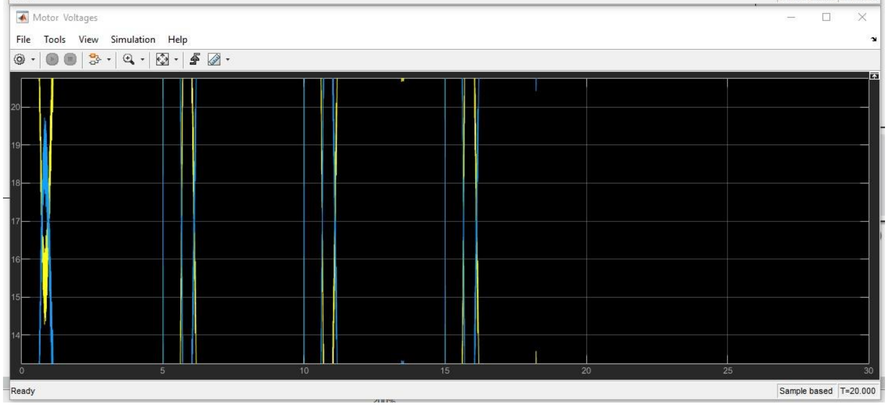


For $k_i = 30$:

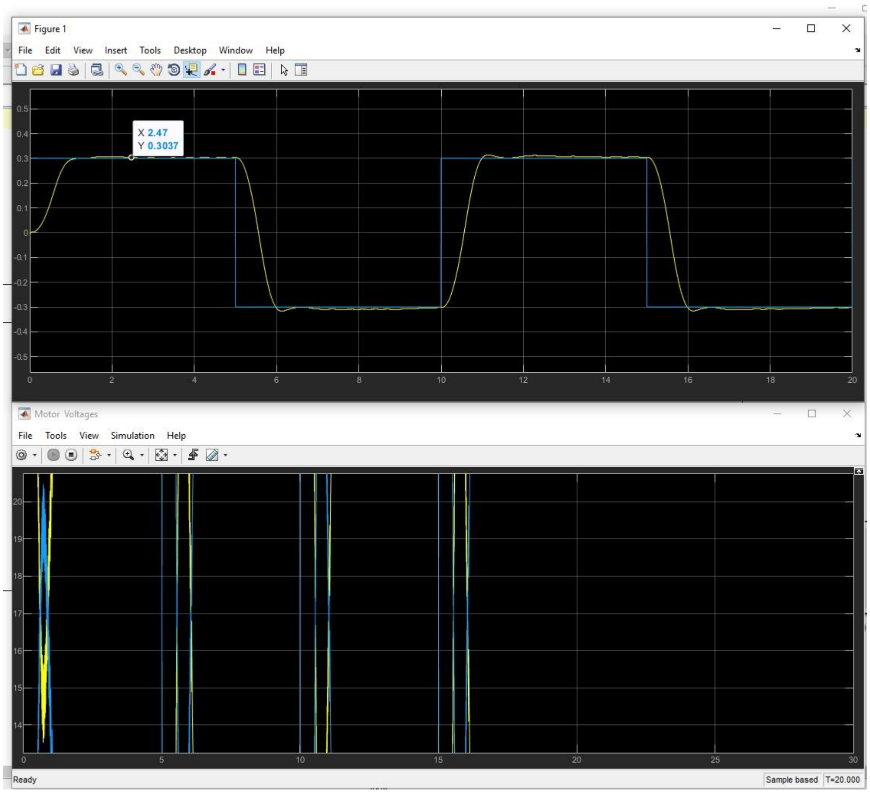


For $k_i = 80$:


Angle
File Tools View Simulation Help
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0 2 4 6 8 10 12 14 16 18 20
Ready
Sample based
T=20.000


Motor Voltages
File Tools View Simulation Help
20
19
18
17
16
15
14
0 5 10 15 20 25 30
Ready
Sample based
T=20.000

3. Choosing $K_i = 40, K_d = 30, K_p = 75$ – we get the response as required:



2.4 Response Tuning

It matches 😊

Part 2 – Aero Simulation

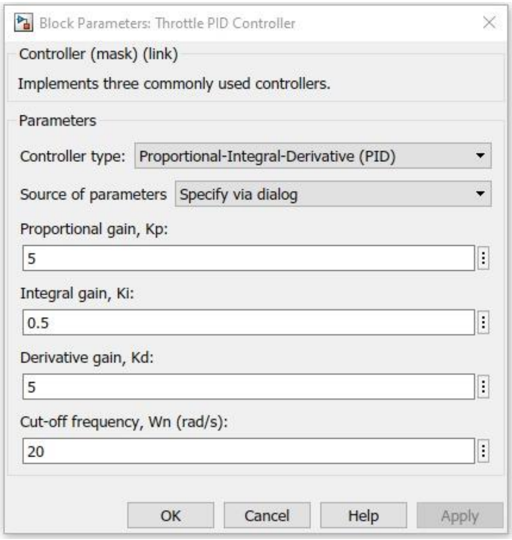
In lab questions

2. In Lab

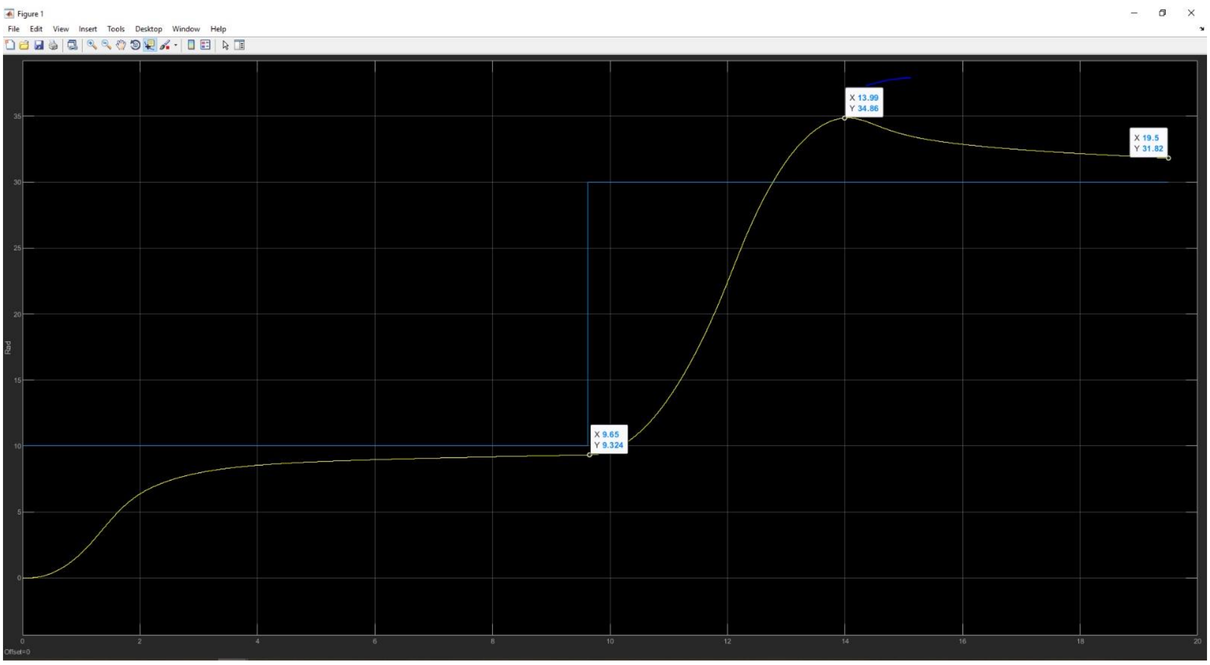
2.1 Throttle PID Controller

2. $K_i = 40, K_d = 30, K_p = 75$

3. The parameters:



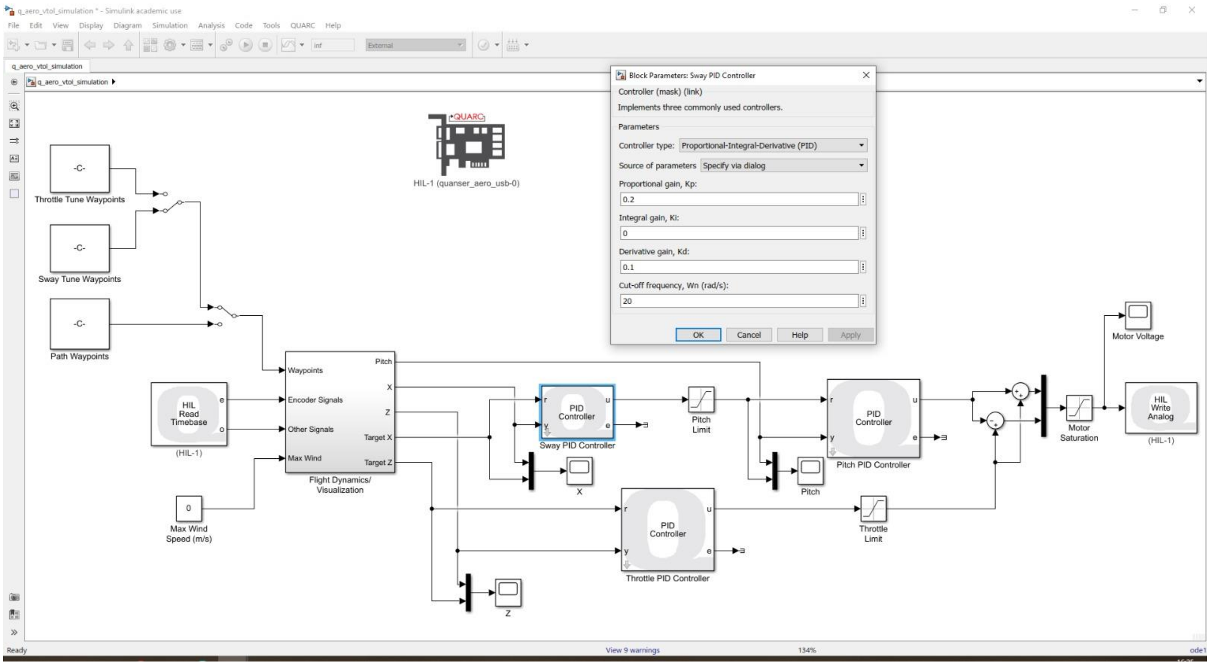
We got:



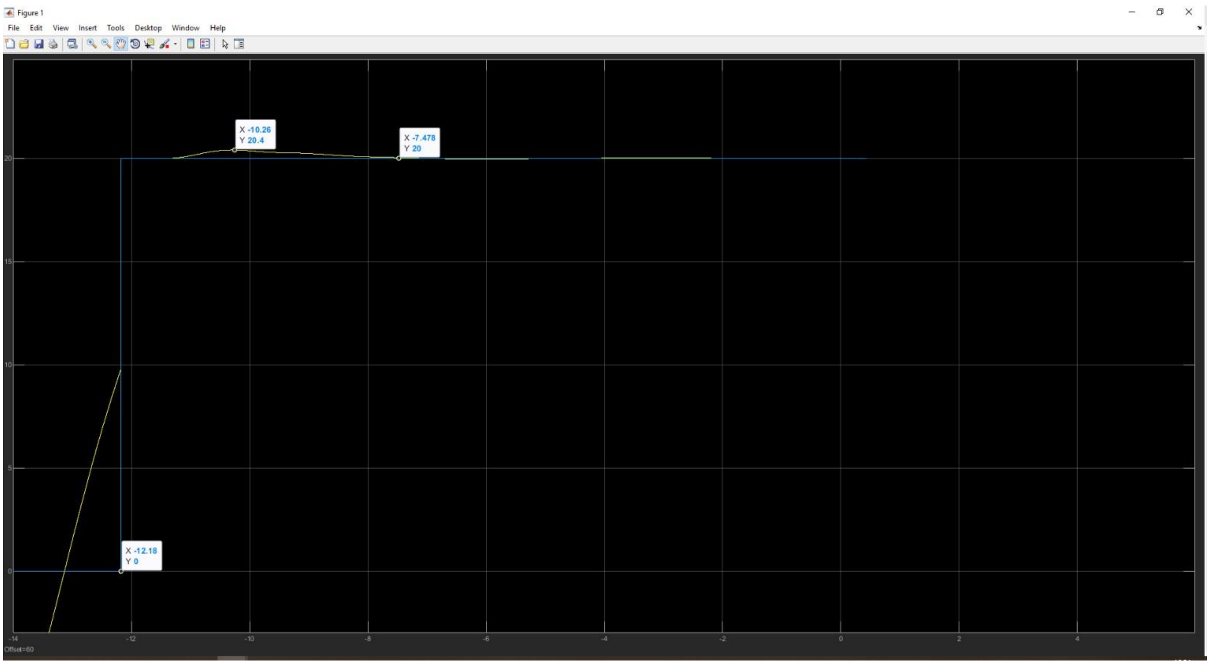
$$OS = \frac{34.86 - 30}{30} \cdot 100 = 16.2\%, t_{set} = 19.5 - 9.65 = 9.85 \text{ sec}$$

We can see z axis position is achieved.

5. The parameters:



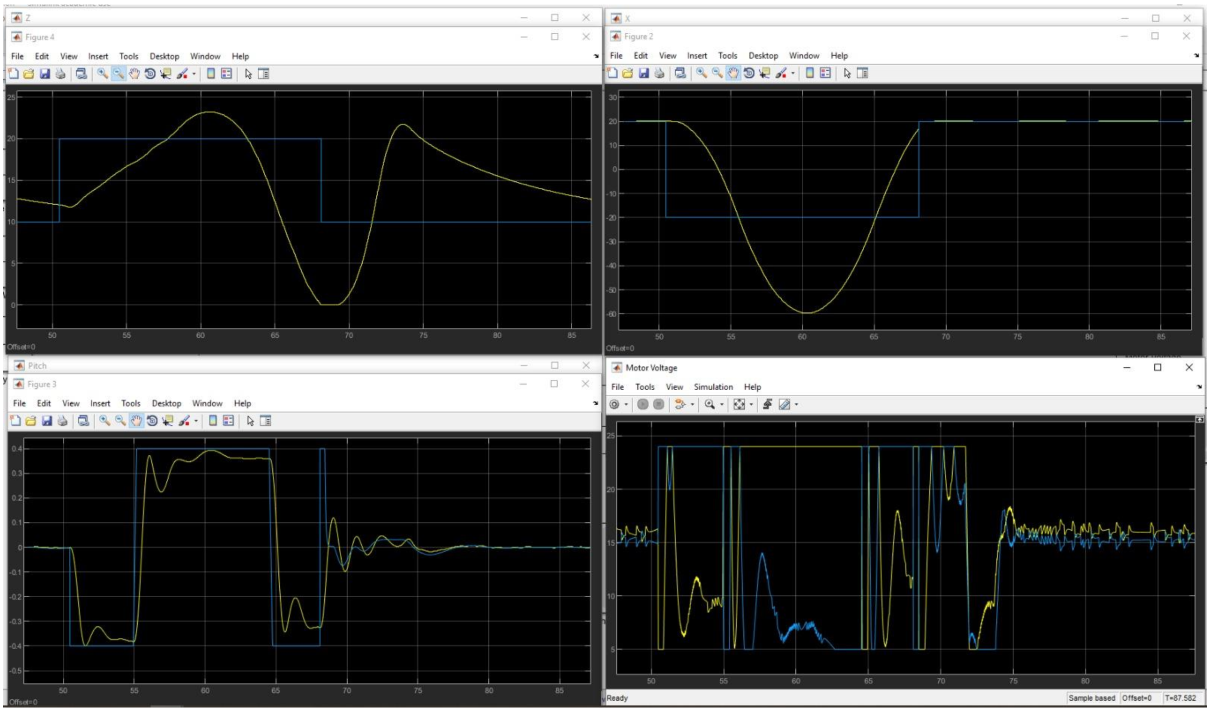
We got:



$$\mathrm{OS} = \frac{20.4 - 20}{20} \cdot 100 = 2\%, \mathrm{t_{set}} = 7.4 \text{ sec}$$

Considering the response time of the inner loop and the outer loop for a cascade controller configuration, it is essential to ensure that the inner loop is significantly faster and well-tuned to handle its dynamics independently, allowing the outer loop to operate effectively with an assumption of near-instantaneous inner loop response.

6. We got:



The responses indicate that there is some level of interaction between the x-axis and z-axis commands. When a command is applied along one axis, it appears to influence the response along the other axis. This is evident from the oscillations and changes in the response curves when the command signals change.

In our case and our parameters, the assumption of independence and minimal interaction in a parallel control configuration does not hold for the observed system, we should have change the sways parameters more for better results but due to the time in the lab we couldn't change more values.