Summary:

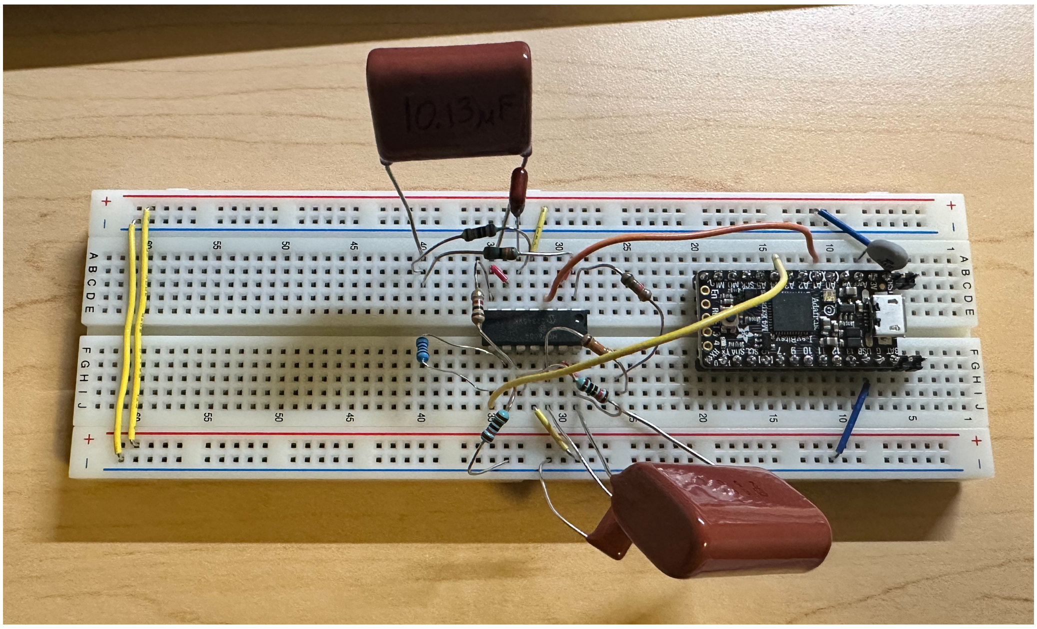
In our laboratory, we are focusing on the Proportional-Integral-Derivative (PID) design of a 4th order system. Compared to a 2nd order system, a 4th order system is significantly more complex, as it introduces additional poles and zeros that need to be considered in our design.

Our main objective is to integrate the Kp, Ki, and Kd parameters into our system. Specifically, we employ Ki and Kp to counteract system disturbances. Throughout the experiment, we closely observe how these parameters influence the system and adjust the disturbance accordingly.

One of the key challenges we face is the process of breadboarding, primarily due to its intricate nature. Another challenging aspect is implementing the Up, Ui, and Ud formulas into the feedback system. This is especially true for Ui, as it necessitates consideration of the Up_km1 value, thus making the implementation far from straightforward.

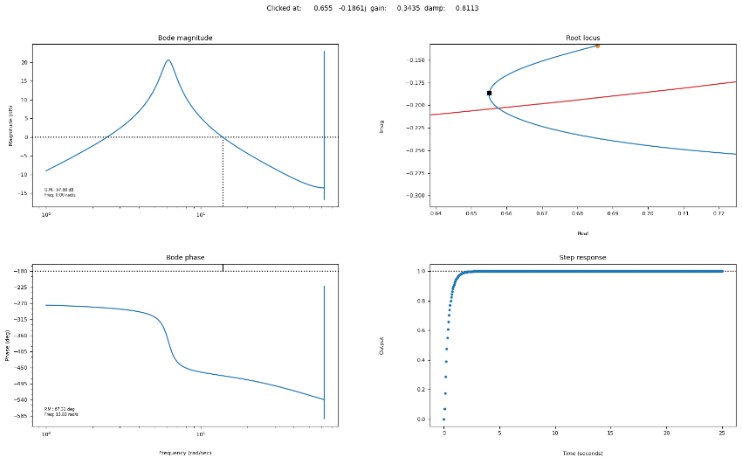
Once we overcome these hurdles and successfully accomplish the above tasks, we are able to generate the desired data. Subsequent analysis of the generated plots reveals a mild oscillation in the response (r to y plot). This is an inherent characteristic of a 4th order system, which, due to its increased complexity, exhibits more oscillations and is consequently harder to dampen into a smooth line, resulting in a longer settling time (Ts).

In conclusion, the design and implementation of a PID control system for a 4th order system is a challenging but rewarding endeavor, as it provides valuable insights into system dynamics and control mechanisms. At the end we do achieve our control goal.

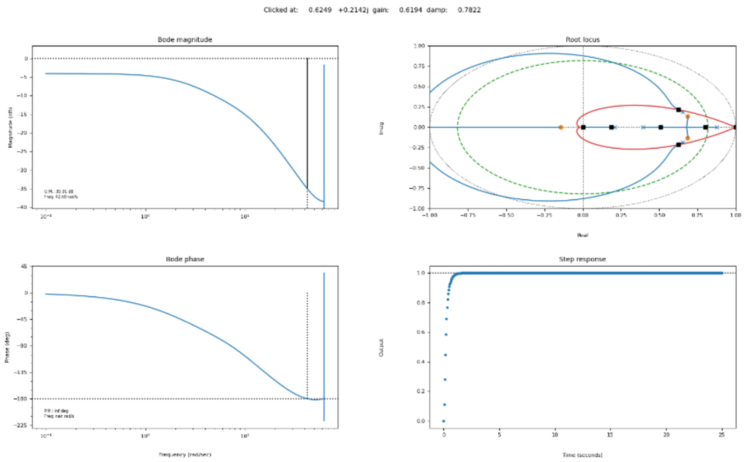


Design Description:

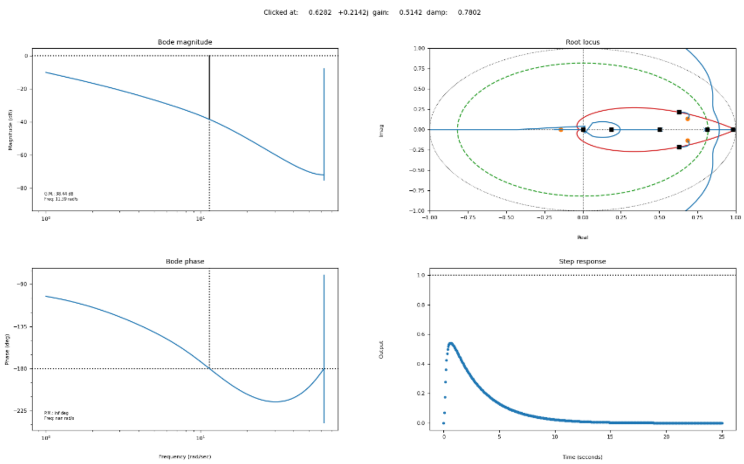
$$K_p = 0.0, K_i = 0.0, K_d = 0.0\ ;\ K_d\ increase$$



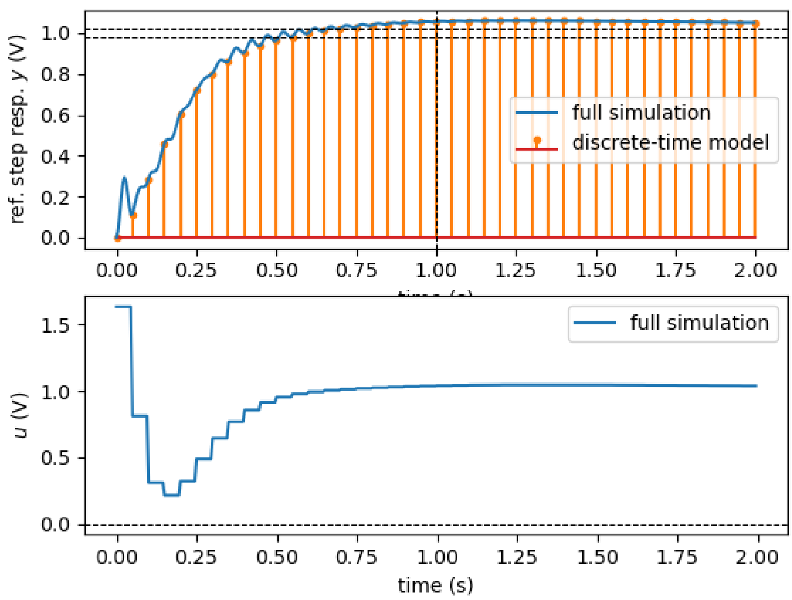
$$K_p = 0.0, K_i = 0.0, K_d = 0.3435\ ;\ K_p\ increase$$

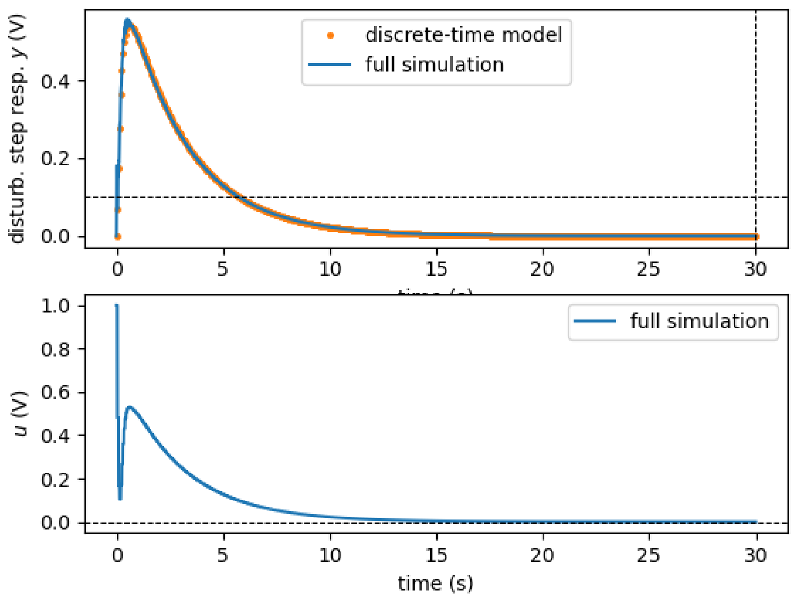


$$K_p = 0.6194, K_i = 0.0, K_d = 0.3435\ ;\ K_i\ increase$$



$K_p = 0.6194, K_i = 0.5142, K_d = 0.3435$ Result:

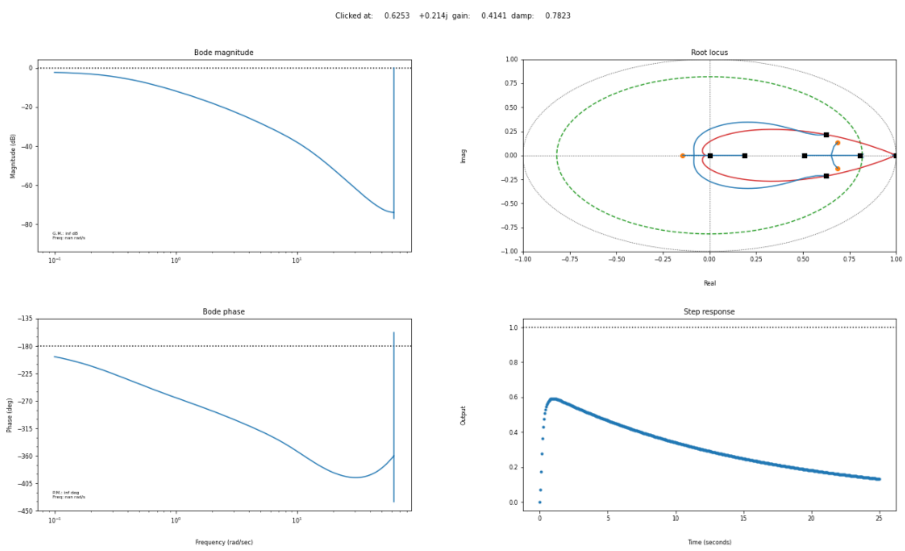




As the plot shown, there is way too much overshoot. However, there are lots of space to modified in the disturbance response. Hence, tune down the Ki.

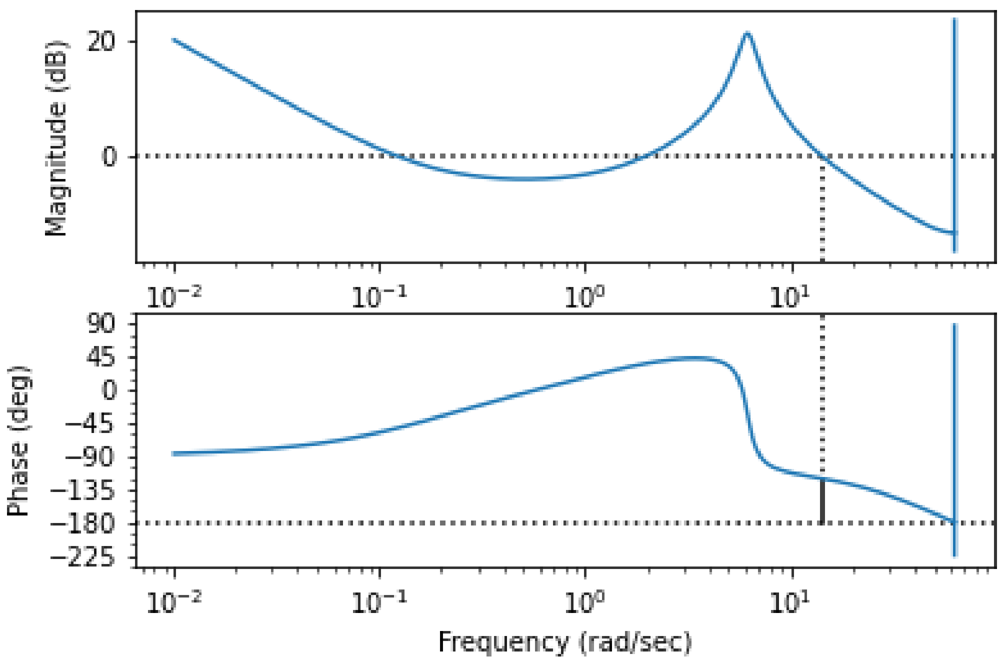
$K_p = 0.6194, K_i = 0.5142, K_d = 0.3435; K_i\ decrease$

We pick decrease 0.418, $K_{i,new} = 0.5142 - 0.4142 = 0.1$



$K_p = 0.6194, K_i = 0.1, K_d = 0.343$ Result:

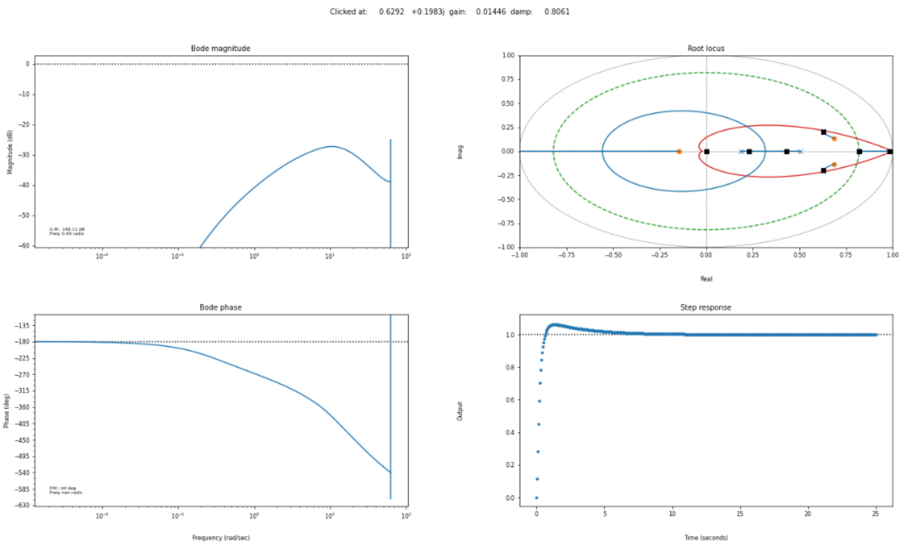
Gm = -120.51 dB (at 0.00 rad/s), Pm = 59.70 deg (at 14.30 rad/s)



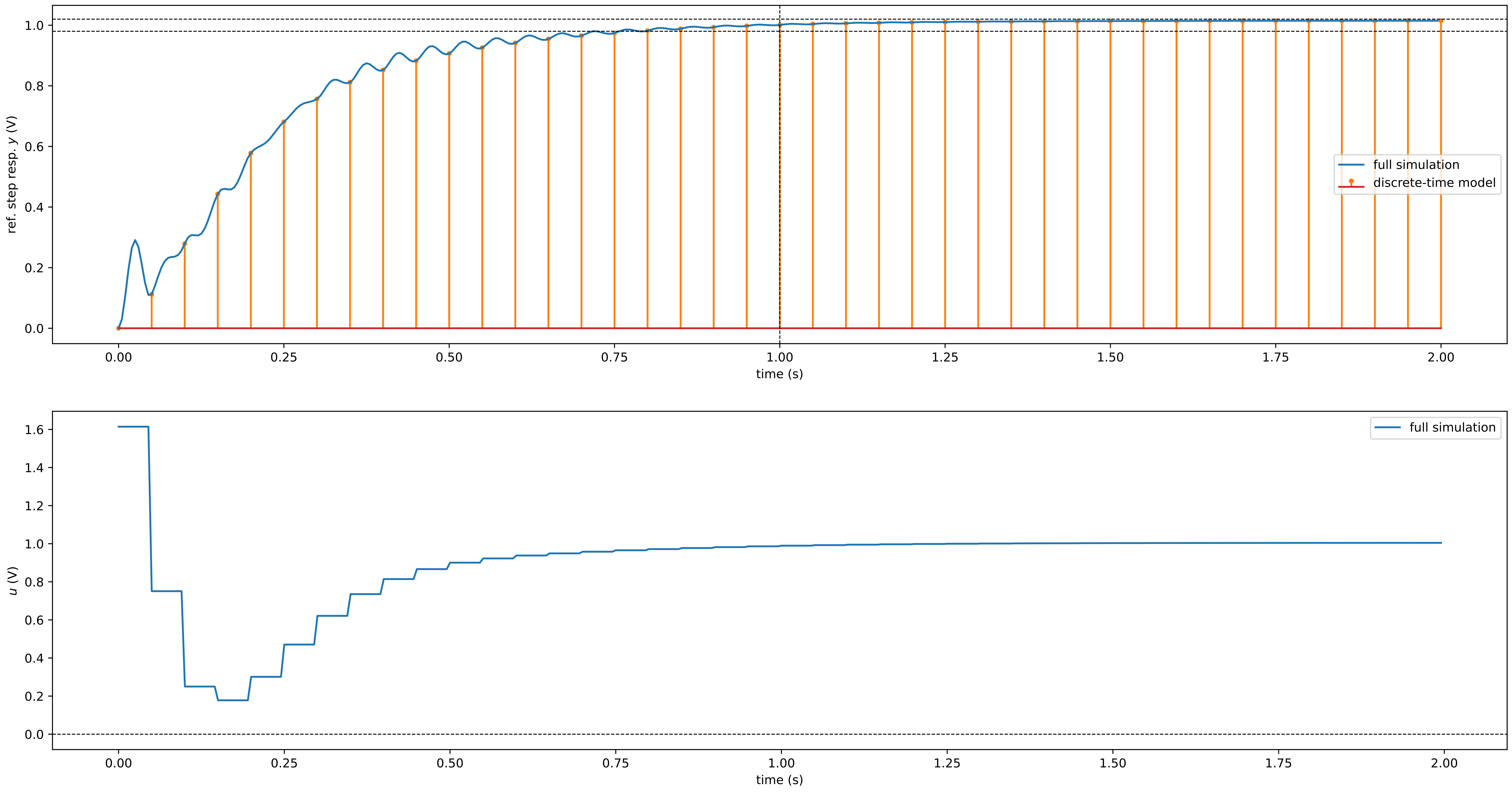
The Gm do not fit, increase Kd.

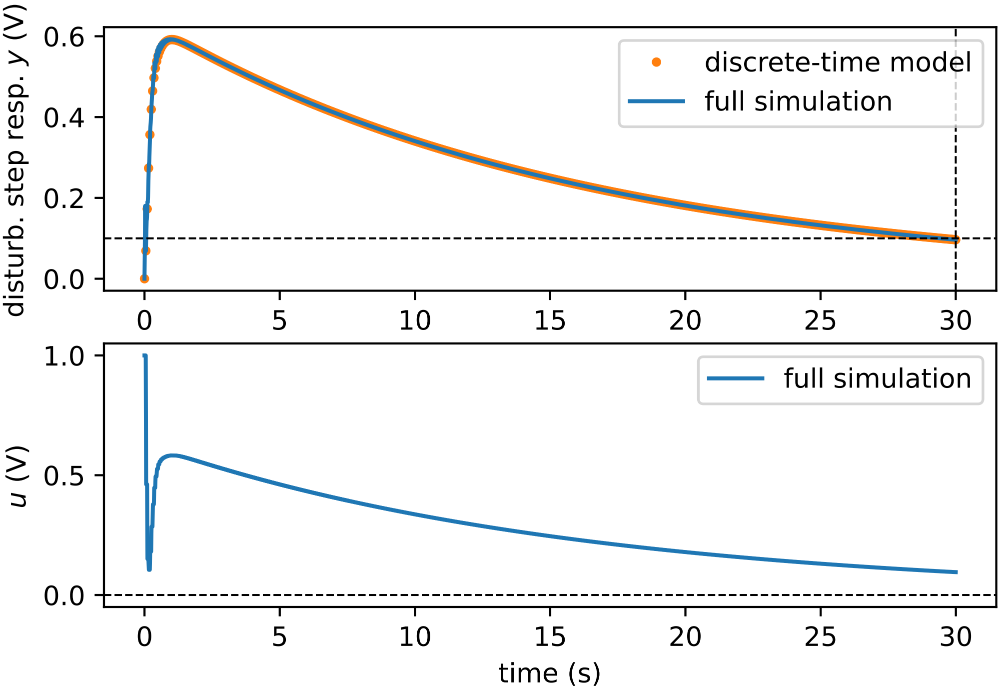
$$K_p = 0.6194, K_i = 0.1, K_d = 0.3435, K_d\ increase$$

$$K_{d,new} = 0.3435\ 0.01446 = 0.35796$$

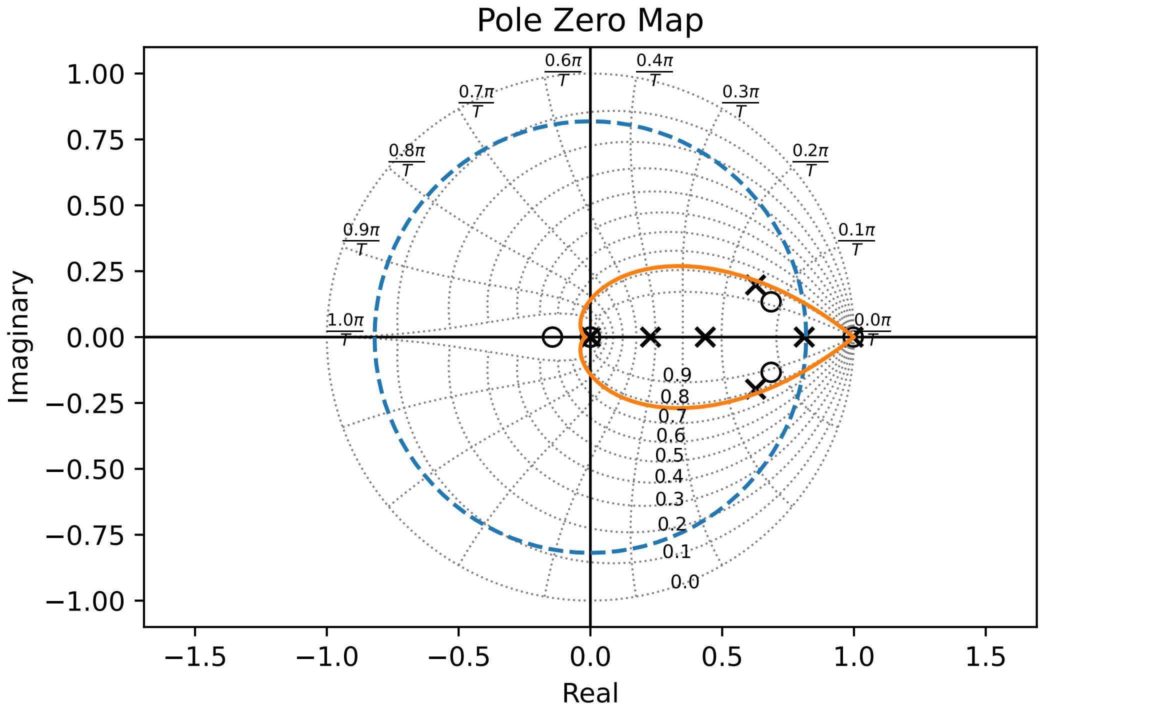


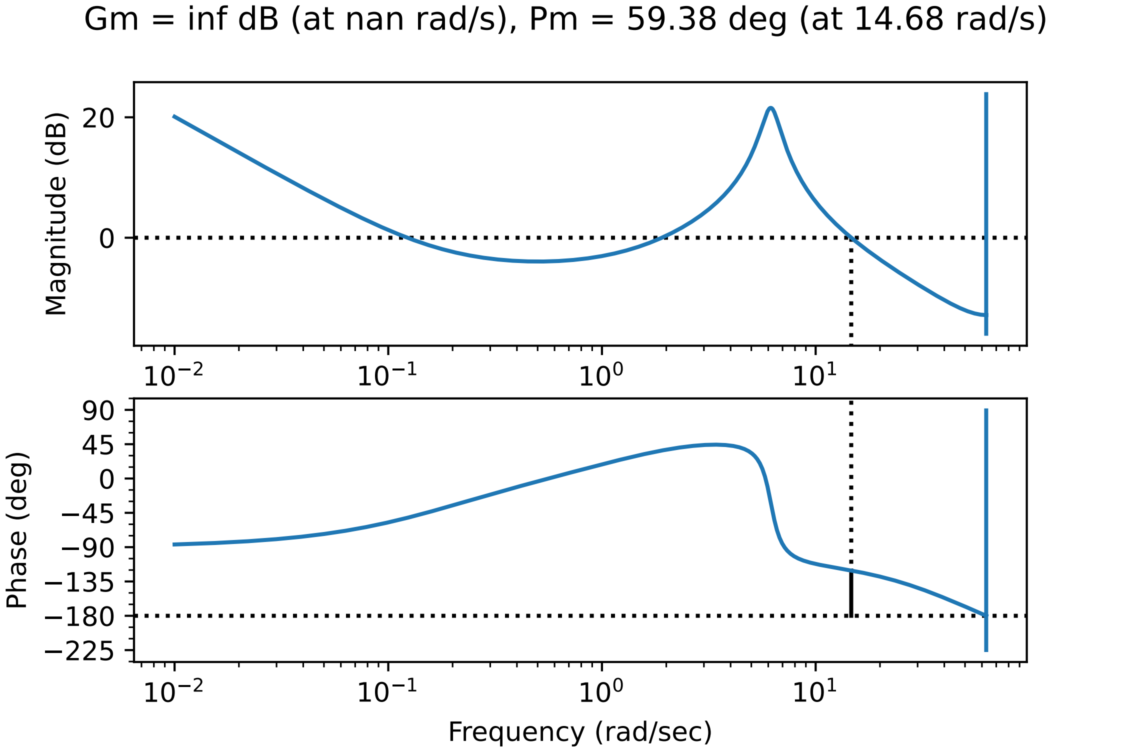
$K_p = 0.6194, K_i = 0.1, K_d = 0.35796$ Result:





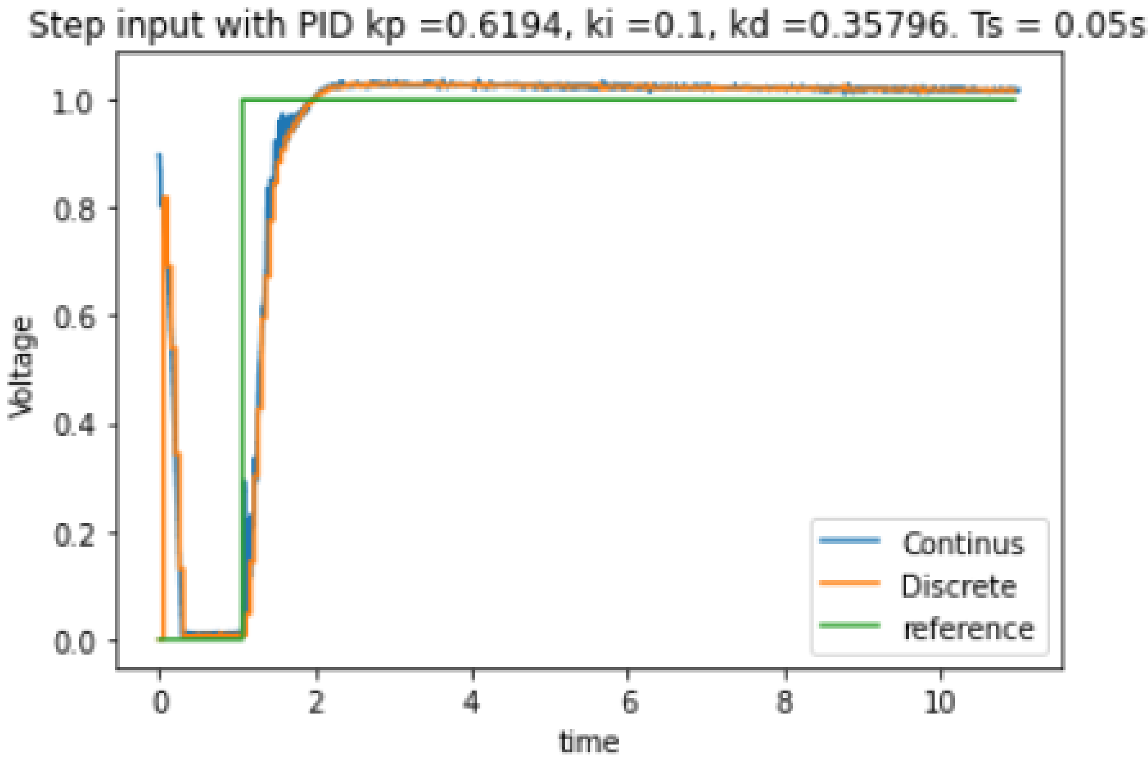
disturb. step resp. y (V)
0.6
0.4
0.2
0.0
discrete-time model
full simulation
0
5
10
15
20
25
30
u (V)
1.0
0.5
0.0
full simulation
0
5
10
15
20
25
30
time (s)

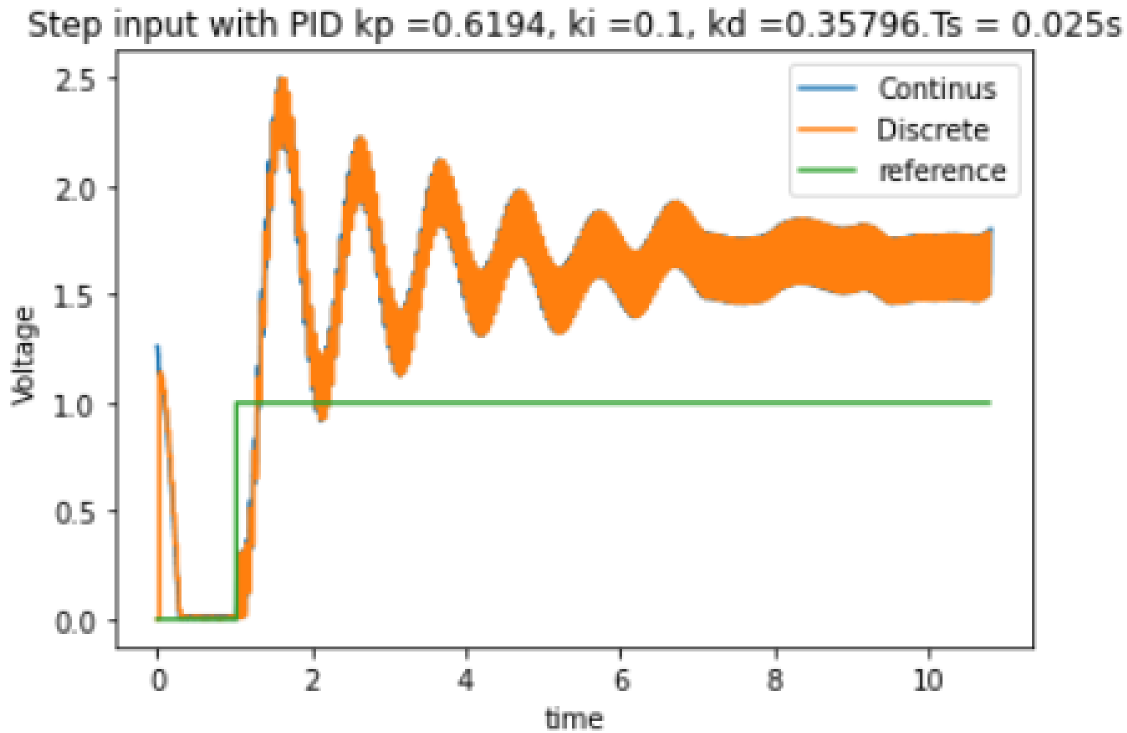

Pole Zero Map
Imaginary
Real
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
0.6π/T
0.4π/T
0.7π/T
0.3π/T
0.8π/T
0.2π/T
0.9π/T
0.1π/T
1.0π/T
0.0π/T
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0



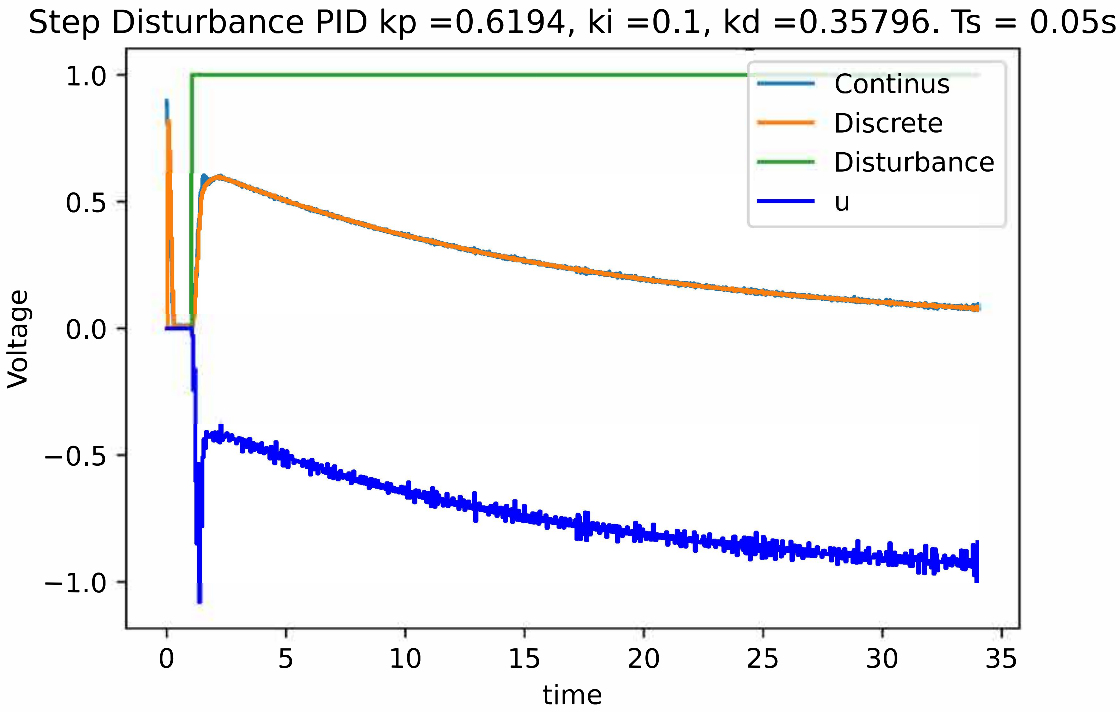
Gm = inf dB (at nan rad/s), Pm = 59.38 deg (at 14.68 rad/s)
Magnitude (dB)
20
0
10^{-2}
10^{-1}
10^{0}
10^{1}
Phase (deg)
90
45
0
−45
−90
−135
−180
−225
10^{-2}
10^{-1}
10^{0}
10^{1}
Frequency (rad/sec)

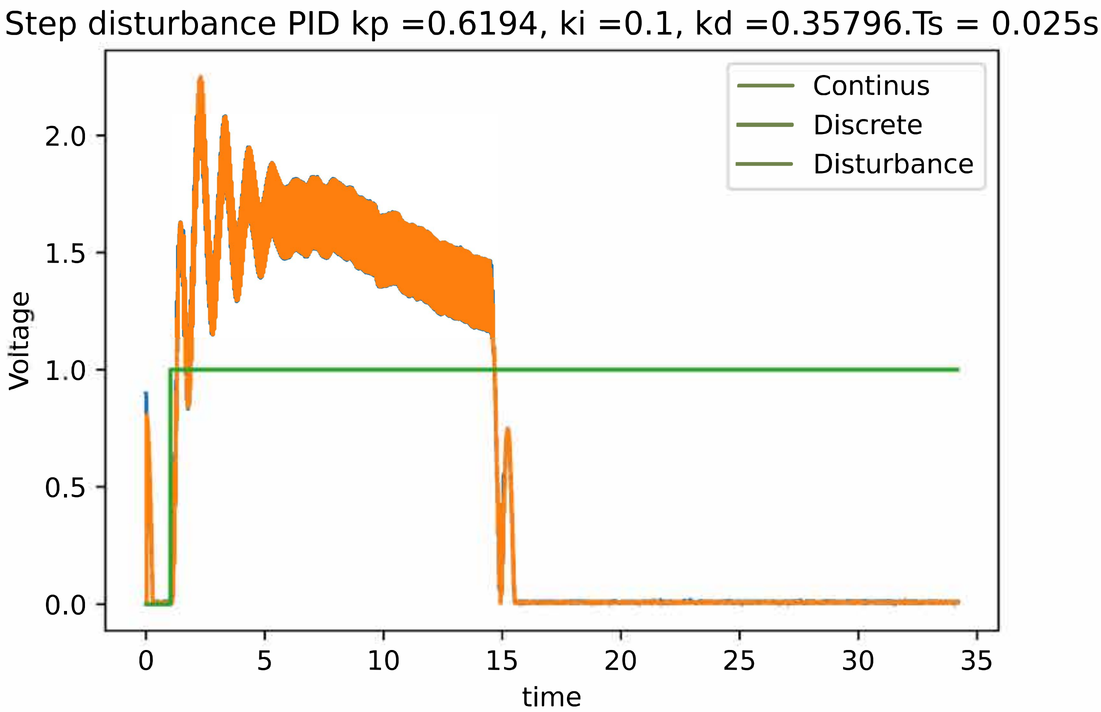
HIL IMPLIMENTATION

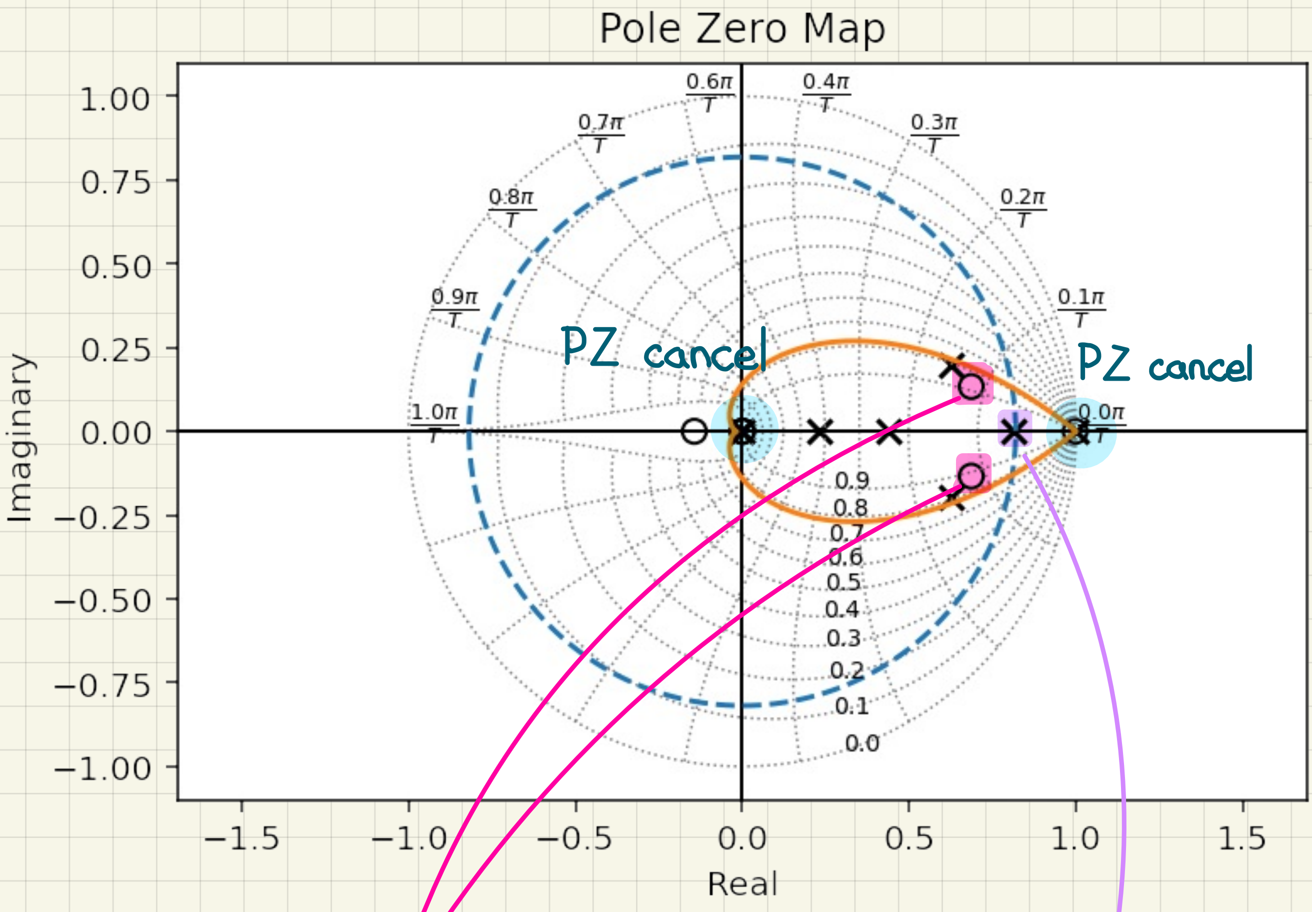




According to Nyquist sampling theorem. If we lower the sampling time (Ts), it means we are increasing the sampling frequency (fs = 1/Ts) . In this LAB set, it cause Aliasing. If the increased sampling frequency is still less than twice the highest frequency of the signal, aliasing occur. High-frequency components can appear as low-frequency components in the sampled signal.


Step Disturbance PID kp =0.6194, ki =0.1, kd =0.35796. Ts = 0.05s
Continus
Discrete
Disturbance
u
Voltage
1.0
0.5
0.0
−0.5
−1.0
0
5
10
15
20
25
30
35
time


Step disturbance PID kp =0.6194, ki =0.1, kd =0.35796.Ts = 0.025s
Continus
Discrete
Disturbance
Voltage
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
30
35
time



Dominate Pole

Zero pairs.

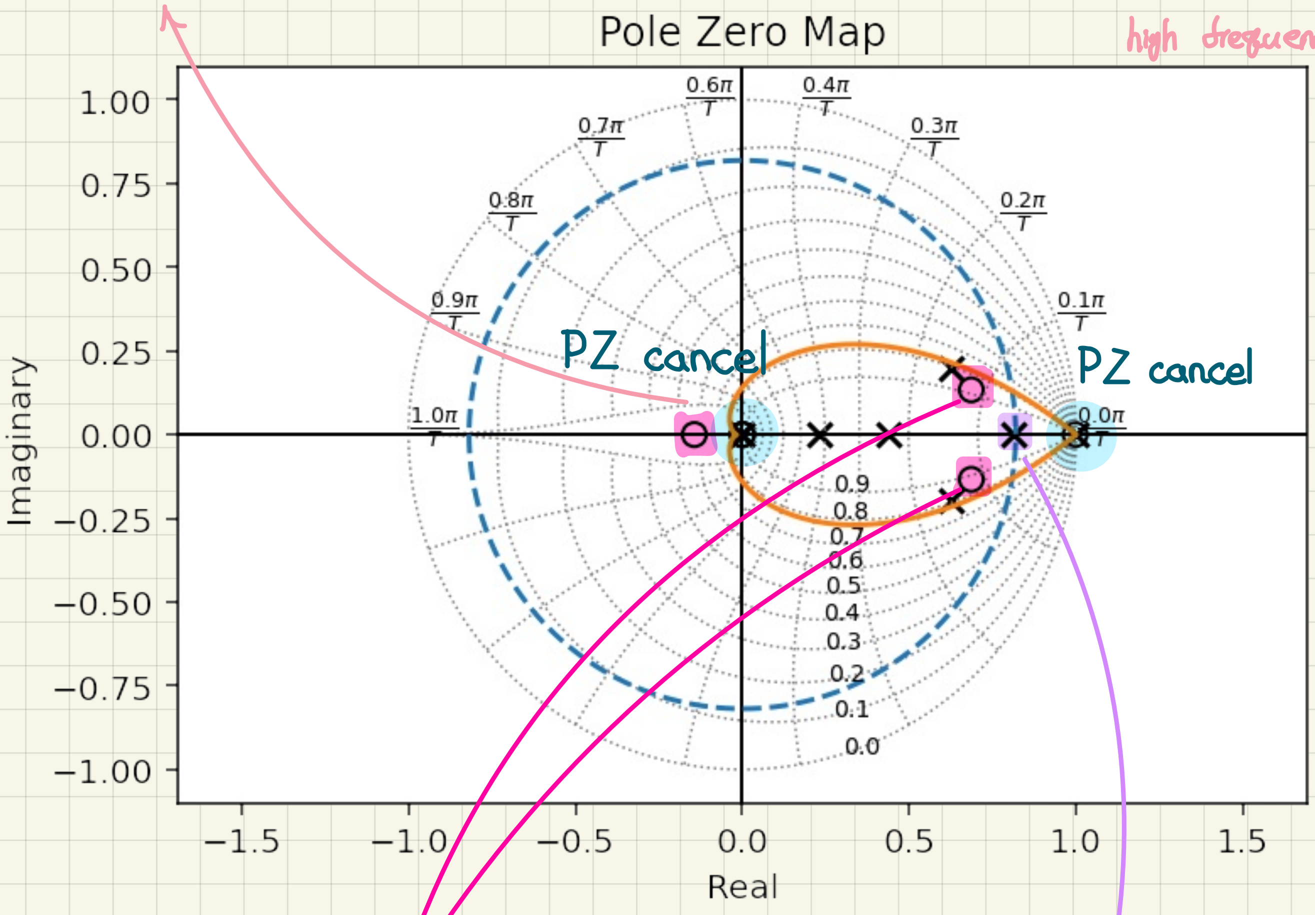
All poles are in unit circle.

Hence, there will be stable.

Pretty close inside the oriange line.

Therefore, expect to see small overshoot at the result.

Reject high frequency. But it too close to (0,0). Hence, not good high frequency reject.



Zero pairs.

Better disturbance reject at

low frequency.

Also, because it is not close to the unit circle.

The settelling time d to y may not fast enough, compare the zero if it is close to unit circle.

Dominate Pole

All poles are in unit circle.

Hence, there will be stable.

As the PZ map shown above and what we can get the information from the map. It does fit the HIL output result. Therefore, we can say PZ map does gave us much information to letting us predict the real system.