Homework 4 – Adaptive Controller Design

Yi Chen

3/21/2020

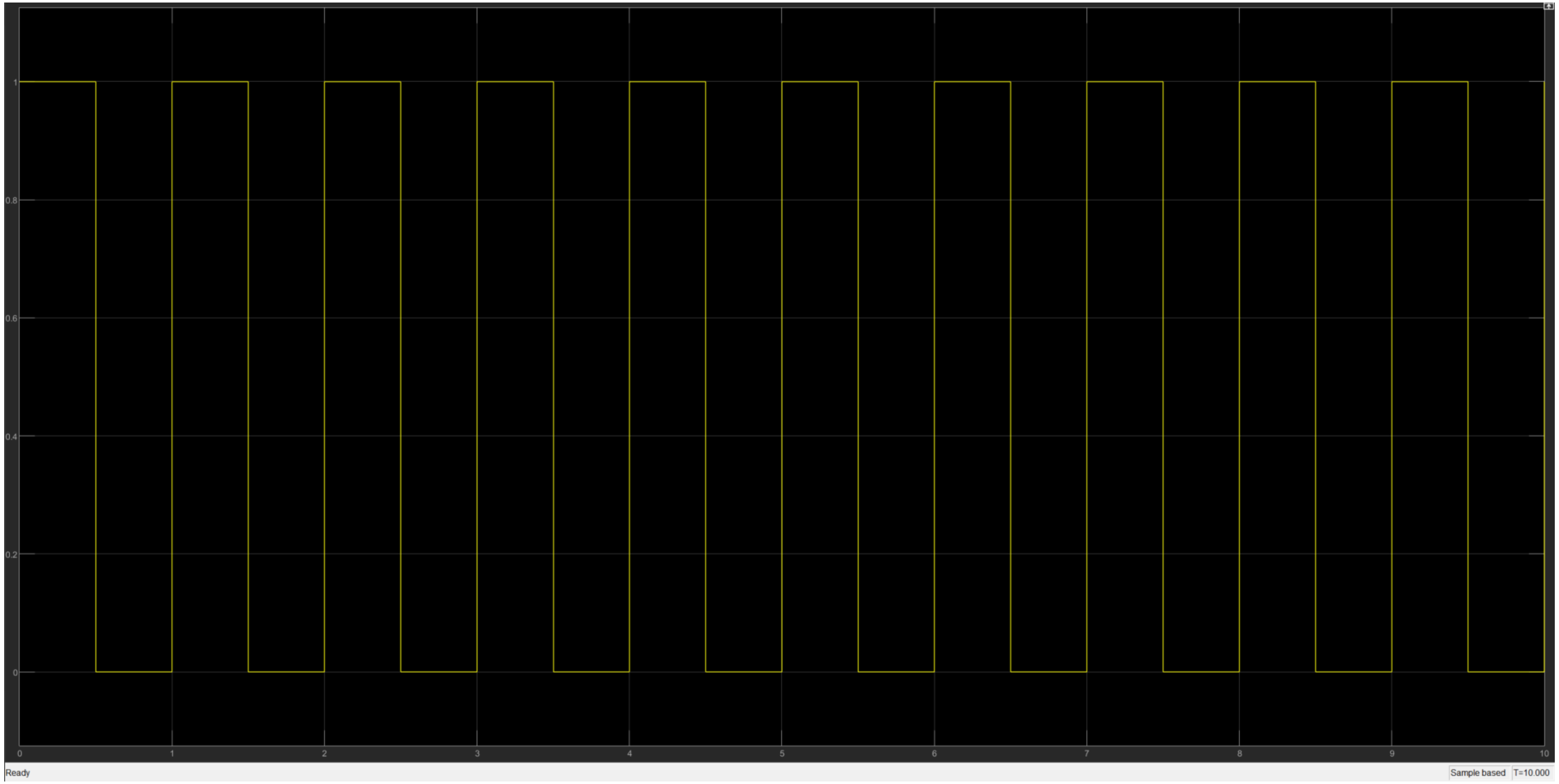
Control objective

- Indirect adaptive controller for PPC and LQG methods
- Direct adaptive control for MPC
- Compare fixed controller versus adaptive controller and see if adaptive controller converges to fixed ones.

Note from professor:
Now you need to get more concise. You are plotting responses and there are too many cases without comments.
There should not be a non adaptive controller that is unstable.
The idea is to design them well, since you know the plant.
Then you can ask the adaptive controller to converge to the same response.
Your final conclusion shows the misconception.
You should not be comparing adaptive and non-adaptive transients but if the adaptive finally converges to the nonadaptive.

Reference input

- frequency: 1 Hz, amplitude: 1

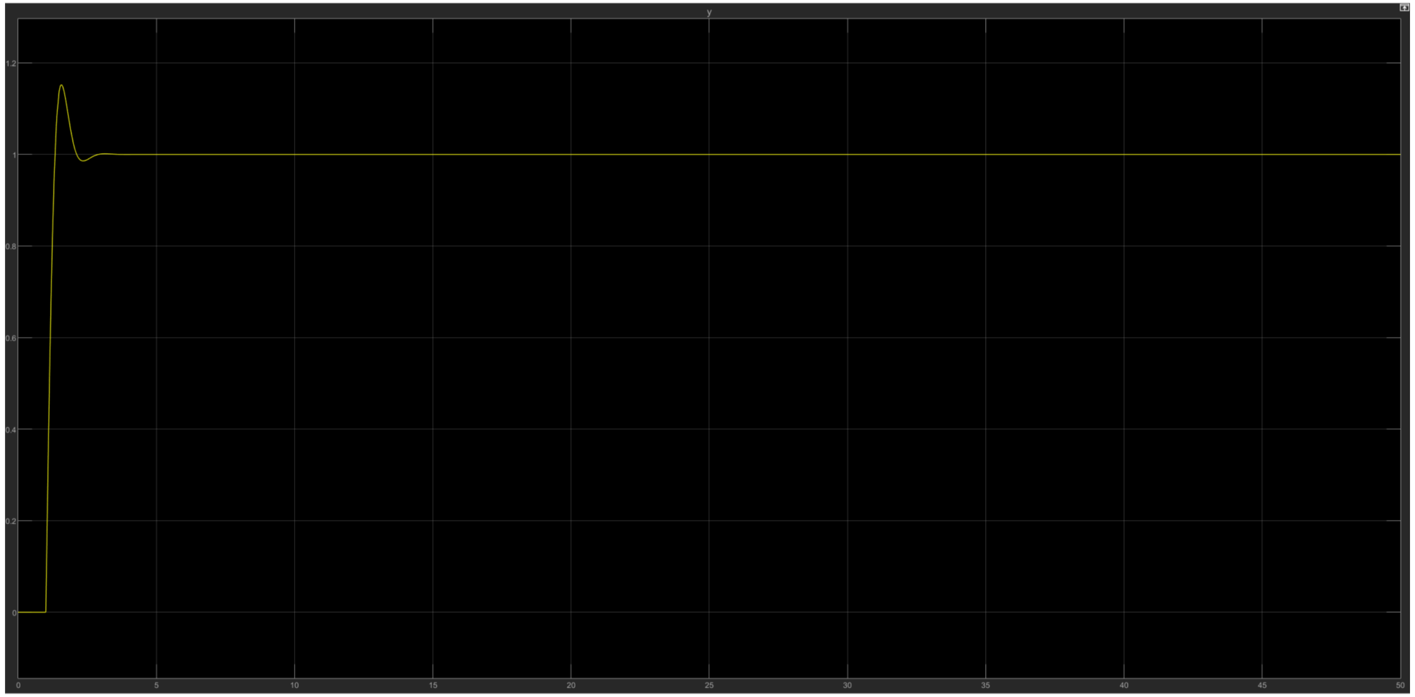


Open-loop Plant 1

- Given step input

Open-loop Plant 2

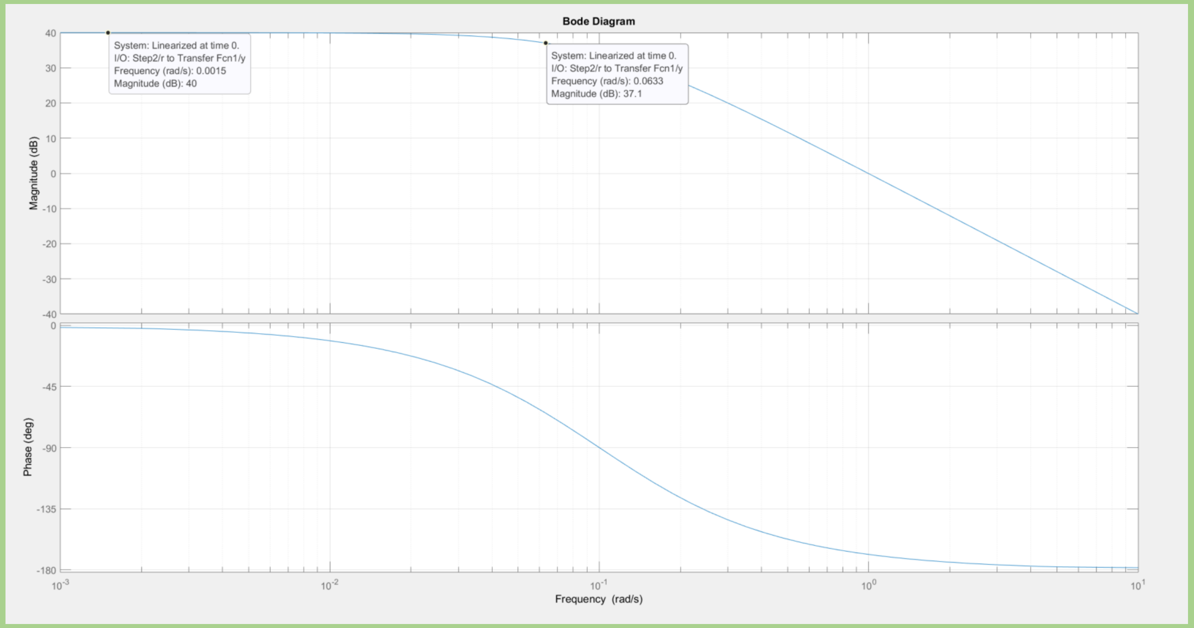
- Given unit step input
- Overshoot is about 11%
- Settling time is about 3 seconds



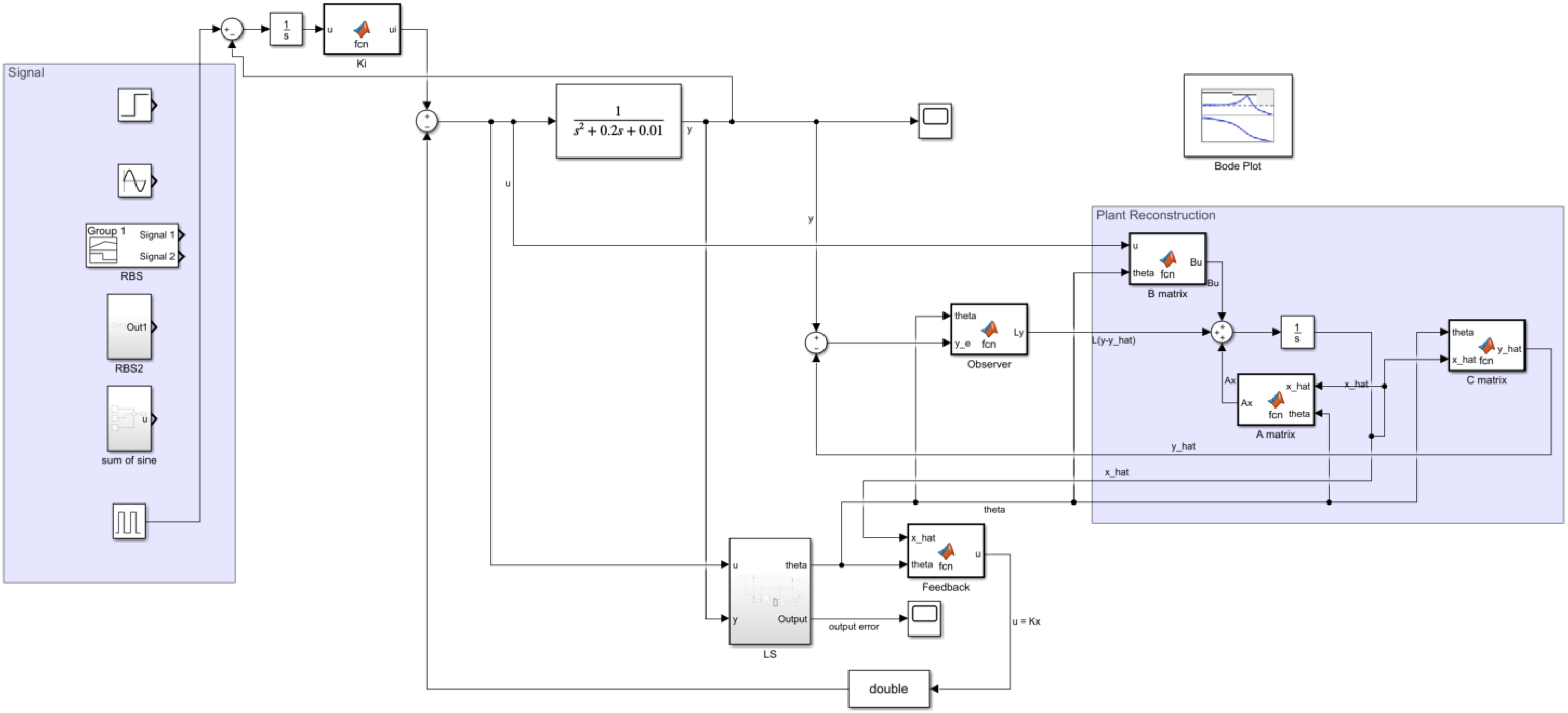
Plant 1:

$$P = \frac{1}{s^2 + 0.2s + 0.01}$$

- Open loop pole: -0.1, -0.1
- Open loop bandwidth: 0.0633
- Settling time: 75s
- Overshoot: 0
- Controllable: yes
- Observable: yes

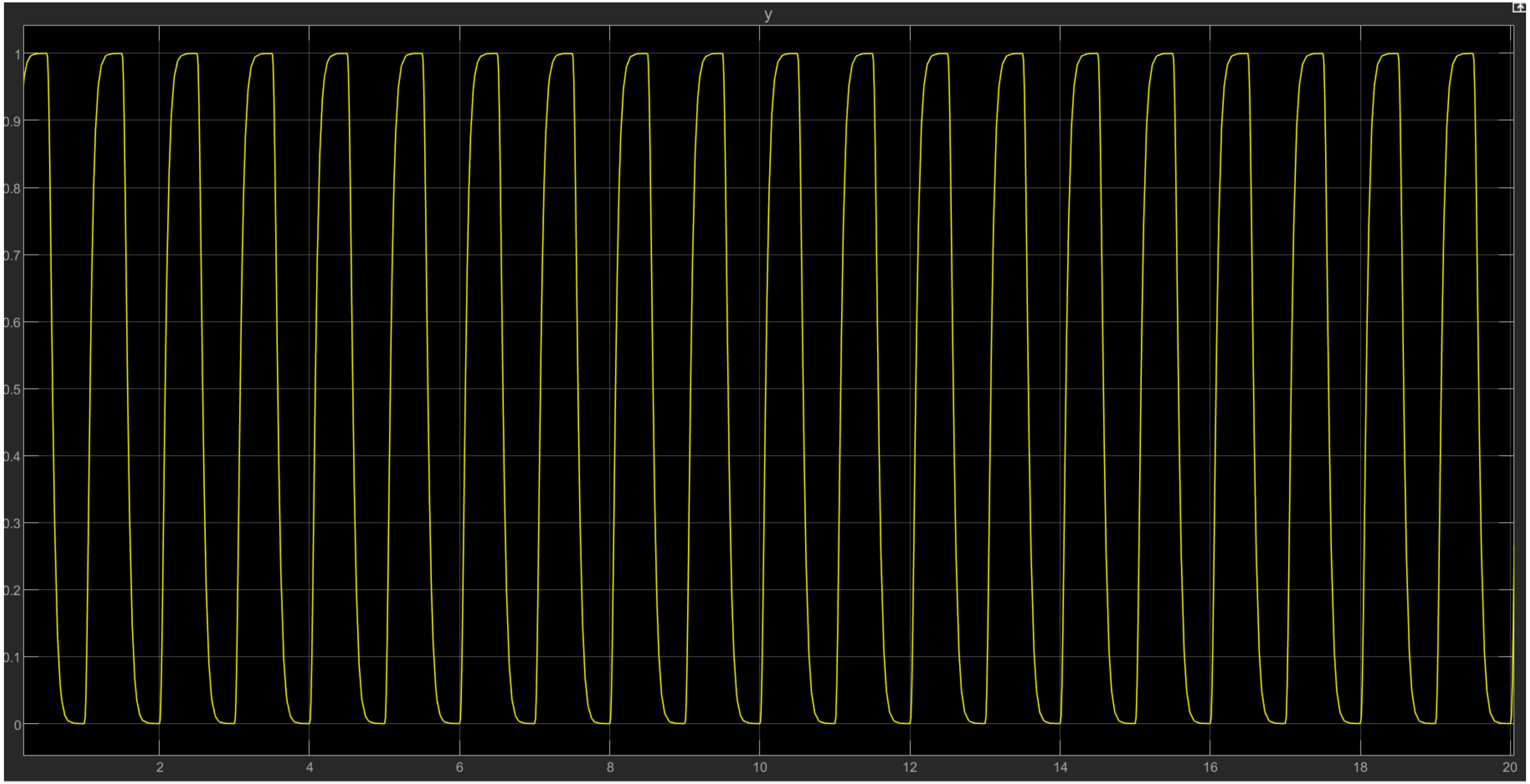


PPC – setup (adaptive): Least Square



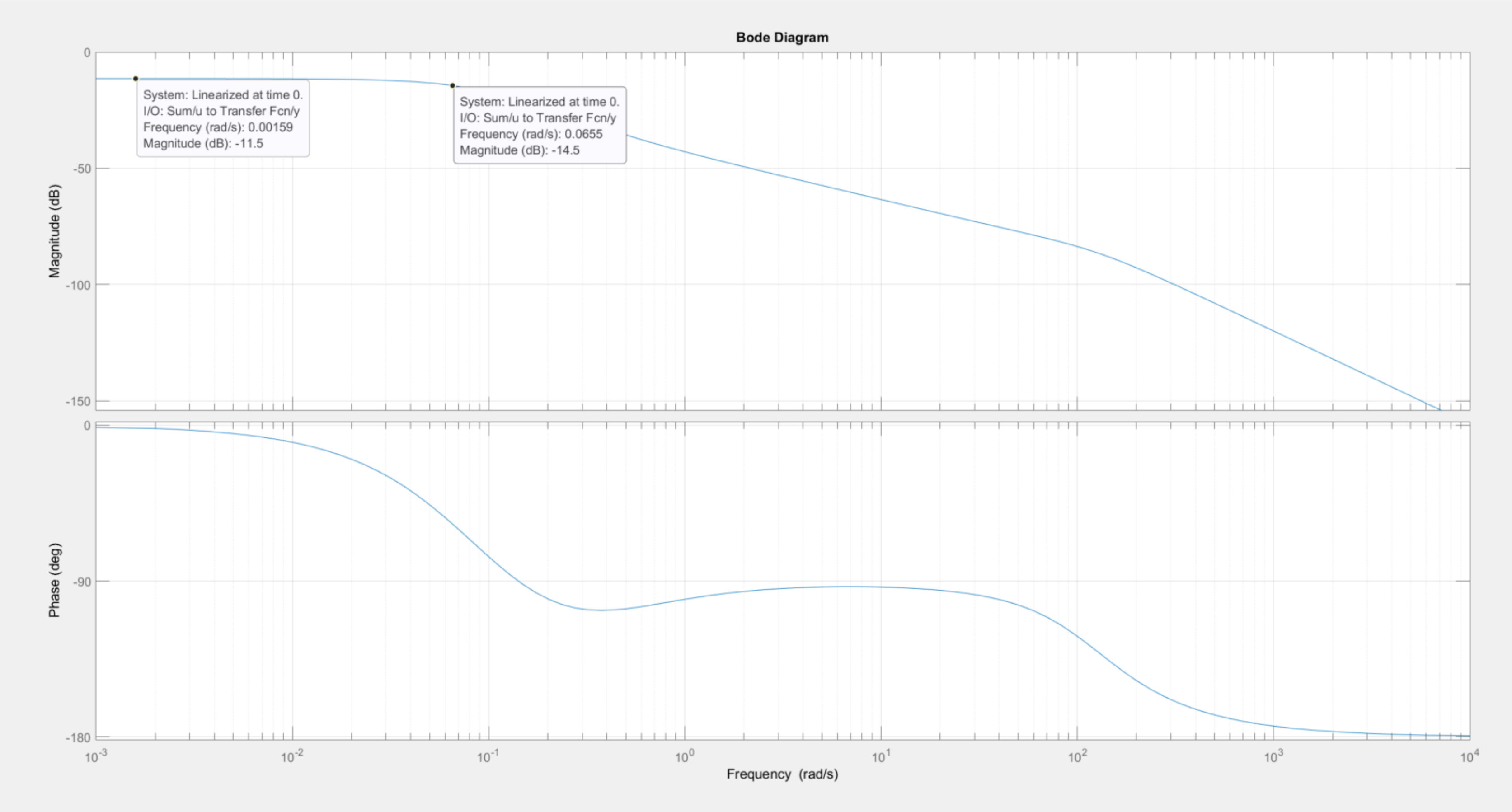
PPC – P1 – System response – non-adaptive

- Poles: -30+0.69805i ,-30-0.69805i ,-50
- Designed be fast enough to track input reference signal



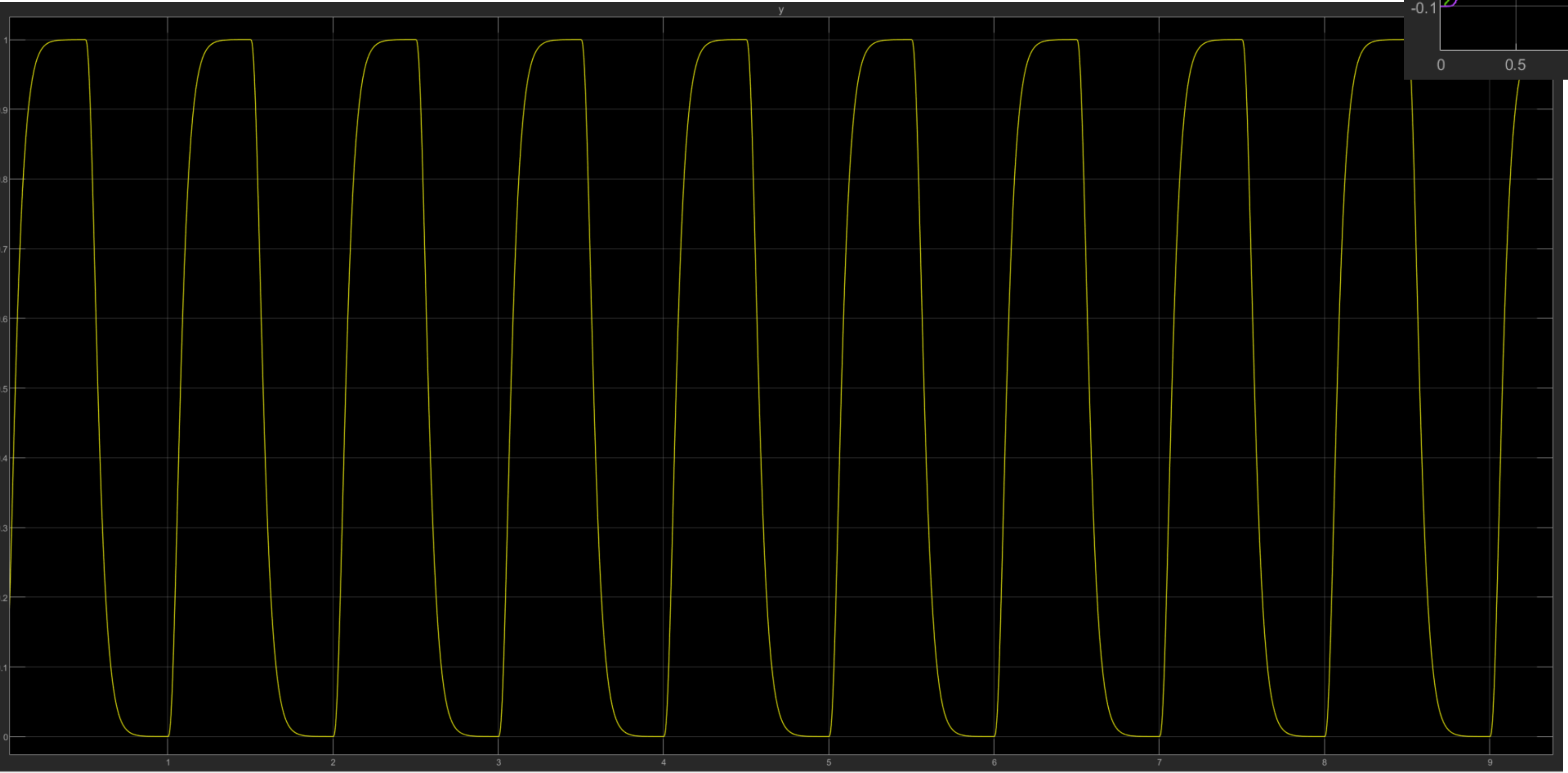
PPC –Frequency response

- With K designed having pole = -30+0.69805i -30-0.69805i
- Pole for Ki = -50
- Bandwidth = 0.0655



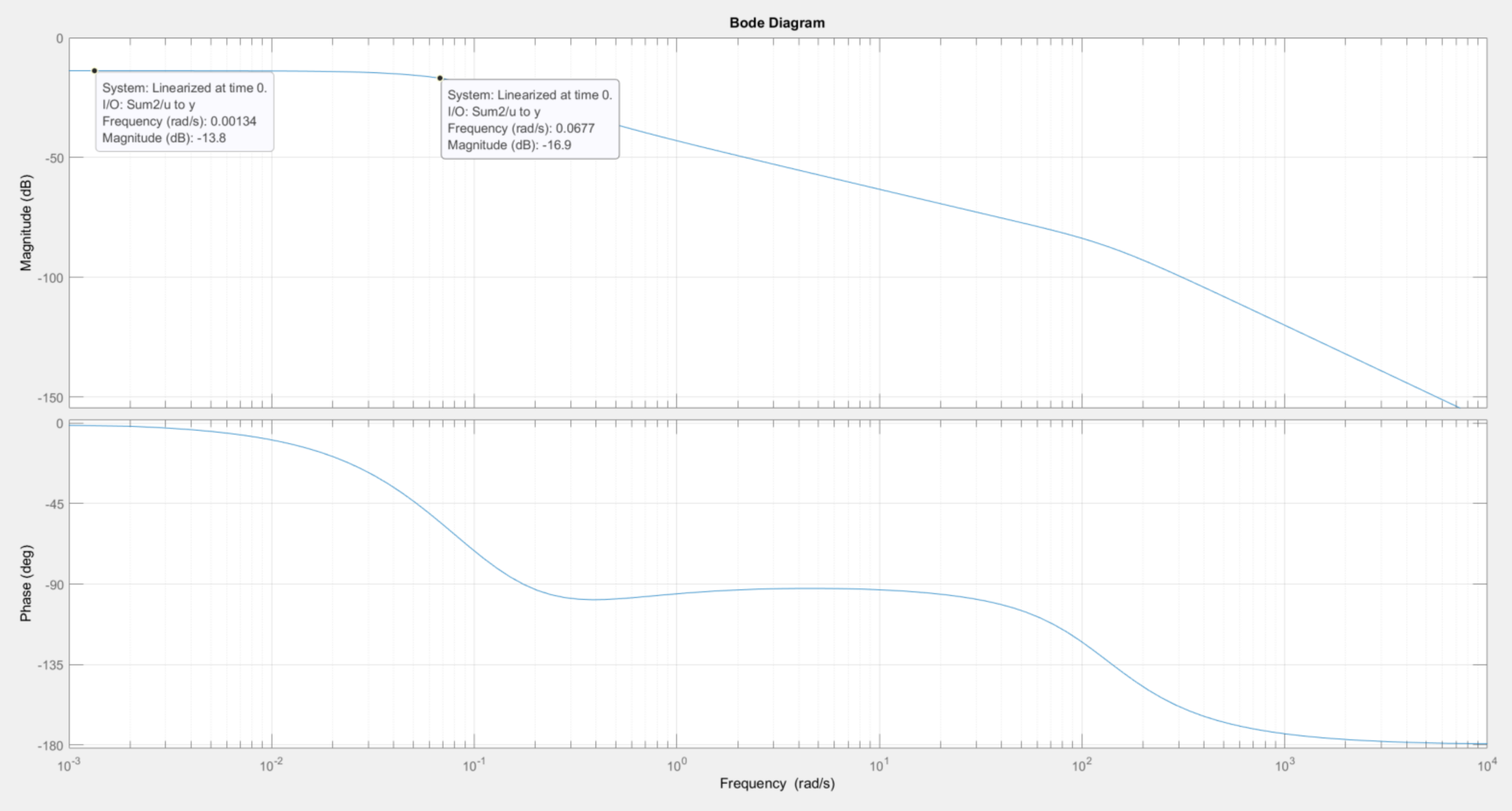
PPAC– System response

- Initial param: [0.1, 0, 1.1, 0.1, 0.1]

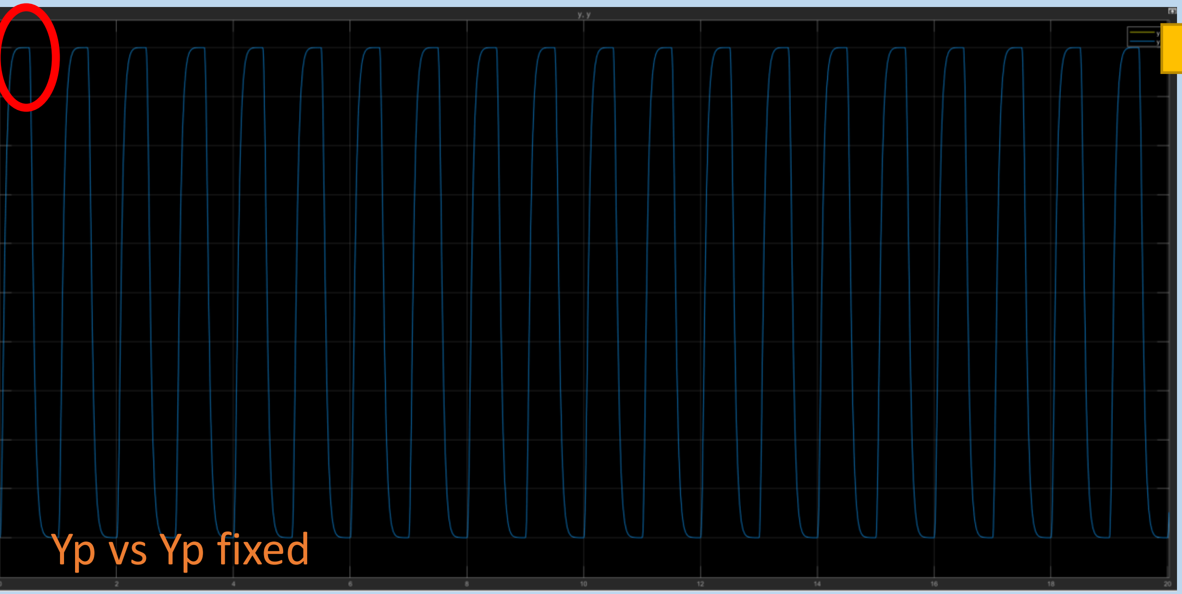


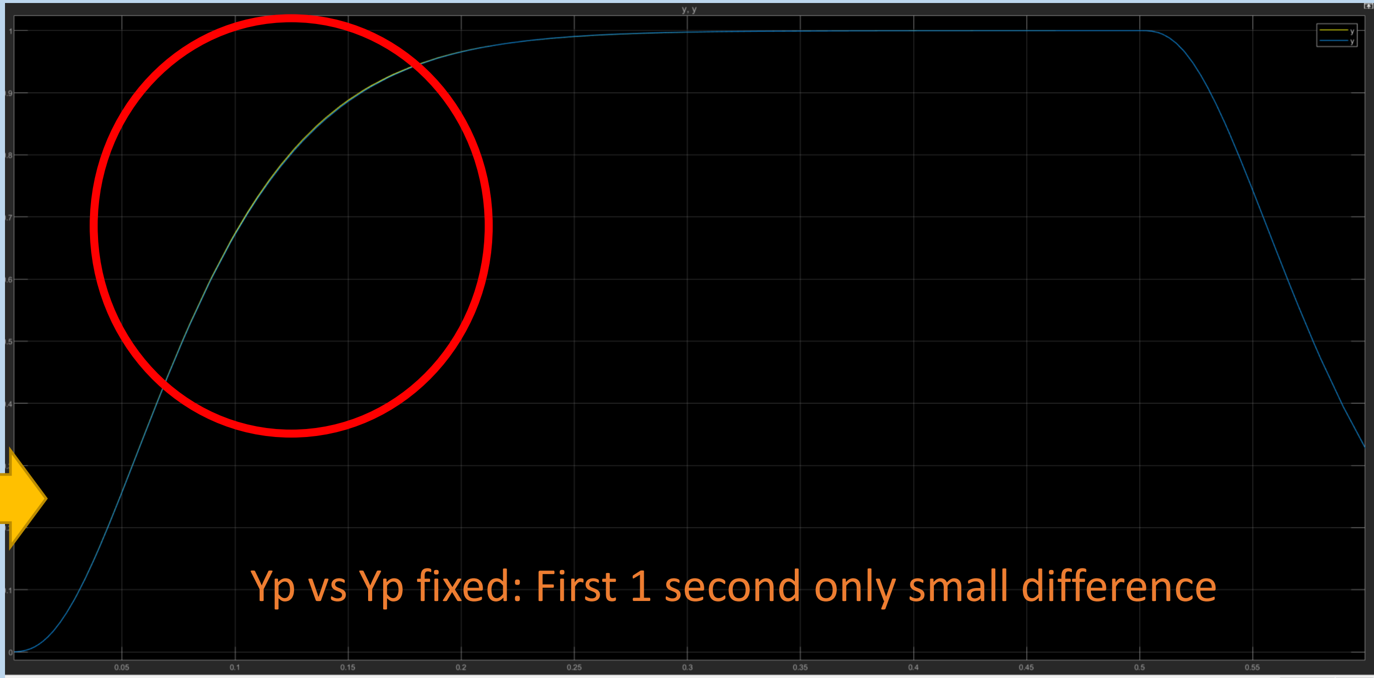
PPAC– Frequency response

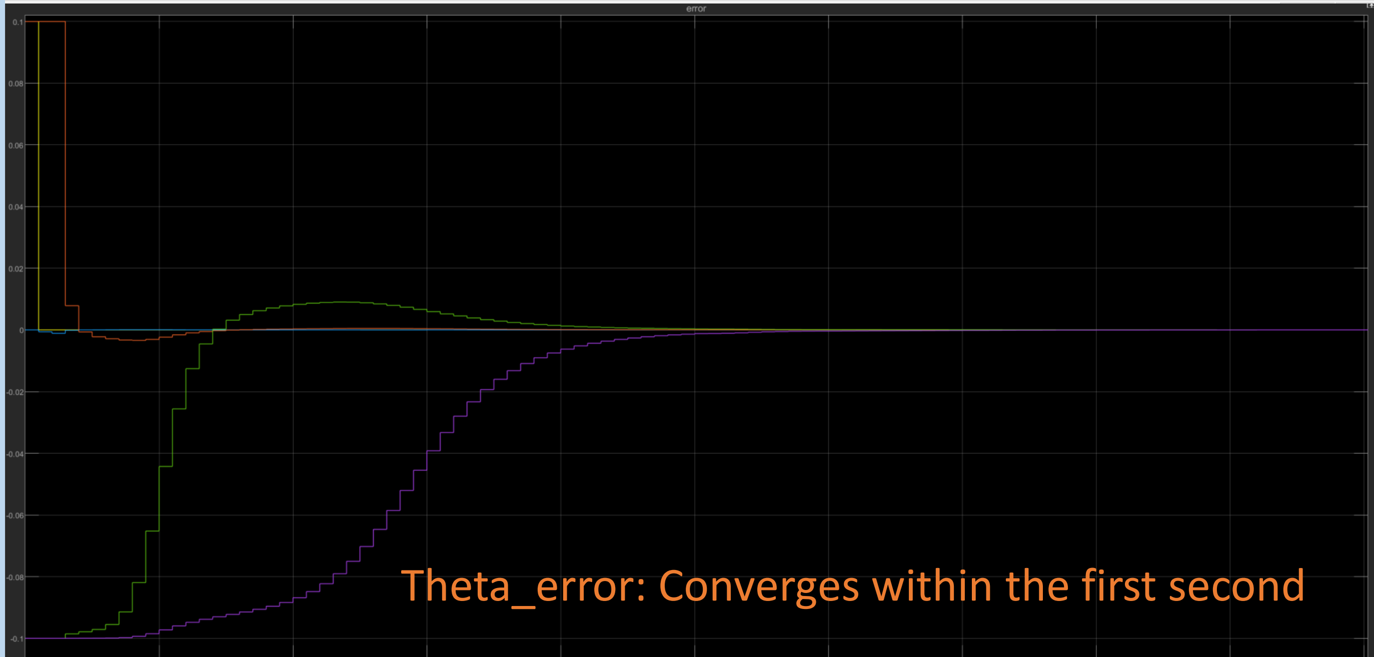
- With K designed having pole = -30+0.69805i & -30-0.69805i
- Pole for Ki = -50
- Bandwidth = 0.0677



PPAC vs PPC comparison – Plant 1

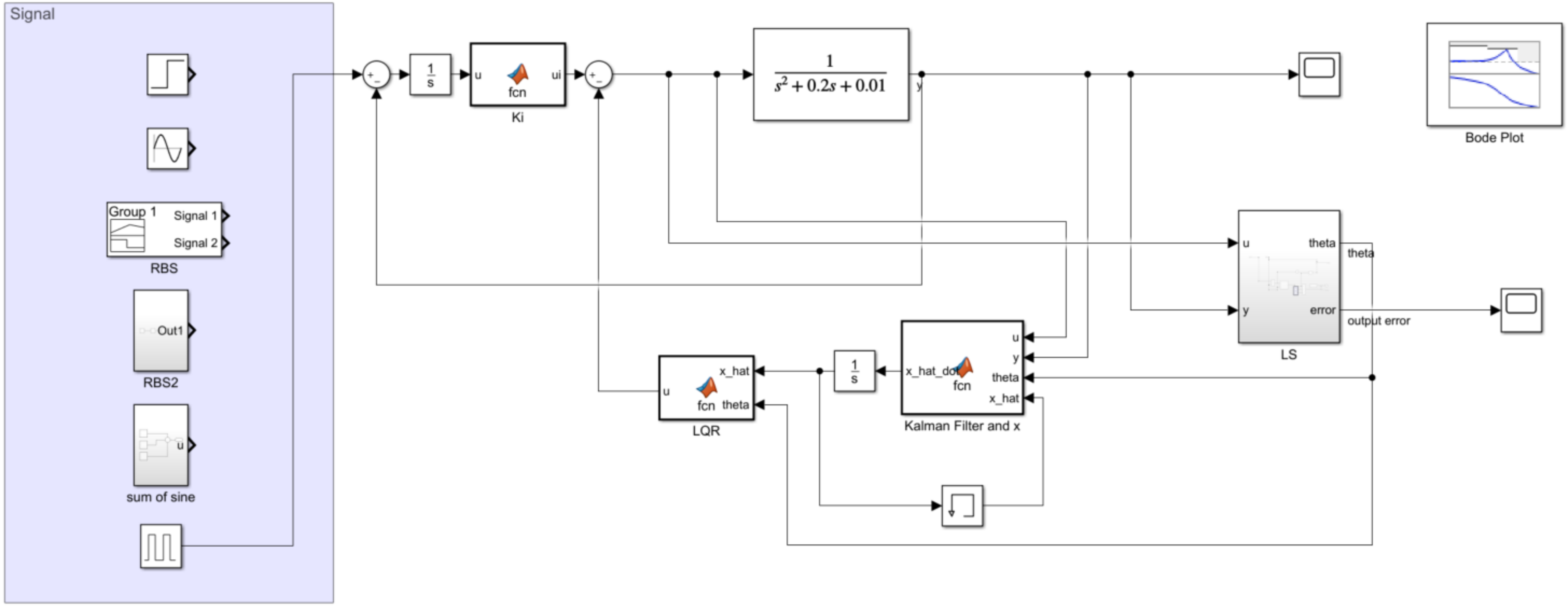






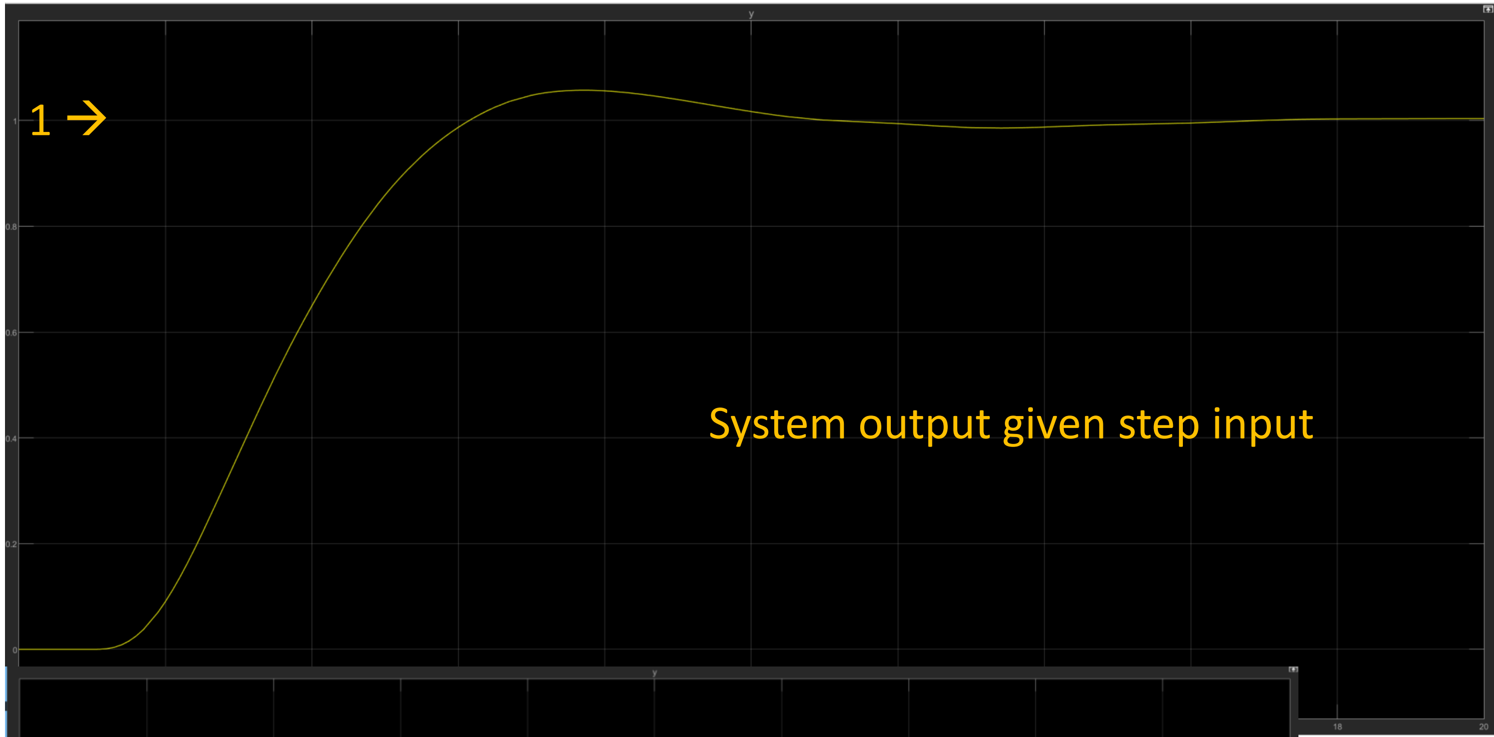
LQG – system setup - Adaptive

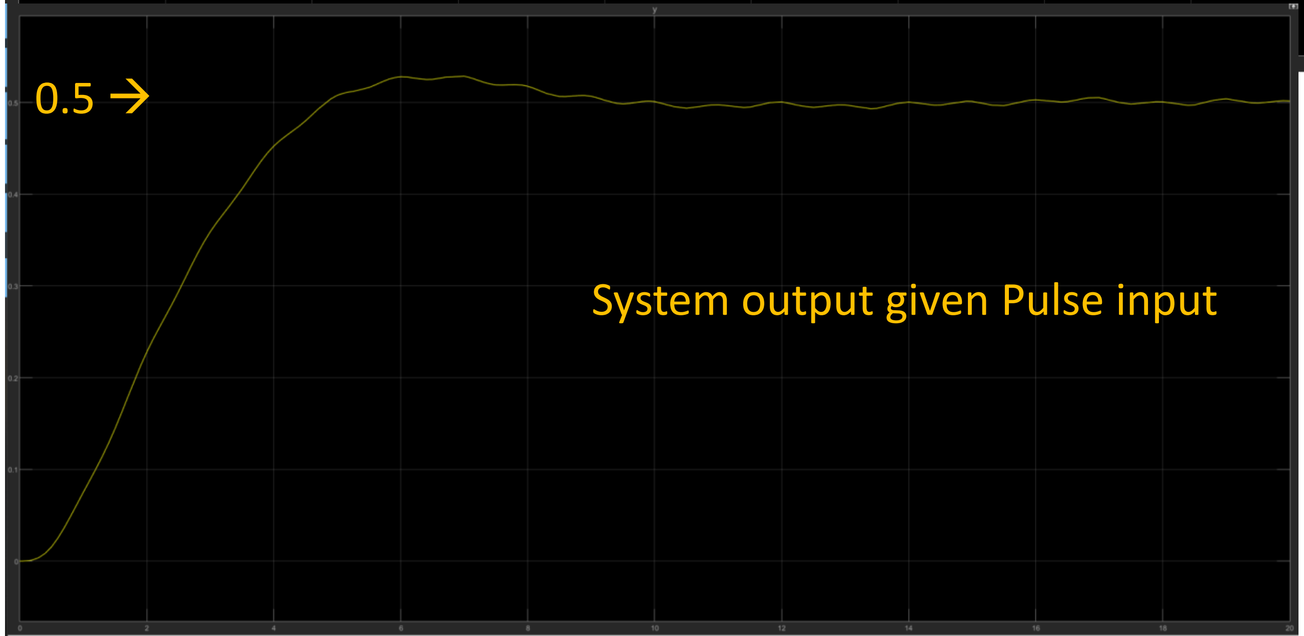
- Indirect controller (LS algorithm) was implemented



LQG – P1 – system response (non-adaptive)

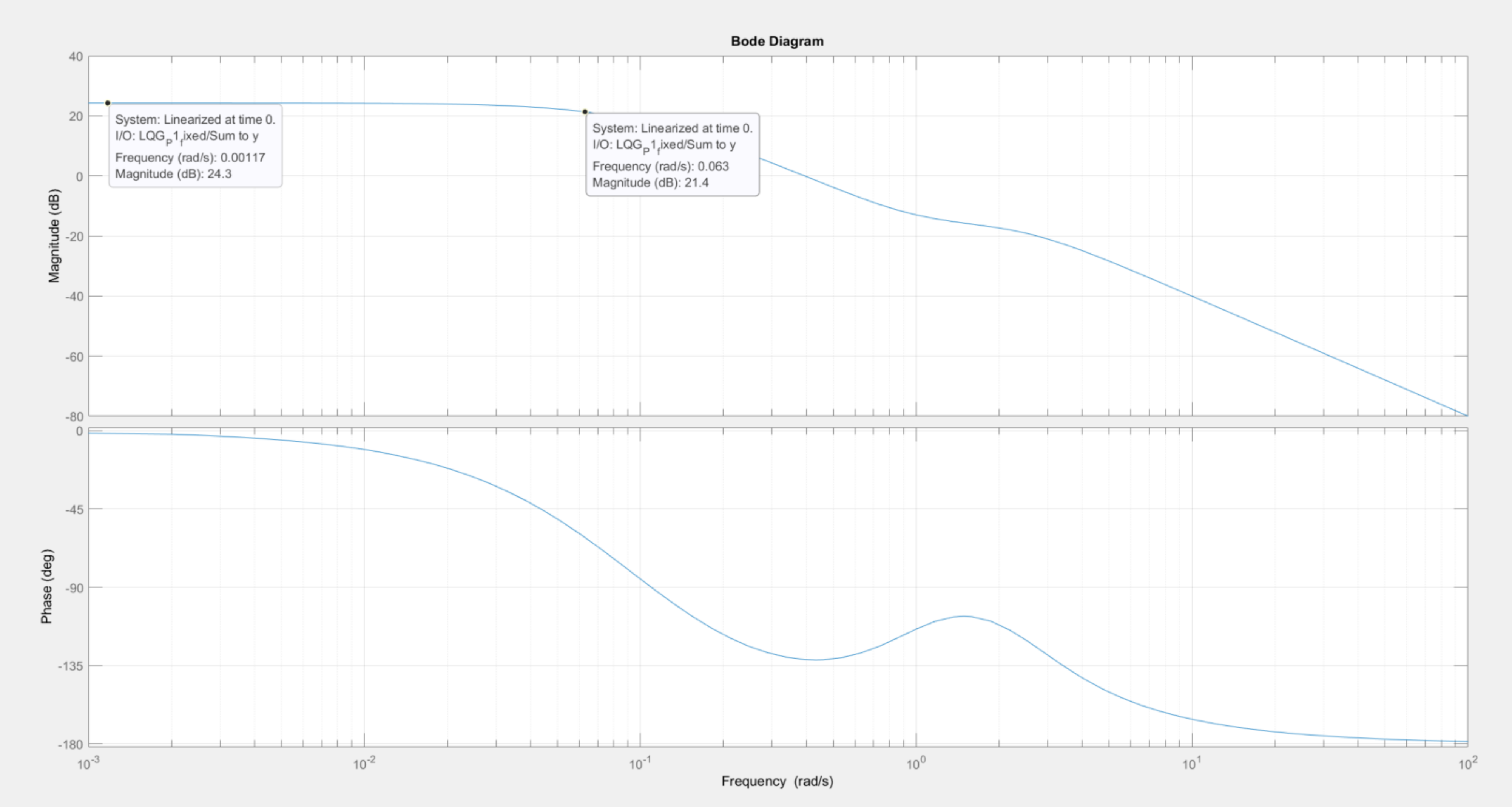
- R = 1
- Q = I
- KF: Q=R=10





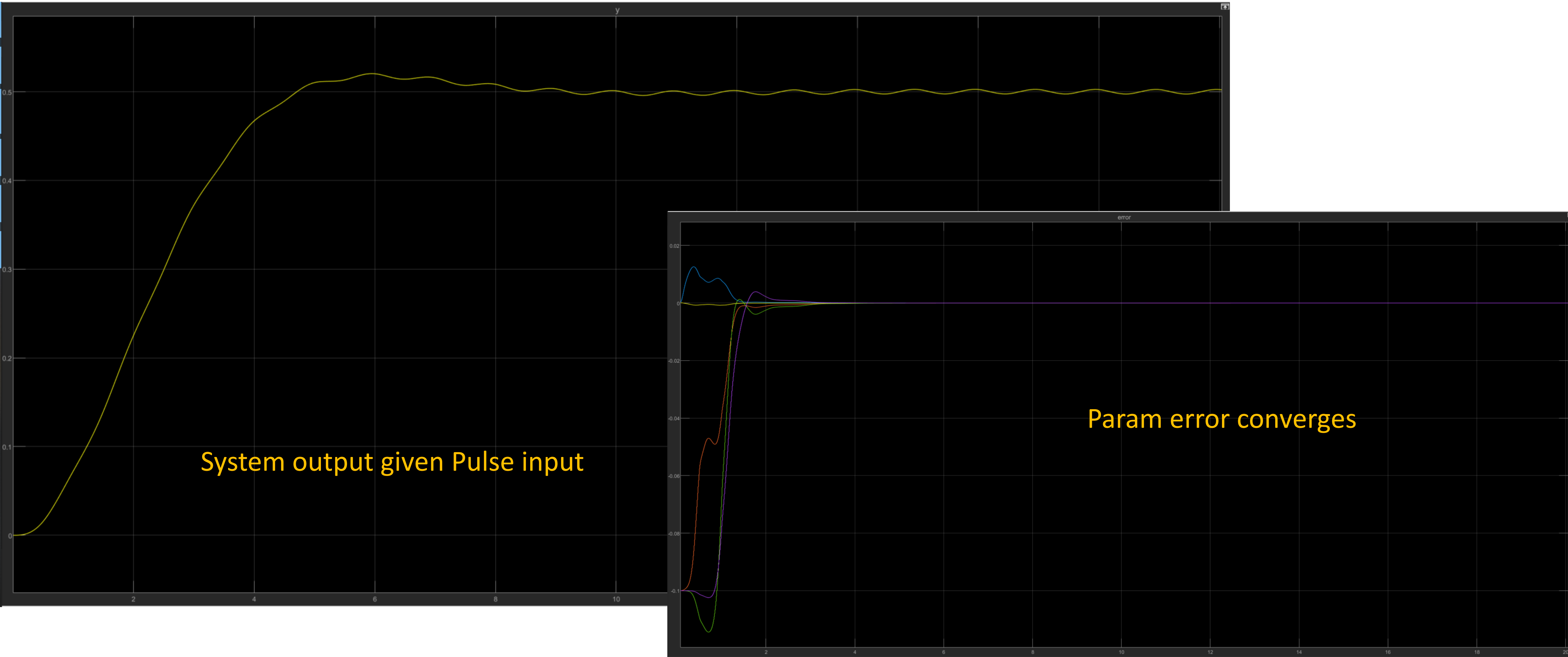
LQG – P1 – Frequency response (non-adaptive)

- Bandwidth: 0.063



LQG – P1 – system response (adaptive)

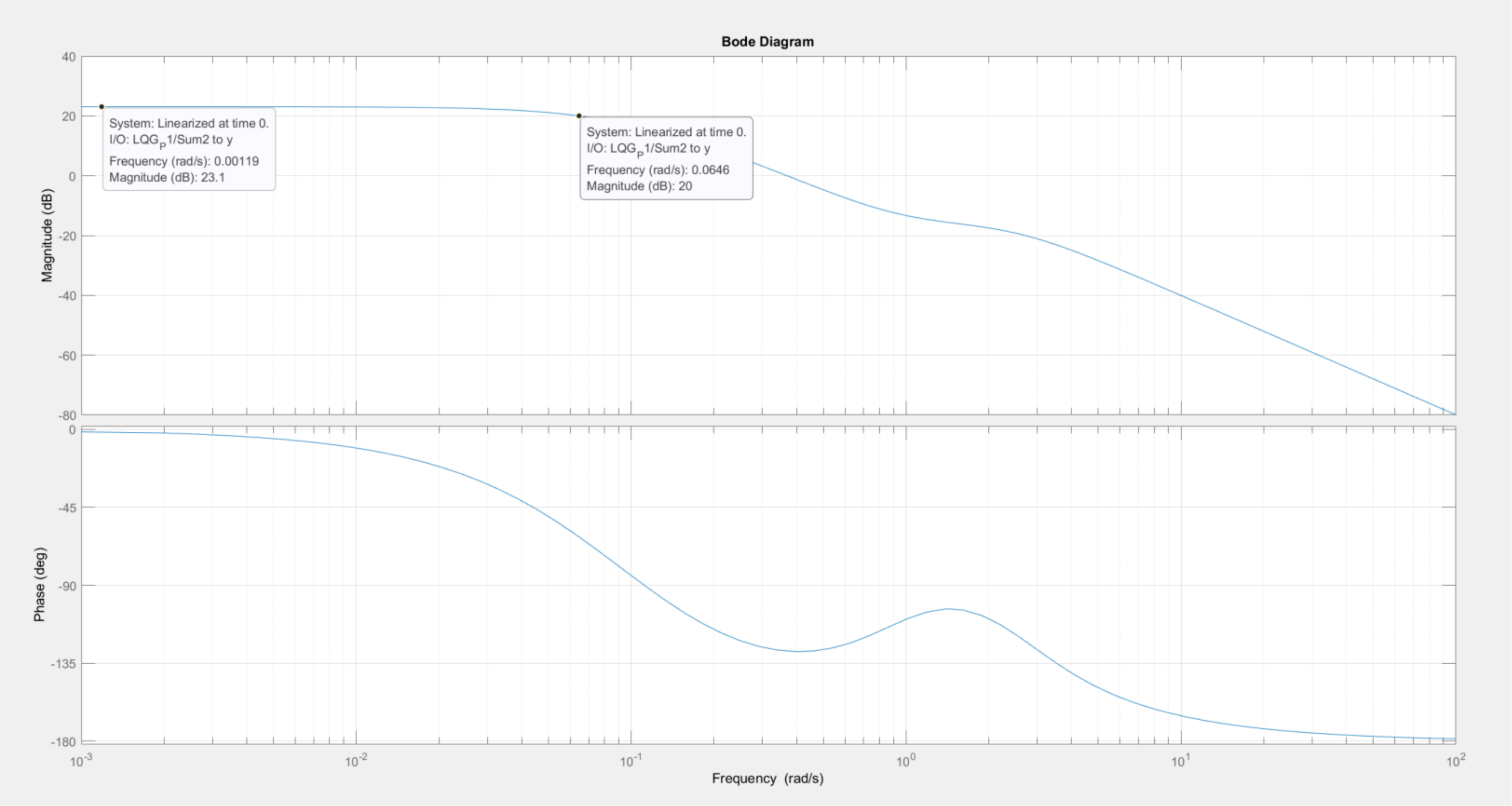
- Step size = 0.01s
- Q=I, R = 1



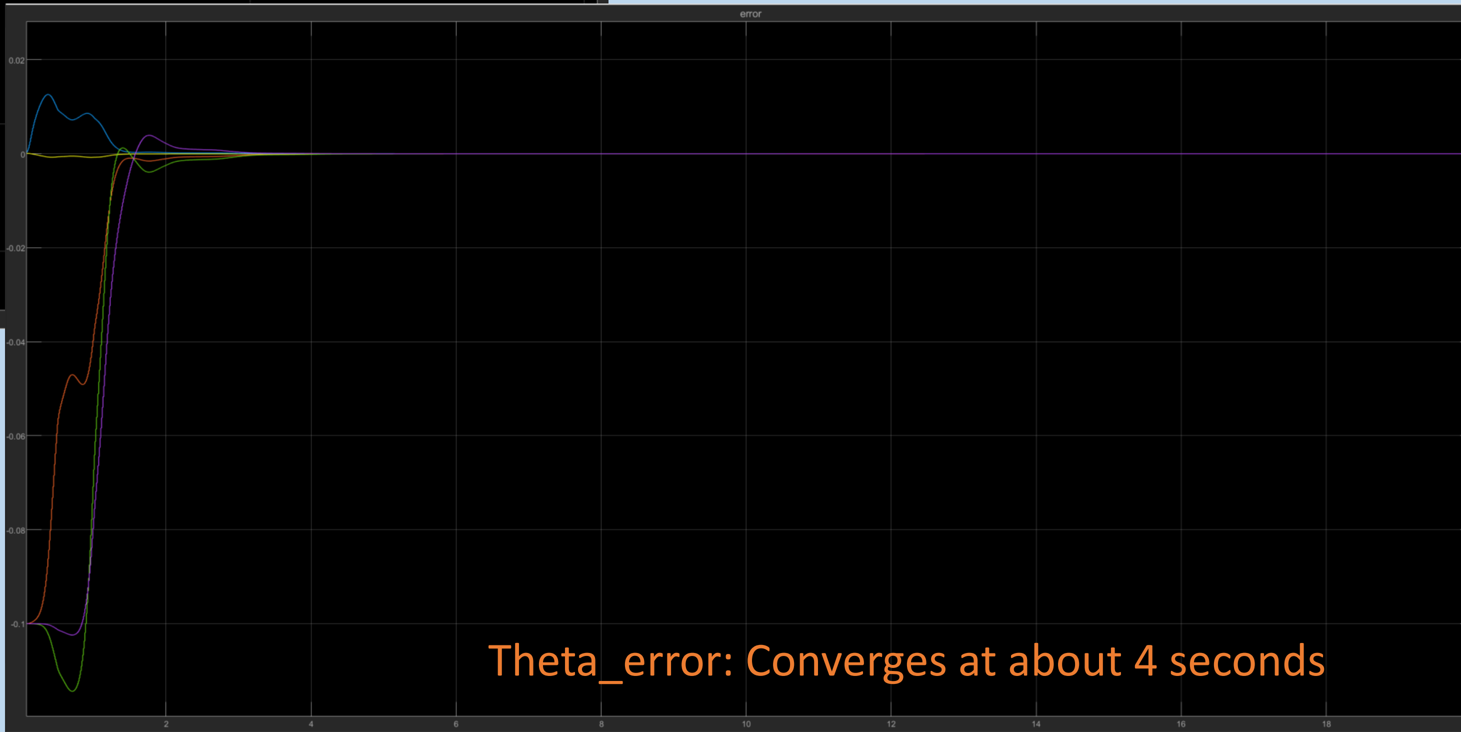
LQG – P1 – Frequency response - adaptive

#TODO

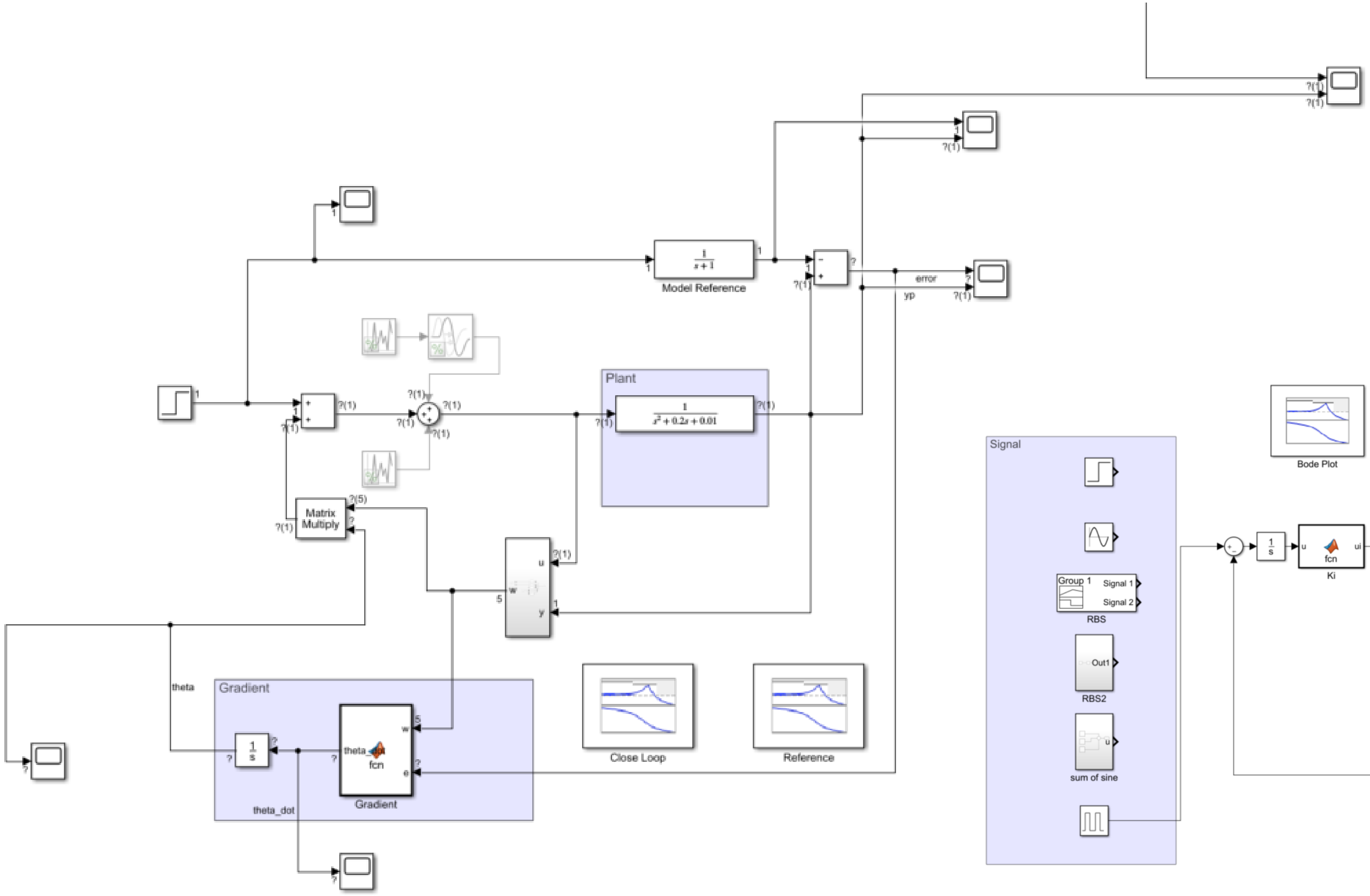
- Bandwidth: 0.0646



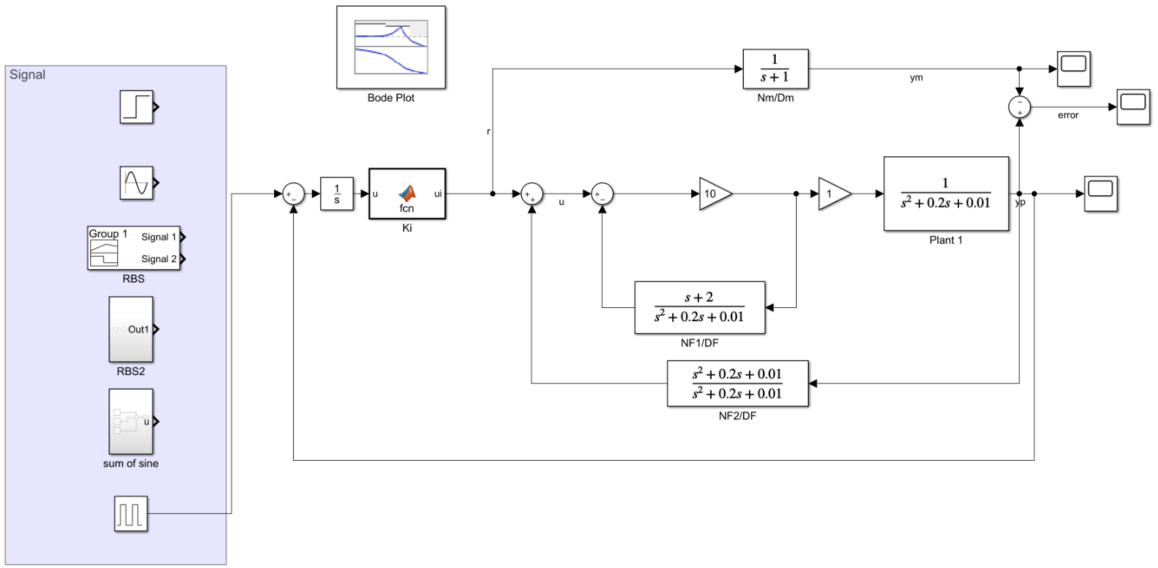
Adaptive LQG vs LQG comparison – Plant 1



MRC – system setup



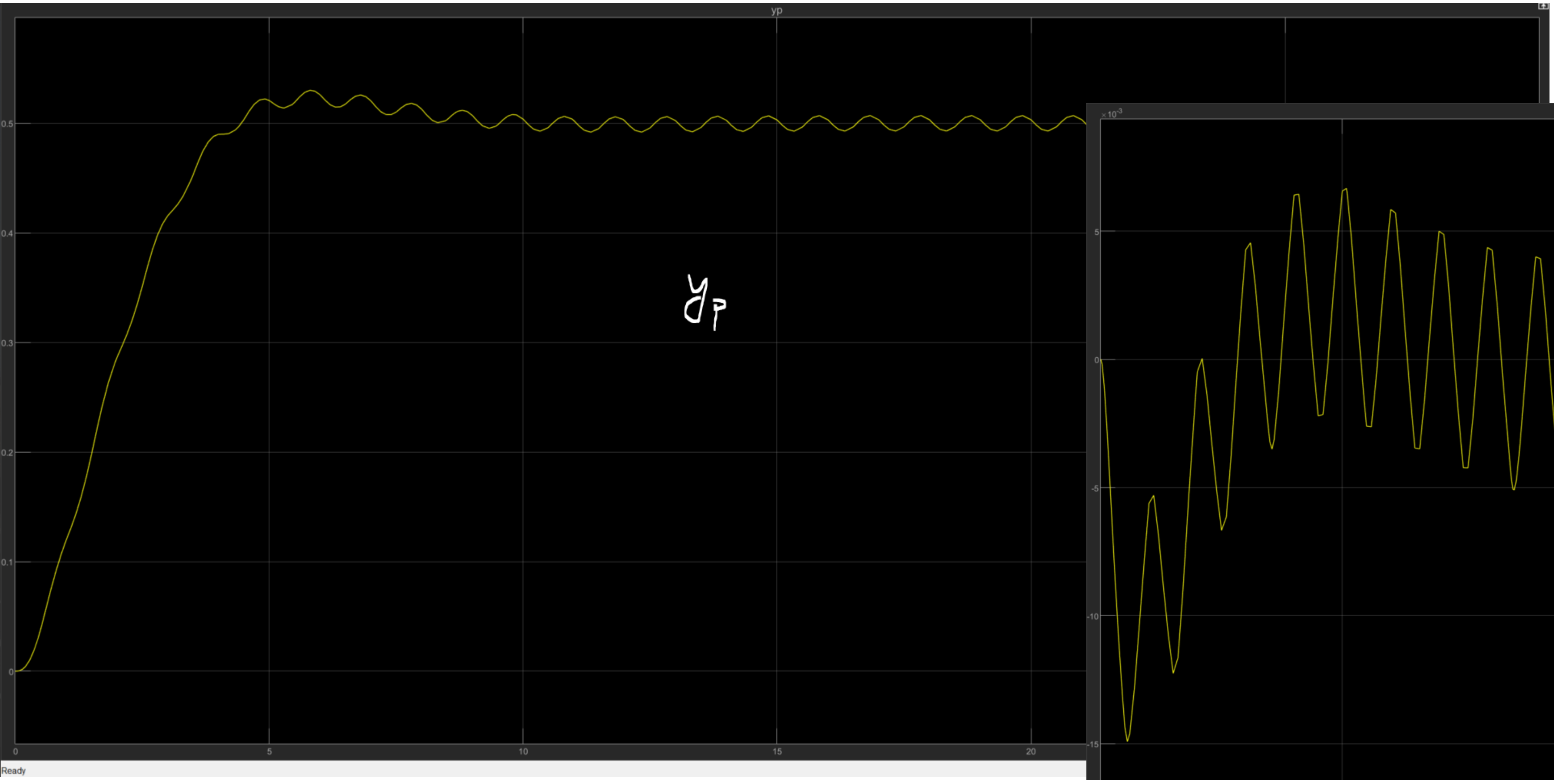
MRAC

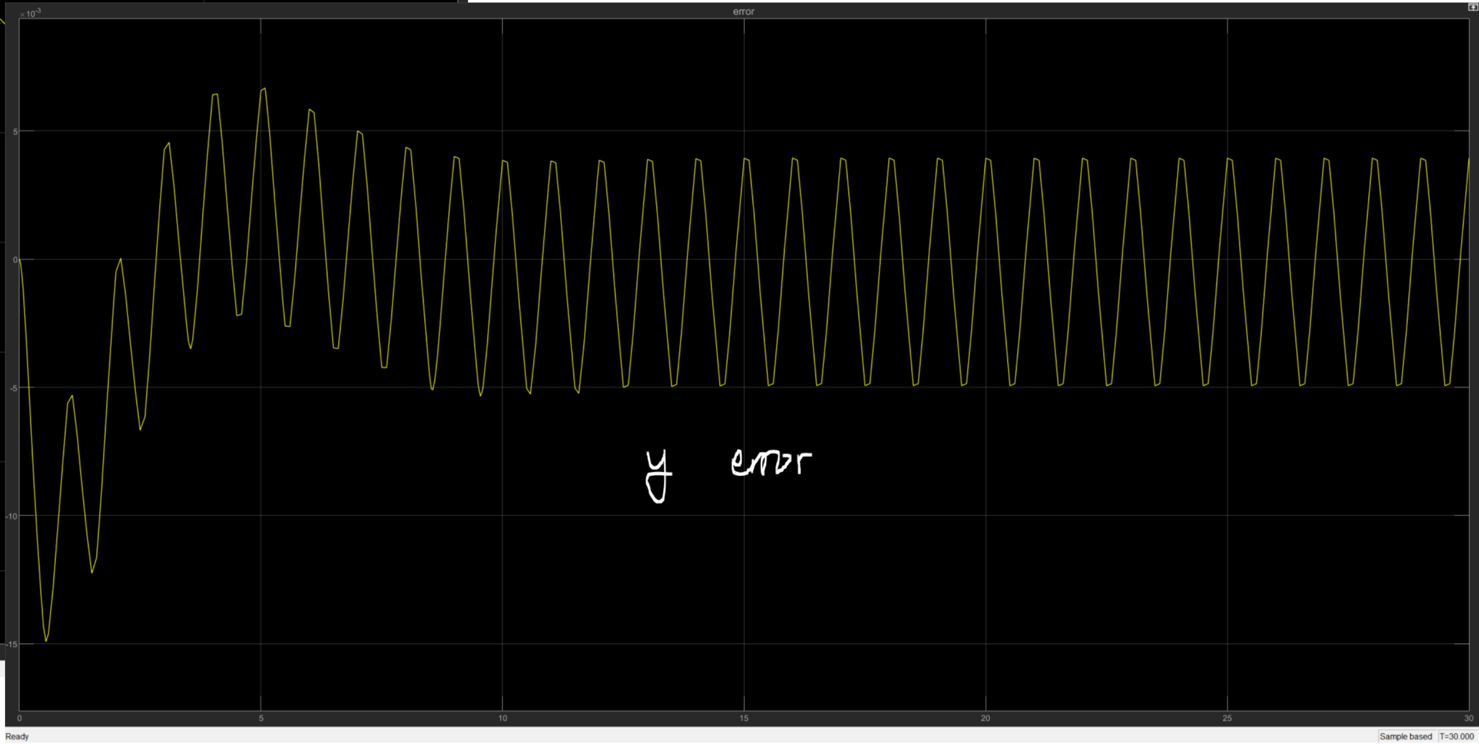


MRC

MRC – P1 – System response – non-adaptive

- The system was given a pulse train input
- The error to reference model are small (<0.5)

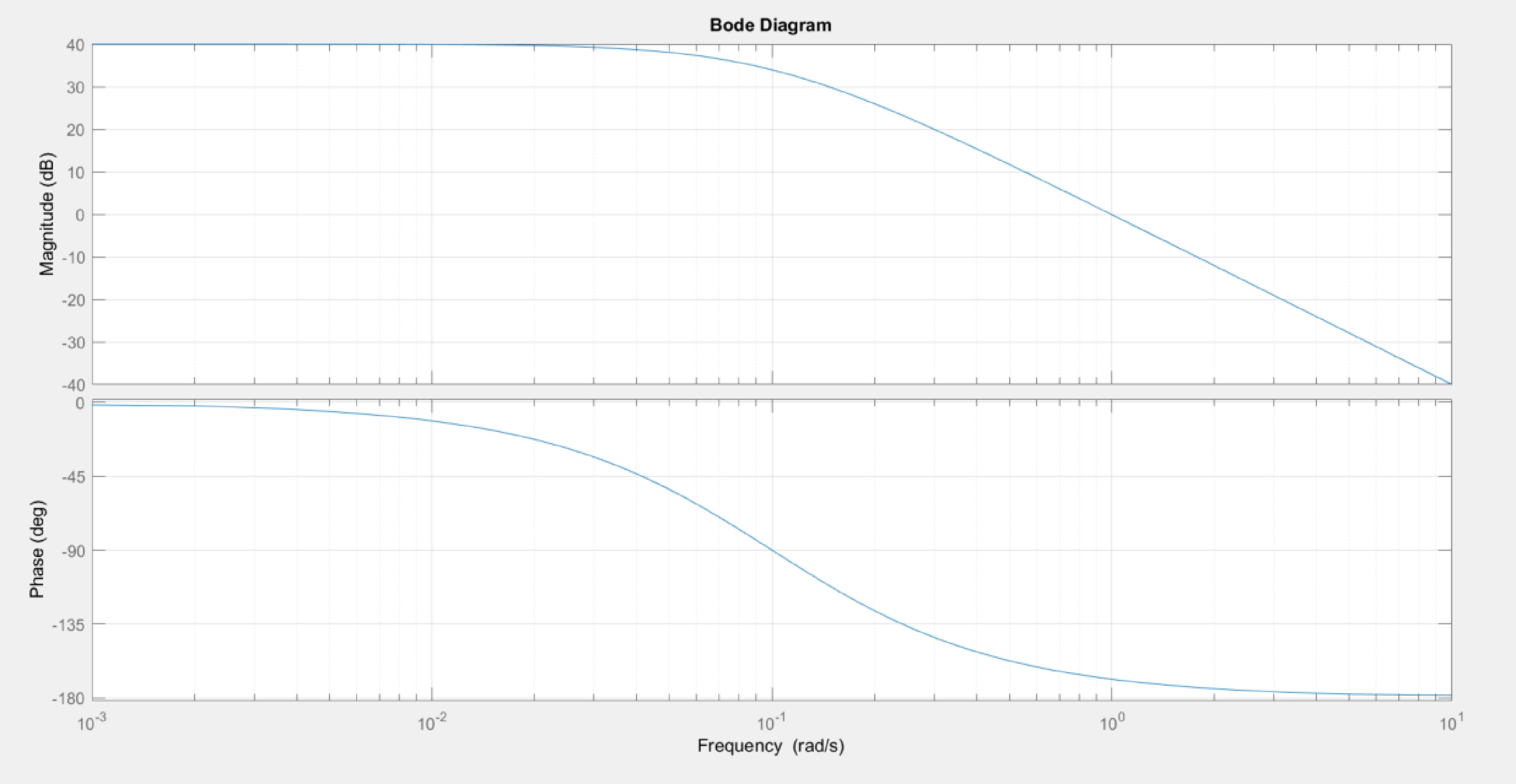




MRC – P1 – Frequency response – non-adaptive

#TODO

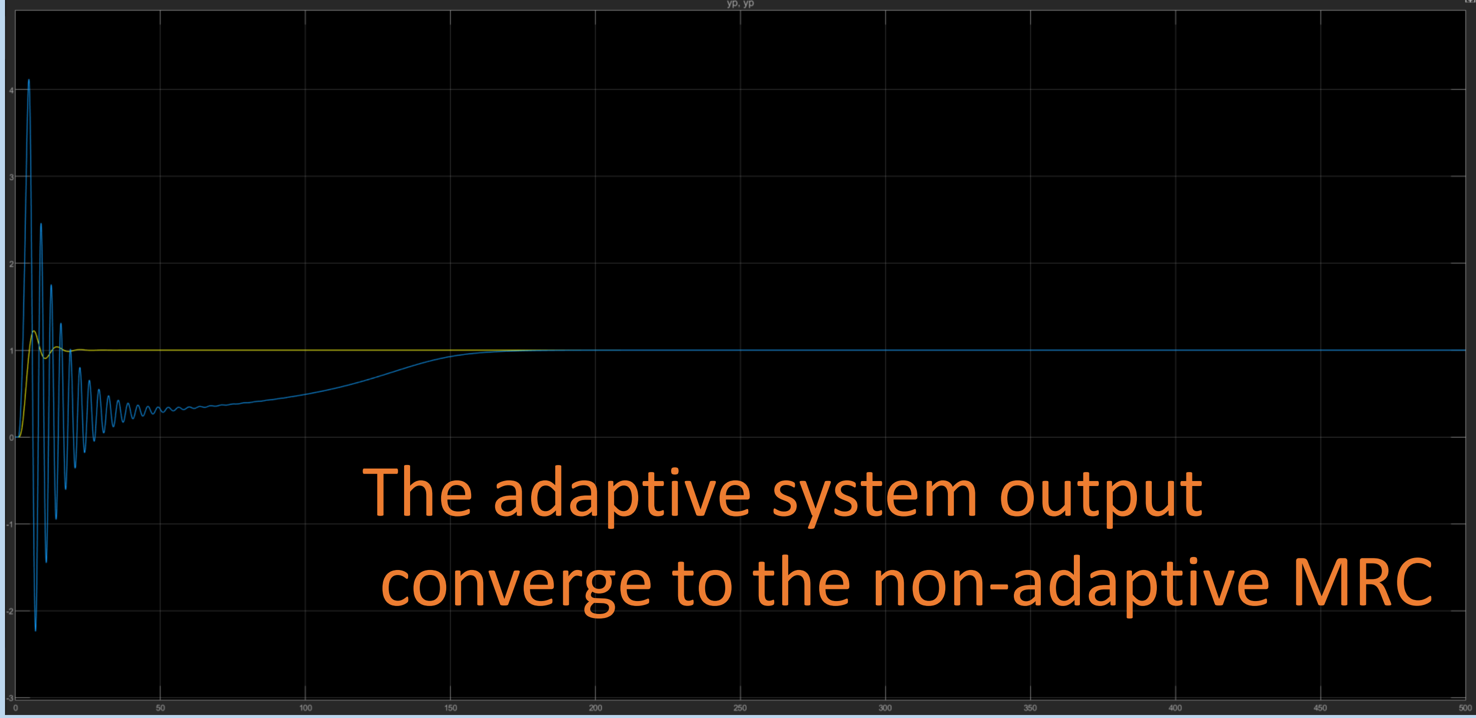
- Desired bandwidth: 1 rad/s



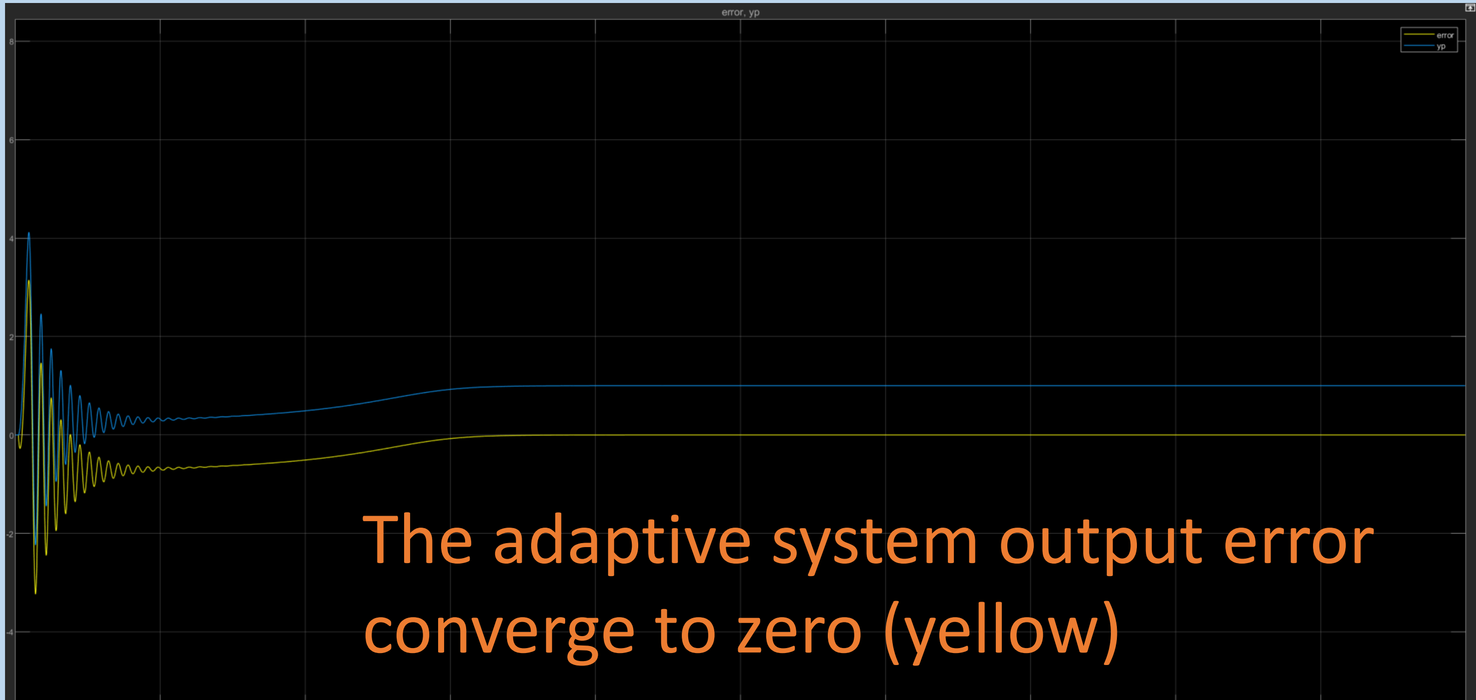
MRAC – P1

#TODO: where should the param converge to?

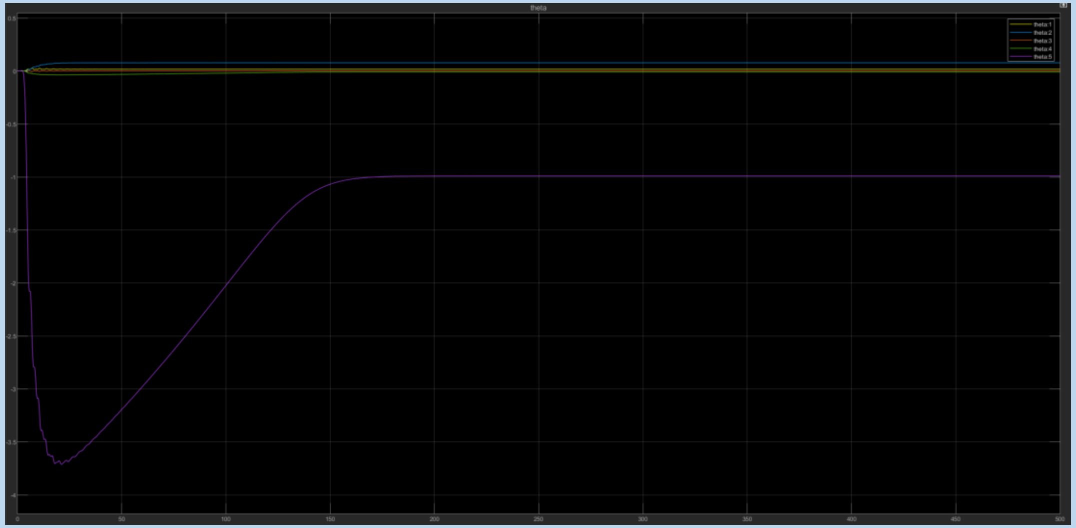
- Param converge to:
- [0.017 0.078 0 -0.01 -1]
- This trial was given a step input



The adaptive system output converge to the non-adaptive MRC



The adaptive system output error converge to zero (yellow)



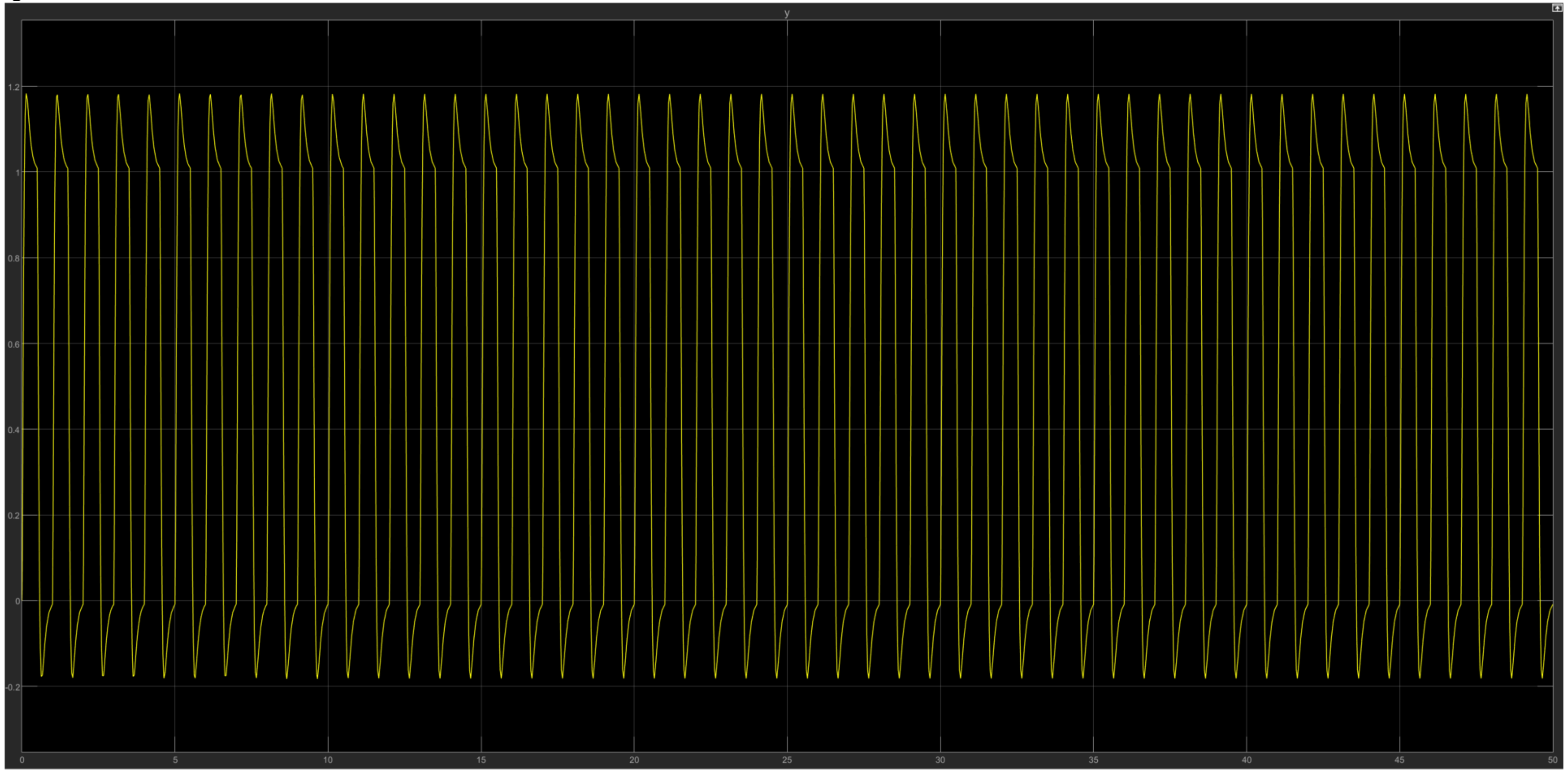
Plant 2:

$$P = \frac{4s + 25}{s^2 + 6s + 25}$$

- Open loop pole: -3+
- Open loop bandwidth:
- Settling time: 3%
- Overshoot: 11%
- Controllable: yes
- Observable: yes

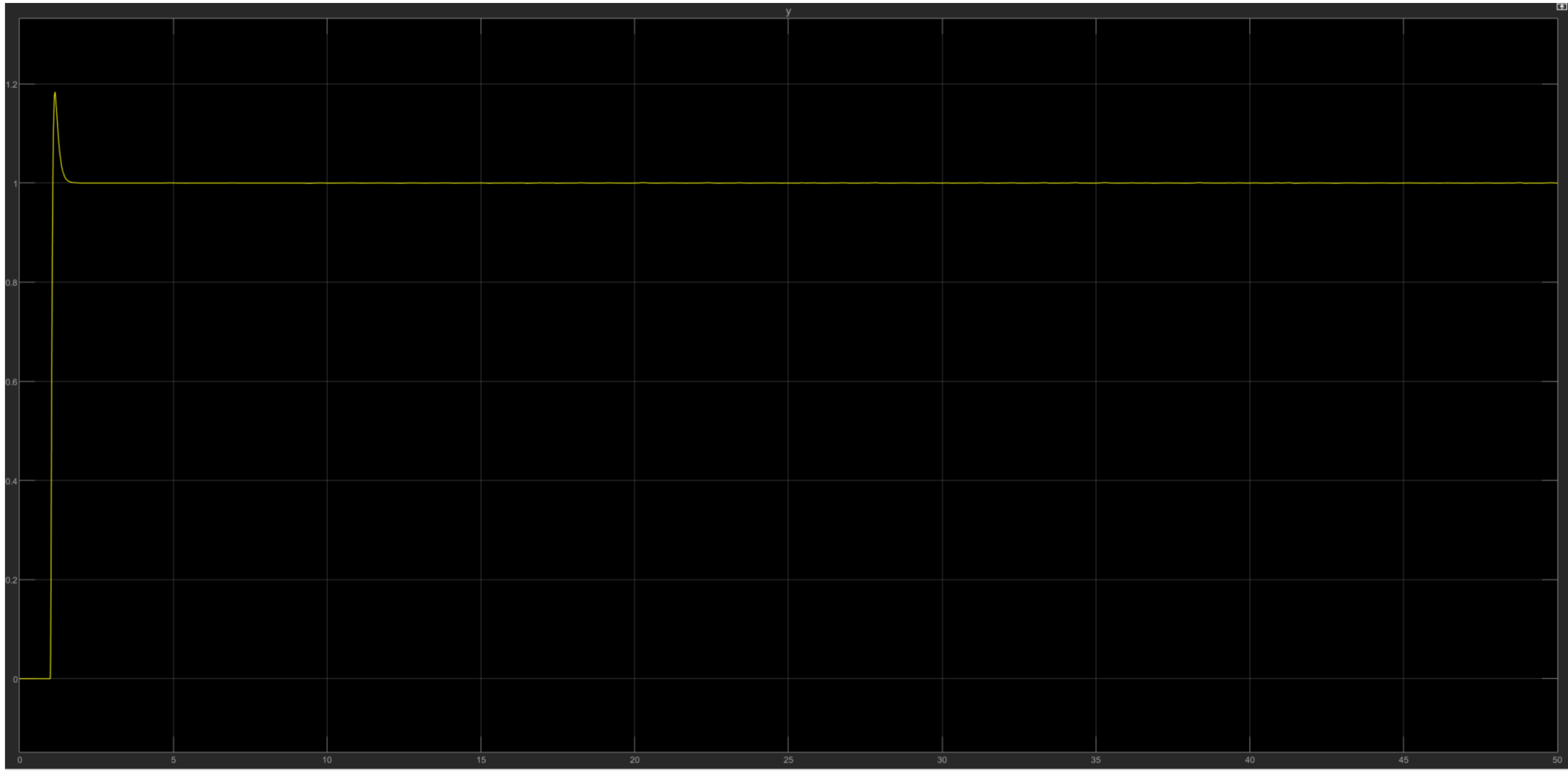
PPC – P2 – System response - non-adaptive

- Poles are designed to be [-30+4i, -30-4i, -10], 10 times farther from open loop pole
- Reference input is **pulse train**

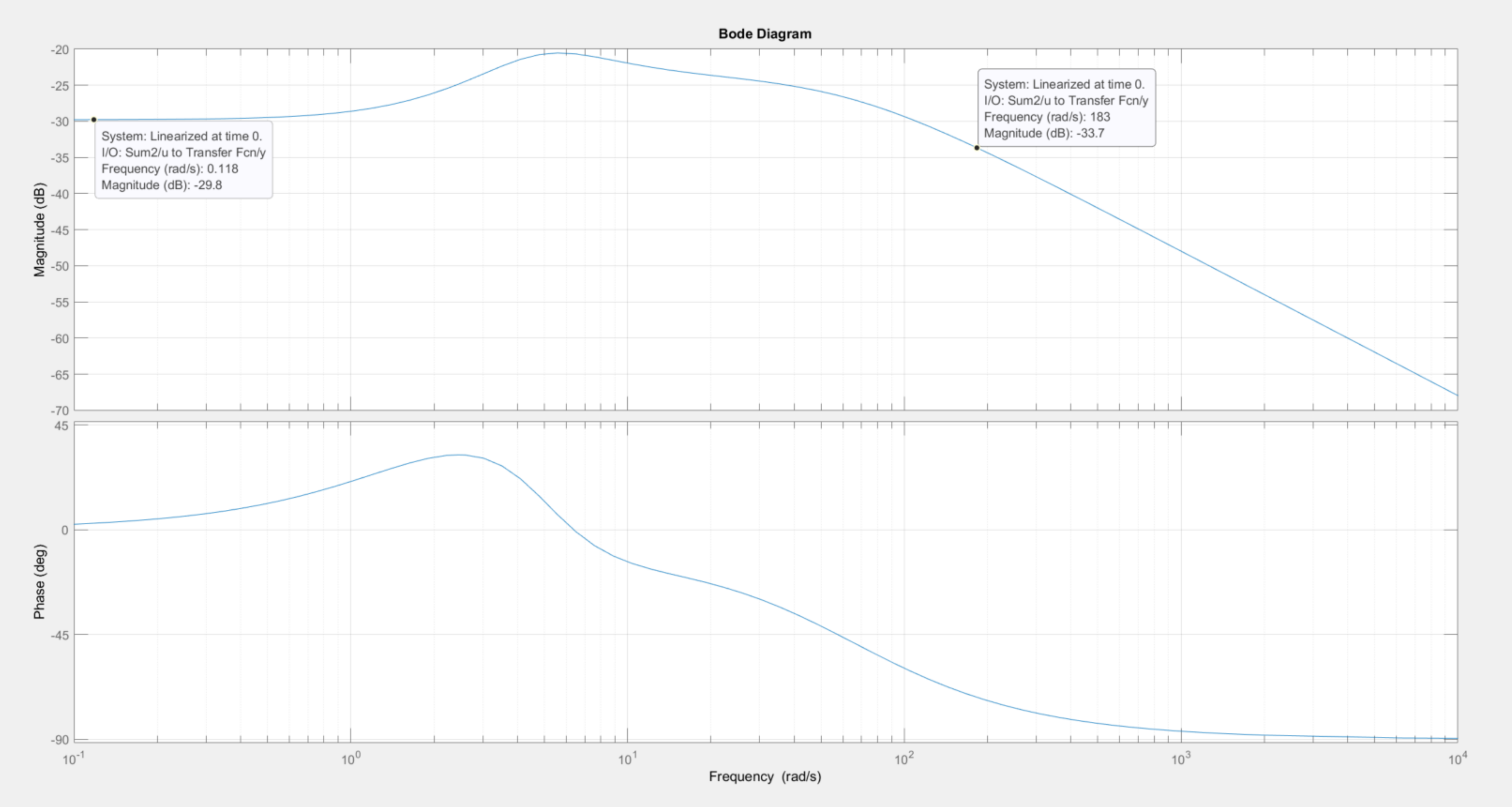


PPC – P2 – System response

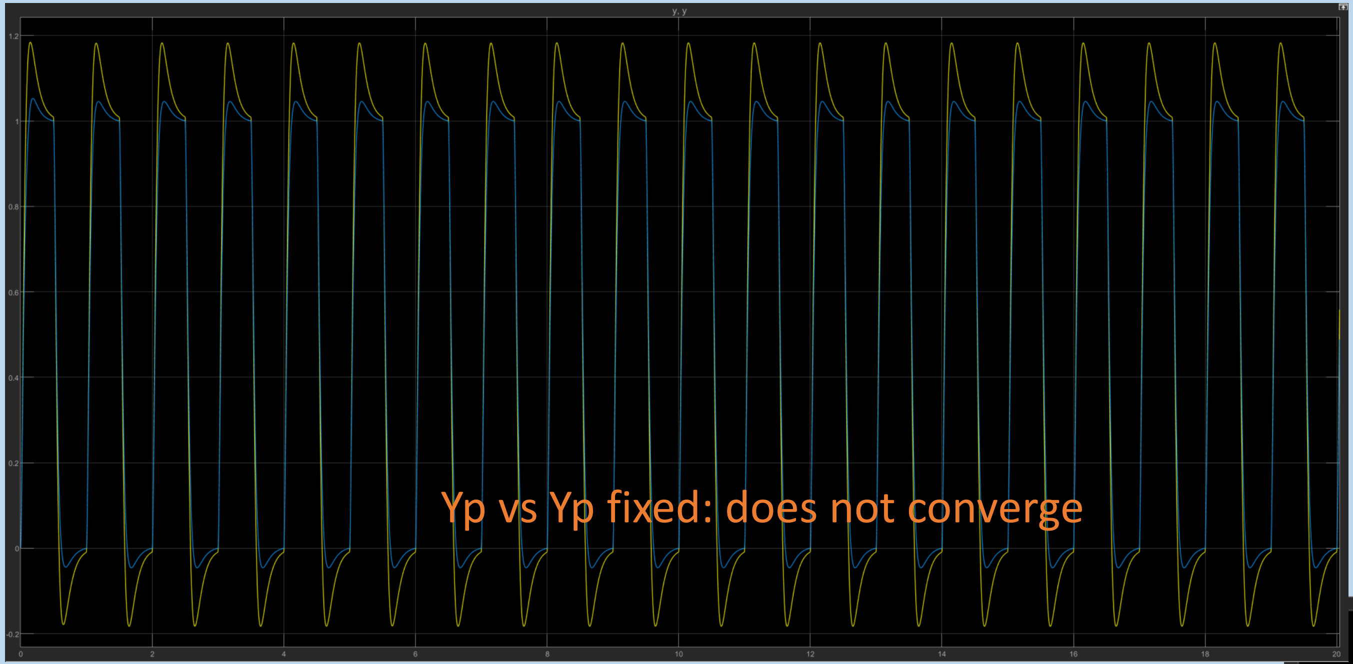
- Poles are designed to be [-30+4i, -30-4i, -10], 10 times farther from open loop pole
- Reference input is a **step**



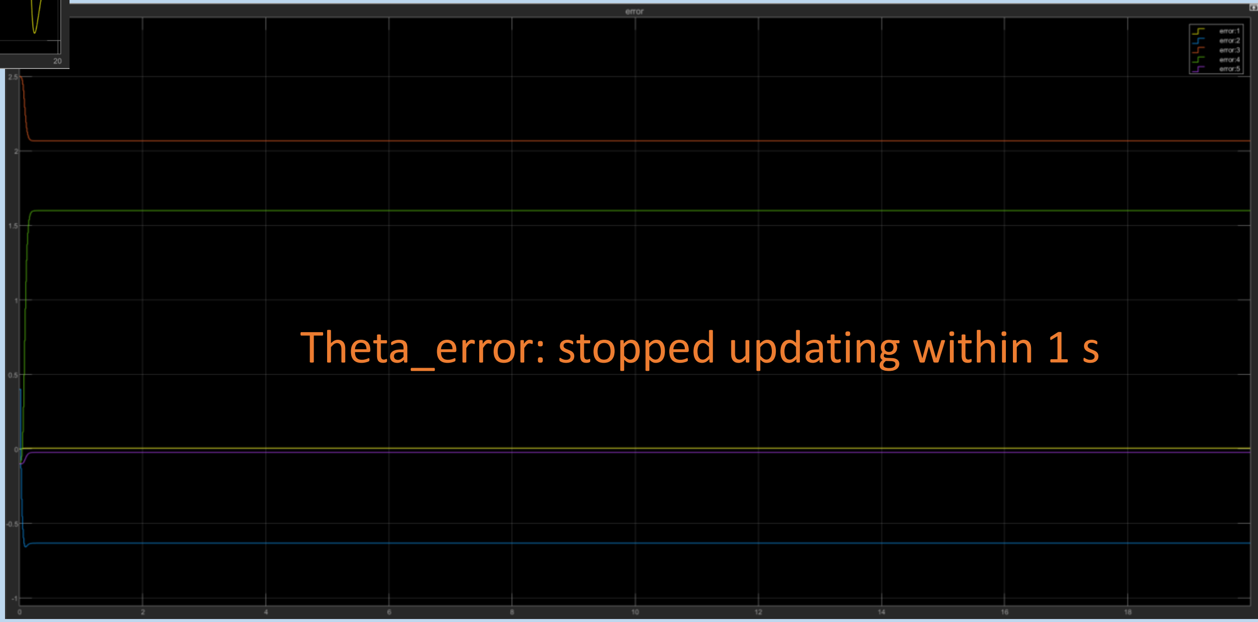
PPC – P2 – Frequency response



PPAC vs PPC comparison – Plant 2



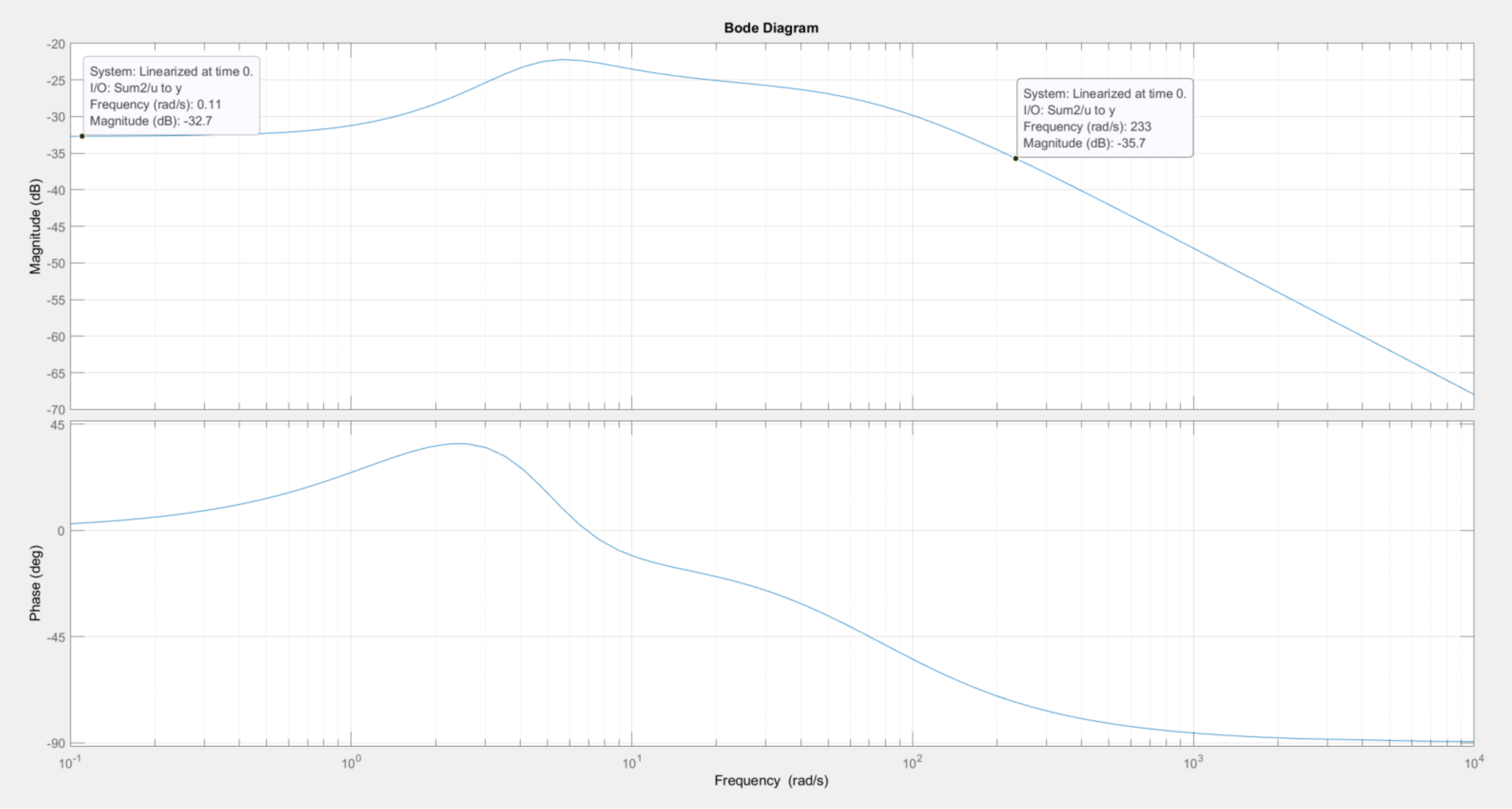
I have tried various gamma for LS algorithm, and they converge to different parameters. If I set gamma to be 1, the param would grow too fast and the system would blow up.



I have also attempted PRBS injection, with frequency from 1Hz to 10 Hz, but none of them helped the parameters to converge, even if they altered the converged number a little bit.

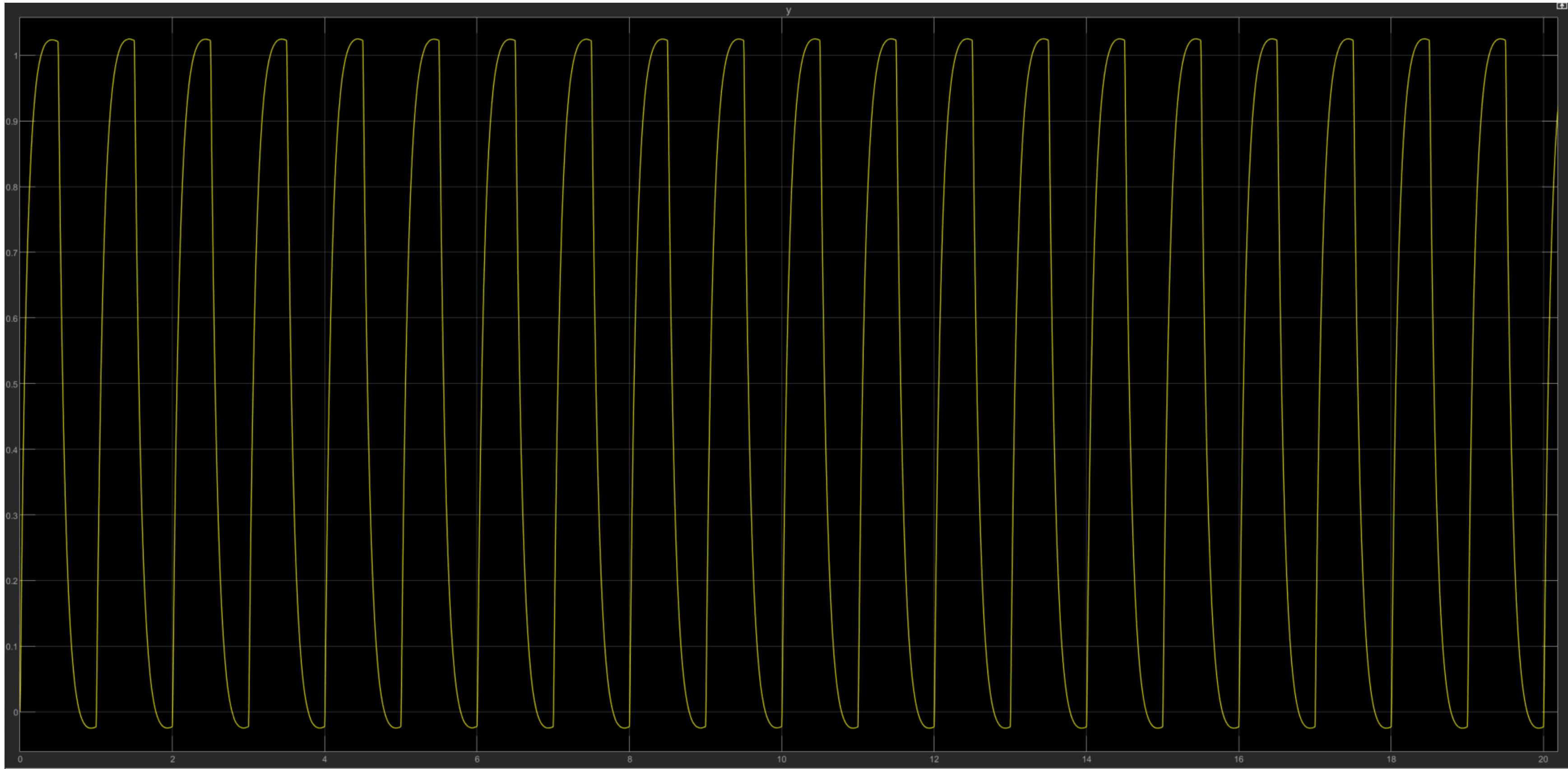
PPAC – P2 – Frequency response - adaptive

- Bandwidth= 233
- When designing this controller, I was attempting to have the system able to track the input. Therefore the high bandwidth



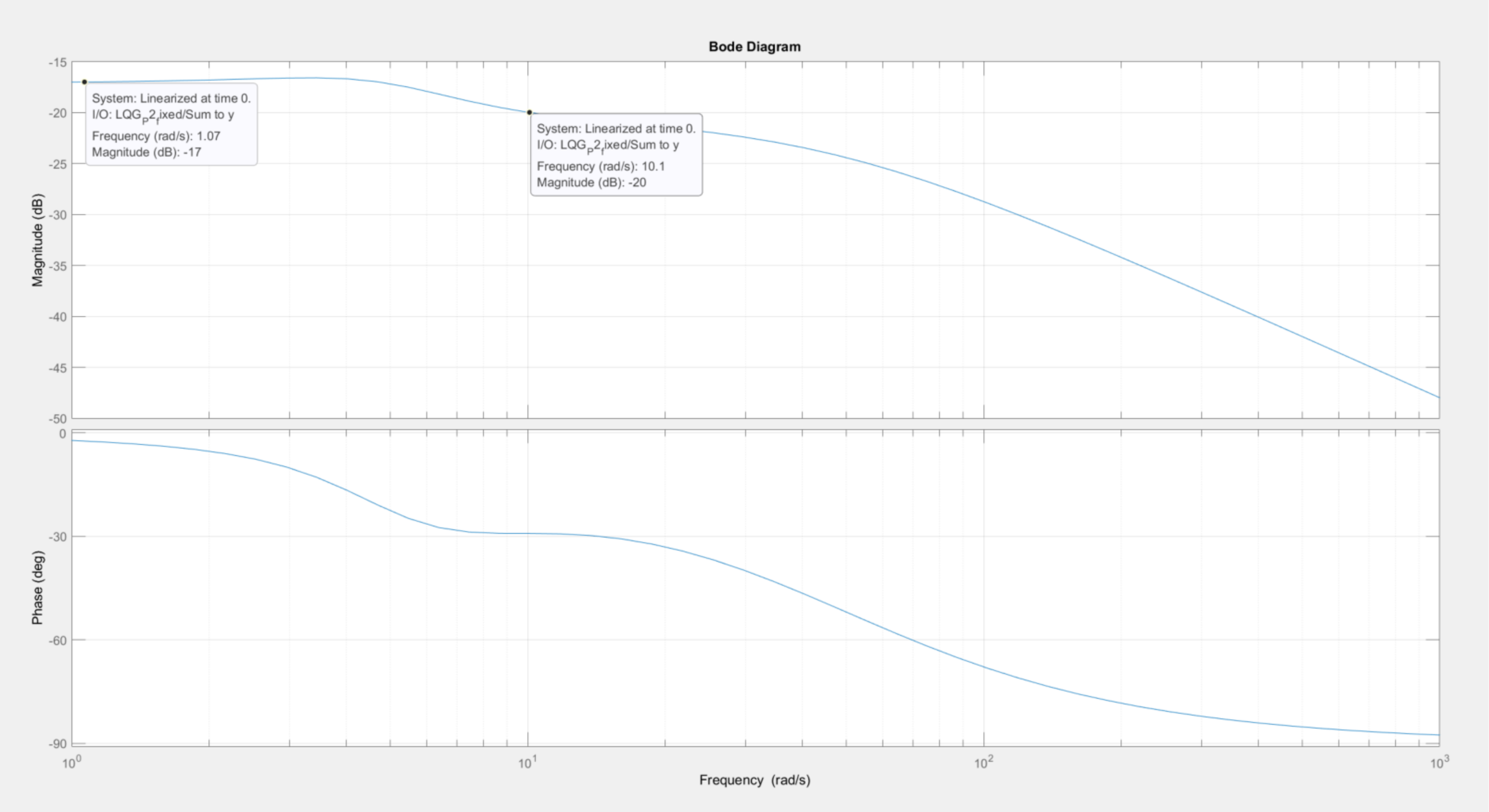
LQG – P2 – fixed - system response

- KF: Q=R=10
- Q = [100 0 0; 0 100 0; 0 0 1000]
- R = 0.001



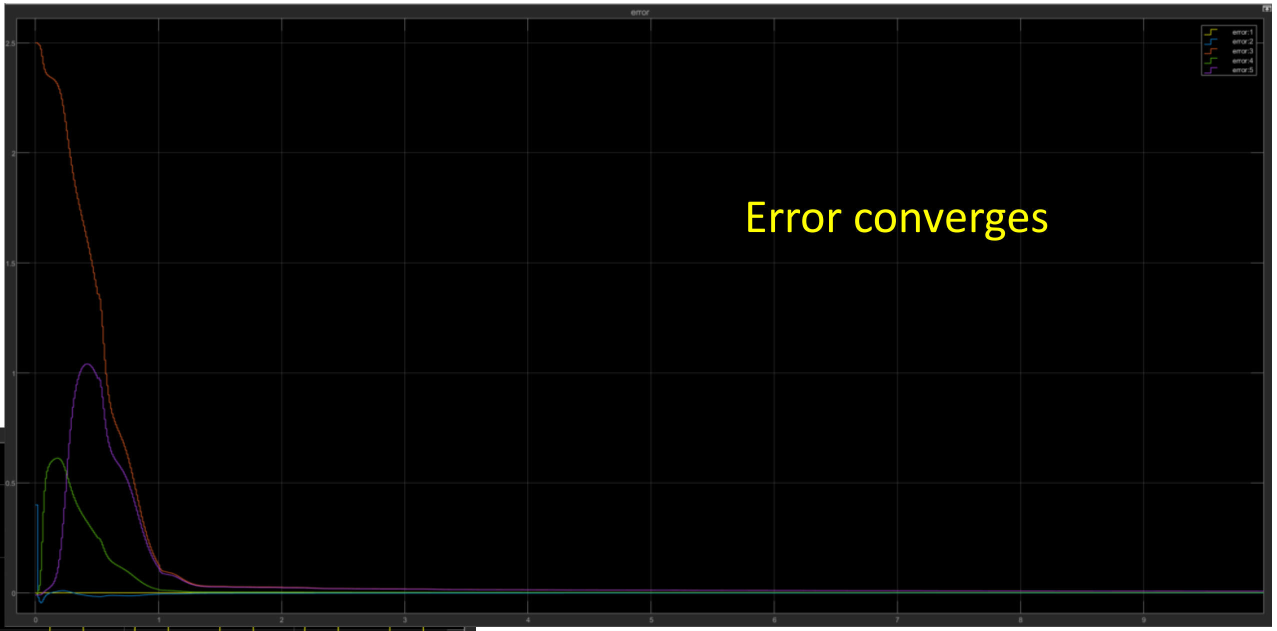
LQG – P2 – fixed - Frequency response

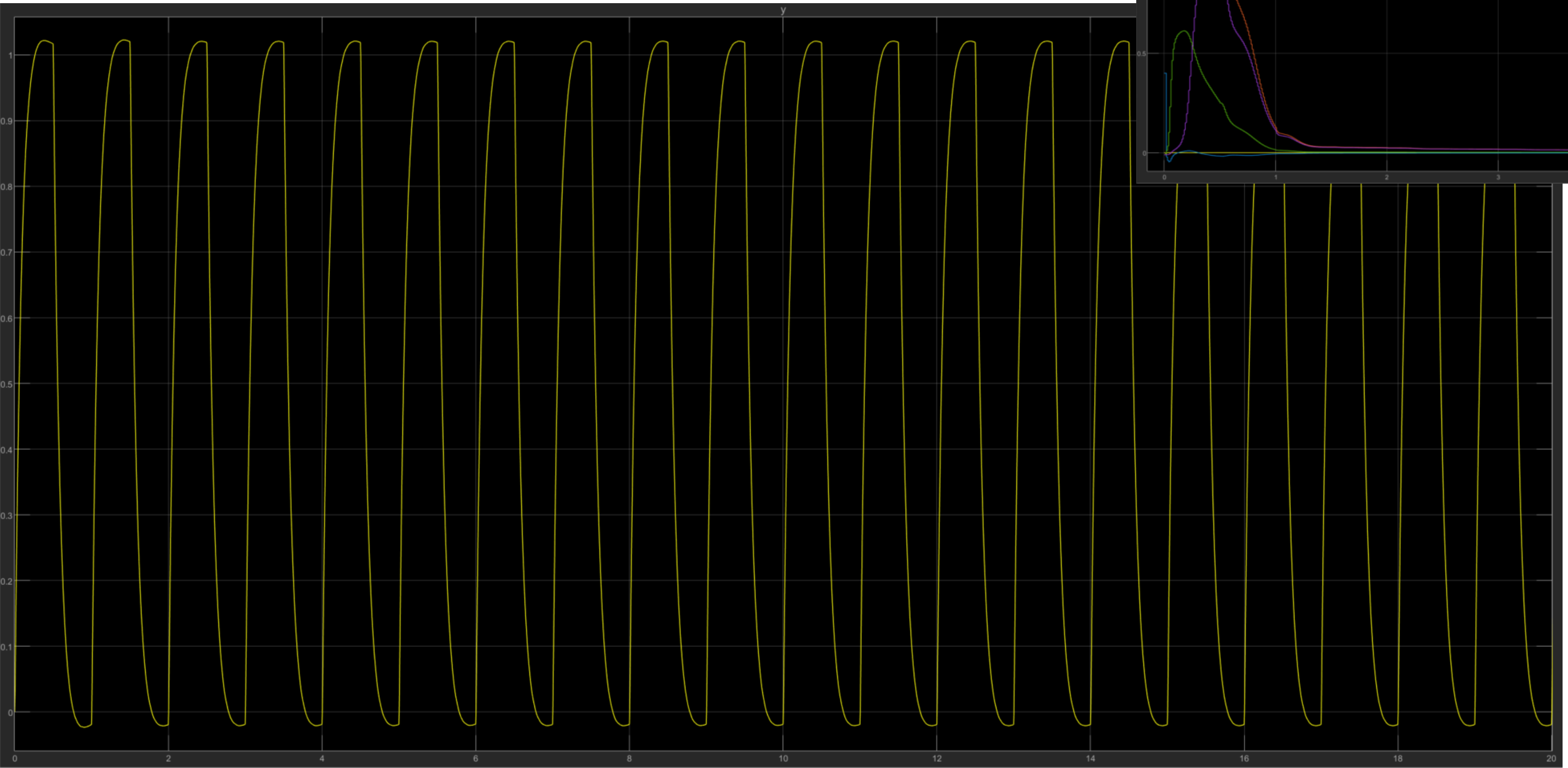
- Bandwidth: 10



LQG – P2 – adaptive - system response

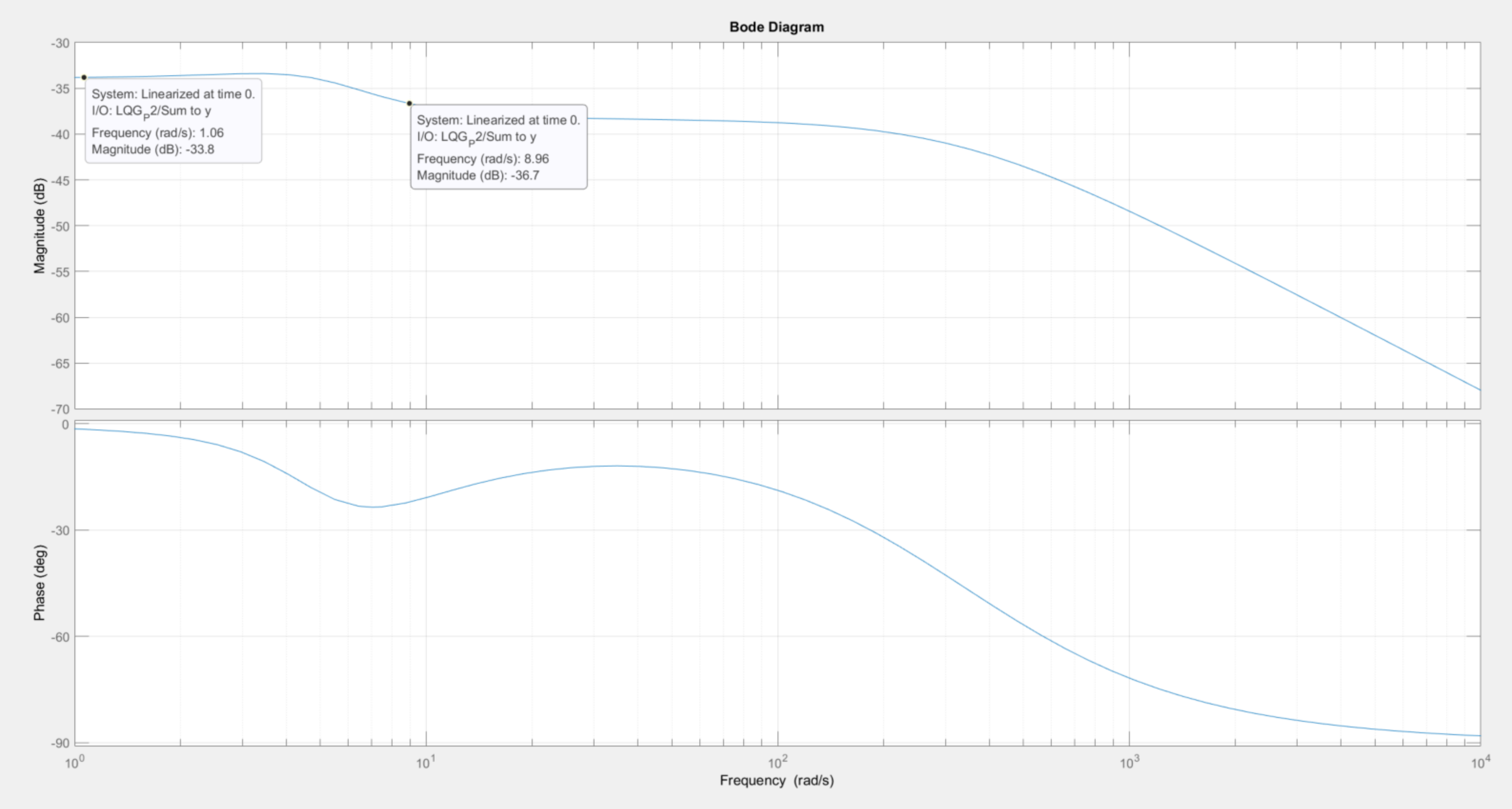
- KF: Q=R=10
- Q = [100 0 0; 0 100 0; 0 0 1000]
- R = 0.001
- Gamma = 1



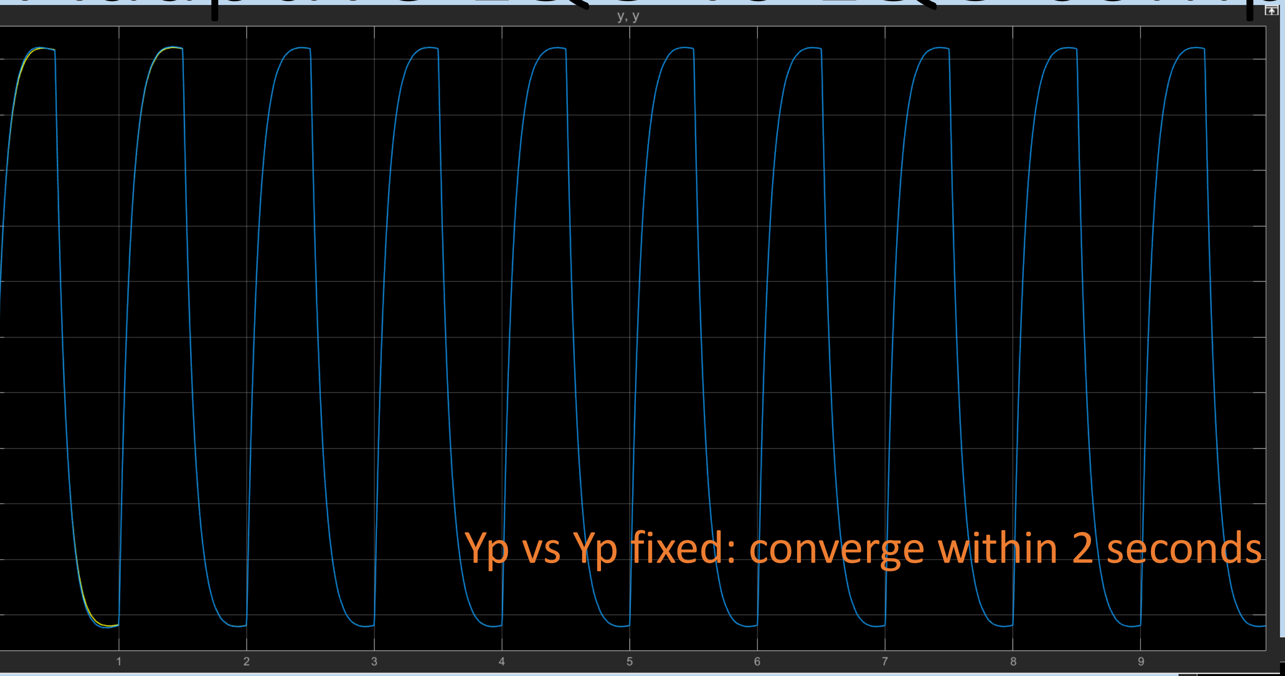


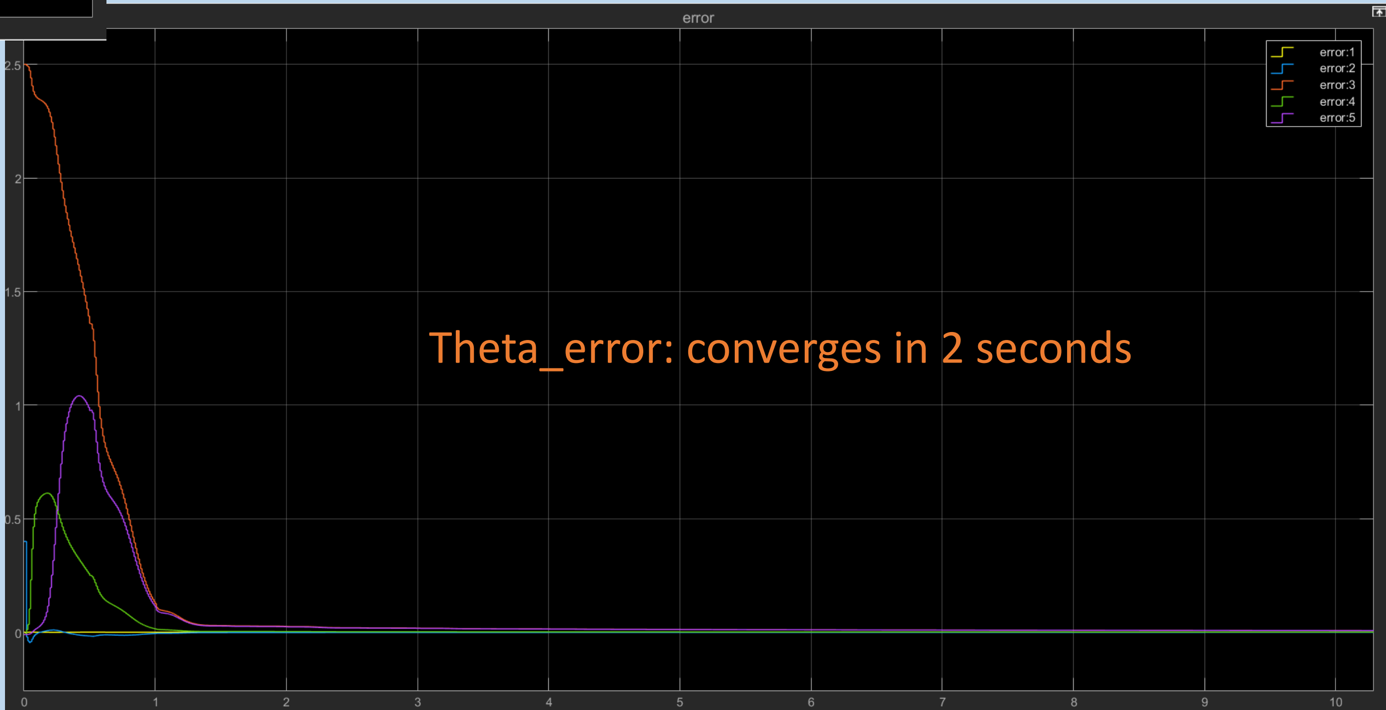
LQG – P2 – adaptive - Frequency response

- Bandwidth: 9



Adaptive LQG vs LQG comparison – Plant 2





Summary

- We designed a fixed controller that tracks the reference input, then tested that the adaptive controllers **converge** to the fixed ones.
- The adaptive controllers are able to converge to the fixed controller, with least square algorithm and 10% error from actual parameters.
- The gain (gamma) for the least square algorithms had to be lowered by 10^{th} order to prevent the system from blowing up.
- Note that sometimes the system response might look right, but the actual parameters are incorrect. More study of the params that the algorithm converges to are required.