UNIVERSITY OF WESTMINSTER

INFORMATICS INSTITUTE OF TECHNOLOGY

Informatics Institute of Technology

Department of Computing (B.Eng.) in Software Engineering

Coursework (2021/2022)

Module Name -: ROBOTIC PRINCIPLES

Module Code -: 5ELEN018W

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Date of Submission -: 27/02/2022

Acknowledgement

We are honestly thankful to Informatics Institute of Technology for providing us this great opportunity to write an Analysis Report. This Coursework was a huge impact to improve my skills and get a knowledge to work with MatLab.

I am also grateful to our Introduction to Information Technology module lecture Ms. Nipuni Perera for guiding and helping us in every stage of this research. Without their guidance it would have been very difficult for us to prepare the report so clearly and meaningful.

I hope this Coursework will help all those who interested in robotics, to get a knowledge.

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1. Part I.a: Analyzing and modeling the basic system (plant)

The software used was MATLAB R2022a. In MATLAB, the Simulink toolset is applied. The automobile is designed with an Open-loop control. The car had a 1000kg point mass. The prismatic joint's damping coefficient was 50 N/(m/s). Following the execution of the aforementioned, the following observations were made: The car fell into the earth's gravitational pull. After that, I made a subsystem.

To shift the orientation of a connected automobile, a rigid transformis used. (The prismatic joint was not altered.) In relation to the joint, the car is orientated. Rotated prismatic joint along Y axis to move automobile along X axis. As indicated below, another prismatic joint was used to rotate the automobile back to its original position (Y axis). The input was set up to produce the actuation force, and the velocity in sensing was added.

A constant of 500 was added. A Simulink PS converter was used to connect a constant (constant value) to a prismatic joint (force vector). Its input signal unit was changed to Newton.

Car moved in the expected axis, as planned. (On the X-axis) A PS Simulink converter was linked to the other prismatic joint, and a scope was joined to the PS Simulink converter to examine the change in velocity of the automobile.

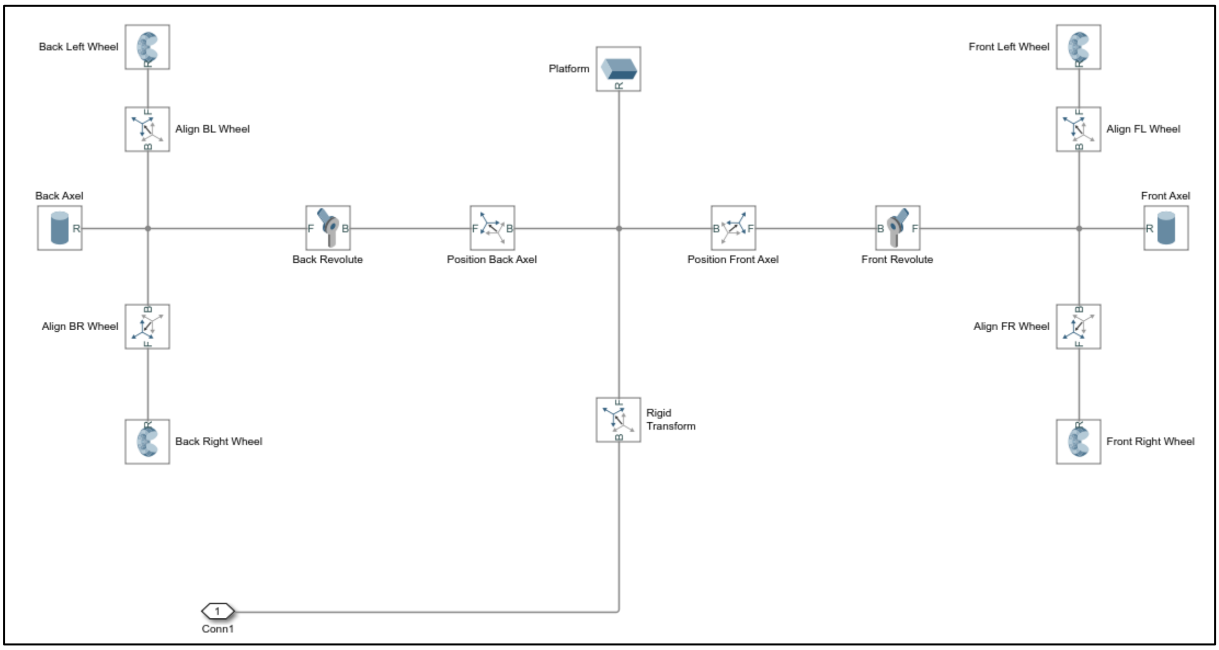

Figure 1: Subsystem of Car

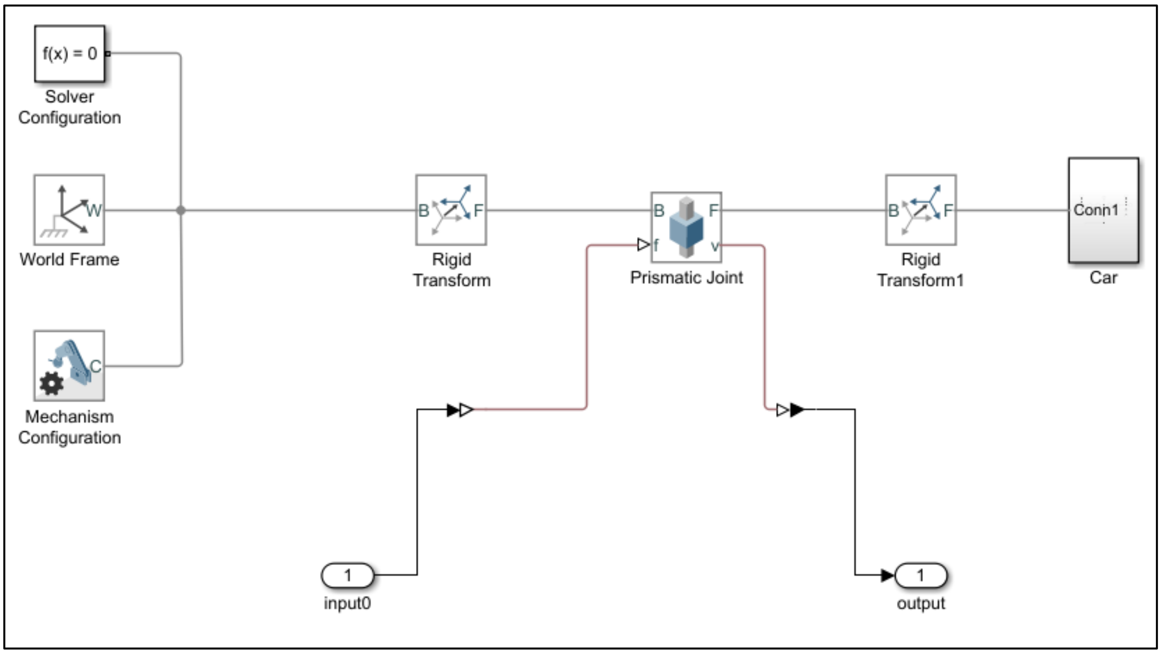

Figure 2: Subsystem of input and output

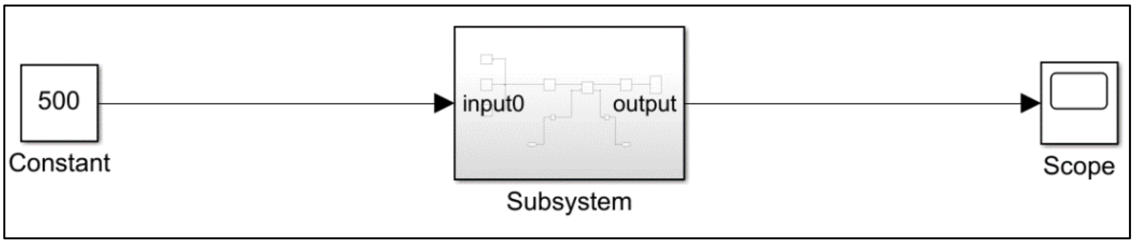

Figure 3: Controller system

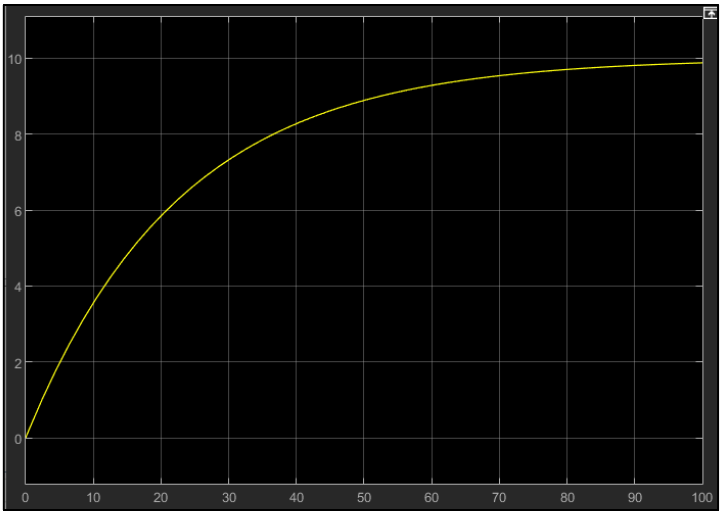

Figure 4: Scope

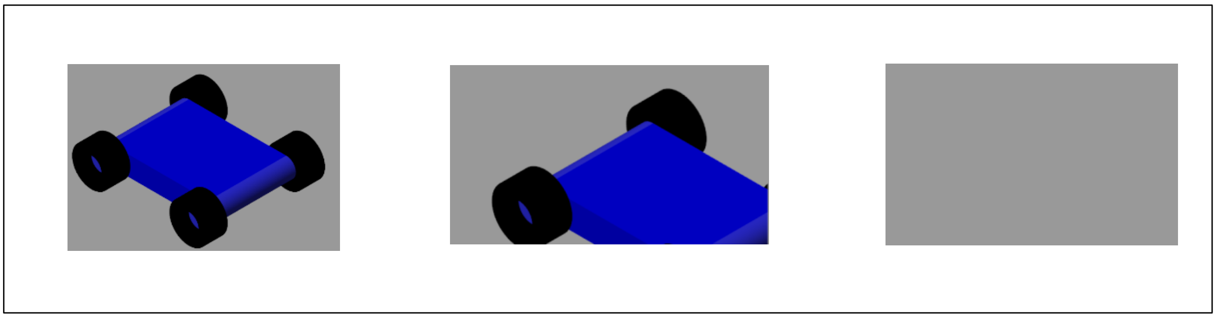

Figure 5: Car movements

2. Part I.b: Building PID controller and tune the controller

This is where a closed-loop control is started. The constant value (in velocity-> so this applies to speed) is utilized in such a way that the input and output are balanced (Constant value is 500ms-1). A PID and a sum block are did add. [The output of the constant value, variable is sent to the (wrong) PID for adjustment.] The error was adjusted to 0 with tuning the PID.

There are no oscillations when it settles at 500. The proportional gain is equal to 1, and the integral gain is equal to 1. Derivative gain equals 0 I changed the constant numbers to 1.5 and 200, however the graph's form did not change. PID values were modified both before and after the update.

The time it took to settle was shorter than the early stage. To reduce overshoot, many adjustments were made. With the least amount of overshoot, a smoother curve might be achieved. Input sensorless graph from time response analysis. It demonstrates how the system reacts in the event of an input disruption.

Increase the response speed by moving the response time slider to the right (open loop bandwidth). With the highest value, gain in the Controller parameters table grows and eventually drops.

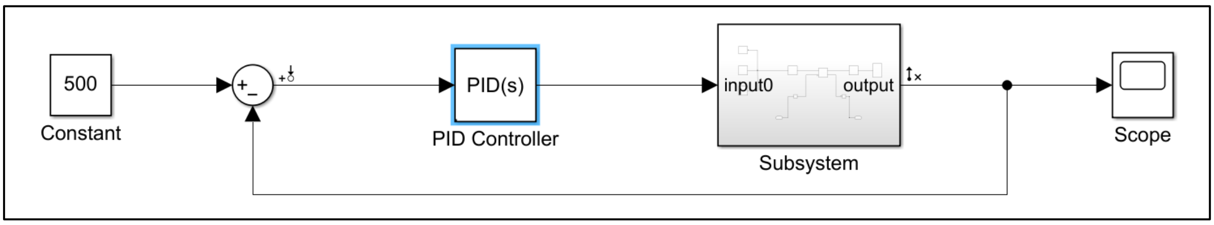

Figure 6: Implement the controller system

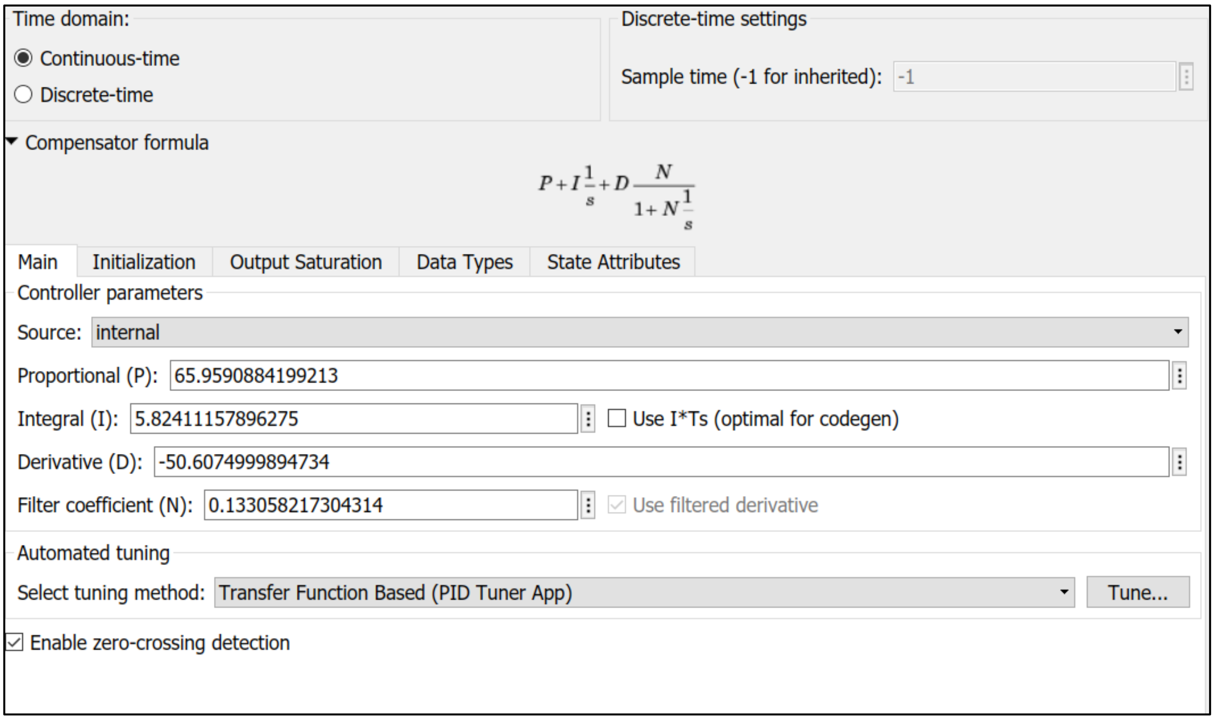

Figure 7: Fine-tune the controller

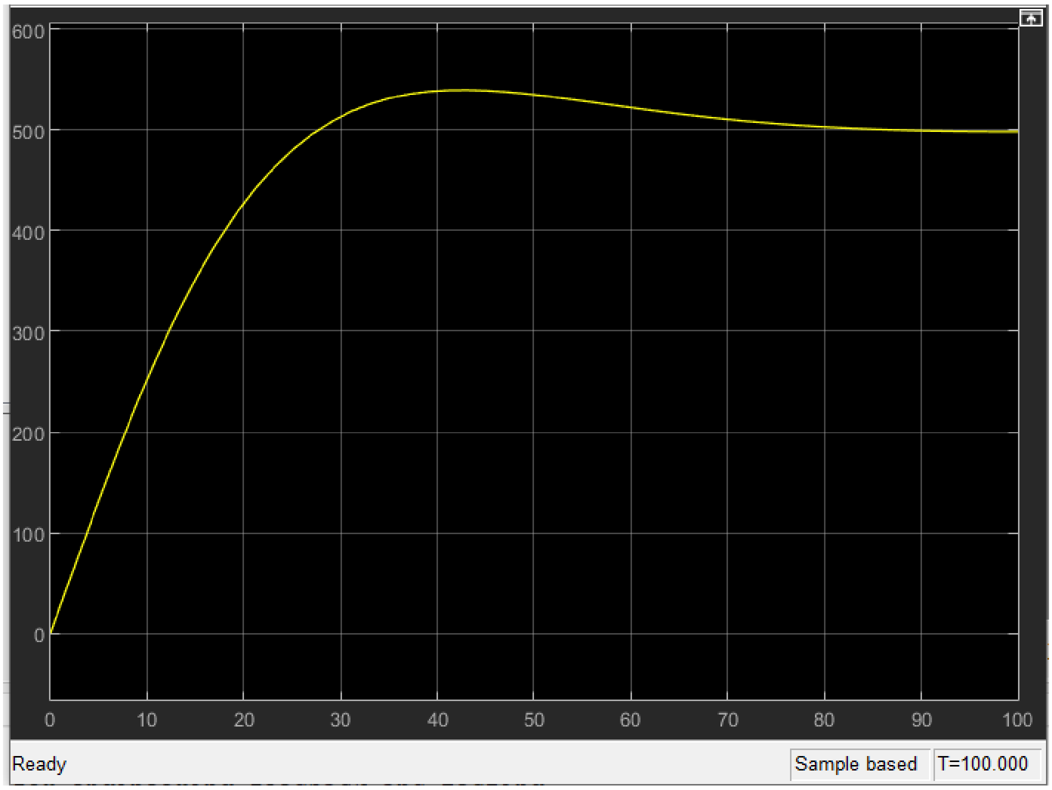

Figure 8: New scope

3. Response Diagrams

3.1. Bode Diagram

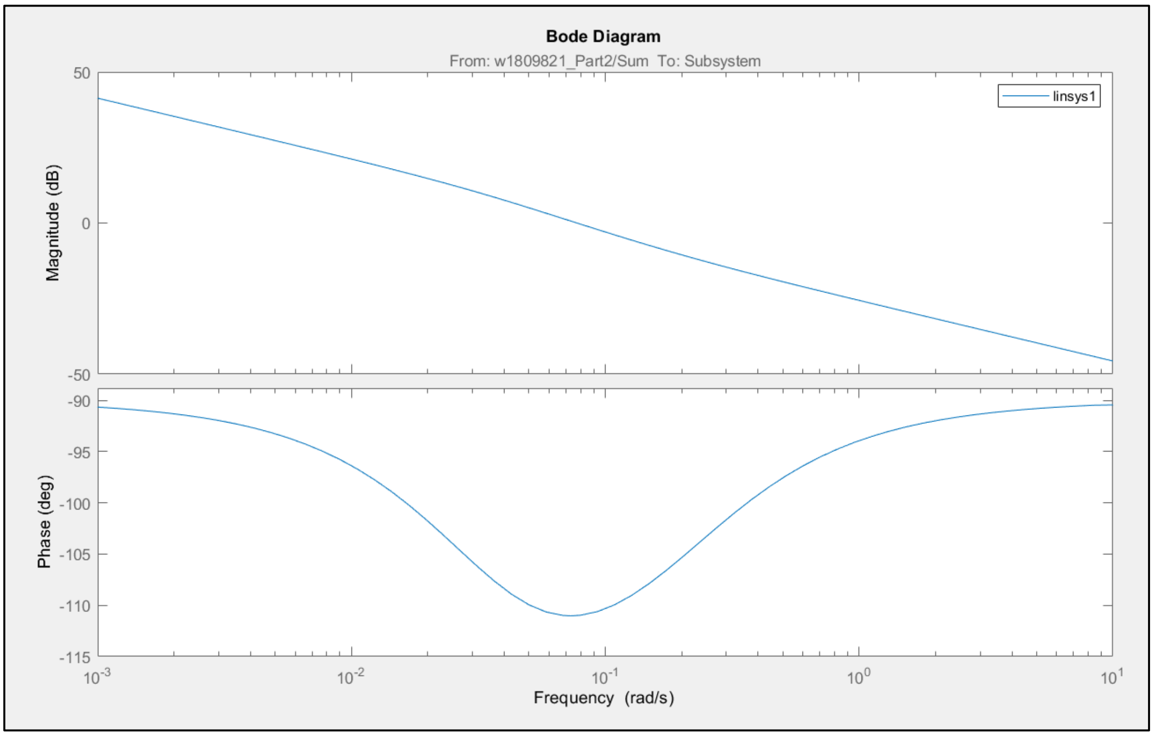

Figure 9: Response Diagrams 1-Bode Diagram

The first diagram presents the magnitude in decibels(dB) of the system's reaction when input is applied, and the second diagram presents the output, indicating how much it is in sync or out of sync with the phrase(deg).

3.2. Nyquist Diagram

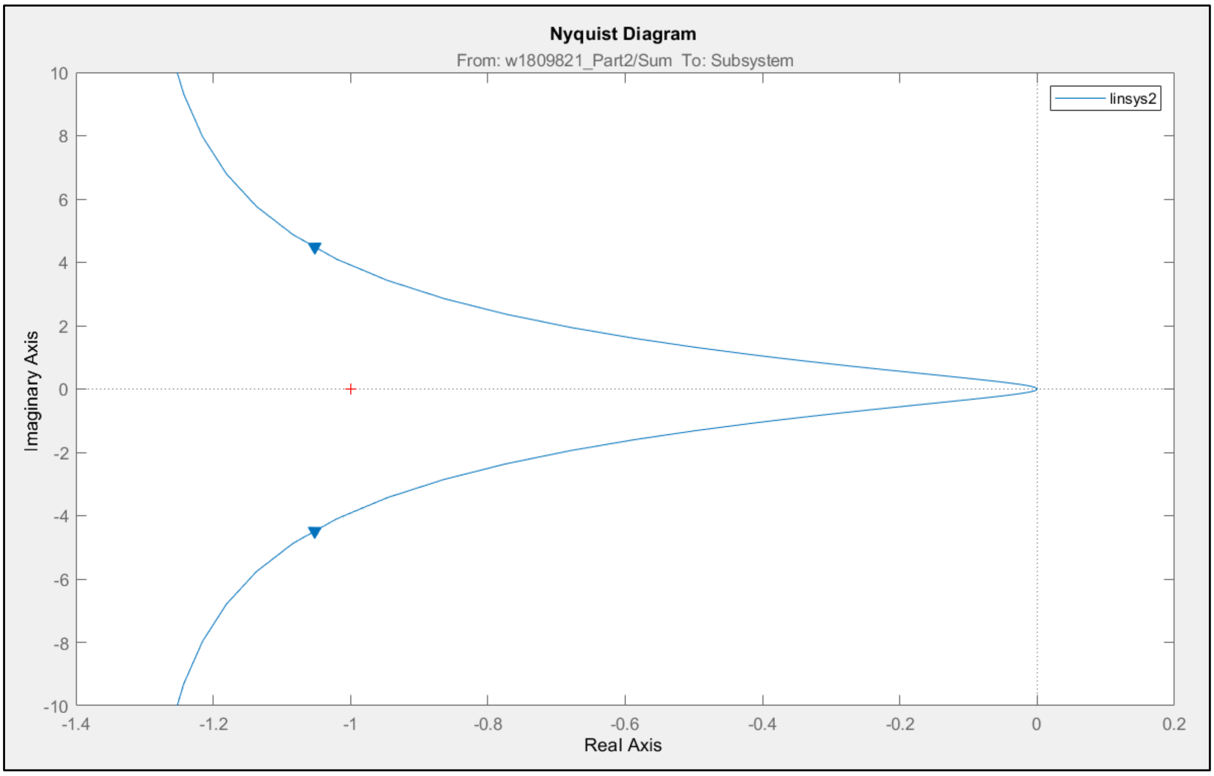

Figure 10: Response Diagrams 2-Nyquist Diagram

As kind of a function of frequency, this diagram shows the real axis and imaginary axis components of our model response.

3.3. Nichols Diagram

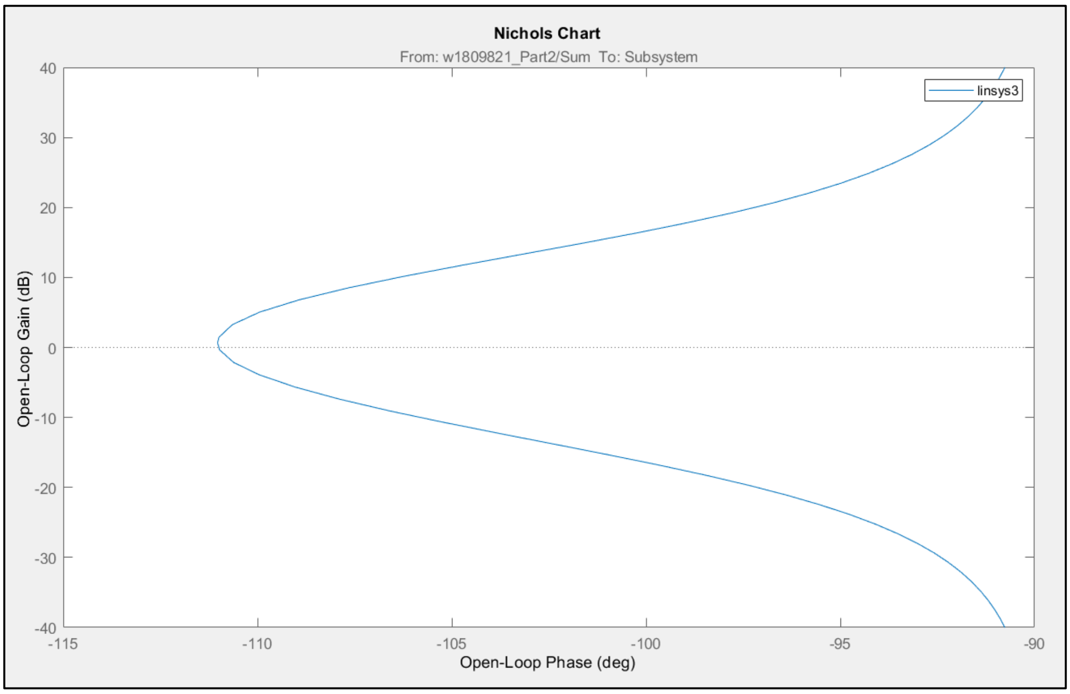

Figure 11: Response Diagrams 3-Nichols Diagram

The magnitude and phase of the system responses as a function of frequency are represented in this image. Briefly said, it refers to the difference between open-loop gain(dB) and open-loop phase(deg) response.

4. Analysis of Response Diagrams

4.1. Bode Diagram

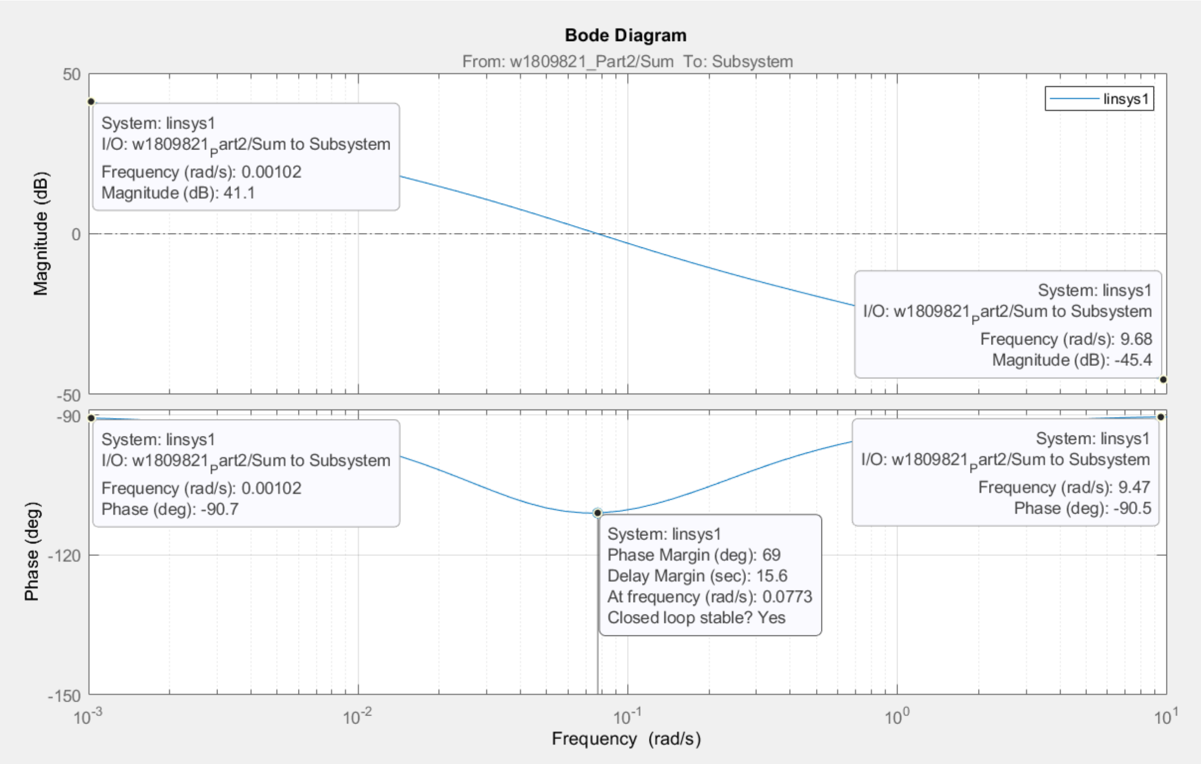

Figure 12: Analysis of Response Diagrams 1-Bode Diagram

When the frequency is increased, the amplitude steadily decreases, according to the input. The phase begins at (-90.7) degrees. And it achieves a phase margin of 69 degrees (-180 degrees to the point) before dropping to (-90.5) degrees.

According to the diagram, the Car model's phase margin is 69 degrees. When we talk about phase margin, we may deduce that no amount of gain will cause the system to destabilize, implying that the gain margin is limitless.

4.2. Nyquist Diagram

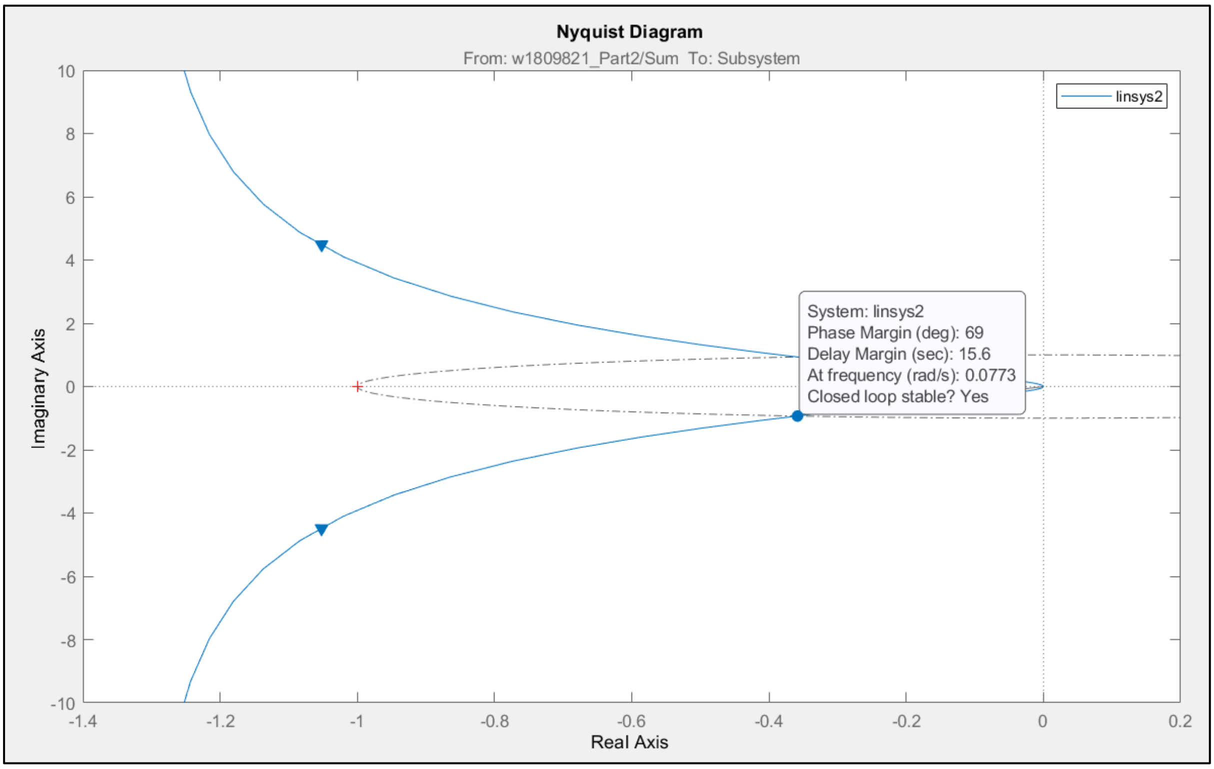

Figure 13: Analysis of Response Diagrams 2-Nyquist Diagram

The system appears to be stable in this figure since it oscillates about 0 and does not finish in (-1). And, like in the preceding graph, it achieves a phase margin of 69 degrees.

4.3. Nichols Diagram

This plot is similar to the bode plot in that it displays the gain versus phase response. Likewise, in a bode diagram, gain begins at 39.5 dB with a phase of (-90.8) deg, progresses to a Phase margin of 69 degrees, and then returns to a gain response of (-39.7) dB with a phase of (-90.8) deg. And, as previously stated, the Closed loop is stable.

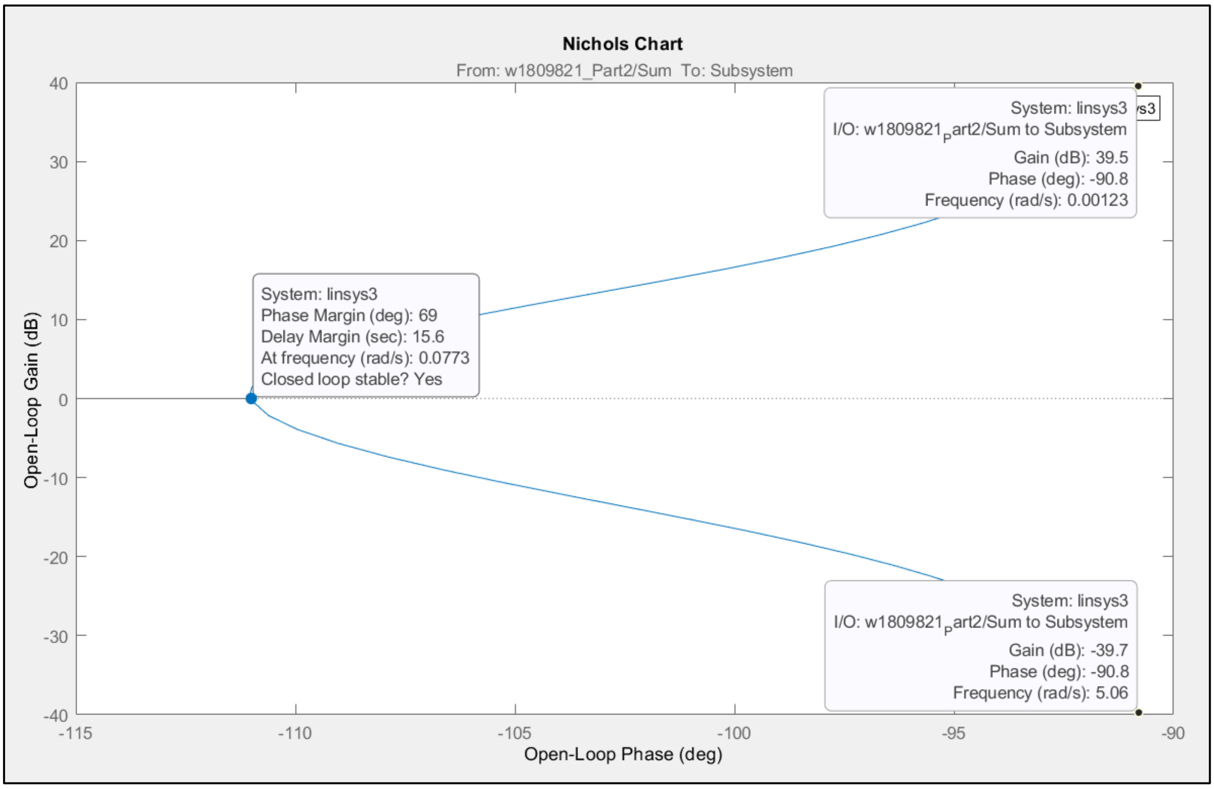

Figure 14: Analysis of Response Diagrams 3-Nichols Diagram

5. Analysis of stability and suitability

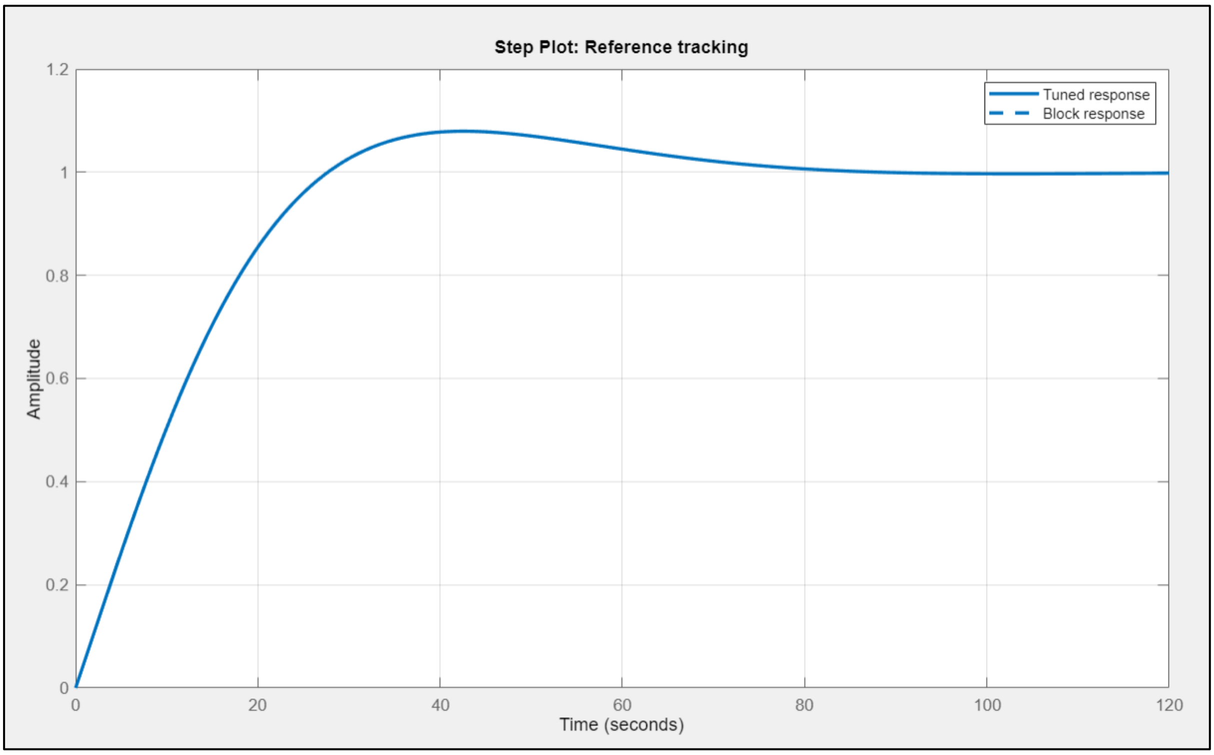

Figure 15: Step Plot-Referencing tracking

This diagram represents the tuned and block responses of the PID Tuner app, as well as how the amplitude stabilizes over a period of 100 seconds (step plot). Here is a more detailed analysis of the diagram.

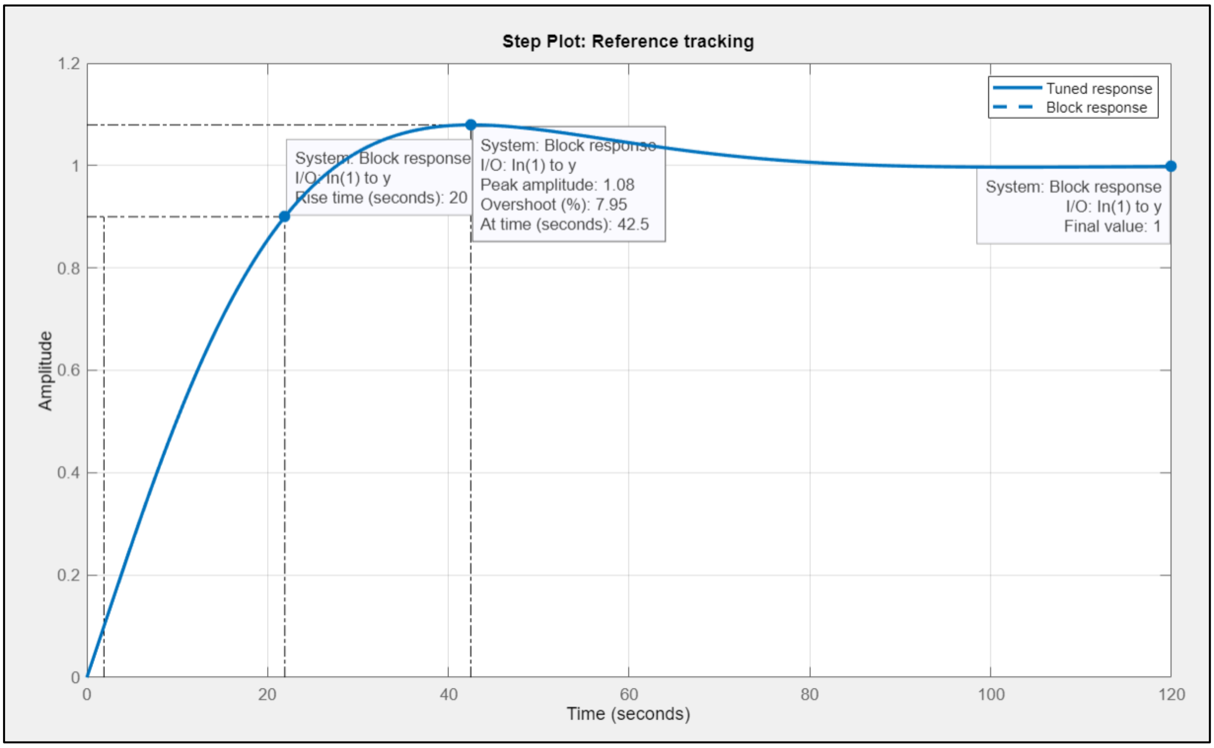

Figure 16: Step Plot-Referencing tracking(Analysis)

As can be seen in the diagram above, the car begins its ascent time in 20 seconds due to the system's block response. After that, we can see the car's peak response with an amplitude of 1.08 in 42.5 seconds. Its overshoot has decreased to 7.86 percent, a lower percentage. The last marker denotes the response's steady state at amplitude 1.

We can observe that the Tuned and Block PID answers have the same values based on the Controller parameter. With the tuned and block responses, the Closed - loop system is stable.

Controller Parameters

	Tuned	Block
P	65.9591	65.9591
I	5.8241	5.8241
D	-50.6075	-50.6075
N	0.13306	0.13306

Performance and Robustness

	Tuned	Block
Rise time	20 seconds	20 seconds
Settling time	70.7 seconds	70.7 seconds
Overshoot	7.95 %	7.95 %
Peak	1.08	1.08
Gain margin	Inf dB @ NaN rad/s	Inf dB @ NaN rad/s
Phase margin	69 deg @ 0.0773 rad/s	69 deg @ 0.0773 rad/s
Closed-loop stability	Stable	Stable

Figure 17: PID Tuner App Parameters