Coursework Report

Robotic Principles (5ELEN018C.1)

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Introduction

A simple vehicular system (plant) was created using MATLAB Simscape. A prismatic joint for the vehicle to move in the -x axis. A damping coefficient of 50 N/(m/s) was added to the prismatic joint and a point mass of 1000kg was given to the body of the model. The output was captured as speed. This plant was made into a Simulink Subsystem.

PID Tuning

A PID controller was added to the above subsystem which was used to bring the vehicle to a desired speed and maintain that speed. A constant of 500 was given to the PID block. A scope was also connected to the system to obtain the output. In order to tune the model, initially, the P, I and D values were given manually and then the PID was tuned using the PID Tuner by analyzing the Step Plot and adjusting the Response Time and Transient Behavior for reducing the steady-state error, rise time, overshoot and settling time. After the model was tuned, Fig. 1 shows the output in the scope.

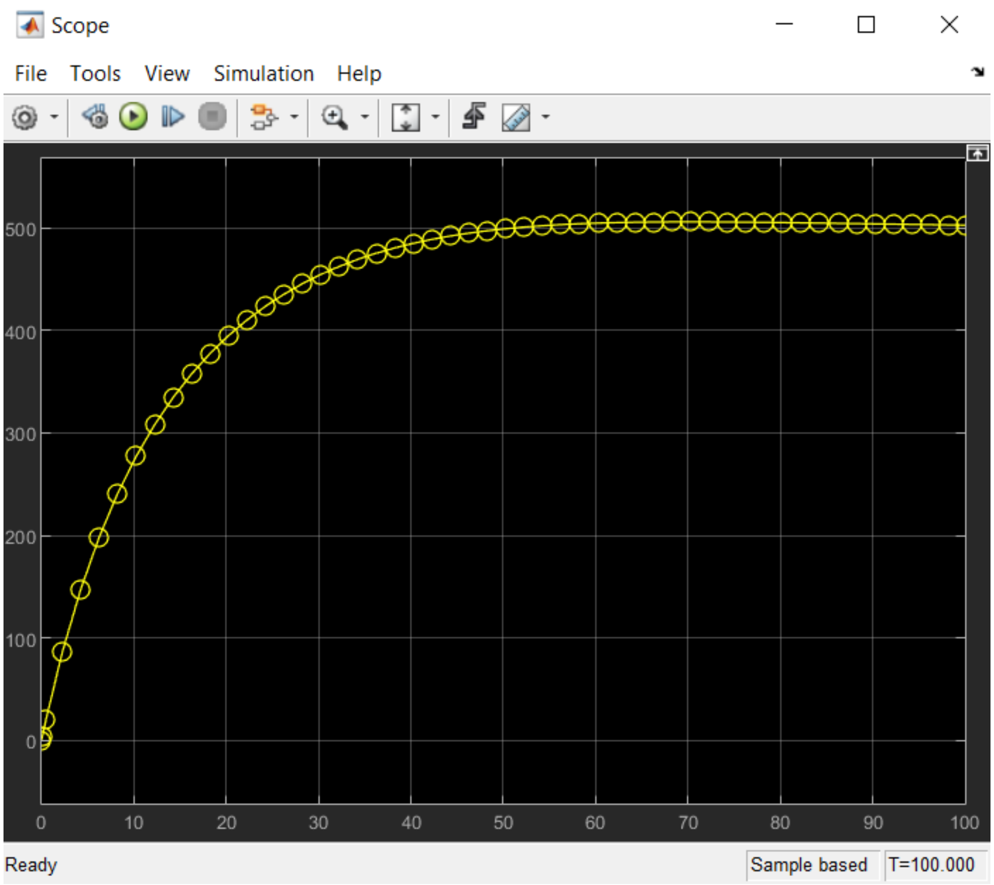

Figure 1: Scope

Figure 2: Step Plot: Reference tracking

The following PID values were obtained after tuning from Fig. 2.

Controller Parameters

	Tuned	Block
P	80.7781	80.7781
I	4.2839	4.2839
D	131.3793	131.3793
N	0.12854	0.12854

Figure 3: Control parameters

Analysis 1: Time Response Analysis

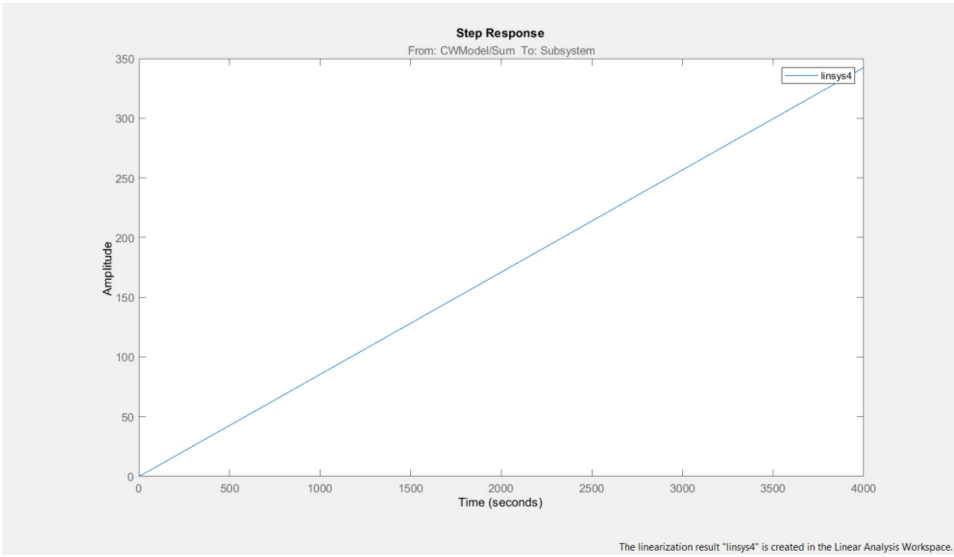

Figure 4: Step response

In order to do the Time Response Analysis to obtain the performance and robustness of the system, the step plots for input and output disturbance rejection as well as the reference tracking were analyzed. The following figure shows the robustness and stability of the tuned model.

Performance and Robustness

	Tuned	Block
Rise time	27.9 seconds	27.9 seconds
Settling time	42.8 seconds	42.8 seconds
Overshoot	1.23 %	1.23 %
Peak	1.01	1.01
Gain margin	Inf dB @ NaN rad/s	Inf dB @ NaN rad/s
Phase margin	90 deg @ 0.0747 rad/s	90 deg @ 0.0747 rad/s
Closed-loop stability	Stable	Stable

Figure 5: Performance and Robustness

As can be seen in the above Fig. 3, the rise time and settling time are quite high but has a lower overshoot of only 1.23% (hence peak is 1.01). Therefore, this compensates the rise and settling time and provides stability to the system.

The above Fig. 5, the step response plot which was obtained from Model Linearizer shows the increase of amplitude with time and hence is synonymous with the step plot for reference tracking.

The following figures show the input and output disturbance rejection step plots.

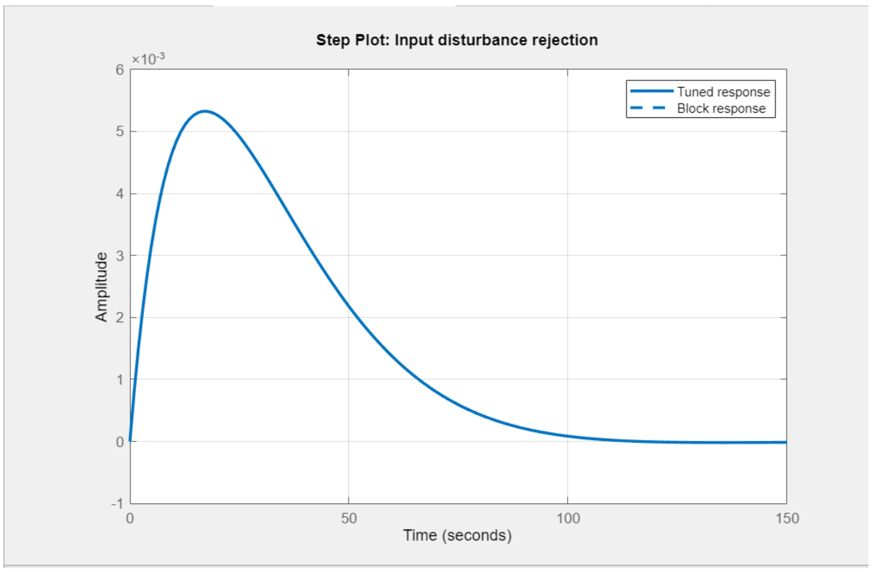

Figure 6: Step plot: Input disturbance rejection

As can be seen from Fig. 4, the input disturbance rejection shows a larger peak. Although it is necessary for this to be low, lowering this will increase the overshoot and rising time, therefore, this was adjusted accordingly.

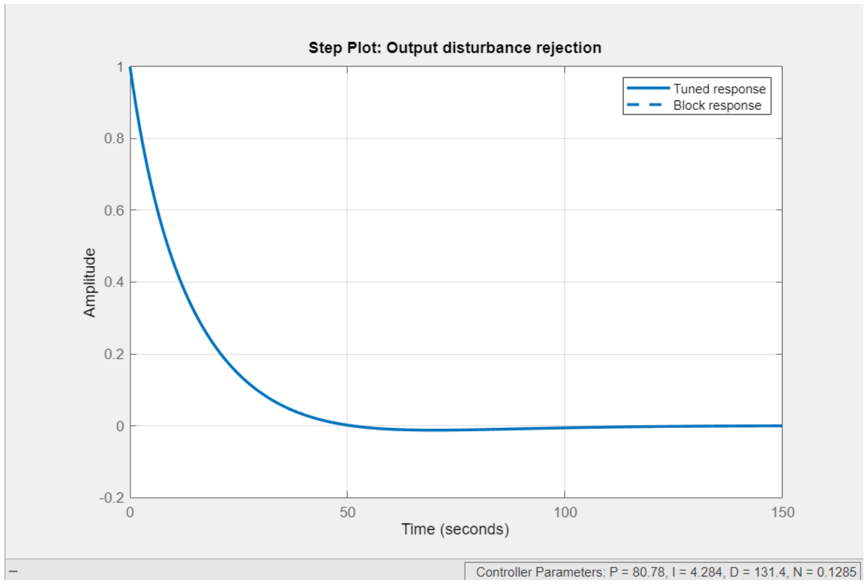

Figure 7: Step plot: Output disturbance rejection

From Fig. 5, the output disturbance rejection is quite stable as it has a lower time and does not show any odd fluctuations.

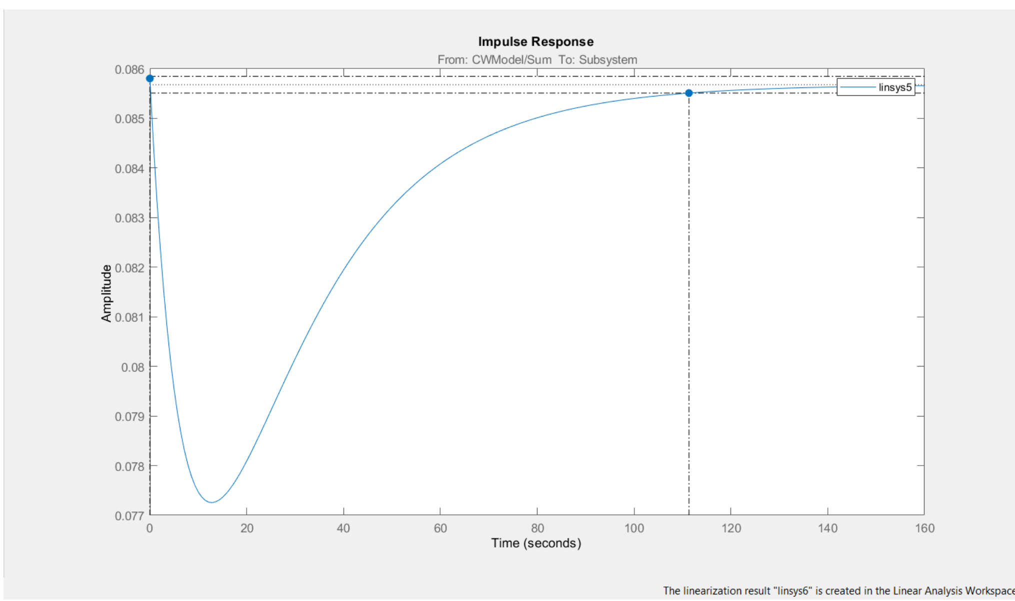

Figure 8: Impulse Response

Fig. 8 above shows the Impulse response plot. Here, the system does a single oscillation and reaches stability.

Analysis 2: Frequency Response Analysis

For the frequency response analysis, an input and output perturbation were added to the model and the Bode, Step, Nichols and Nyquist plots were analyzed for stability.

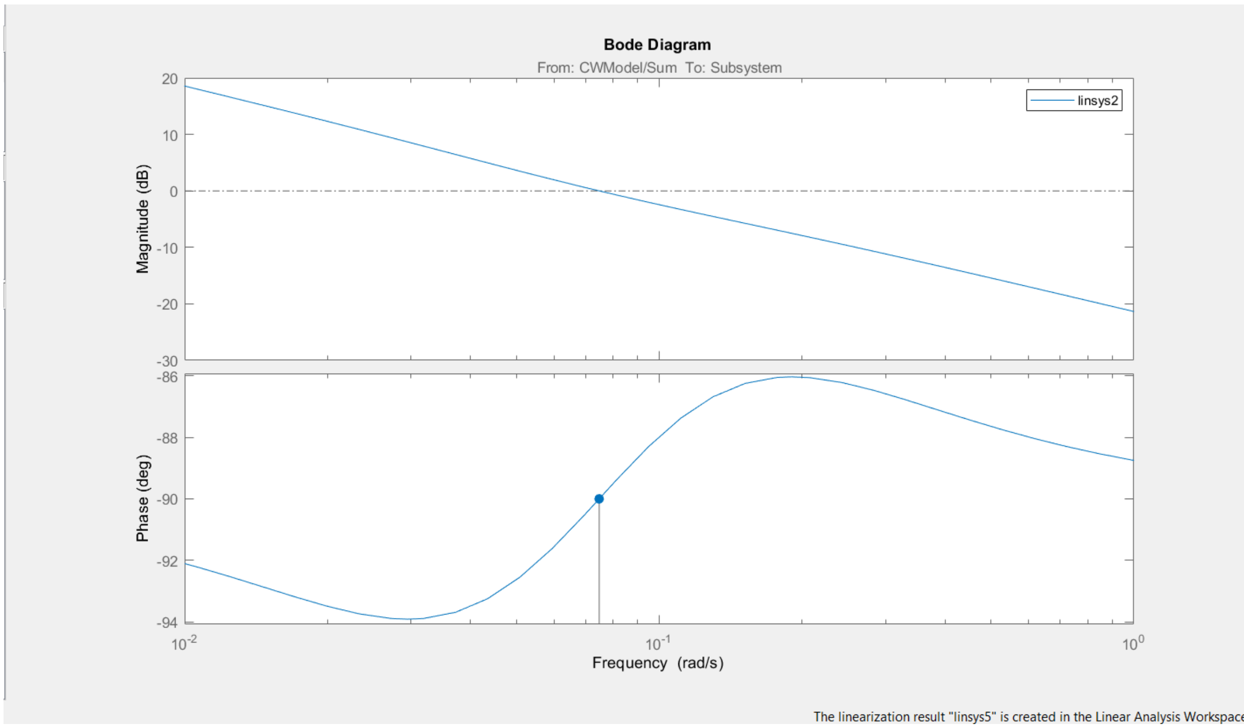

Figure 9: Bode Diagram

The above Fig. 6 shows the Bode diagram with the minimum stability margins. The first diagram, which has a minimum stability margin of 0dB shows the reduction of magnitude with the increase of input frequency. Here the phase margin is low and therefore peak response is quite low therefore, the performance is higher.

The second diagram, which has a minimum stability margin of 180 deg shows the change of phase with frequency. Initially, the phase starts low but with the increase of frequency, it goes down but gradually increases. Here the gain margin tends to infinity because it never goes beyond 180 deg which means that the model cannot be destabilized by gain.

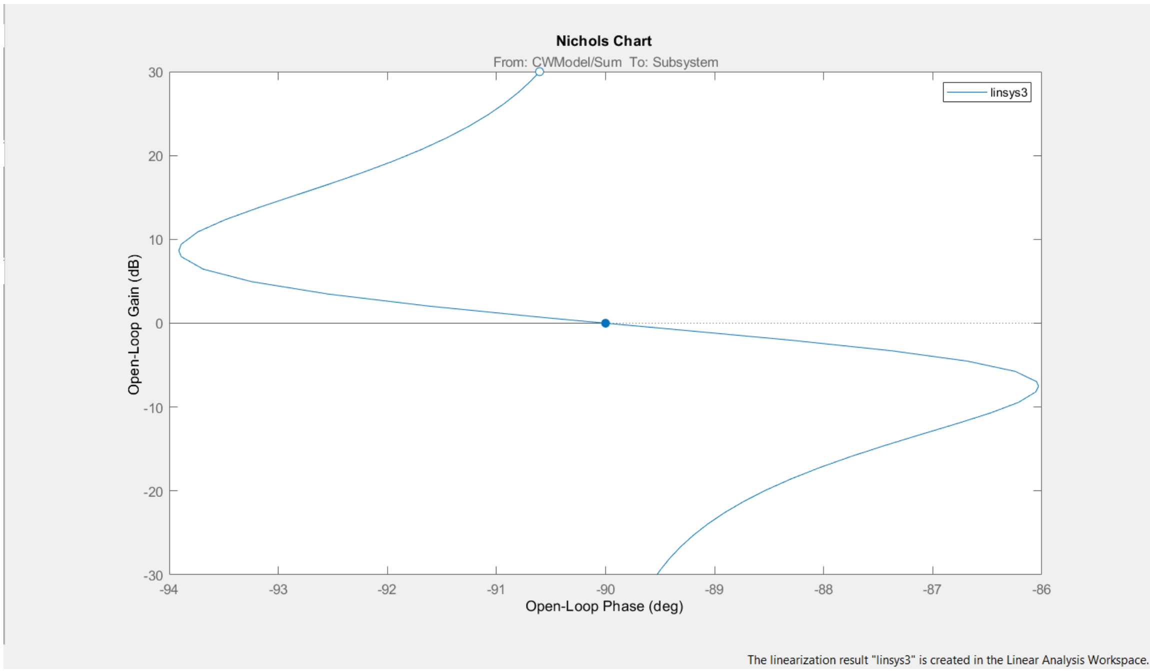

Figure 10: Nichols Plot

The figure above describes the Nichols plot, which shows the change of gain with phase. This plot combines both the diagrams of the Bode plot, in essence. Here the system is stable because the curve meets the 0dB position when it is at -90 deg.

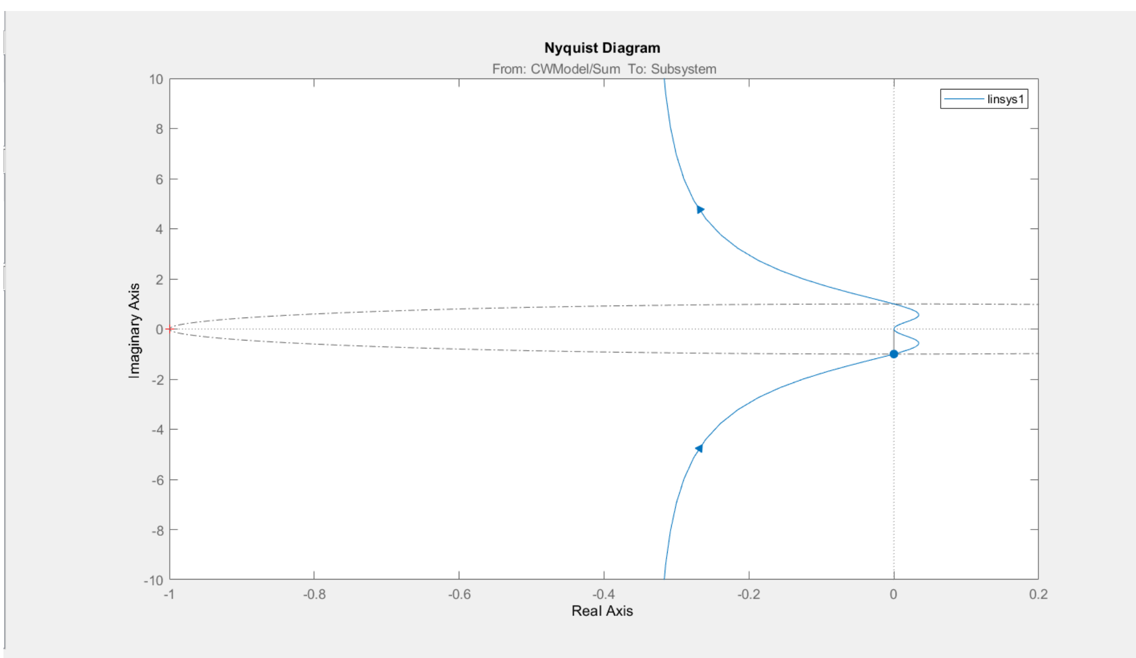

Figure 11: Nyquist Plot

Fig. 7 above, shows the Nyquist plot. Here, the plot does not encircle (-1,0). Therefore, the system is stable.

Conclusion

The analysis of the system done above proves the stability, robustness and performance of the model even when uncertainties occur. Analysis was done using both the time and frequency domain. Since this is a simple vehicular model that is expected to reach a certain velocity and maintain that velocity for a given period of time, the uncertainties that could be expected for such a system in a real-world scenario would include the condition of the road the vehicle travels on, the traffic conditions, the engine condition of the vehicle, the condition of other parts such as the brake system, etc. These uncertainties could lead to a higher overshoot and/or peak response. But the model was tuned such that those uncertainties would not destabilize the model.