8 Report

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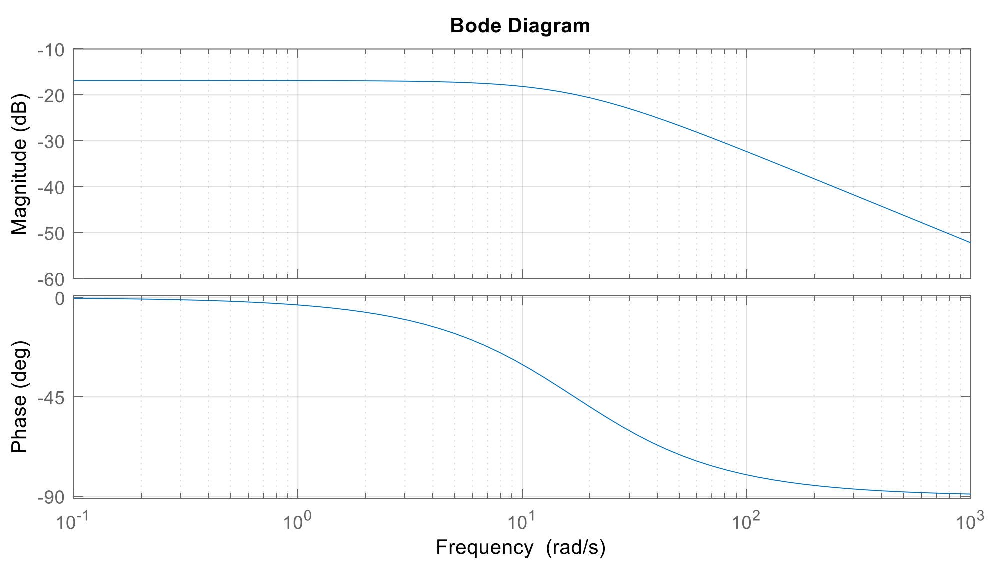
Name of Lab Assistant: Özgür Diyar Kozan

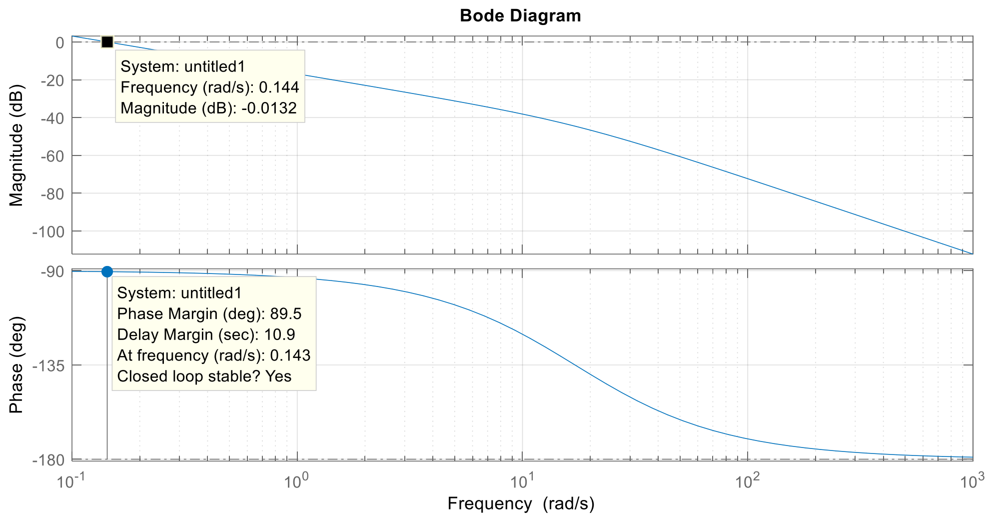
7.2. Simulation of the servo Plant with a Phase-Lead Controller

Step 2:

Plant only bode plots:



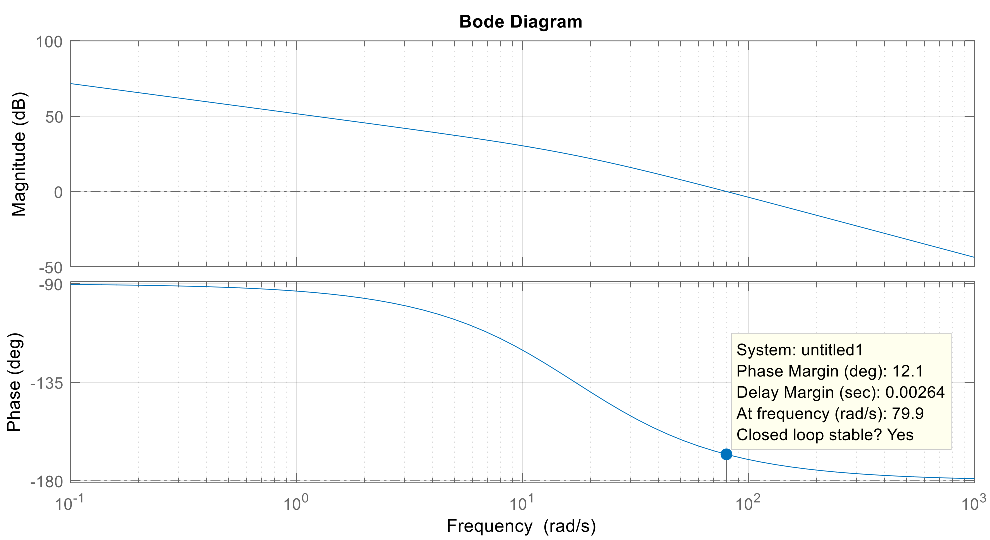
Plant with H(s) bode plots:



Gain required on dB = 68.5 K = 2660

Step 3:

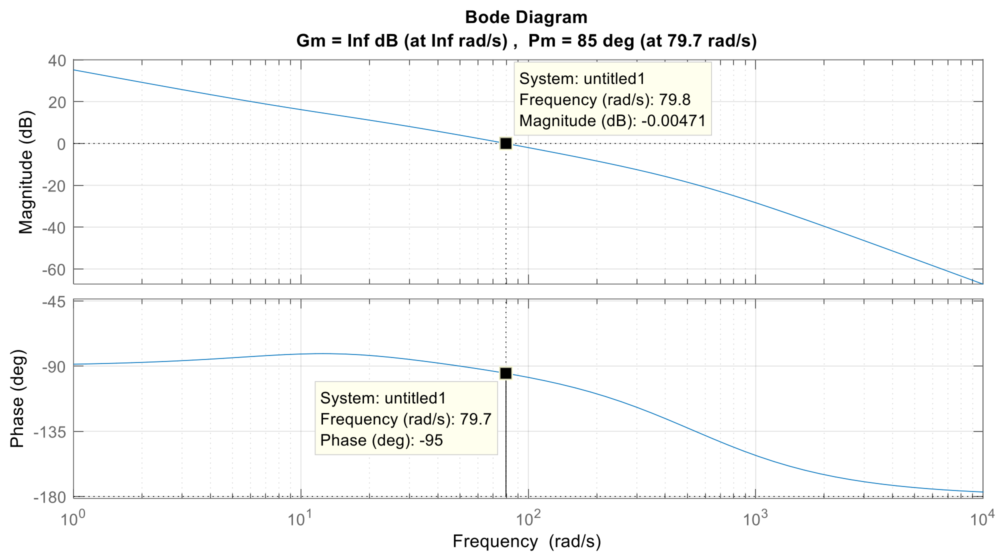
Plant with H(s) and K bode plots:



$\Phi_c = 72.9°$

Step 4:

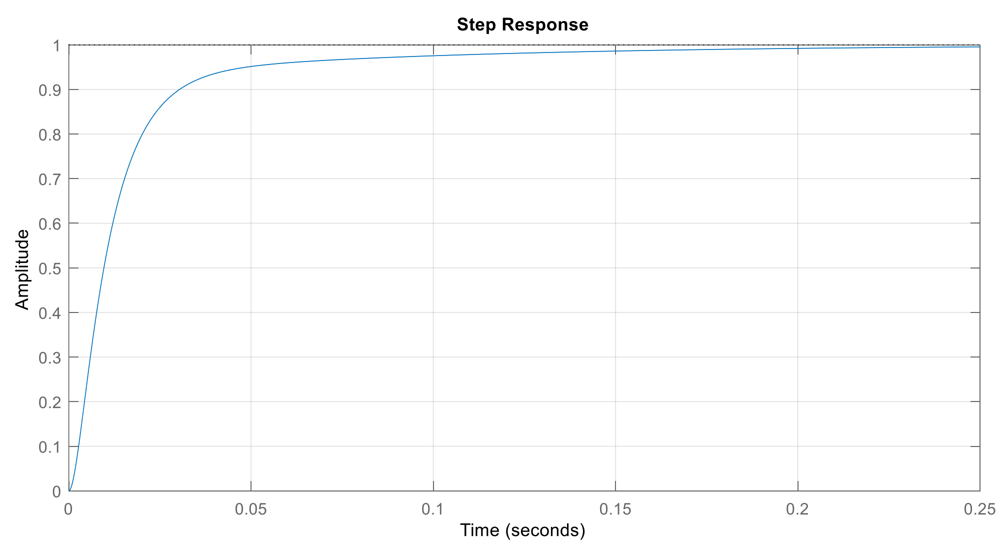
Bode plots for compensated full system:



Our compensated system met the design requirement for the phase margin precisely. Cross-over frequency was 0.2 rad/s off which is acceptable.

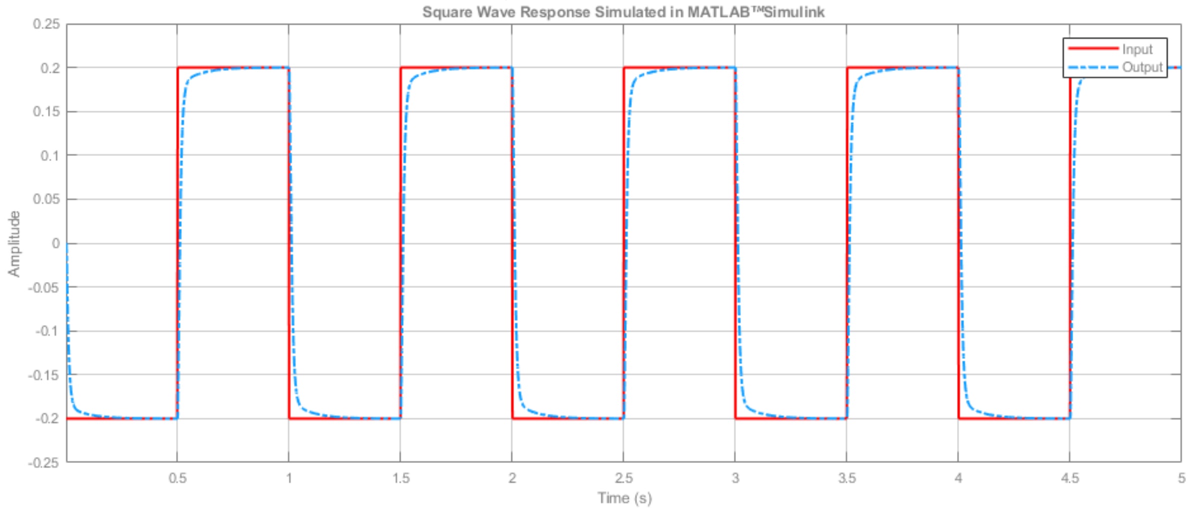
Step 5:

Step response of full compensated system



Step 8:

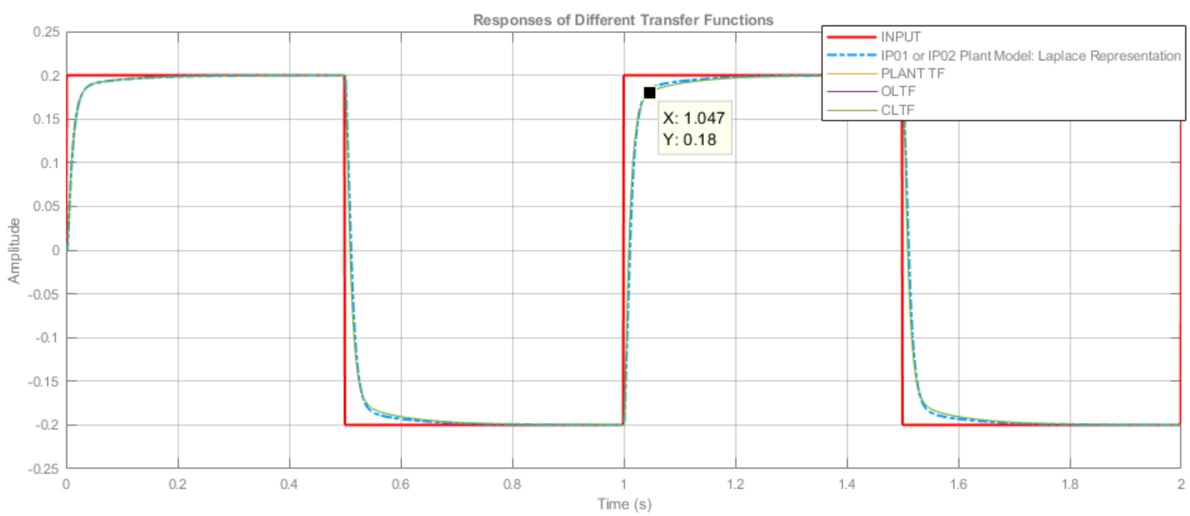
Velocity Response Simulation



The response is consistent with our previous step response simulation done on MATLAB™.

Step 9:

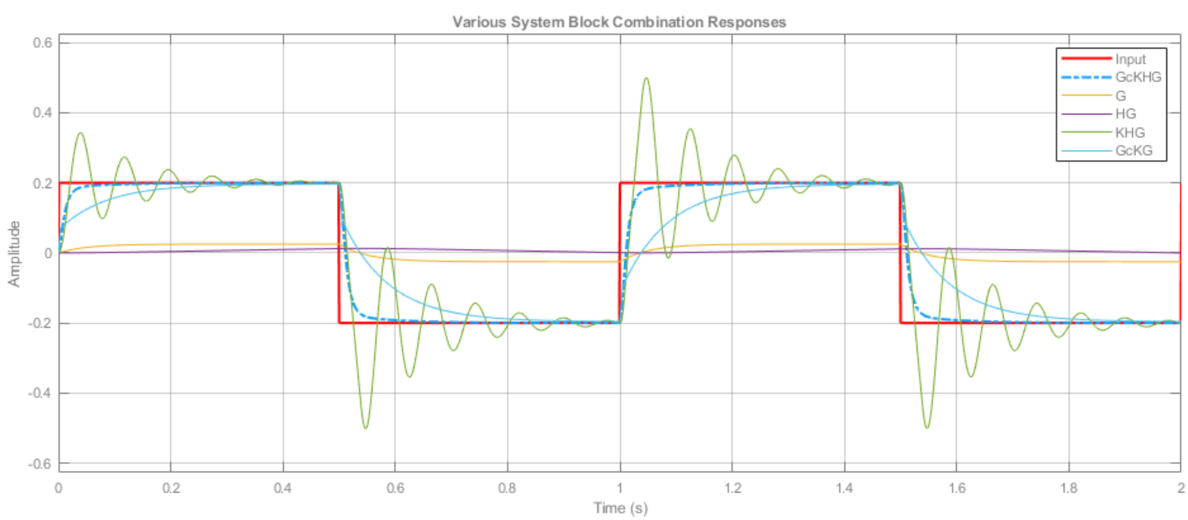
Transfer Functions Plotted on MATLAB™Simulink



As we condense the model to obtain a single transfer function, the CLTF, we lose information about how the different elements affect the workings of the model. This means we cannot inspect the in-between signals like tracking error as we merge blocks together. However, having a single transfer function has the advantage of working with a simple, short expression when calculating different parameters.

Step 11:

Compensator Design Step Responses

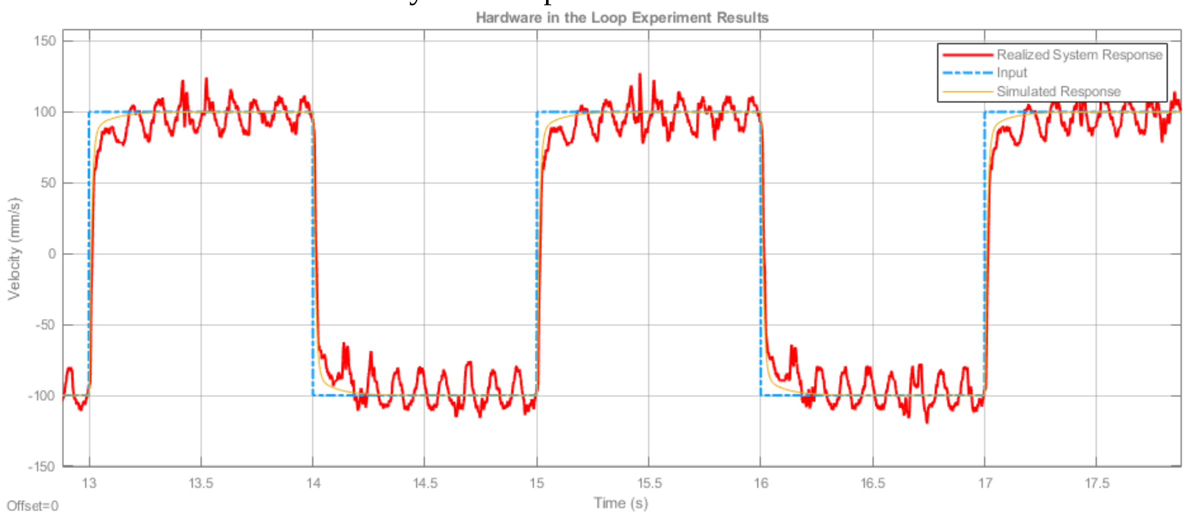


We were able to once again verify our design's response with the GcKHG trace. We observed that the plant by itself in the G trace displayed the high steady state error we had calculated in the Preliminary Work. The KG trace, with its integrator, should display zero steady state error, but due to its low speed, we do not see it catch up to the reference signal before the input switches. Additionally, we observe the effects of integral windup, in which the error left over from the previous input value affects the system. The KHG trace displays severe oscillations, which are also evidenced by the low phase margin of 12°. In the GcKG trace we observe the small steady state error we had calculated in the Preliminary Work.

7.3 Real-Time Implementation of the Phase-Lead Controller

Step 7:

Realized System Response with Simulation Results



Step 8:

The actual speed of the cart follows the simulated signal acceptably with the exception of high frequency oscillations. The oscillations are inferred to be caused by the noise amplified by the derivative filter of the speed measurement. As commonly known, derivative operations amplify the high frequencies. This phenomenon could be mitigated using low pass filters on the signal path.

Another reason might be due to the uneven friction caused by the motor. Noting that the as the motor rotates the periodic effect of uneven friction is observed on the velocity. As a final remark when rotating the motor by hand this friction is felt once per turn.

There is also a small delay on the output compared to the simulated response. It could be caused by the use of real life components in the system and discrete nature of those.

9 Knowledge Test

1. What is the gain cross-over frequency?

The frequency at which the gain of a system is unity (0 dB). Mostly this term is useful for the systems with a single cross-over point.

2. What is the phase margin? How did you decide on the value of phase added by the phase-lead compensator?

The phase margin is the difference between -180° and the phase of the system at the gain cross-over frequency. This value indicates the system's stability and how damped a response it will have.

The phase value was chosen such that the phase margin of the system would satisfy the design requirements when added onto the preexisting phase margin.

Intended PM – Current PM = Additional phase

3. Why did we use H(s) block in this experiment?

The H(s) block was used to eliminate the reference step steady state error. This was necessary since the design specifications required the steady state error to be zero for step reference.

4. What is the difference of using a PID type controller and phase-lead compensator?

The lead compensator acts as a "realizable D" block for the system, damping the system response. Adding an integrator to this, as we have with the H(s) block, we obtain almost a "realizable PID" controller of our own, with an integrator, a damper and a gain.

In that sense, the phase-lead compensator is only the D term of a PID controller.

5. Explain the phase-lead compensator design procedure.

The first step is to obtain the transfer function of the plant. Then the current phase margin is calculated and using the design criteria the extra phase needed is found. Using the well-known transfer function of the phase lead compensator the parameters, alpha and omega_c are selected. Finally the closed loop transfer function is simulated in order to verify the results.