ECE 311 - Lab 2

Deniz Uzun, Anusha Shekhar, Rayyana Kambris

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1 - INTRODUCTION

In this lab, we focused on the design of a cruise control system for a cart. In section 2.1, we simulated the open loop response of our cart to periodic square wave input. In section 2.2, we experimentally determined the values of two parameters a and b, by plotting the velocity and transfer function graphs. In section 2.3 we implemented a proportional controller to regulate the speed of the cart. In section 2.4, we implemented a proportional-integral controller. In sections 2.3 & 2.4 we observed the effects of K on the steady state error to determine which controller performs better for our purpose.

2 - EXPERIMENTS

2.1 OPEN LOOP RESPONSE

Include here the open loop response (position and velocity) of your cart to periodic square wave input.

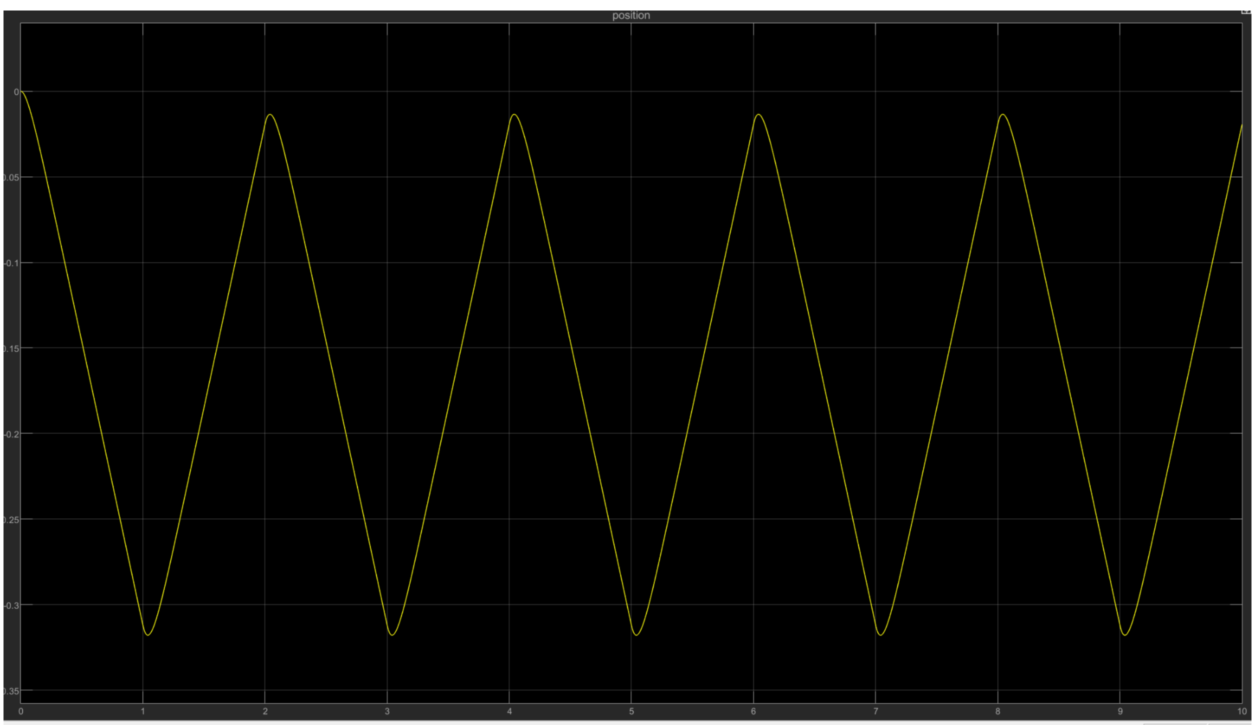

Figure 2.1.1: Open loop response of the position of the cart.

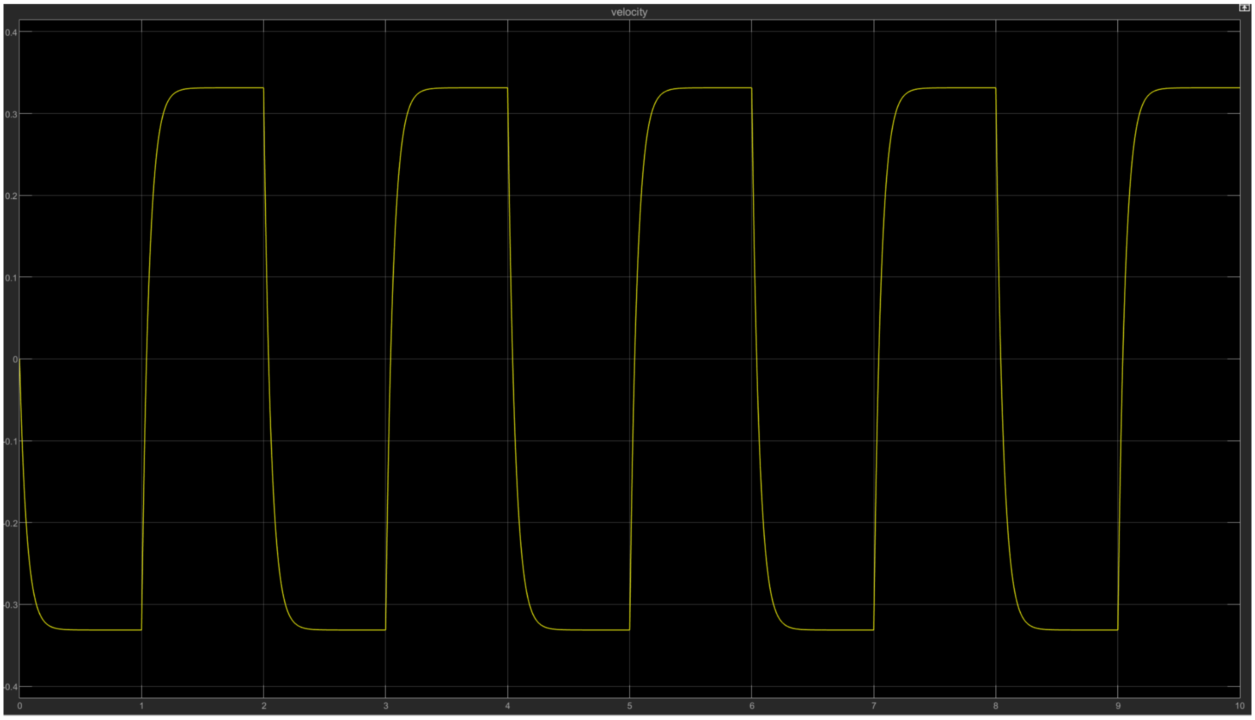

Figure 2.1.2: Open loop response of the velocity of the cart.

2.2 IDENTIFICATION OF MODEL

In this section you will discuss your estimation of the parameters *a* and *b*.

1. The plot showing the response for your initial guess for the parameters *a* and *b*

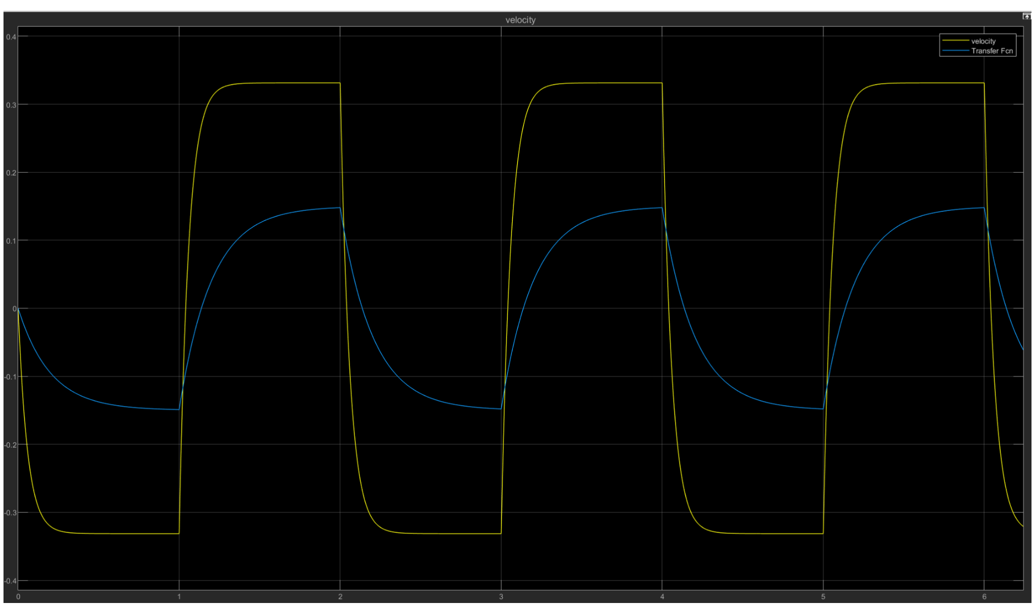

Figure 2.2.1: Plot showing the velocity response and transfer function response for a = 0.5 and b = 5.

2. The derivation of the expression *a=f(b)* (check the lab instructions), including the plots where you measure the output variation **Δ***v*

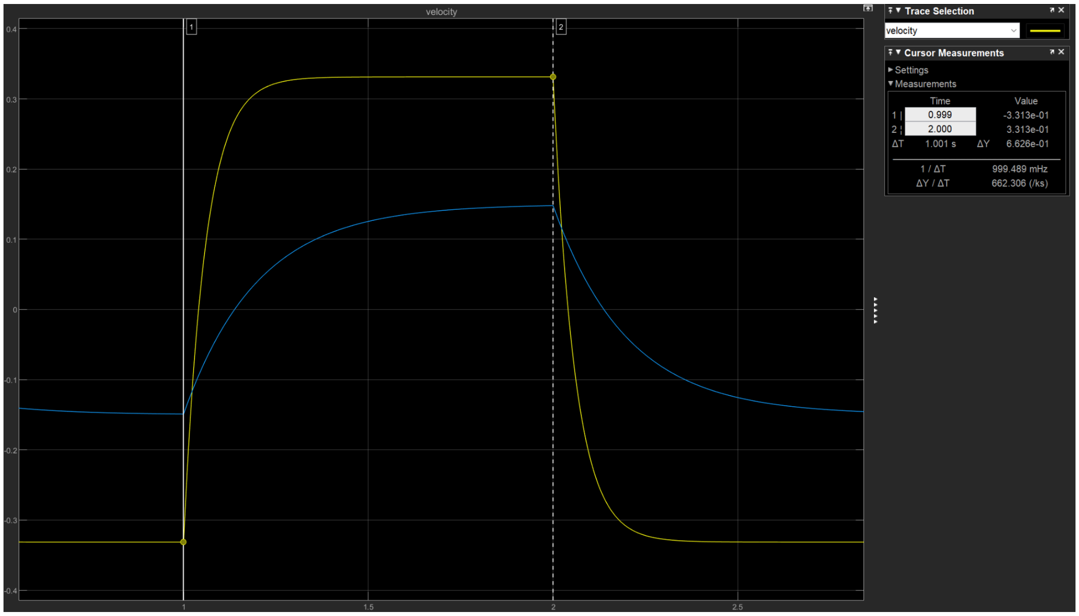

Figure 2.2.2: Plot showing the output variation Δv over half a period.

As shown in Figure 2.2.2, the output variation Δv over half a period is 0.6626.

The derivation for a = f(b) is as follows:

- $$\lim_{t \to \infty} v(t) = v_t = \frac{V_0 \cdot a}{b}$$

$$\Leftrightarrow \quad a = \frac{v_t \cdot b}{V_0}$$

$$\Leftrightarrow \quad a = \frac{\Delta v \cdot b}{V_0}$$

→ For $b = 5$, $V_0 = 3$, and $\Delta v = 0.6626$, $a = 1.1043$

For a = 1.1, we get the following plot:

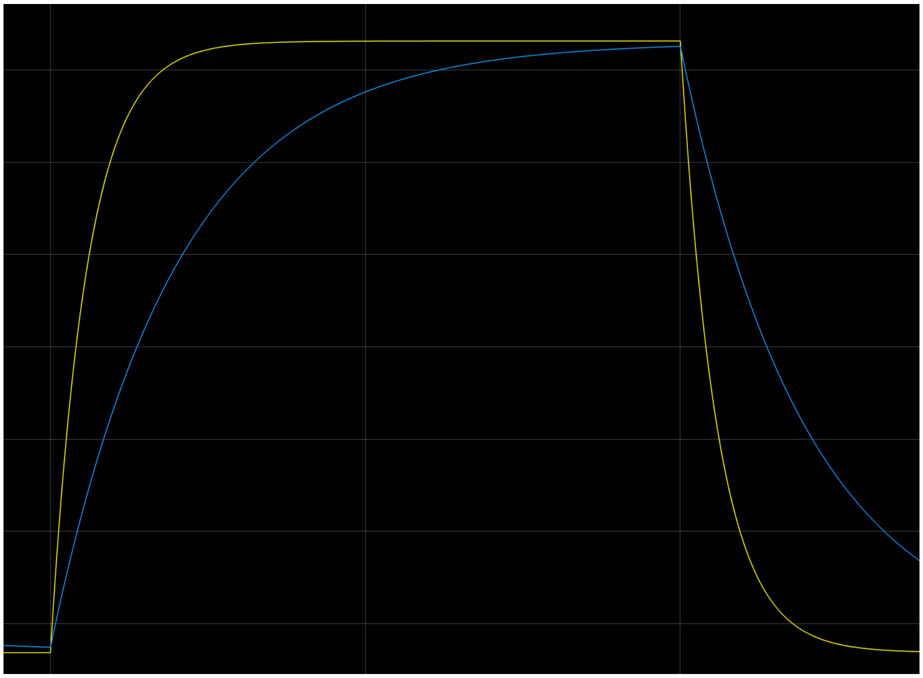

Figure 2.2.3: Plot showing the velocity graph and the transfer function graph for a = 1.1, and b = 5.

As we can see in Figure 2.2.3, the steady-state model and the actual transfer function graph coincide.

3. The final choices for *a* and *b* and the corresponding plot response

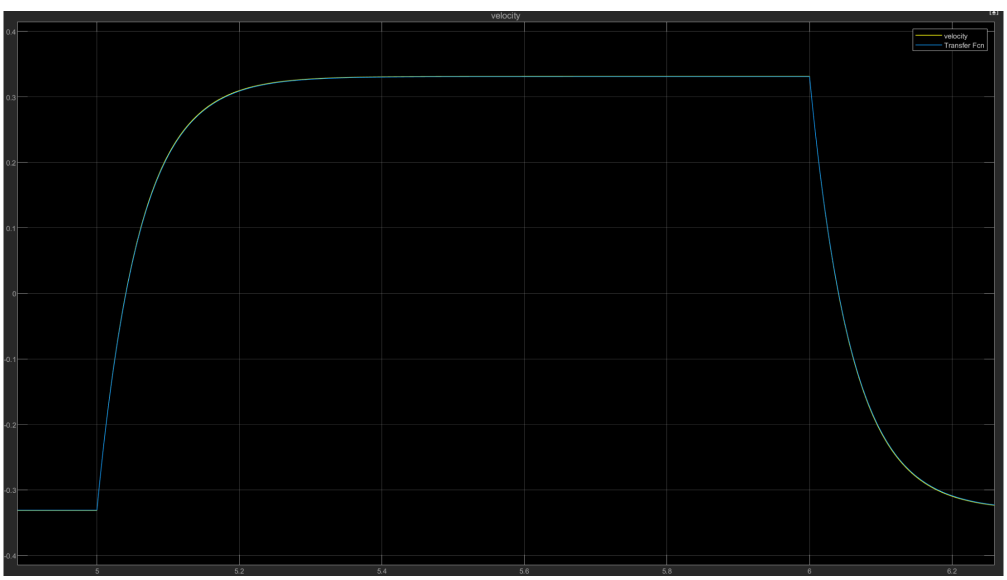

Figure 2.2.4: Plot showing the velocity graph and the transfer function graph for a = 3.75 and b = 17.

As shown in Figure 2.2.4, the discrepancy between the transfer function waveform and that of the velocity, is very minimal. Hence, we choose b = 17, and a = 3.75 for this model.

2.3 PROPORTIONAL CONTROL

In this section you will discuss your findings regarding the proportional controller.

Be sure to include the following material and discussions:

1. Your hypothesis about the asymptotic tracking performances with a P controller

The offset is defined as the difference between the desired and actual values of the output. Since we have set it to zero, we can expect the error to asymptotically tend to zero.

2. The first closed loop response for your closed loop system with $K=5$

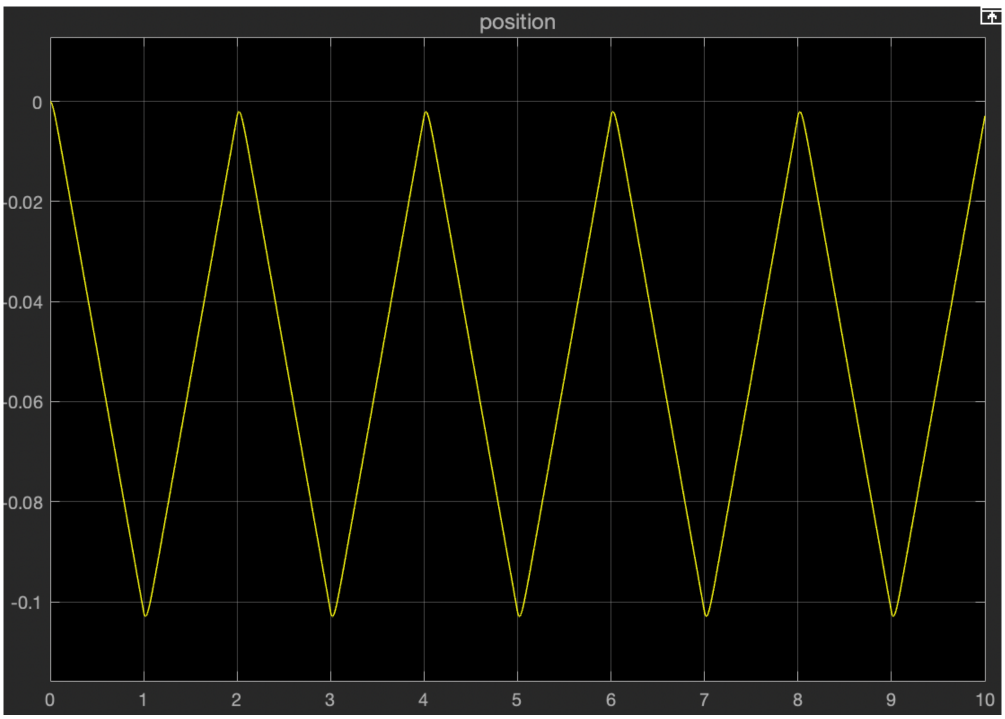

Figure 2.3.1: Position plot for K = 5

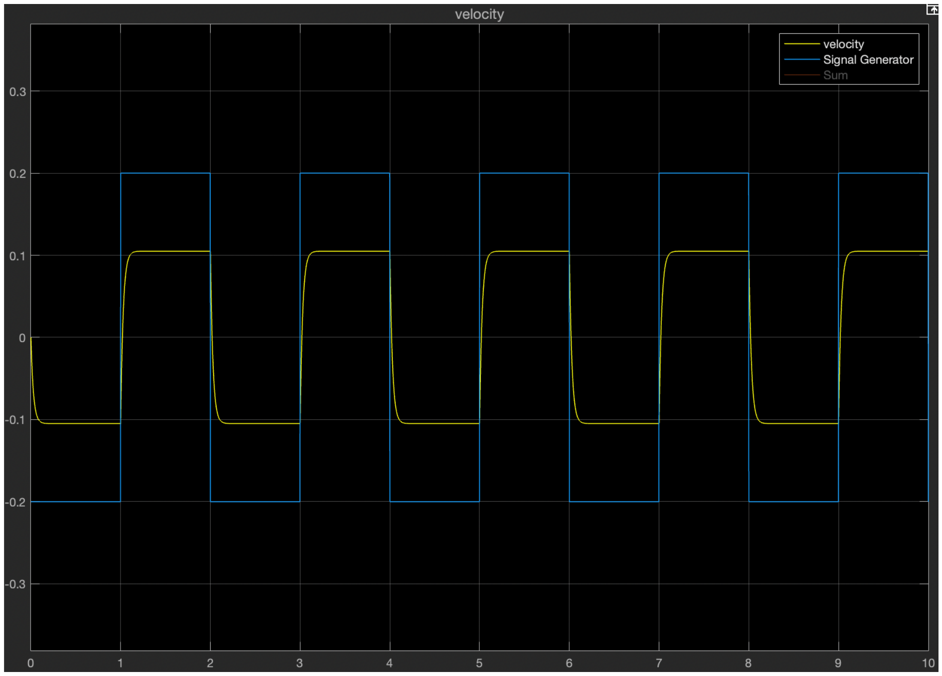

Figure 2.3.2: Velocity plot for K = 5

3. Your comments about the matching of the experimental data and initial theoretical hypothesis

The graph attached in question 2 is the output position. To get the velocity, we differentiate this triangle wave to get a square wave, which is the desired velocity that we used as our input. Thus, this experimental data matches our initial theoretical hypothesis that the error tends to zero with a zero offset.

4. Your hypothesis about the effect of an increasing controller gain *K*

In the P controller, as we increase the controller gain K, we expect the steady state error to converge to 0.

5. Two more plots for increasing values of *K*

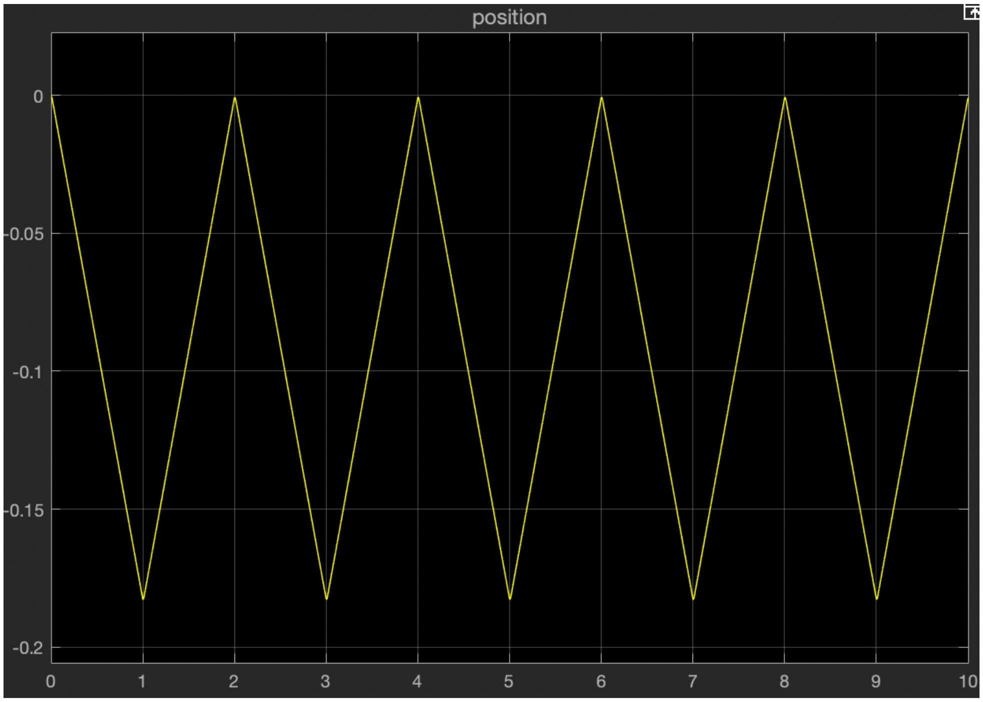

Figure 2.3.3: Position plot for K = 50

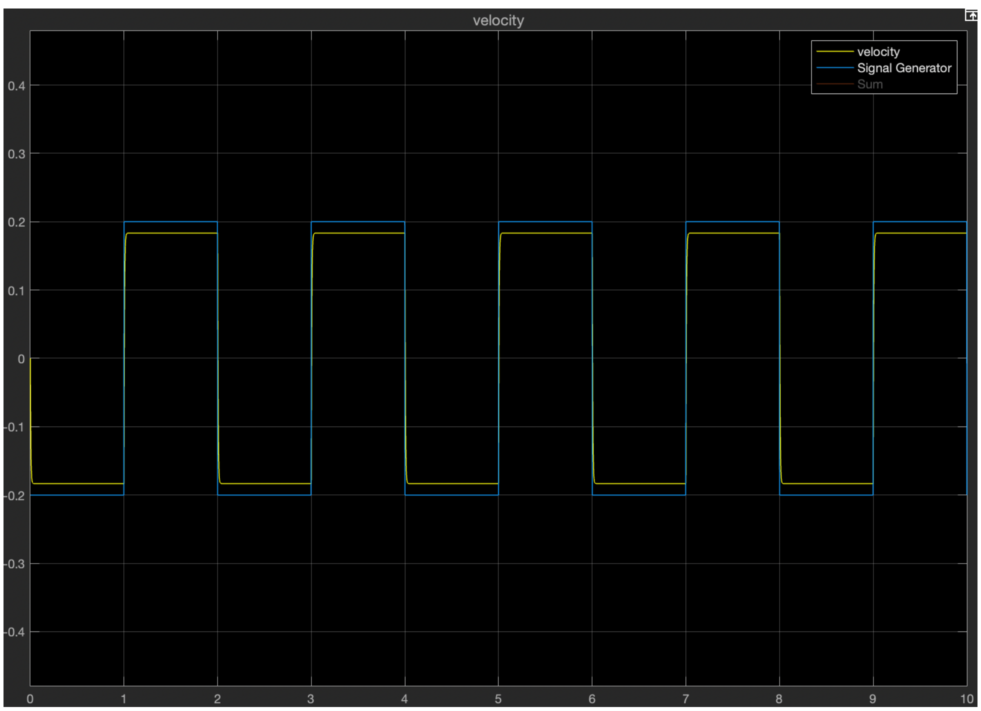

Figure 2.3.4: Velocity plot for K = 50

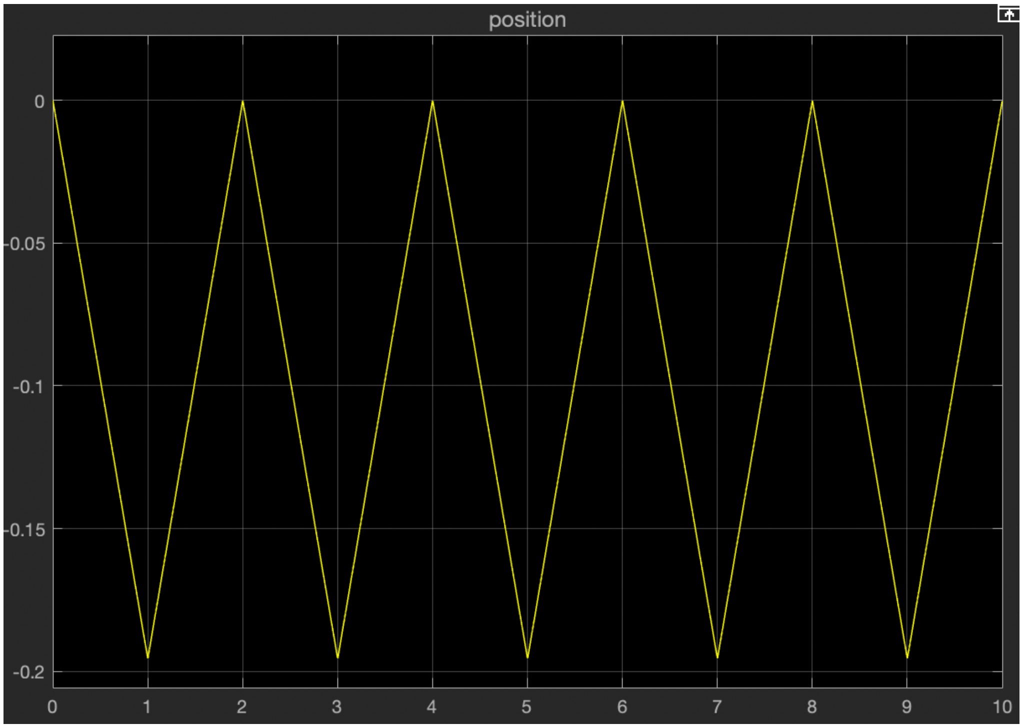

Figure 2.3.5: Position plot for K = 200

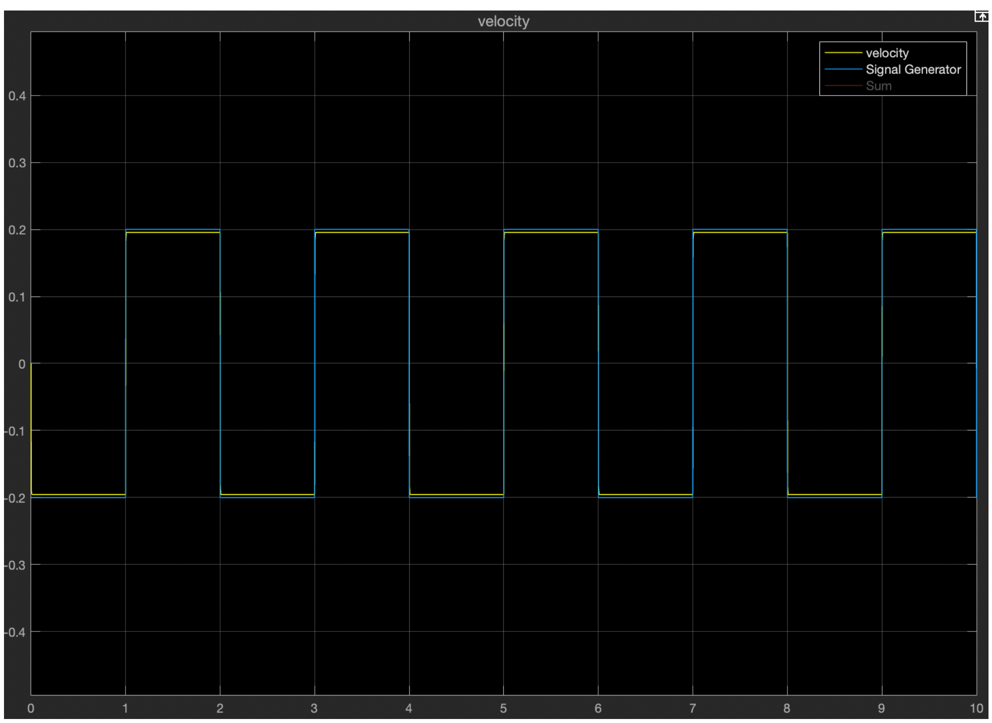

Figure 2.3.6: Velocity plot for K = 200

6. Your final considerations about the effect of an increasing *K*

We know that the following equations apply to the P controller: $E(s) = V0(s+b) / [s(Ka+s+b)]$ and $ess = Vob / [Ka+b]$. Thus, from this experiment, we can conclude that for the P controller, the steady state error converges to 0 as K approaches infinity. As the error tends to 0, the output velocity gets closer to the desired velocity, as can be seen from the velocity plots in figures 2.3.2, 2.3.4, and 2.3.6.

2.4 PROPORTIONAL-INTEGRAL CONTROL

In this section you will include the following material and discussions:

1. Your first simulation plots with the proposed values of *K* and *T_i*

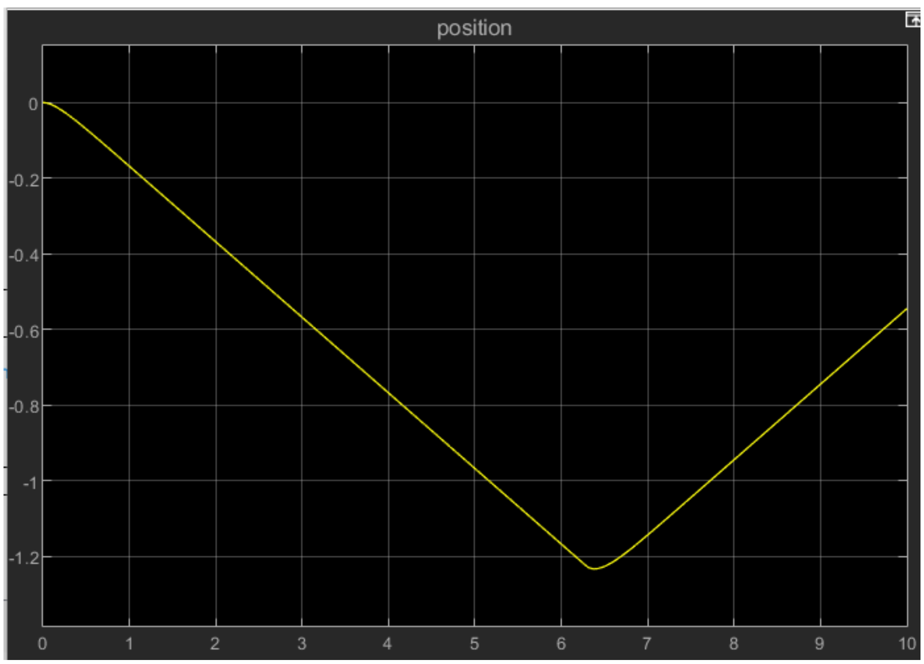

Figure 2.4.1: Position plot for K = 2 and Ti = 0.07.

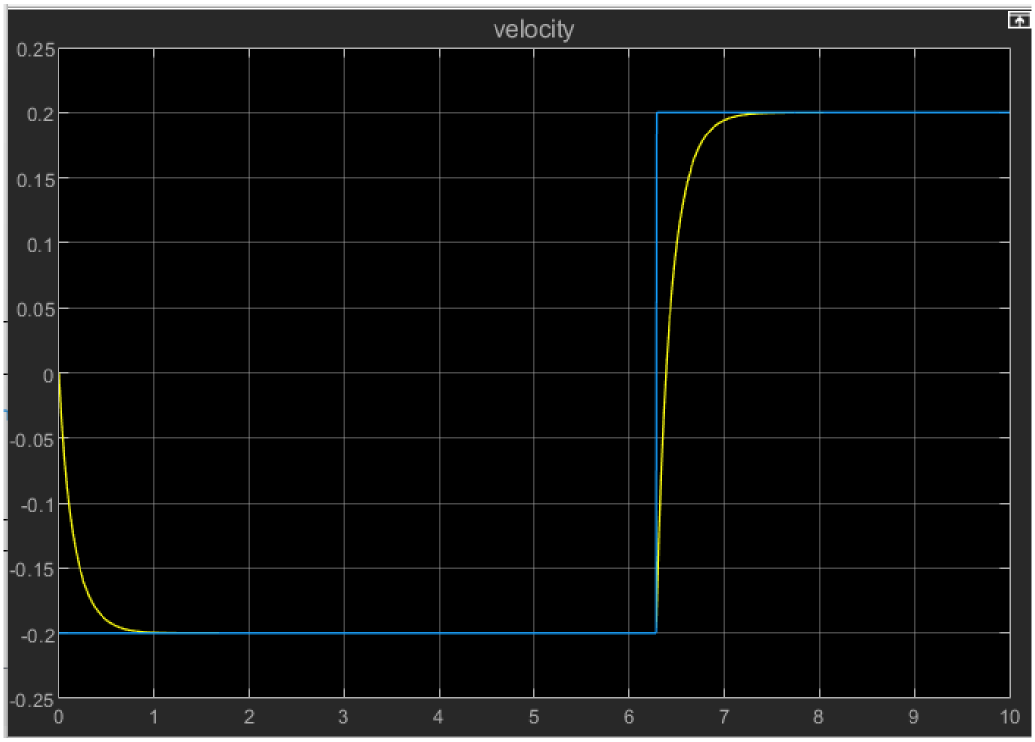

Figure 2.4.2: Velocity plot for K = 2 and Ti = 0.07.

2. Two more plots for increasing values of *K*

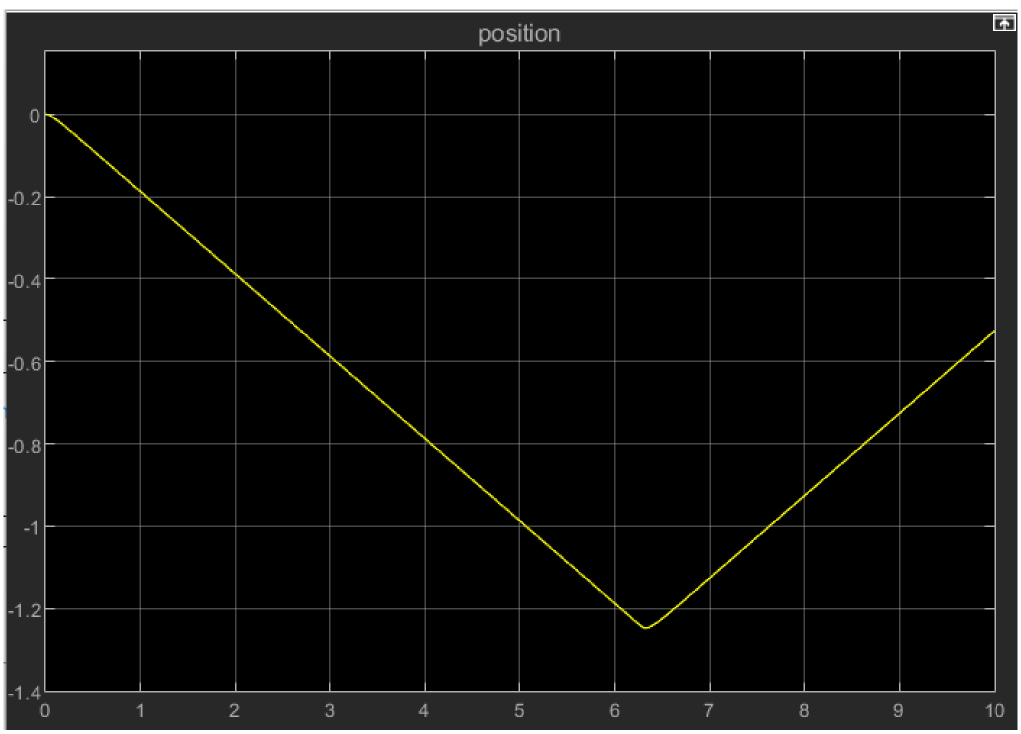

Figure 2.4.3: Position plot for K = 7 and Ti = 0.07.

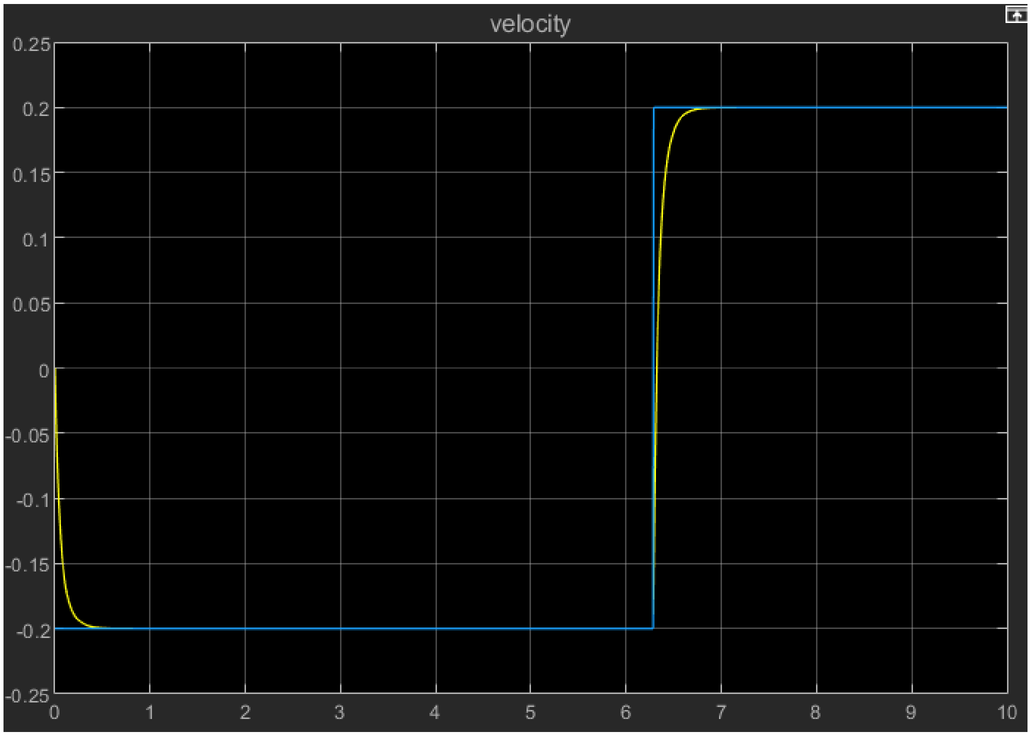

Figure 2.4.4: Velocity plot for K = 7 and Ti = 0.07.

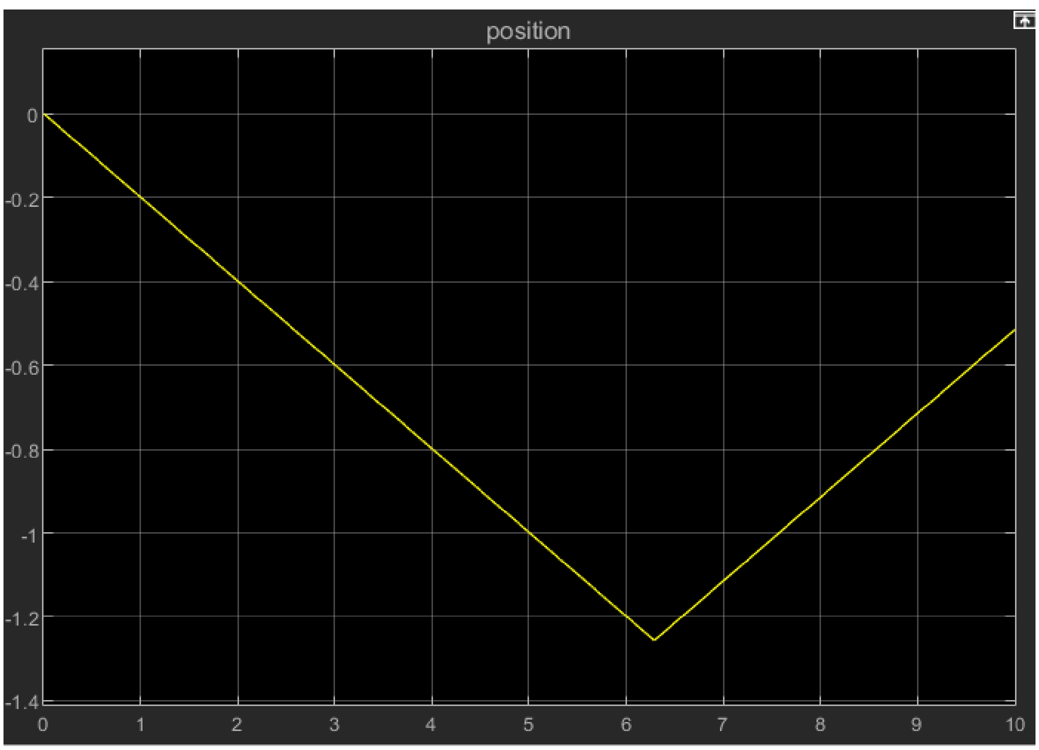

Figure 2.4.5: Position plot for K = 50 and Ti = 0.07.

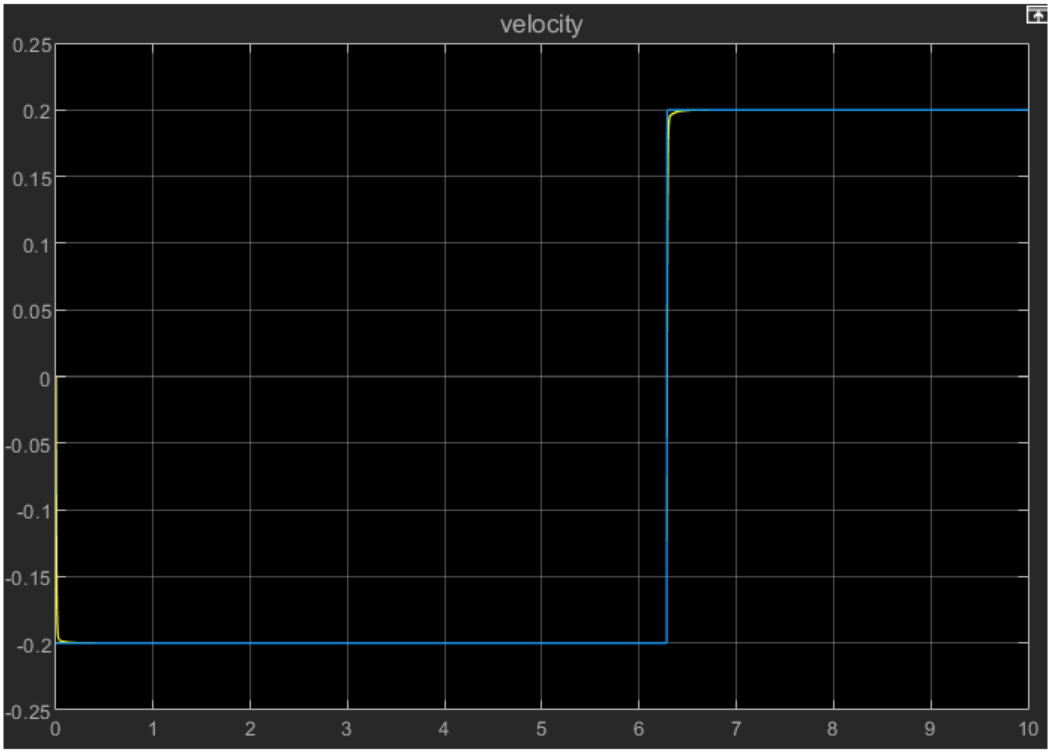

Figure 2.4.6: Velocity plot for K = 50 and Ti = 0.07.

3. Discuss about the effect of an increasing *K*

   For the PI controller steady state error converges to 0 for any value of K. As we increase K, we reach the steady state quicker, therefore it results in better tracking of our initial signal. Higher values of K result in a slight overshoot of average velocity.

3 - CONCLUSIONS

In this section you need to answer the following questions:

1. How does changing the control parameters affect the closed loop performance?

   For the PI controller steady state error converges to 0 for any value of K. As we increase K, we reach the steady state quicker, therefore it results in better tracking of our initial signal.

   For the P controller the steady state error converges to 0 only when K approaches infinity. Therefore increasing K would increase the performance of the P controller.

2. How does the performance of the P and PI controllers compare?

For the PI controller: $E(s) = TiVo$ / $[Tis+K(Tis+1)]$ and $ess = e(\infty) = 0$ by Final Value Theorem. In the PI controller steady state error converges to 0 for any value of K. The integral part of the PI controller eliminates the steady state error.

For the P controller: $E(s) = V0(s+b)$ / $[s(Ka+s+b)]$ and $ess = Vob$ / $[Ka+b]$ Therefore, in the P controller the steady state error converges to 0 only when K approaches infinity.

Therefore, The PI controller performs better than the P controller regardless of the value of K.

3. Which controller is best suited for our objective, i.e. tracking a square wave signal?

   The PI controller is best suited for our objective of tracking a square wave signal and regulating the speed of the cart due to the fact that any value of K results in a minimal steady state error.