Advanced Control Lab- Final report 1

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Experiment objective

The objective of this experiment is to get familiar with experimental setup, laboratory process, data acquisition interface and computer software (MATLAB Simulink) by actuating a DC motor and collecting the data. This lab is a preparation of the labs which will take place in the future.

Experiment summary

For this experiment we followed the instructions of the experimental set up. We used Matlab and Simulink to read the 2 encoders impulses output in the unit of degree by adding specific gains. Then, we measured the angles for the arm by adjusting and changing the constant inputs (0 to 1, 1 to 0, 0 to –1, and –1 to 0) and observed the changes taking place in the DC motor output as a result of open loop control. We then displayed and saved these results and analyzed them and made our observations.

Questions that arise during the experiment

5.1 Encoder output reading

• What is the input channel for each one of the encoders? What is the arm encoder and the pendulum encoder?

Answer:

Channel 1 for arm encoder, and channel 2 for pendulum encoder.

The arm encoder is related to the angular position of arm, and the impulse encoder output signal is generated when the arm rotates; Similarly, the arm encoder is related to the angular position of pendulum, and the impulse encoder output signal is generated when the pendulum rotates. We can get information about angular position, rotation direction, count, etc. from the encoder output.

• **What is the positive turn direction of these encoders?**

Answer: Clockwise is positive for both arm (from the top view) and pendulum encoder.

• **What are the obtained units?**

Answer: The obtained unit is pulse

• **Are the encoder outputs continuous or discrete signals? Explain your answer. This question refers to the values which the encoders output.**

Answer: the encoder outputs are discrete signals because they only have two outputs: zero signal and impulse output, which make the whole output signal in a square wave form.

• **What can be deduced from the previous fact about the measurement errors, and the expected behavior of the control system? Consider, for example, the control system that stabilizes an inverted pendulum.**

Answer: the measurement errors will keep accumulating as the impulse number increases. For a control system which stabilizes an inverted pendulum, it probably needs more settling time before the oscillation decays, and the system enters a steady state. The encoder output signal will oscillate as well due to the vibration.

5.2 Physical measurements

5. The pendulum encoder output can be converted to degrees. Obtain the conversion gain assuming the direct connection between the pendulum and the encoder.

6. Determine the conversion gain that transforms the arm encoder output to the arm angle expressed in degree.

For arm encoder, 9000 impulses for one rotation (2π). For pendulum encoder, 2000 impulses for one rotation. (2π) Therefore, in our case, for the **arm**, the gain is $\frac{\mathbf{360}}{\mathbf{9000}} = \mathbf{0.04}\left[\frac{\boldsymbol{degree}}{\boldsymbol{pulse}}\right]$ and for the **pendulum**, the gain is $\frac{\mathbf{360}}{\mathbf{2000}} = \mathbf{0.18}\left[\frac{\boldsymbol{degree}}{\boldsymbol{pulse}}\right]$.

We derive the following impulses numbers by rotating the arm/pendulum for several rounds and divide the displayed values by number of rounds. Then, we divide $360°$ by the impulse per round to make the gain unit.

Gear ratio calculation

From the arm encoder, which is connected directly to the DC motor, we read the pulse number for the rotor is around 9000 per rotation. For No.4 station, the number of pulses per shaft revolution for channel 1 of the arm encoder is 500. It should be noted that because of the quadrature mode of the data acquisition board, we need to multiply a factor of 4.

$$Gear\ ratio = \frac{9000}{4 \times 500} = 4.5 : 1$$

Pictures of the Simulink files

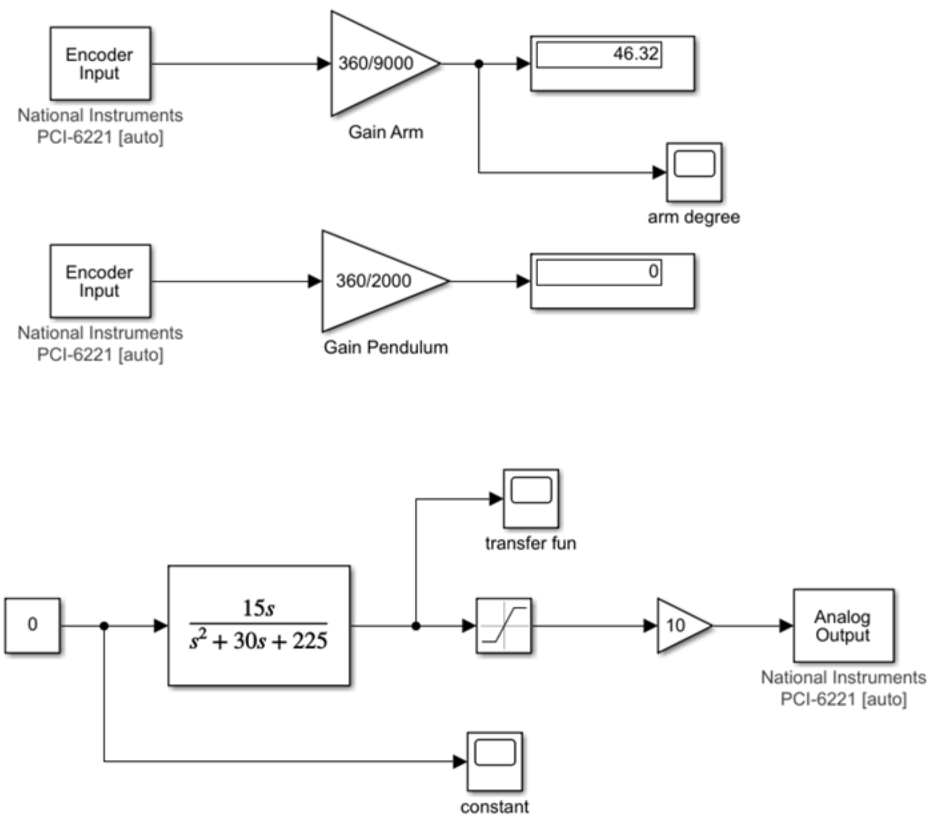

Figure.1 MATLBA Simulink built during the experiment.

Time-Dependent Graphs from The Experiment

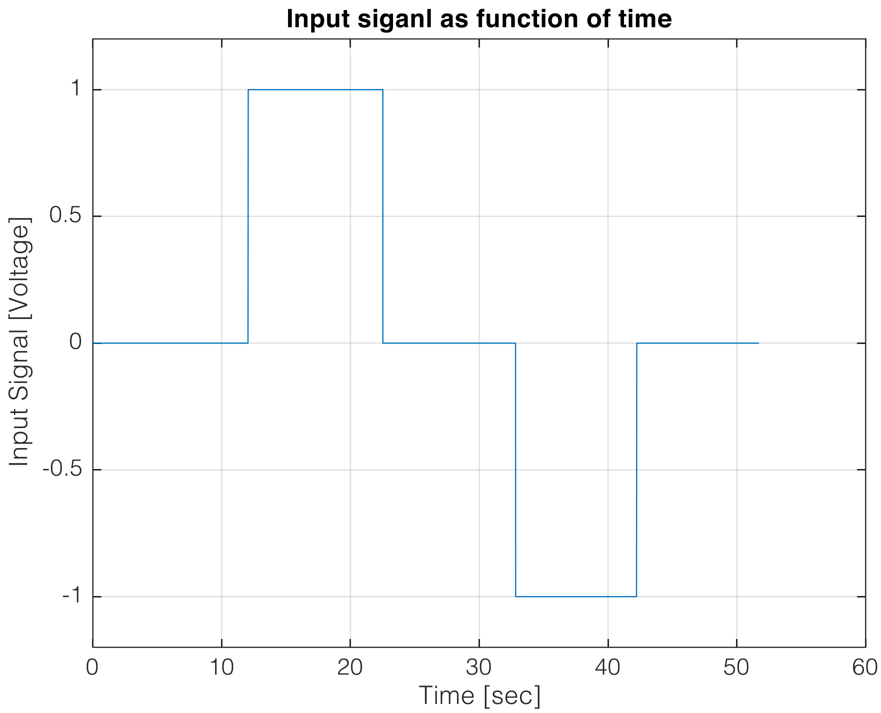

Figure.2 the input signal to the actuator vs time

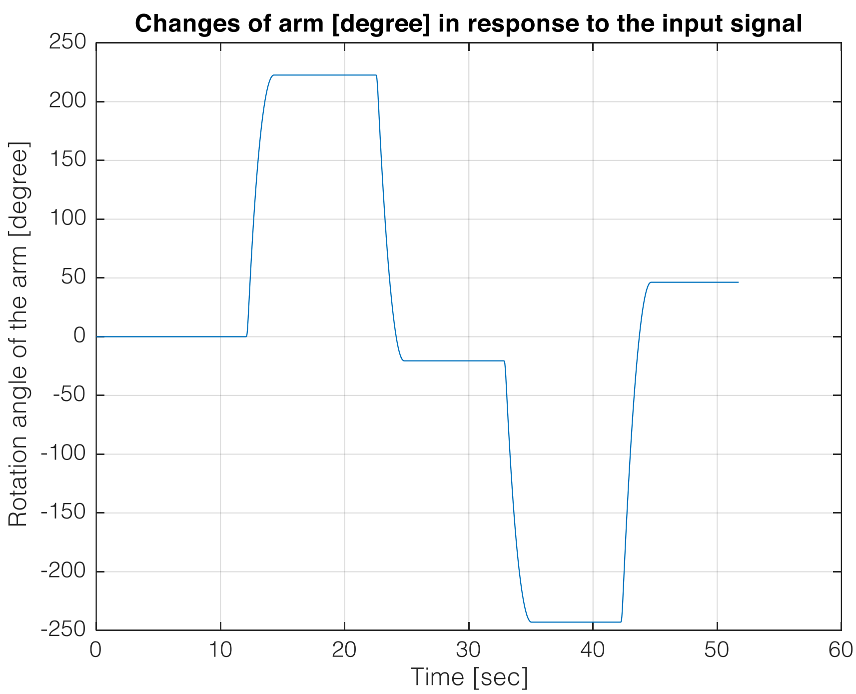

Figure.3 the degree of arm vs time in response to the input signal.

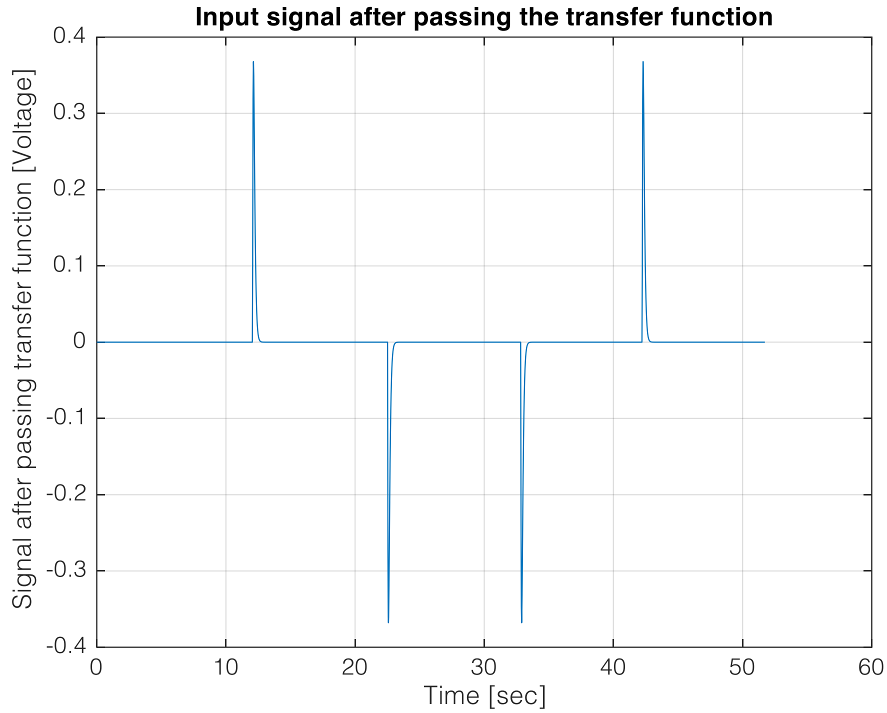

Figure.4 input signal after passing the transfer function vs time vs time

Section 9:

Q1) What is the direction of arm movement obtained as a result of positive voltage input to the DC motor?

Ans) From the graphs of the input and output functions. When the input voltage is positive, the angular values in the output graphs go from 0 degrees to around 230 degrees. This angular range represents the clockwise direction of the pendulum. Hence the direction of the arm for positive input voltage is clockwise.

Q2) Is this direction the same as the positive direction of the arm encoder? What does it mean, if these positive directions are same? What does it mean, if these positive directions are not same?

Ans) Yes, the direction of the arm movement is the same as the positive direction of the arm encoder. This means that the encoder has the same sign as voltage input and motor arm. If the positive directions are not the same, then the voltage input will be in the opposite sign for the encoder and the arm will spin in the opposite or the counterclockwise direction.

Q3) What is the contribution of F?

Ans) The transfer function F makes the signal smoother, and when we take, $\lim_{s\to 0} F(s) = 0$ and it converts unit step response into a pulse, which is more controllable.

Q4) • Suppose F' =$\frac{7.5s}{s^2+30s+15^2}$ instead of F =$\frac{15s}{s^2+30s+15^2}$. Are the unit step responses the same? Explain.

Ans) No, the new transfer function F' step response will also be half the size of the step response of function F. Also, the second transfer function will make the response of the system faster. But one side effect of this will be control trade off, and it will make the control effort large.

Conclusion

In this experiment, we learn the devices and the software we are going to use in the remaining labs. We get familiar with the encoder readings and understand how to change the impulse output into physical unit. In this experiment, we run the appropriate real-time application to actuate the DC motor in an open loop and saw how the transfer function smooth the signal and make the response controllable, and how a saturation block can avoid unexpected response due to incorrect reference input. By analyzing the data, we understand how arm responses to actuation as well as the relationship between the sign of voltage input, arm encoder and arm direction.

Suggestions for improvement

Since we are controlling the system with an open loop, we ought to avoid external disturbance such as the vibration of experimental setup during the experiment. Otherwise, we will see unwanted errors in the output.

Appendix

```
load data_0.mat

t=d1_0.time
y=d1_0.signals.values
figure(1);plot(t,y);grid on;
xlabel('Time [sec]');ylabel('Rotation angle of the arm [degree]');
title('Changes of arm [degree] in response to the input signal');


t2=d2_0.time
y2=d2_0.signals.values
figure(2);plot(t2,y2);grid on;
```

```
xlabel('Time [sec]');ylabel('Input Signal [Voltage]');
title('Input siganl as function of time');
ylim([-1.2,1.2]);

t3=d3_0.time
y3=d3_0.signals.values
figure(3);plot(t3,y3);grid on;
xlabel('Time [sec]');ylabel('Signal after passing transfer function');
title('Input signal after passing the transfer function');
```