

ECEN 380

Signals and Systems

Lab #2

MATLAB / Simulink & Signals

Objectives

- Continue to learn MATLAB commands.
- Become familiar with Simulink®.
- Use MATLAB to analyze signals.
- Practice recognizing signal properties.

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Preamble

This lab is not intended to make you an expert in Simulink; however, this lab will introduce you to some basic features which will allow you to complete the assigned tasks.

As you proceed through each part, record anything new you learn or find useful/interesting. **Include this list in your lab report.**

1) Useful Commands

Throughout the semester you will come across multiple commands and will need to know how to use them in order to solve homework problems and lab tasks (see Table 1). Each lab will require you to search some of the commands in advance. In order to familiarize yourself with the commands, you will have to look them up in the help and write a similar description and example of your own. Although the entries in Table 1 are divided by functionality, keep in mind that a command may actually have multiple uses within different context.

Table 1 – Useful MATLAB Commands

Command window / Workspace	Symbolic Math	Common & Basic Functions		Graphs	Signal / Filter analysis		Polynomial, Vector, or Matrix
clc	subs	abs	log2	axis	fft	ss	conv
clear	sym	angle	max	ezplot	freqresp	ss2ss	deconv
	syms	conj	mean	figure	freqs	ss2tf	find
	symsum	cos	min	hold	freqz	ss2zp	length
	symprod	exp	real	legend	ifft	tf	linspace
		Element-wise multiply .*	sin	plot	impulse	tf2ss	logspace
		Element-wise power .^	sqrt	plot3	impz	tf2zp	norm
		log	sum	pzmap	lsim	tfdata	ones
		log10	special characters	pzplot	phasez	zp2ss	residue
				stem	sawtooth	zp2tf	residuez
				stem3	square	zpk	roots
				subplot			size
				title			mldivide
				xlabel			mrdivide
				ylabel			zeros
				zplane			

2) Procedure

2.a) Part A

If you have completed the MathWorks Simulink Onramp, this part {2.a) Part A} is optional; **include the completion certificate in your lab report.**

If you opted not to complete the Onramp, create tutorial script for the MATLAB commands color-coded red found in Table 1. For each command, include a simple description and an example of the main use of the command. You may use the MATLAB help as reference, but you may not copy their example verbatim. Then **publish the script as an html file** and save it as a web archive (.mht).

2.b) Part B

The function ECEN380L2H is available on Canvas (Ilearn). The function prototype is as follows:

```
function [ny, y] = E380L2H(nx, x, H)
```

where,

Variable name	Description
x	Input signal vector
y	Output signal vector
nx	Input time vector
ny	Output time vector
H	System selector (1, 2, 3)

Come up with different x and nx vectors to test with each of the three systems (H = 1, H = 2, and H = 3). Based on the output of the function, determine whether the system could be memoryless, causal, linear, and time invariant. **Show your input and output vectors, plots, and justify your answers.** (Hint: This part is similar to problem 1.75 and 1.76).

2.c) Part C

1. Research about quantization noise and about aliasing and record your findings.
2. Set up and configure Simulink and the N.I. Breakout board by following the steps outlined in Section 3: Simulink
3. Using the function generator and the oscilloscope, set up a 2 Hz 1V peak-to-peak sine wave. Set the scale so that about 4 to 5 periods are visible. Connect a second probe to the analog out of the N.I. breakout board. It will likely be zero (or at least a constant) until the Simulink model is run.
4. In a Simulink model, connect an Analog Input block to a Scope block. Configure the Analog Input block to use the N.I. breakout board and PCI card with a 10ms sample time. Then, connect the signal from step 1 to the computer.
5. Run the model (Ctrl + T).
6. Open the Scope and wait a few seconds for data to be captured. Then, stop the model (Ctrl + Shift + T).
7. Take a screenshot of the scope waveform. Then, zoom in the horizontal axis so that 5-10 periods are visible. Take another screenshot of the waveform. Also, take a third screenshot of the oscilloscope showing the input and output signals to and from the N.I. breakout board.
8. Repeat steps 3 through 7 for a sine wave at 20Hz, 200Hz, 500Hz, and 1002Hz, taking screenshots and recording your observations for each of the frequencies.

Your final report should include a total of **15 screenshots**.

9. Can you still measure the correct period at each frequency in Simulink?
How or why not?
10. Try to explain why the 1002Hz signal looks the way it does in Simulink.
11. Could we recover the original waveform at each frequency? How or why not?

3) Simulink

MATLAB Simulink is a block diagram environment for model-based design. With Simulink you may perform multidomain simulation, automatic code generation, and continuous test and verification of embedded systems.

According to [MathWorks](#), Simulink: ... provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB®, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis.

For this lab we will use Simulink to observe and manipulate signals. To access Simulink, open MATLAB and type Simulink in the command window and press enter. The Simulink Start Page should then open. The blocks available depend on the different toolboxes purchased with the MATLAB license. To use the blocks, you must first place them in a Simulink model.

Create a new Simulink Model by pressing *Ctrl + N* or by clicking the box labeled 'Blank Model'. If you already have a project open, you can also click on the button labeled 'New' shown in Figure 1.

Once a model is open, you may drag (not double-click) blocks from the Simulink block library browser to add them to the model. After placing a block in the model, you may edit the block parameters by double-clicking the block.

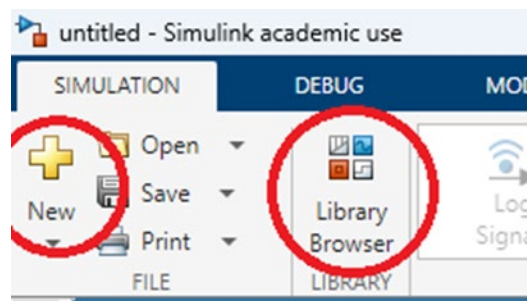


Figure 1 – New Simulink Model button (left) and Block Library Browser (right)

For this lab, you will use three different Simulink blocks: Analog Input, Analog Output, and Scope, all of which can be found by opening the Library Browser button shown above. The analog input and output blocks are found within the Simulink Desktop Real-time library, while the scope is found under Simulink > Commonly-used blocks.

3.a) Configuring the Analog Input/Output Block with the N.I. Breakout Board

To allow the computer to read any external signals, we will need to configure the Analog Input block so that it connects to the National Instruments breakout board (See Figure 2) which can be found in each STC-151 lab station. This configuration process only needs to be done once and will remain configured for both input and output blocks.

1. Connect the N.I. breakout board (See Figure 2), to the N.I. SH68-68-EPM cable (see Figure 3) or the N.I. SH68-C68-S cable (see Figure 4) depending on what is available your lab station.

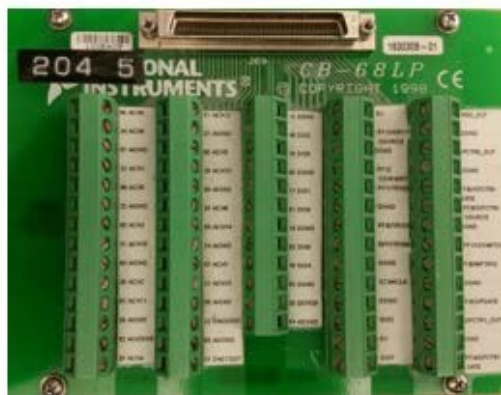


Figure 2 – N.I. Breakout Board



Figure 3 – N.I. SH68-68-EPM Cable



Figure 4 – N.I. SH68-C68-S Cable

2. If a cable is not connected, connect either the N.I. SH68-68-EPM Cable (see Figure 3) or the N.I. SH68-68-S Cable (see Figure 4) to the N.I. PCI-6014 card (see Figure 5) or the N.I. PCI-6221 card (see Figure 6), depending on which one is available at your lab station.



Figure 5 - N.I. PCI-6014 Card Slot



Figure 6 - N.I. PCI-6221 Card Slot

3. Place an Analog Input block from the Simulink Desktop Real-time library into the new Simulink model.
4. Double-click on the Analog Input block to open the Block Parameters: Analog Input window (see Figure 7).
5. If the `< no board selected >` dropdown list says `< no board installed >` or doesn't contain any options, click `Install new board`. Otherwise, select the option, click `board setup`, and skip to step 7.

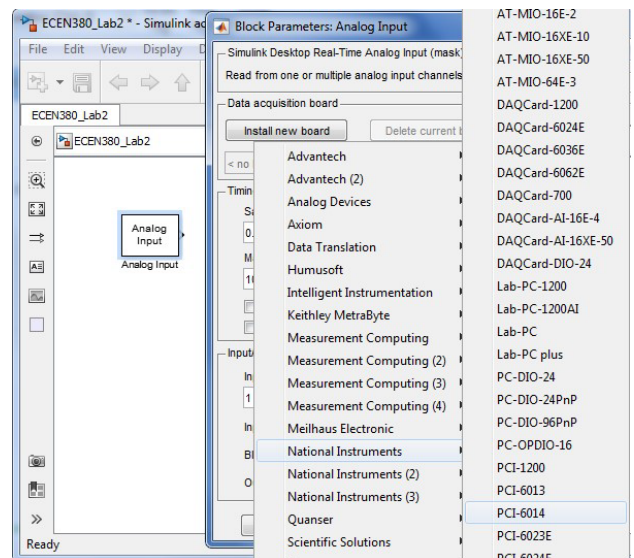


Figure 7 - Board Selection within the Analog Input Window

6. If your station has the PCIe-6321 card, select
National Instruments (2) > PCIe-6321 from the list.

If your station has the PCI-6014 card, select
National Instruments > PCI-6014 from the list.

If your station has the PCI-6221 card, select
National Instruments > PCI-6221 from the list.

If you are uncertain which PCI card your station has, you can go through each one and click on the 'Test' button until one of them works.

7. Click 'Test' and make sure the board presence is detected (see Figure 8). If the kernel needs to be installed or updated, you will need to contact a lab assistant with administrative privileges.

If the board presence is not detected, make sure the correct PCI board was selected. If the problem persists, either switching computers or rebooting may be necessary.

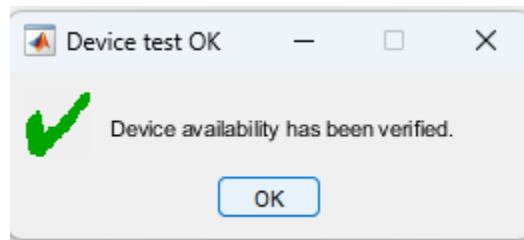


Figure 7 – Board presence verified

8. Select a type of A/D connection, either one is fine, and click OK.
 - If you select **single-ended**, the signals should be connected as shown in Figure 9.
 - If you select **differential**, the signals should be connected as shown in Figure 10.

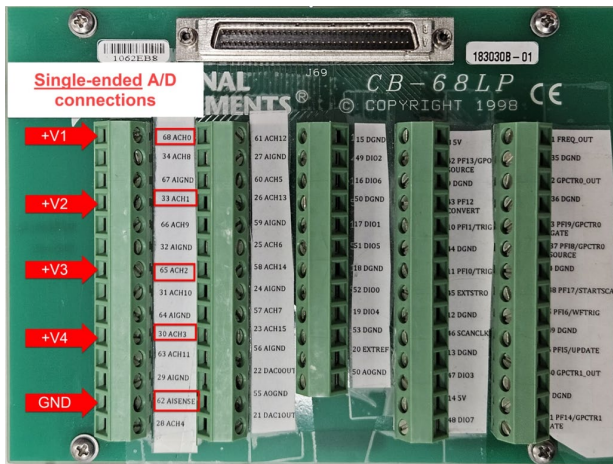


Figure 9 – Single-ended A/D connection

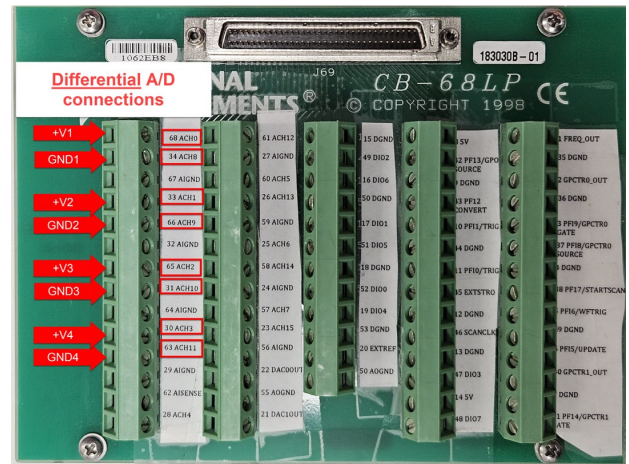


Figure 10 – Differential A/D connection

9. Select the number of input channels as shown in Figure 11.
10. Select a sample time, and click OK;
(Refer to Step 4 in [Part C](#))
11. Place an Analog Output block from the **Simulink Desktop Real-time library** into the Simulink model.

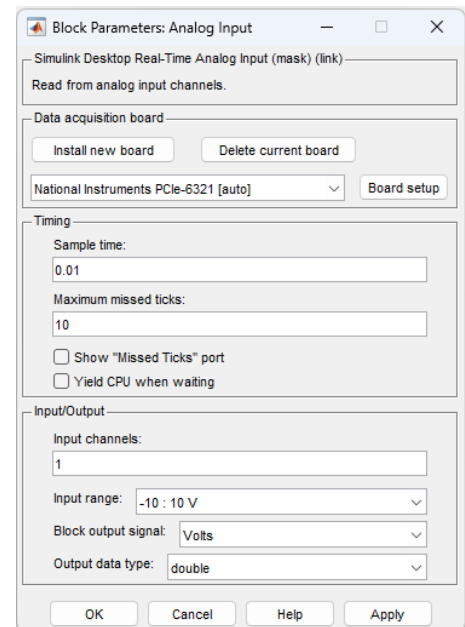


Figure 11 – Analog Input Window
Showing the Input Channel Quantity

12. The process for setting up the Analog Input block is then repeated for the Analog Output block with some differences, with the process outlined below:

Double-click on the Analog Output block to open the Block Parameters: Analog Output window.

13. Select the same N.I. Board selected for the Analog Input block from the dropdown list.

14. Select the number of output channels. Refer to the connections shown in Figure 12 to determine the number of output channels you will use.

- Note: The arrows in Figure 12 are not pointing to the ports to the left but are instead pointing to the labels referencing the use of the ports they are coming out from. For this lab, only one output channel should be used.

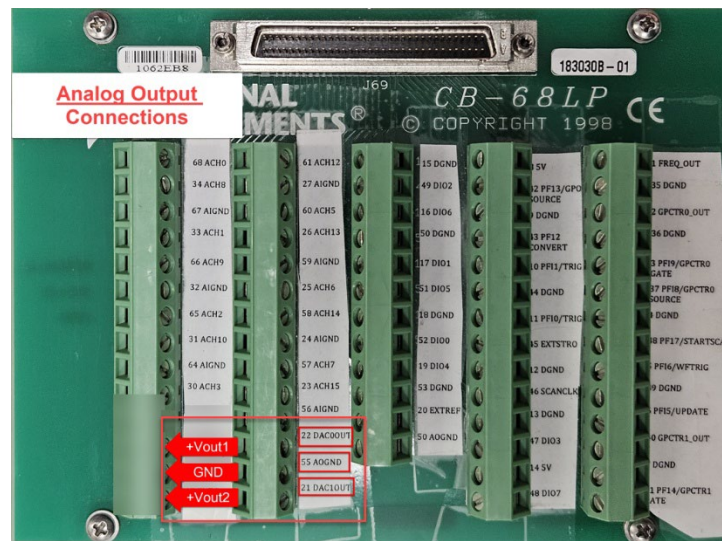


Figure 12 - Analog Output Connections

15. Enter a sample time and click OK.

WARNING: Anything 1ms or faster may cause MATLAB to freeze. It is recommended to start out using 10ms.

3.b) Configuring the Scope Block

16. Place a Scope block from the `Simulink > Commonly Used Blocks` library in the browser into the Simulink model by dragging the icon into the model.
17. Click on the 'Apps' tab, and under the 'Apps' expandable toolbar, look for the `Real-Time Simulation and Testing` section, and click on `Desktop Real-Time` (see Figure 13); alternatively, you can search for the term "Desktop Real-Time", and click on the result. This should create a new tab with the same name.

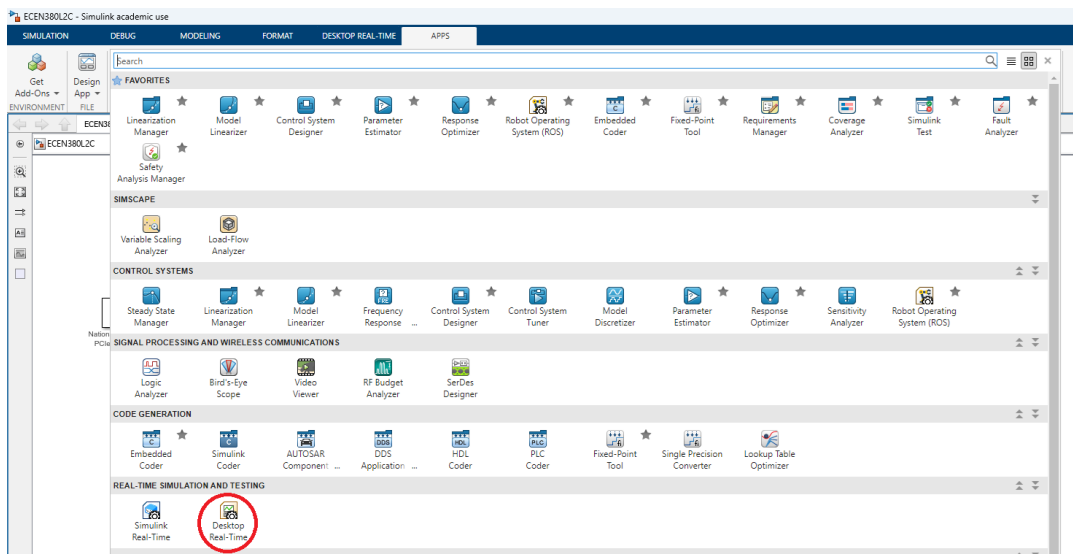


Figure 13 – Desktop Real-Time App

- **Note:** If when setting up the desktop real-time environment you got a window as shown in Figure 14, ensure that the code format is set to be `sldrt.tlc`, as shown below:

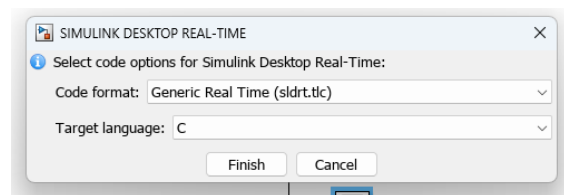


Figure 14 – Desktop Real-Time Setup

18. From the 'Desktop Real-Time' tab, under the 'Prepare' expandable toolbar, click on `Control Panel`, opening the `External Mode Control Panel` window.

19. From there, click the **Signal & Triggering ...** button. Set the duration to 10000 (see Figure 15). Press OK.

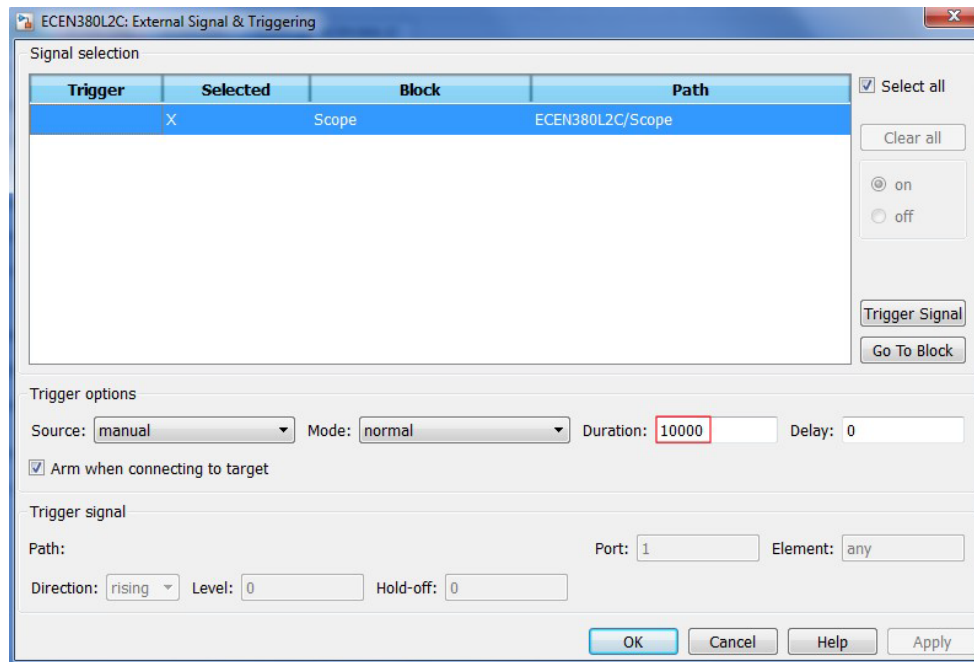


Figure 15 - Signal & Triggering

3.c) Configure and Run the Model as a Real-time Windows Target

20. Open the model configuration parameters by pressing Ctrl + E (or Simulation | Model Configuration Parameters).
21. From Code Generation, if a window appeared when setting up the desktop real-time environment (see Figure 14), ensure that the system target file is set to the system target file to `sldrt.tlc` and set it to that if it is not (see Figure 16).

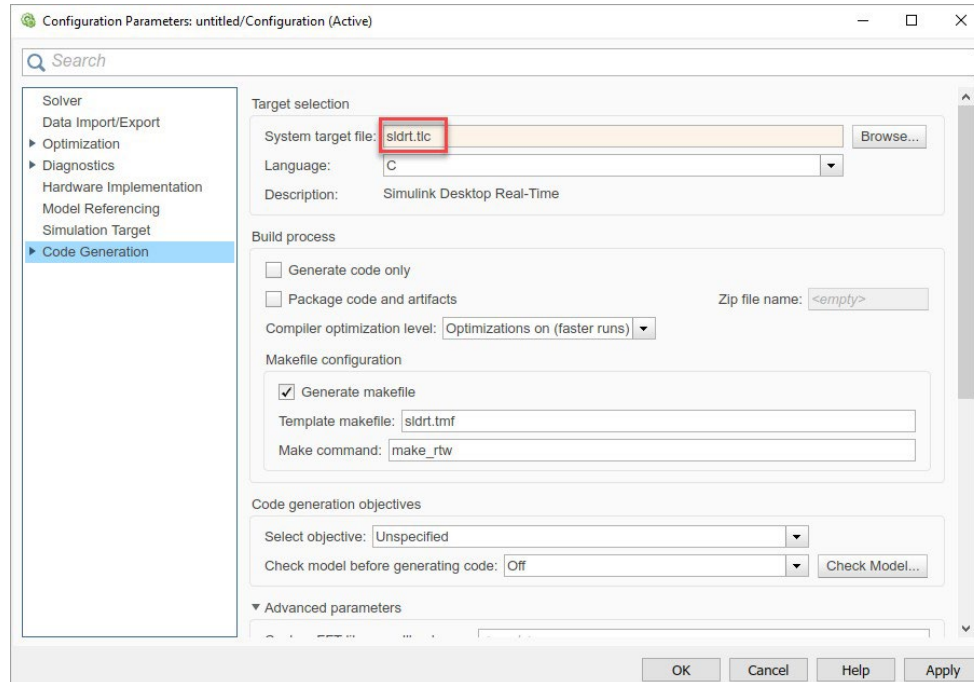


Figure 16 – Model Configuration Parameters

22. From Solver, set a start and stop time for the run time. Stop time may be “inf” to specify an infinite run time. And under the Solver selection type, select Fixed-step. Click OK.
23. Press Ctrl + T to compile, build, connect to the target device, and run the model. Press Ctrl + Shift + T to stop.
 - **Note:** Scopes only store data if they are open before or during runtime. Double click the scope to see the voltage read by the Analog Input module.
24. Setup is now complete. Refer back to [the lab procedure](#) for further instruction.

4) Lab Report Requirements

For your lab report, include a title page containing the following:

- **BYU-I logo**
- **Your name**
- **Class section**
- **Date**

In your report,

- **Include a table of contents showing the order of the different sections from your report**
- **Include a brief abstract detailing what has been done for the lab**
- **Show your work done for the procedure/practice section**
- **Provide a brief explanation of the Simulink blocks used for the lab**
- **Describe the things you learned or found interesting/useful**
- **Write a conclusion.**

Answers and comments about any text marked red in this lab handout should also be incorporated in your report. Make sure that your report is formatted neatly and is of a professional quality and ensure that there are no major spelling or grammatical errors.

Submit your lab report as a single file, either:

- a PDF file (.pdf), or
- a web archive file (.mht).

Also submit

- any MATLAB scripts and Simulink models you created while doing the lab

Your report should follow conventional academic honesty standards, being written by you, and you only, unless express permission has been given by the instructor stating otherwise. **It is not to be written by another person or be written/generated by AI.**

If there are any errors with the procedure or ways on how to improve this lab or procedure, please provide any feedback you may have.

5) Rubric

See ILearn for Rubric.