Lab 6 - Manipulating Robot Arm

Overview

Need MATLAB 2024 A
In this lab we will simulate the motions of a 5 DOF robotic arm with a claw gripper as it moved in real life. The TA will demonstrate the arm executing a simple motion profile with the physical robot arm, then with the motion profile data from the robot you will be able to recreate the motion using a 3D model of the arm in Simulink.

Resources Required:
MATLAB
Simulink
Simscape Multibody

HEBI_5DOF_Gripper.zip
HEBI_motion_profile.xlsx

Description of the System

The robotic arm that will be utilized in this lab is depicted in figure 1. The arm utilizes 7 HEBI actuators and has 5 degrees of freedom with a claw gripper.

Figure 1: HEBI 5DOF Arm with Gripper

Task 1: Physical Model Demonstration and Data

For this task, the TA will perform a brief live demonstration of the HEBI robot arm.

NOTE: A video of the demonstration can also be viewed with following link,

After the demonstration, if you have not done so already, retrieve the data file titled "HEBI_motion_profile.xlsx" from the lab folder in Canvas.

Open the "HEBI_motion_profile.xlsx" file in Excel, or if you don't have Excel, you can open it in Google Sheets. Take note of the data set. It consists of only seven columns of data. The first column is the time in seconds, the other columns of data are the position of the HEBI robot's joints in radians.

1. To get a visual sense of the data, create a "Scatter with Smooth Lines" plot of it. Be sure to include a proper title, legend, and x and y axis labels with units.

Now you have a plot of the robot's joints over the duration it was moving. This provides some graphical insight into how the robot moved. This data will also be imported into Simulink to simulate the movement of the modeled robot arm.

To show completion of this task, save your formatted Excel data and plot and show the TA. Be sure to include this plot in your lab report.

Task 2: Manipulating Robot Arm in Simulink

For task 2, we will be preparing the premade Simulink file with the robot arm model to simulate the same motion profile that was made by the physical arm.

1. Obtain the HEBI_5DOF_Gripper.zip from Canvas and extract the folder. Within the folder, open the HEBI_5DOF_Gripper.slx file, this should open a premade Simulink file with a primary system block as shown in figure 2.
2. Double-click the HEBI Arm subsystem block to open it.

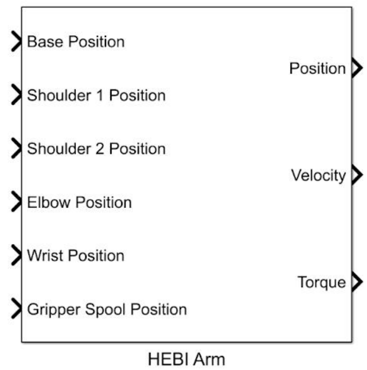

Figure 2: HEBI Arm Subsystem Block

3. Once within the HEBI Arm subsystem, navigate to the model workspace. There will be a block highlighted red indicating there is an error with loading data. The path to the workspace data file must be redefined and reinitialized the into the model workspace in order for the error to be resolved.
4. Within the “Model Workspace" pane, browse for the “HEBI_5DOF_Gripper_DataFile.m” from within the “HEBI_5DOF_Gripper” folder you downloaded from canvas and then click on the “Reinitialize from Source” button, as shown in figure 3.
5. Close the Model Explorer window. Go to Modeling and Update Model. Any errors or warnings shown in the block diagram should be cleared. The block diagram should currently look as it does in figure 4.

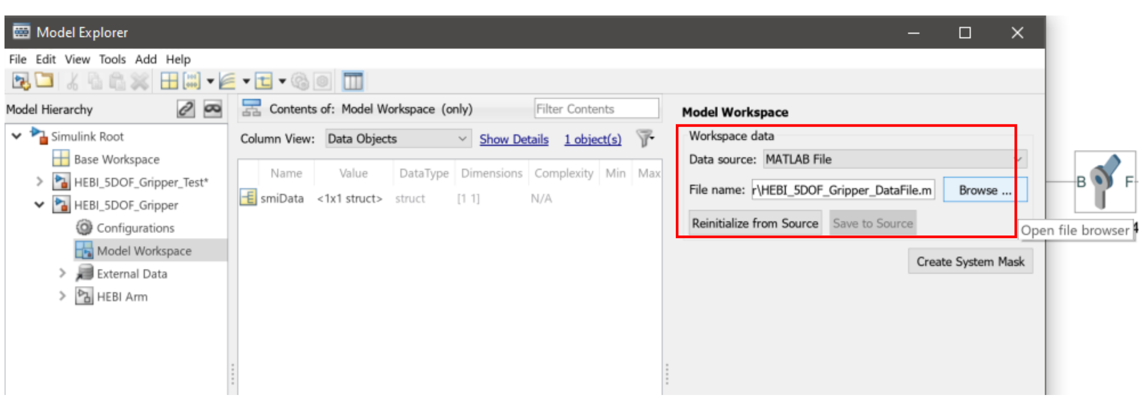

Figure 3: Model Workspace Data Reinitialization

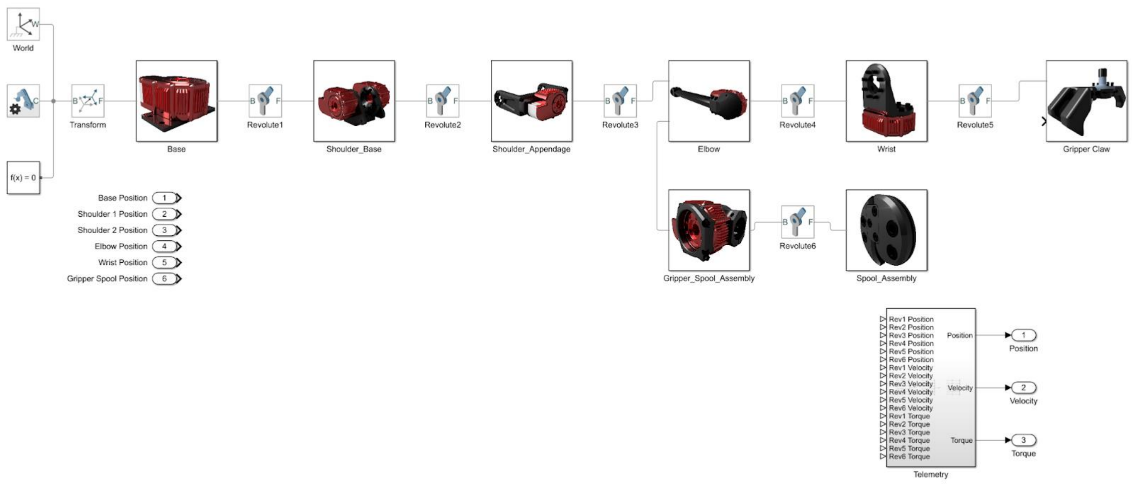

Figure 4: HEBI Arm Initial Block Diagram

6. Within the HEBI Arm Block Diagram, open the Mechanism configuration block. Redefine the Gravity parameter matrix to place earth gravity in the -Z direction as shown in figure 5.

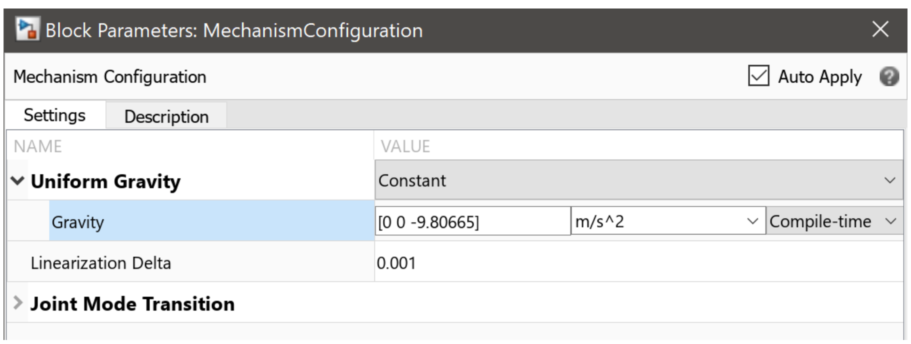

Figure 5: Mechanism Configuration Gravity Parameter

7. Navigate to the "Configuration Parameters" window and adjust the following parameters, as show in figure 6.
   - Stop time = 80 (seconds)
   - Solver: ode23t (mod.stiff/Trapesoidal)
   - Max step size: 0.1 (seconds)

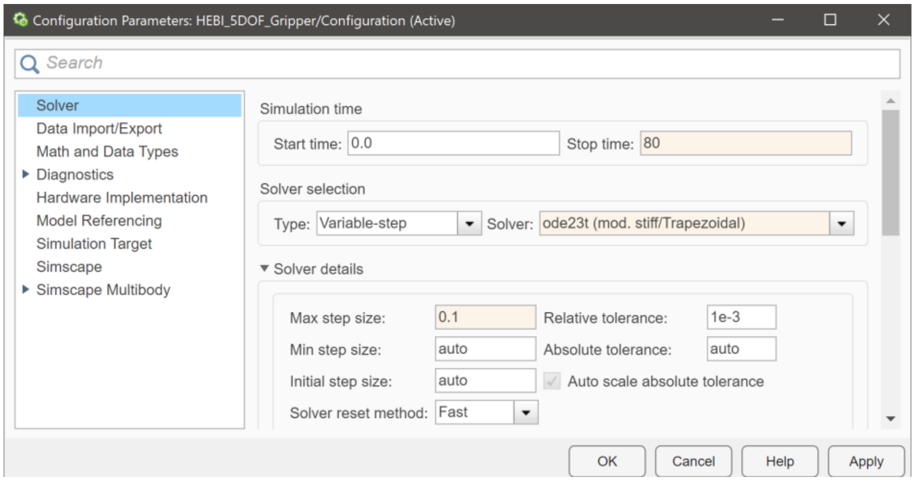

Figure 6: Configuration Parameters

8. Open the "Revolute1" block within the "HEBI Arm Subsystem" and modify the parameters to match the parameters as shown in figure7. Pay attention to the units, they must be using radians and not degrees.
9. Repeat step 8 in setting the same parameters for Revolute joints 2,3,4,5, and 6.

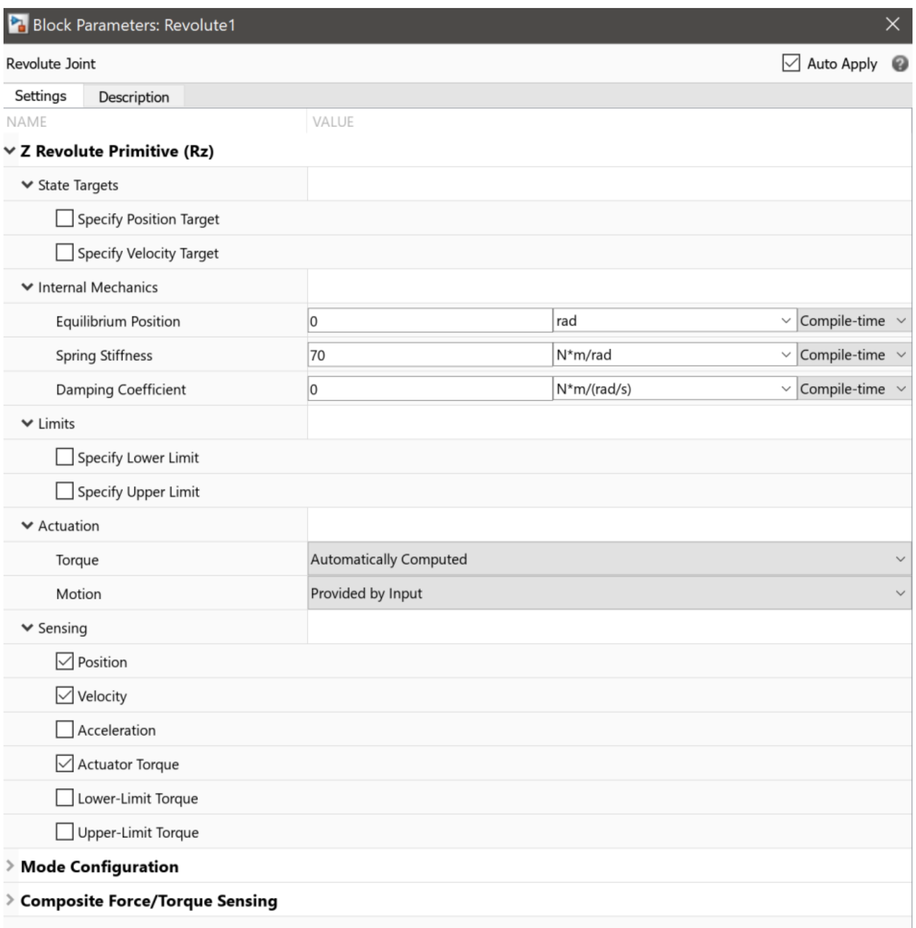

Figure 7: Revolute Block Parameters

Figure 8: HEBI Arm Block Diagram Simulink-PS Converter

10. After making the changes to the revolute blocks, insert a “Simulink-PS Converter” block and place it directly to the right of the “Base Position” connection port. Once placed, connect the “Base Position” connection port to the “Simulink-PS Converter”. At this point, the HEBI Arm block diagram should look as it does in figure 8.
11. Open the newly placed “Simulink-PS Converter” and change the “Input Handling” parameters to the following, as shown in figure 9, then apply the changes and close the block
    - Filtering and derivatives: Filter input, derivatives calculated
    - Input filtering order: Second-order filtering

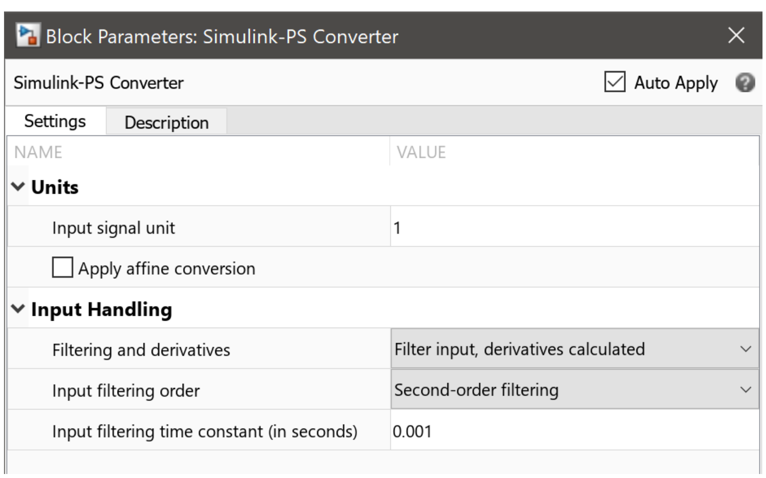

Figure 9: Simulink-PS Converter Parameters

12. Copy and paste the newly configured “Simulink-PS Converter” block you’ve made and place one for each of the other position connection ports below the “Base Position” connection port.

13. Move the “Simulink-PS Converter” block to be positioned under the “Gripper_Spool_Assembly” block and connect the other end of the “Simulink-PS Converter” block to the “q” input port of the “Revolute6” block.
14. Connect the sensing output ports of the “Revolute6” block to the input ports of the “Telemetry” subsystem block as follows:
    - Revolute6 Block: q ⟶ Telemetry: Rev6 Position
    - Revolute6 Block: w ⟶ Telemetry: Rev6 Velocity
    - Revolute6 Block: t ⟶ Telemetry: Rev6 Torque
15. With the setup and connections from the previous steps complete, select the “Gripper_Spool_Assembly”, “Spool_Assembly”, “Revolute6”, and the “Simulink-PS Converter5” block, as well as all the connection lines, as shown in figure 10. Then create a subsystem of the selection by clicking the “Create Subsystem” button or by pressing “ctrl+g” (windows), “cmd+g” (mac).

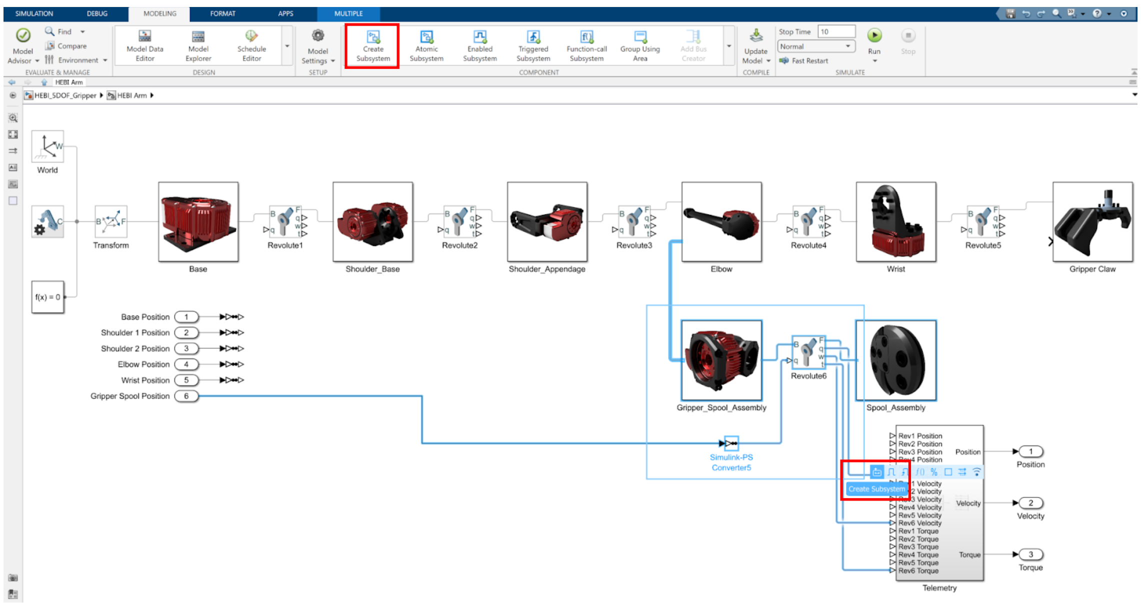

Figure 10: Creating Gripper Spool Subsystem

16. Once the subsystem is created, drag the “F” input port of the subsystem coming from the “Elbow” subsystem to be above the input port coming from the “Gripper Spool Position” connection port.
17. Select the newly created subsystem then select the “Elbow” subsystem block, then click on the “Match size” button found within the “Format” ribbon toolbar, as shown in figure 11. This will resize the newly created subsystem to match the size of the “Elbow” subsystem, which also happens to be the same size as the other robot arm subsystems.

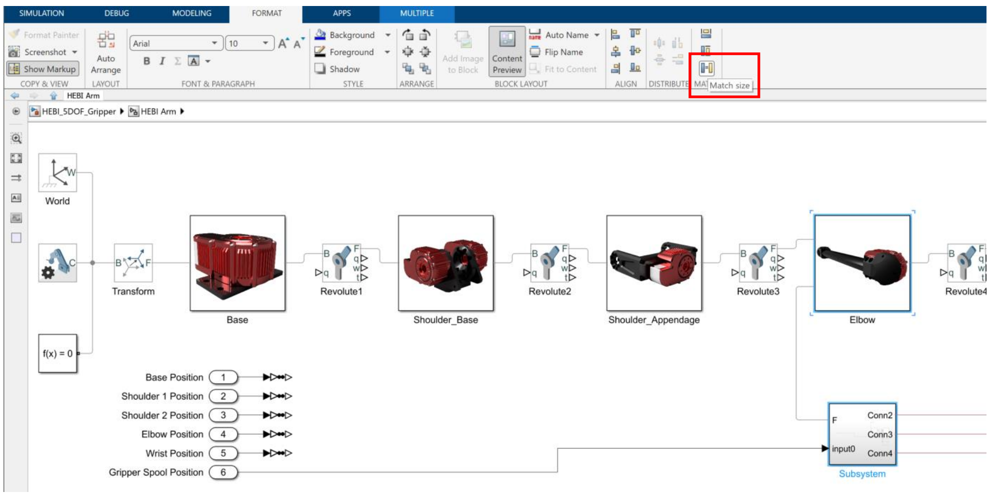

Figure 11: Resizing Subsystem to Match

18. Name the newly created subsystem as “Gripper Spool” and then right-click on the block and select “mask” and “add icon image”. Alternatively, you can click the “Add Image to Block” button found within the “Format” ribbon toolbar.
19. Once the “Add mask icon image” dialog box pops up, browse and select the “Gripper Spool.png” that is within the “HEBI_5DOF_Gripper” folder you have downloaded from Canvas. Check the “Store a copy of the image in the SLX File” box and click ok, as shown in figure 12.

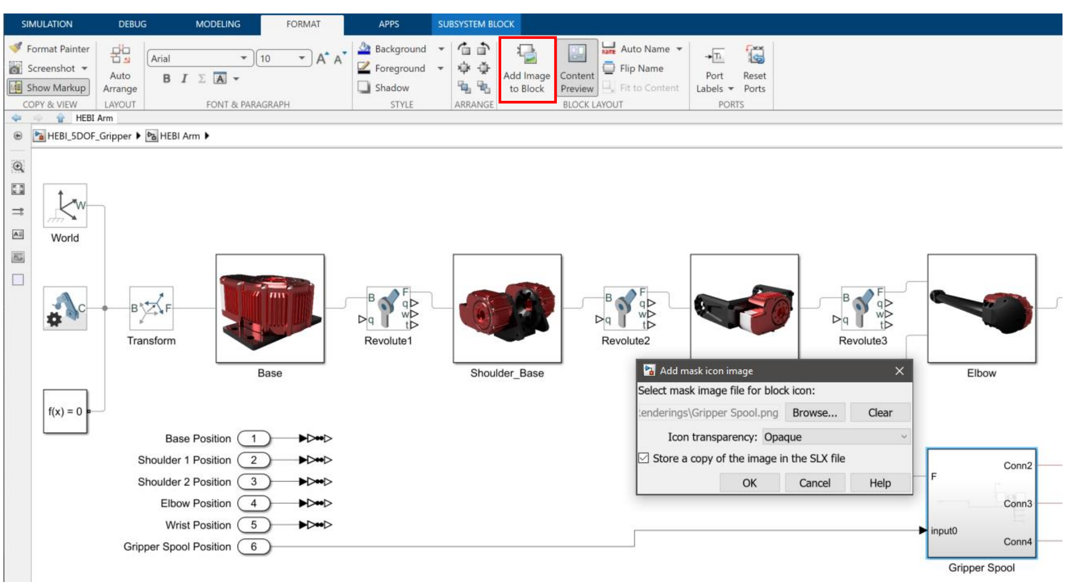

Figure 12: Adding Image to Gripper Spool Subsystem Block

20. Open the "Gripper Spool" subsystem block, neatly arrange the subsystem, and ensure the blocks are named as shown in figure 13.

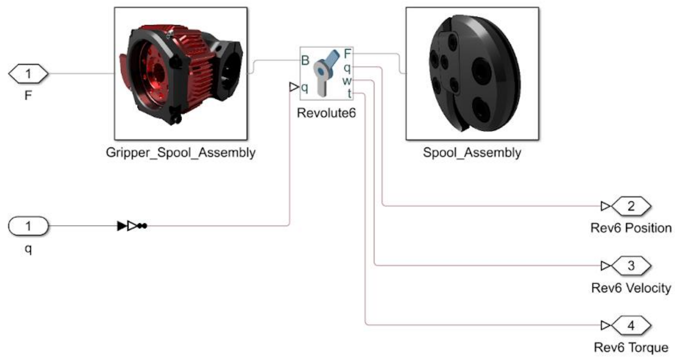

Figure 13: Gripper Spool Subsystem

21. Navigate back to the "HEBI Arm" subsystem and complete it by wiring up the remaining connections from the position connection ports to their respective revolute joints' input ports, and from the revolute joints' sensing output ports to their respective input ports on the "Telemetry" subsystem, as shown in figure 14.

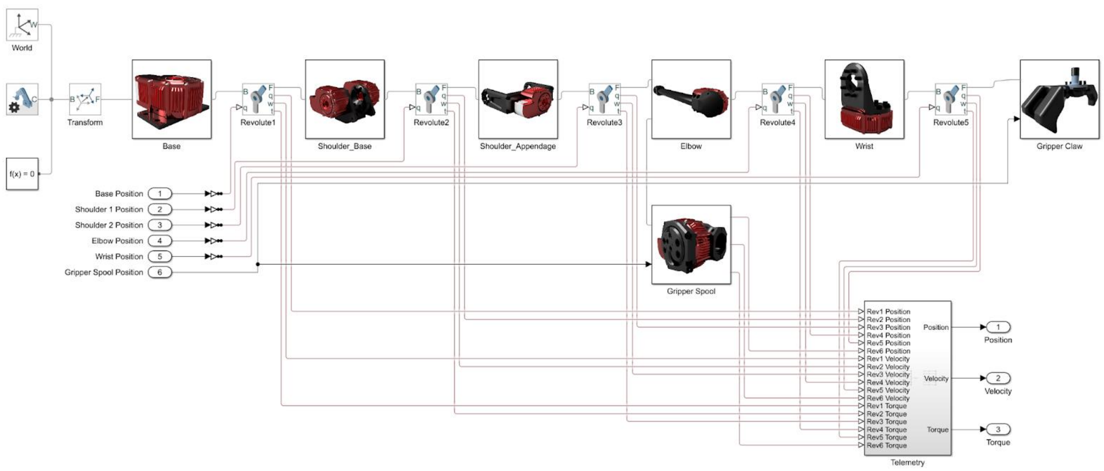

Figure 14: Complete HEBI Arm Block Diagram

22. Capture a screenshot of the completed "HEBI Arm" block diagram to include in your lab report.

23. Navigate back to the initial system workspace that is above the HEBI Arm subsystem block. This is the workspace first seen from steps 1 and 2, when you first opened the HEBI_5DOF_Gripper.slx file.
24. To the left of the HEBI Arm subsystem block, place a "Signal Editor" block. We will now be able to import the HEBI motion profile data into the signal editor block which will then be the import data to each of the revolute joints.
25. Open the "Signal Editor" block, click on "File" then "Import from File…", as shown in figure 15.

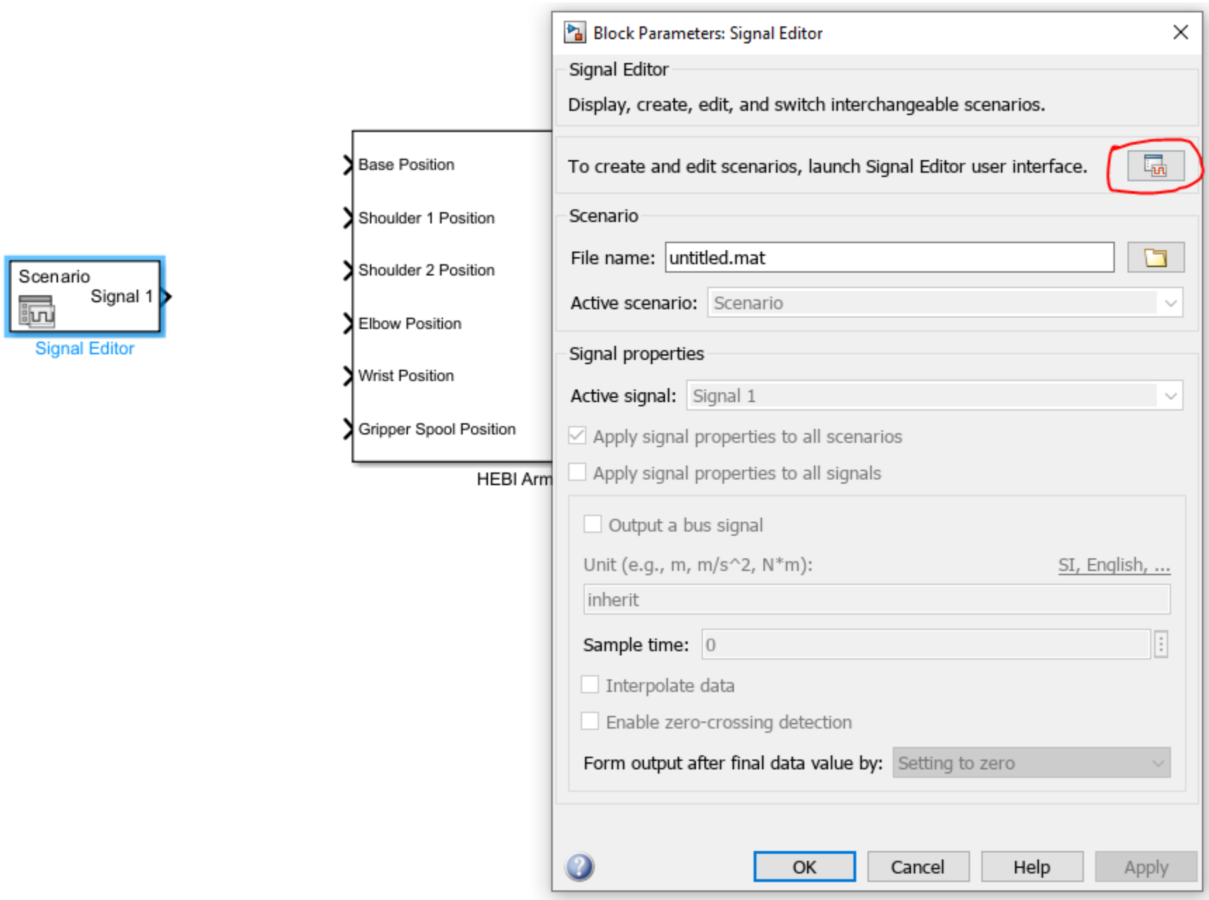

Figure 15: Inserting Signal Editor and Importing Data

26. Once the "Import File" window opens, browse and select the "HEBI_motion_profile.xlsx" file, then click OK
27. It should look like figure 16, then click "apply". Save the existing data when the pop-up dialog box appears.

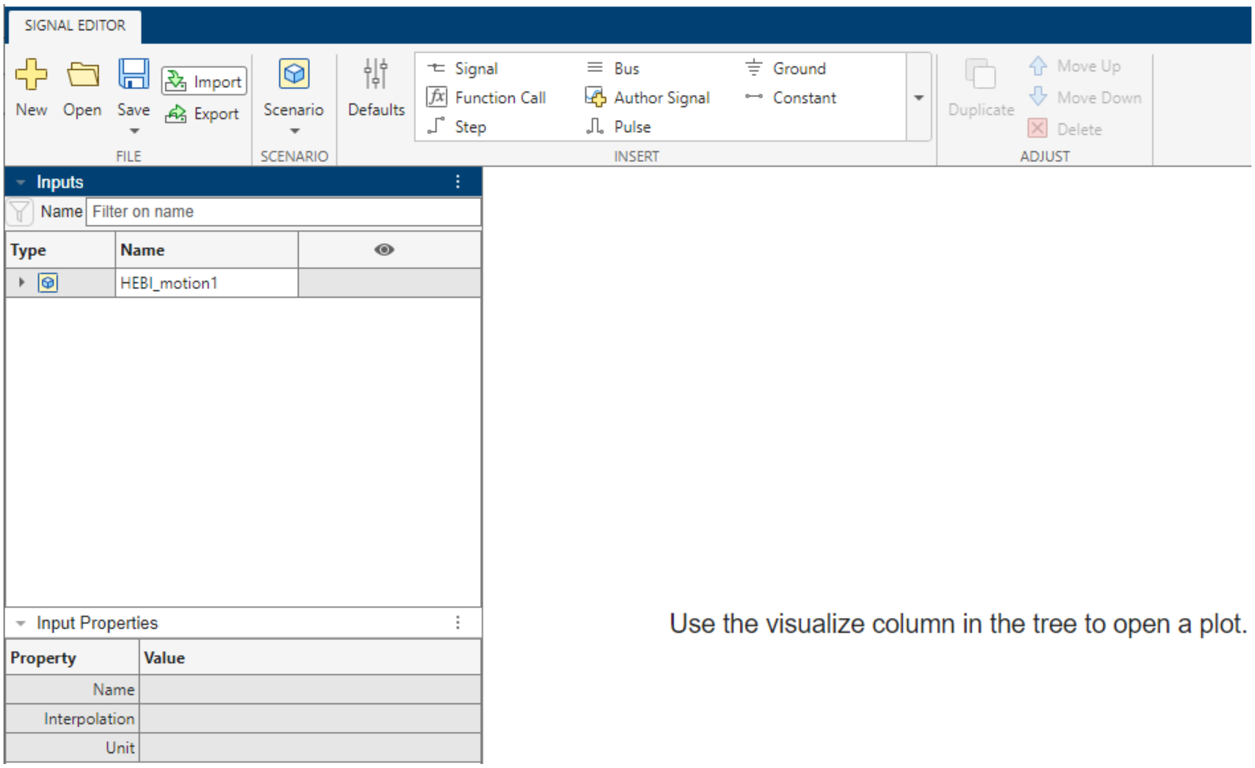

Figure 16: Import File Parameters

28. Select Interpolate data & Apply signal properties to all signals and click Apply. Once the import is complete, observe that the “Signal Editor” block will now have the 6 individual position over time signals for each of the arm’s joints. The block will also create the additional output ports on its right side for each of the new signals.
29. Connect each of the output ports of the “Signal Editor” block to its respective input port on the “HEBI Arm” subsystem block.
30. On the “HEBI Arm” subsystem block, add the “HEBI_5DOF_Position1_square.png” to be the block mask icon, as you did in step 19 for the “Gripper Spool” subsystem block.
31. To the right of the “HEBI Arm” subsystem block, add a “Scope” block.
32. Resize the “Signal Editor” and “Scope” blocks to match the size of the “HEBI Arm” subsystem block. At this point the block diagram should look like it does in figure 17.

Figure 17: Complete HEBI 5DOF Gripper System

33. Open up the "Scope" block and format the scope so that it has a stacked layout for its position, velocity, and torque plots. Set Y-axis scale for windows 2 & 3. Be sure to include proper plot titles, axis labels, legend and color formatting. The color for each of the lines should also be consistent across each of the three plots. Reference figure 18 for how the formatting should look with the simulation plots.
34. With the scope window still open, run the simulation and observe the results. The scope will produce the plots as shown in figure 18 and the 3D model of the arm will recreate the same motion profile in the Mechanics Explorer window as it did with the physical arm.

To show completion of this task, save your formatted plots then show the TA your plots and motion simulations.

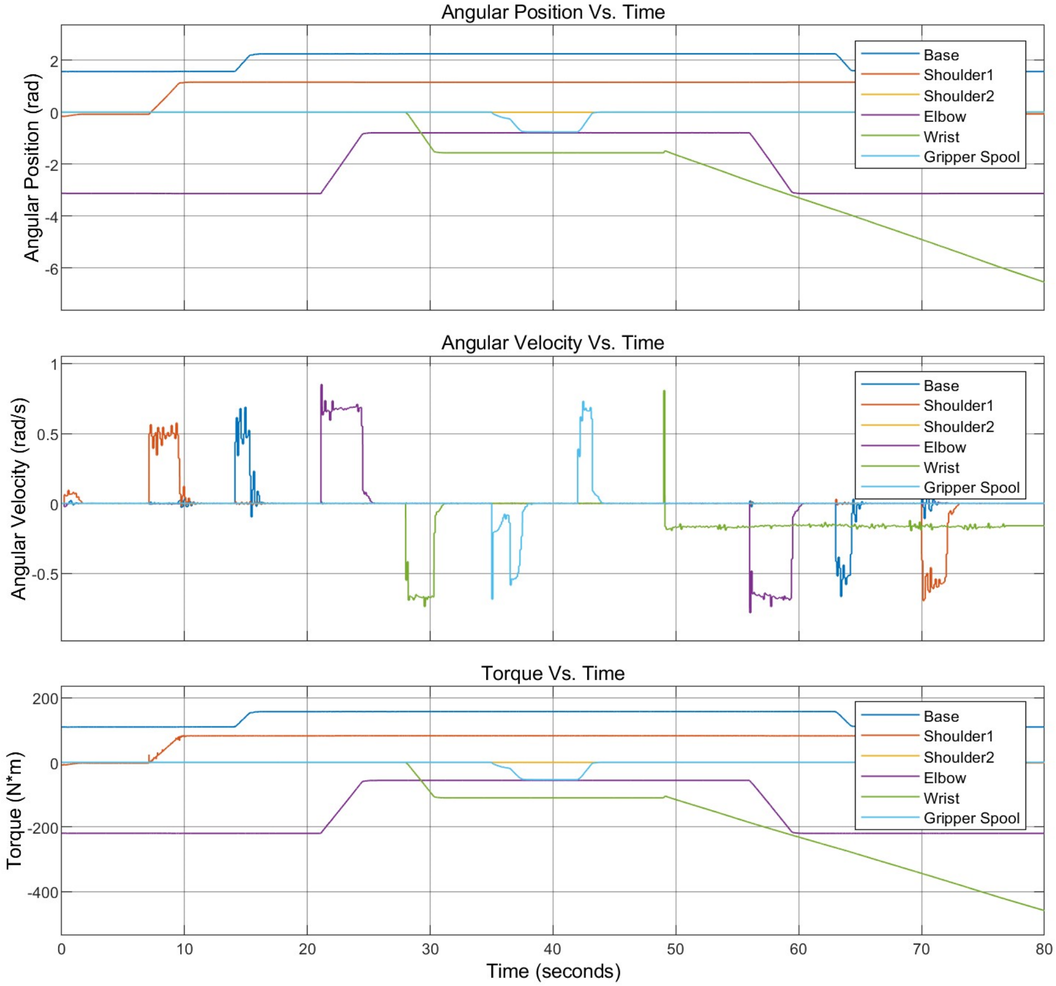

Figure 18: HEBI Arm Plot

Post-Lab Questions

1. From the mechanics explorer window, move the camera to a position to view the HEBI arm in its entirety with the gripper facing the camera and capture a screenshot of it at the 40th second and include it here.

2. Within the scope, use the "Cursor Measurements" tool within the top toolbar to toggle on the "Cursor Measurements", "Signal Statistics", and the "Peak Finder" side panel tools then capture this current view of the scope and include it here.

3. Using the "Cursor Measurements" tool determine the position of the joints in the below table at the 40th second.

	Position (rad)
Base	
Shoulder 1	
Gripper Spool	

4. Using the "Cursor Measurements" tool, complete the below table.

	Peak Velocity (rad/s)	**Peak Torque (N*m)**
Base		
Shoulder 1		
Gripper Spool		