Magnetic Levitation System

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1 OBJECTIVE

This experiment will review the concept of dynamic systems and will show to acquire data in real-time for such system, using Simulink. Normal mode method is used of collecting data in real-time from Simulink. The experiment is designed to show the deign and build of a dynamic system and analysis of such system by collecting the experimental data. This analysis includes open loop, close loop, linear flittering, nonlinear filtering, PID and Neural Network controller for machine learning purposes. You will get some hands on experience of collecting data and performing some classical and advance type of controllers with filterings.

2 SETUP

2.1 REQUIRED MATERIALS

2.1.1 HARDWARE

- Electromagnet
- Sharp IR Sensor
- Magnet
- Arduino Mega 2560
- Motor Shield (DFRobot L298P)
- Crown Bolt Zinc Plated #10-24 x 1/2 in

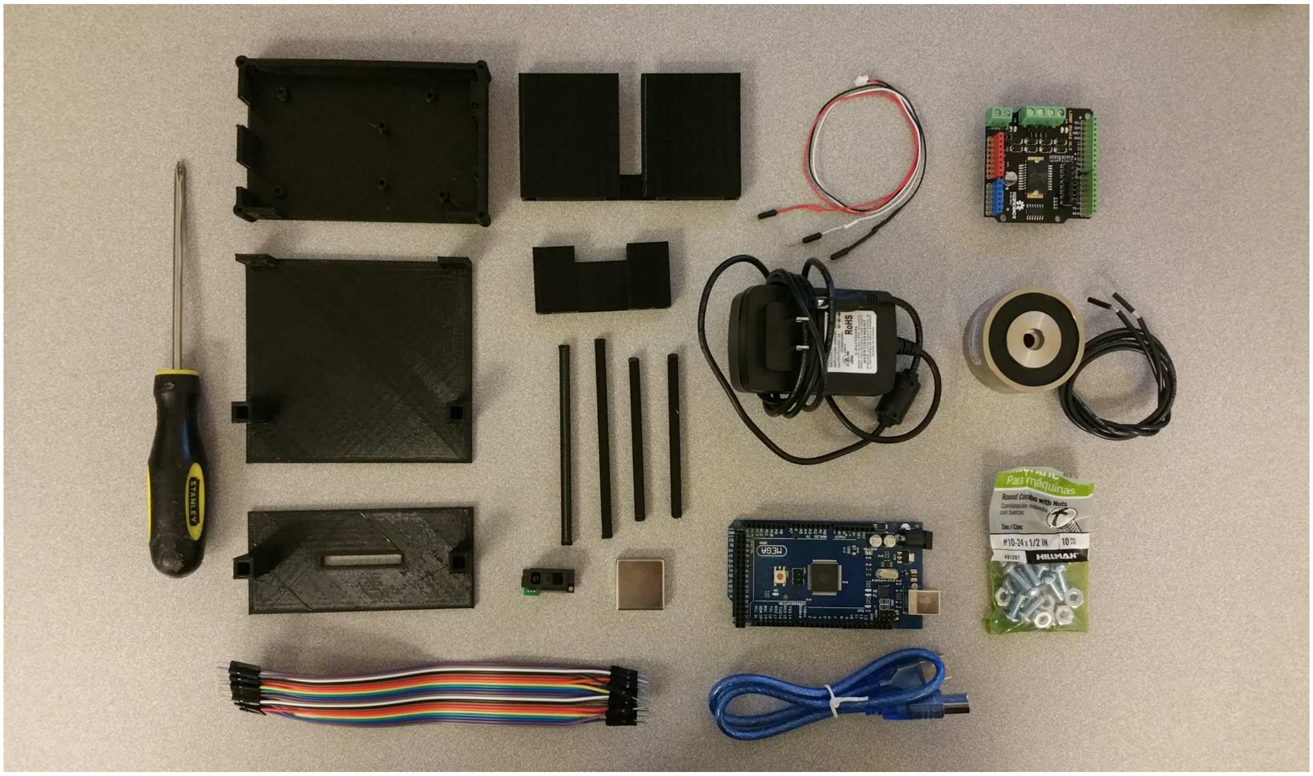


Figure 2.1: Hardware Items

- Loctite Fun-Tak Mounting Putty LOC1270884
- 12VDC 3A Wall Adapter Power Supply
- 0.1 inch (2.54mm) Crimp Connector Housing: 1x3-Pin 25-Pack
- Female Crimp Pins for 0.1" Housings 100-Pack
- Sharp Cable
- 3-D Printed Base
- 3-D Printed Tower
- Sticky Tack
- Small Phillips and Flat screwdriver
- Sandpaper or Sanding Sponge (Optional)

2.1.2 Software

- Matlab/Simulink 2016a or later
  - ⋆ *The steps and images related to Matlab/Simulink for this experiment were created using Matlab/Simulink 2016a. Therefore some steps and images may be a little different if you are not using this version. If you are in fact using a different version, make sure you know the steps for running models onto the Arduino for your version of Simulink.*
- Matlab/Simulink files
- Take Home Labs Arduino Library
- 3-D Printer files

2.1.3 Prerequisite Experiments

The experiments listed below should be completed prior to this one. Steps and hardware from these experiments may be needed or referenced throughout this experiment. It is assumed that you already have the Arduino communicating with the PC, know how to set up and run models in Normal and External Mode, can troubleshoot any of the issues discussed in these three labs, and can 3-D print the required parts.

- Blinking LED
- Simple DC Motor
- Sampling and Data Acquisition
- Intro to 3-D Printing

2.2 Software Setup

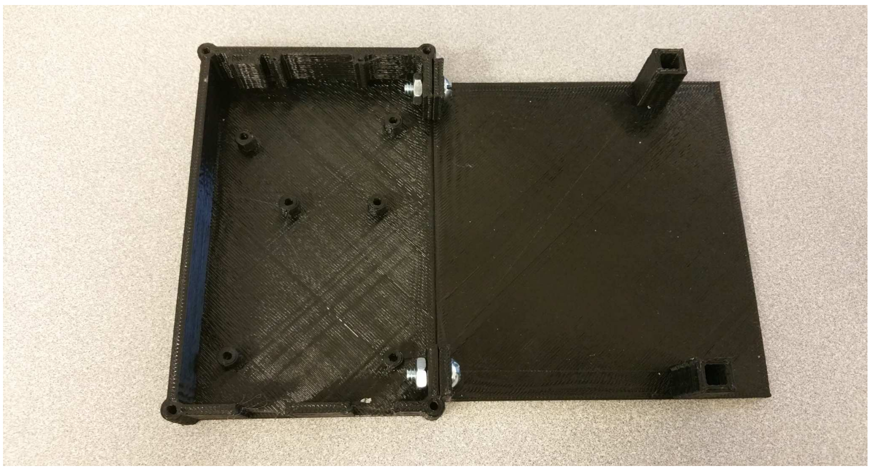
The steps for Software Setup in Sampling and Data Acquisition needed for this experiment. By this time, you should have the THL library on your Simulink Repositories. Downloading and adding additional Simulink blocks to the Simulink Library is covered in the first section. The third section requires downloading the 3-D printer files dedicated to this experiment, so that they can be printed.

1. Open your browser and type in thl.okstate.edu in the URI.
2. Find the Magnetic levitation experiment by navigating to the website.
3. In the rightmost section, select "3-D Printer Files".
4. Also, in the rightmost section, select "softwares files".

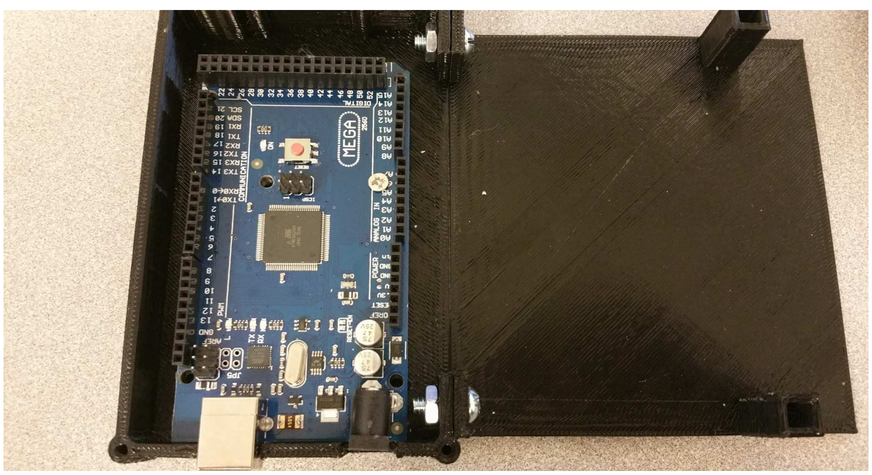
2.3 Hardware Setup

This section contains the instructions for assembling the hardware components. First, the base and extension will be connected to each other with screws and bolts. Second the Arduino will be attached to the base and fixed it with screw to the base, the mother shield will be attached on top the Arduino. Third, the electromagnet will be placed on the extension base then the cover and the tower will be assembled with the strait bars. Next the sharp sensor will be placed on top the tower. Finally the wires and the tape measures will be added to the setup. Please follow the visual instruction below to assemble each parts in order.

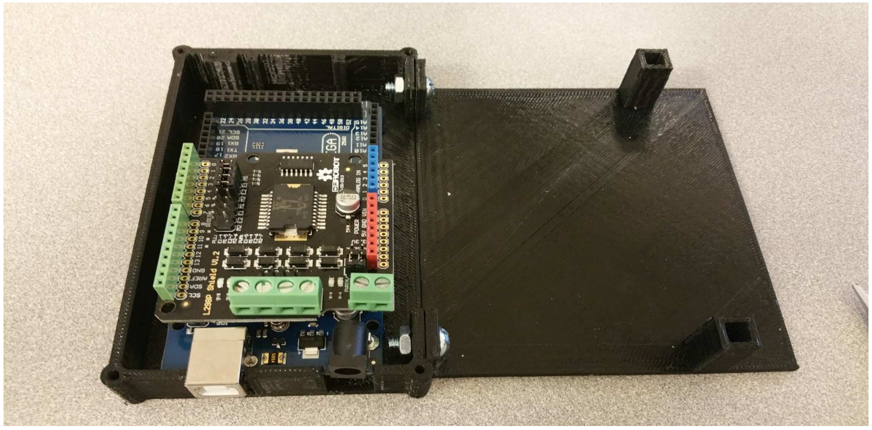
5. First we connect the base with the extension using the screws using the screws and the bolts.



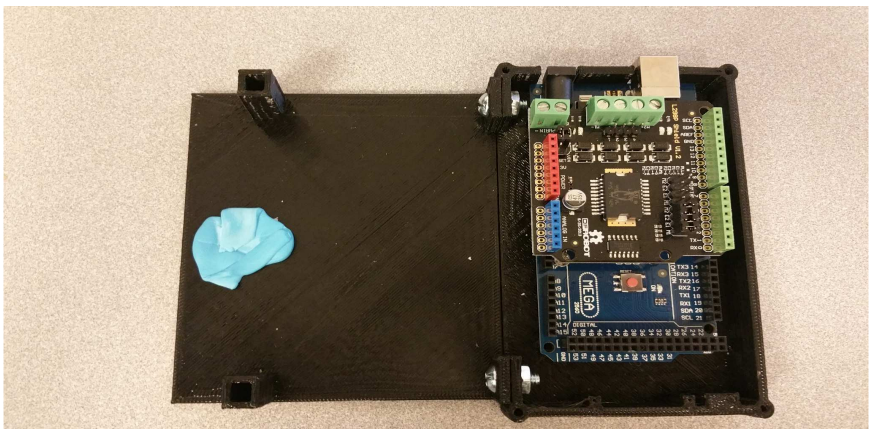
6. Add Arduino in to the base and use the small screws to attach it firmly to the base



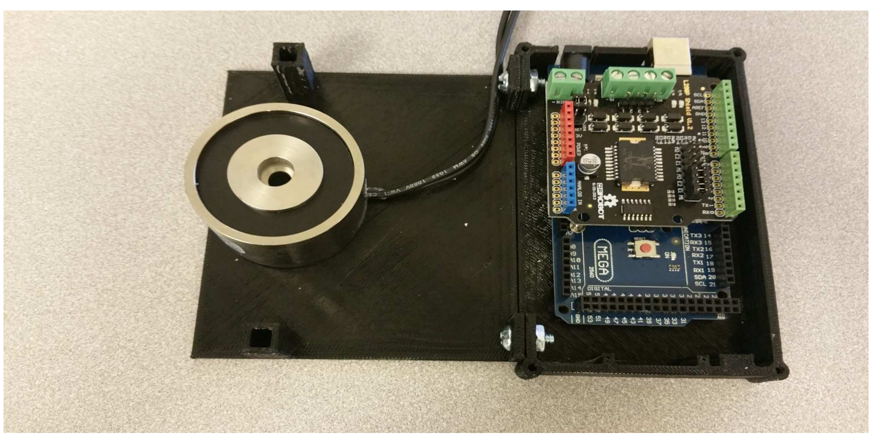
7. Place the motor shield on top the Arduino.



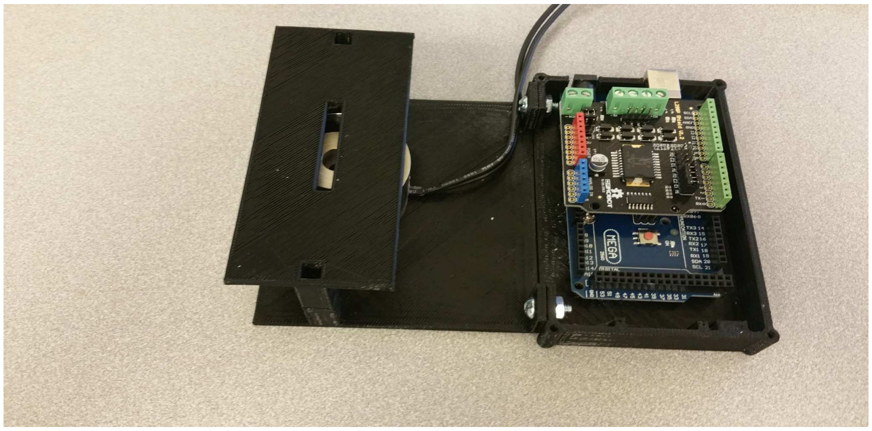
8. Put some sticky tack on the extension base to fix electromagnet.



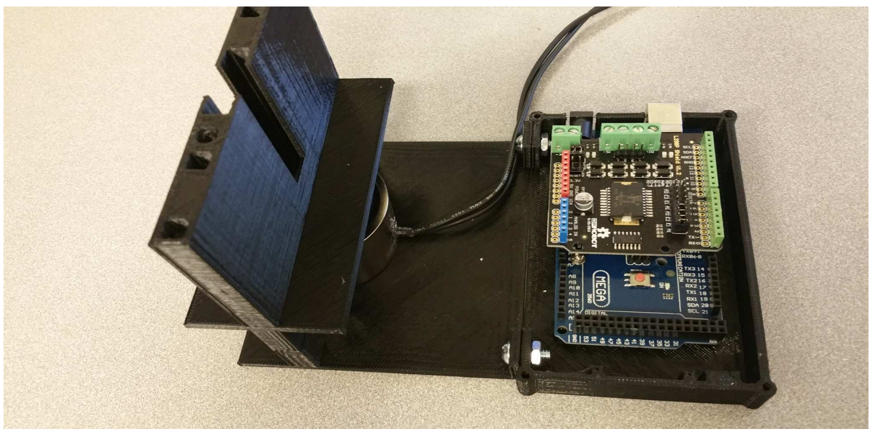
9. Place the electromagnet on the center of the extension piece.



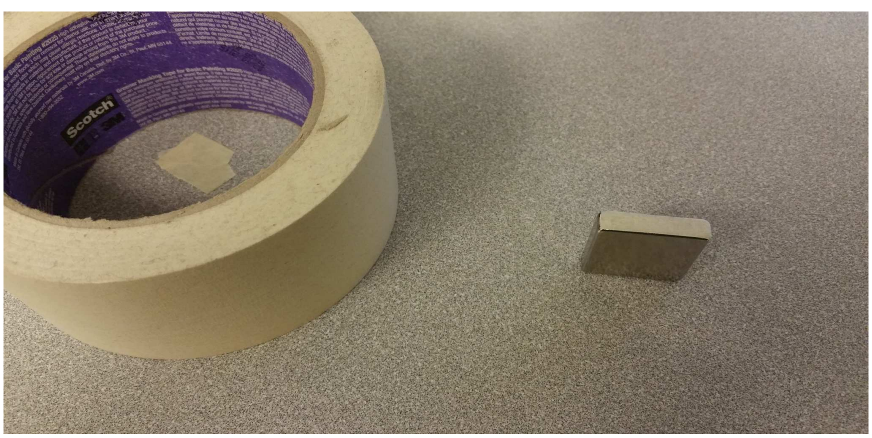
10. Place the protection cover on top of the electromagnet.



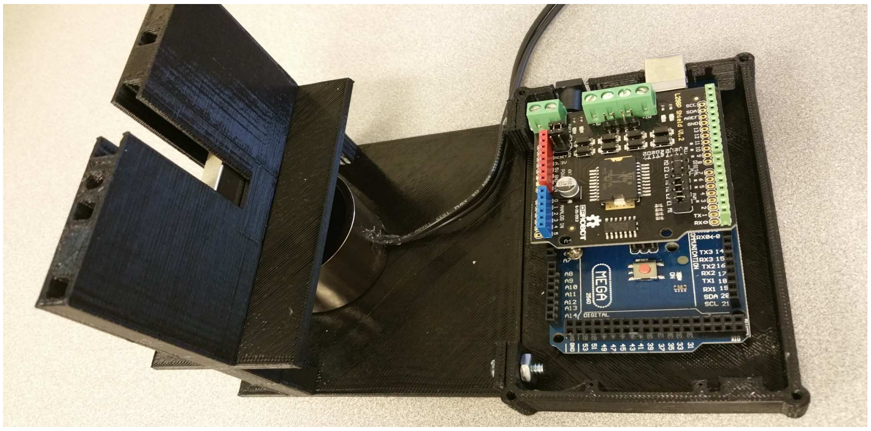
11. Place the tower on top of the protection cover.



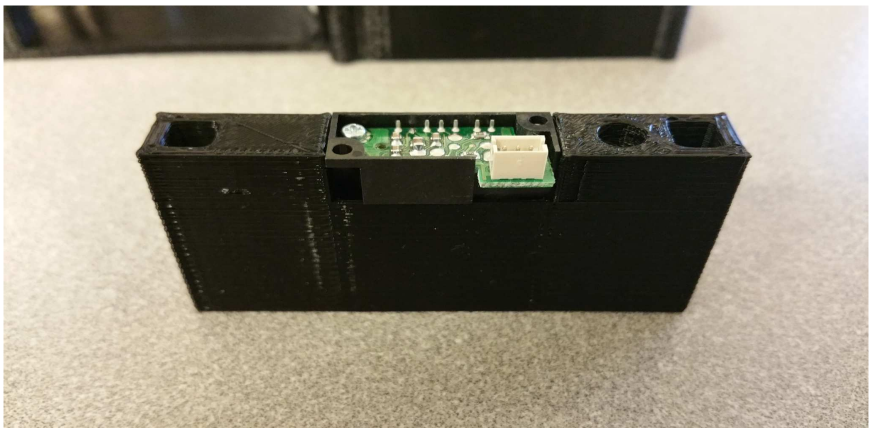
12. Prepare the magnet to find the south and north pole and cover the side by the tape.



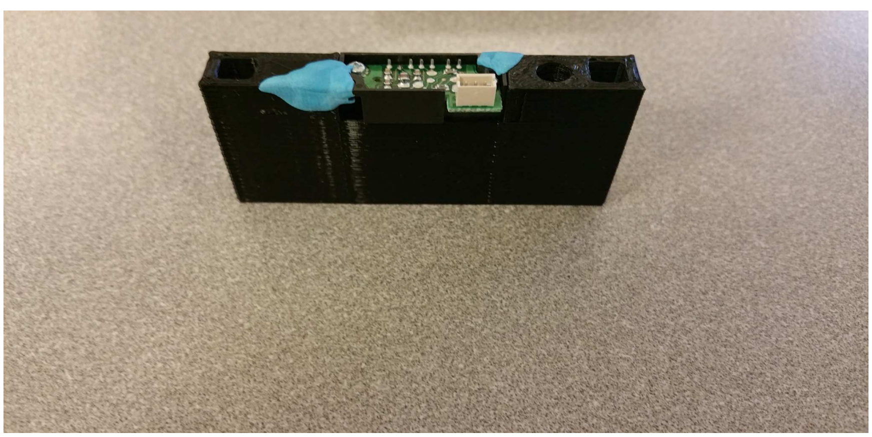
13. Put the magnet inside the tower and let the tapped side will face up.



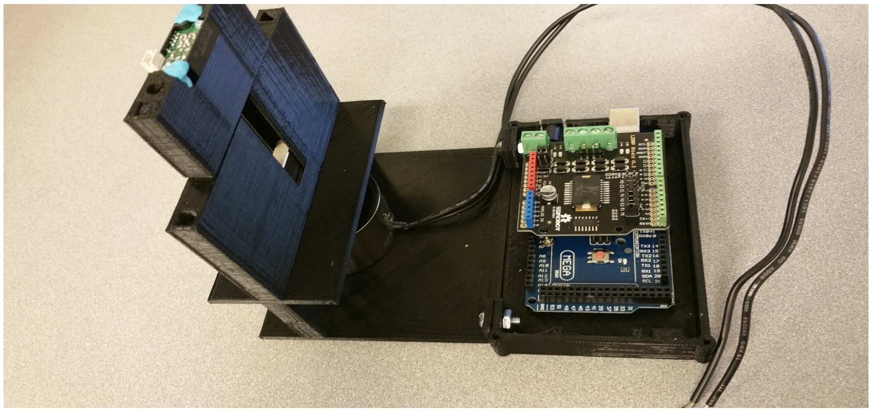
14. Put the sharp IR sensor in the the tower extension.



15. Use some sticky tack to fix the sensor to the tower extension.

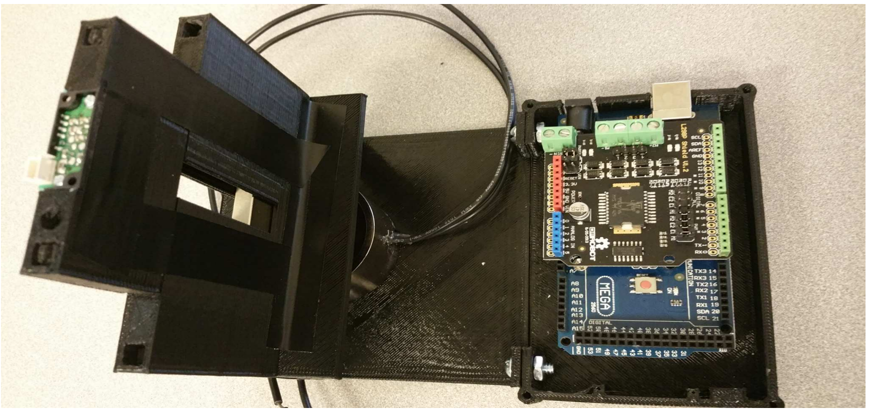


16. Add the tower extension with sharp sensor on top of the tower.

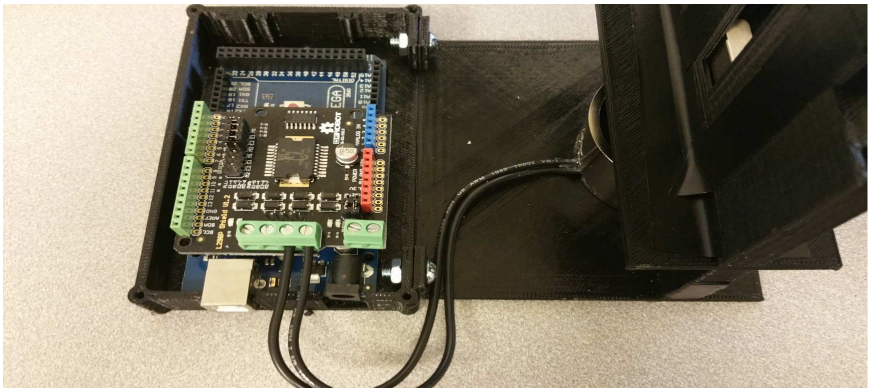


17. Put the rods in to the designed place to be sure everything is firm and use black tape to secure the joints.

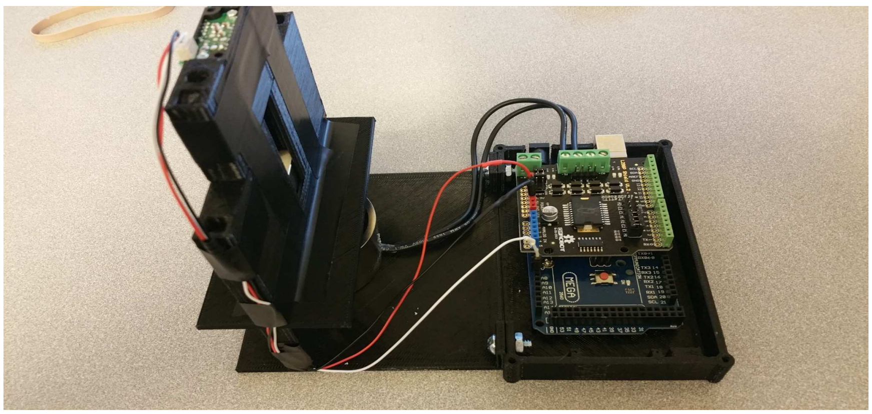
18. Secure the protection cover,tower and tower extension by black tape.



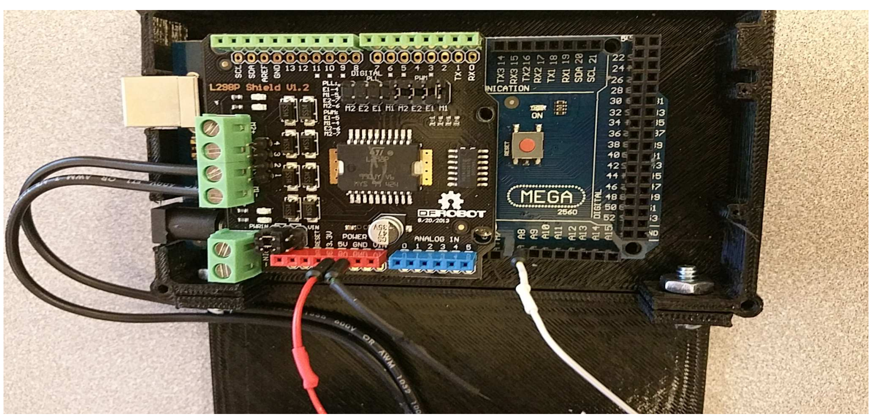
19. Connect the electromagnet to wires to motorshield M+ and M- terminal.



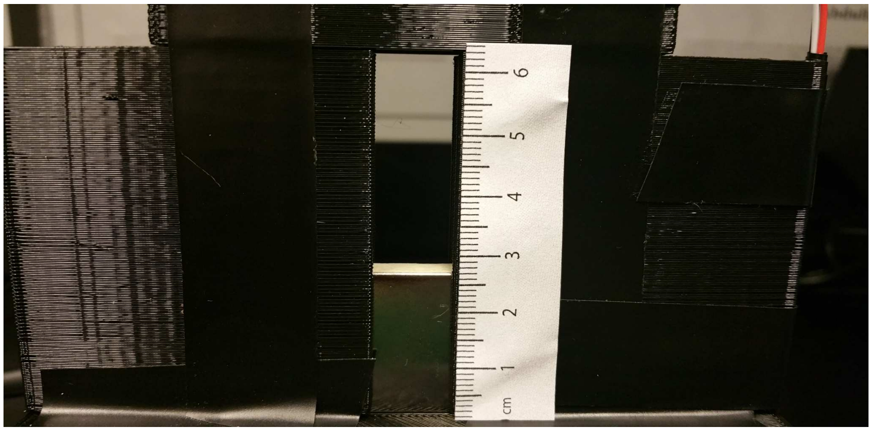
20. Use Female Crimp pins to extend the sharp cables and have 3 wires out (Ground=Black, Vcc=Red and Analog Sigbnal=White).



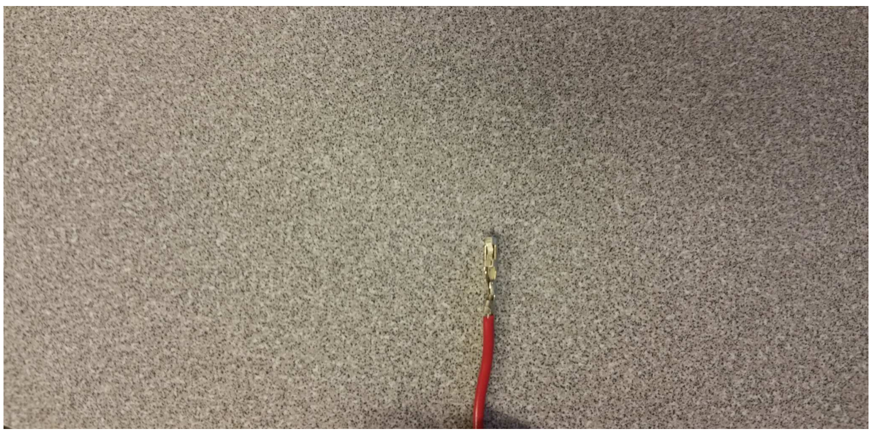
21. Connect ground(balck Wire), Vcc(Red Wire) and Signal(White Wire) to Ground, Vcc of Motor Shield and Pin A8 of Arduino Respectively.



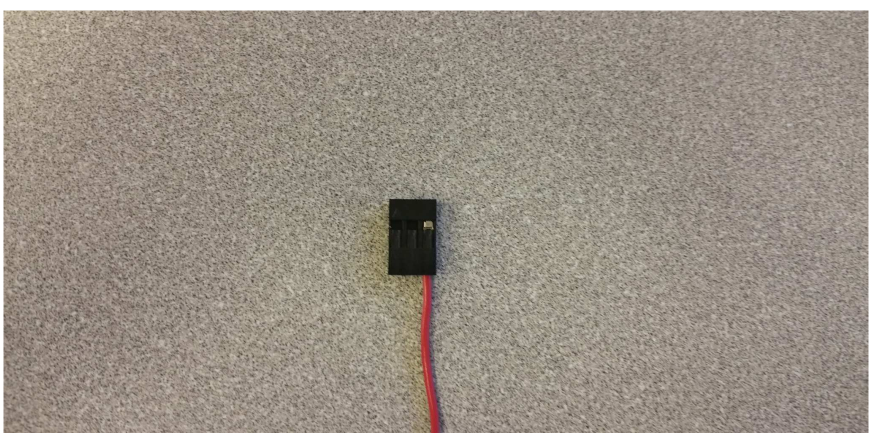
22. Add the ruler paper on the side of the slot of magnet.



23. Extending Sharp sensor cable.



24. Clamp it to housing.



2.4 Software Setup

The necessary software files that are needed for this experiment can be downloaded from the Take Home Labs webpage. One method for downloading the files is shown in the steps below.

25. Open your internet browser and navigate to `thl.okstate.edu`
26. On the left side of the Homepage, select "Courses"
27. In the middle section of the Courses page select "Neural Network"
28. In the middle section of the Neural Network page find couple experiments.
29. You can select any experiment and find the "Software/Code" in the rightmost section. A zipfile named *by nam eof experiment* should download.
30. Right-click the file and choose "Extract All...", or any other method of extracting files on your PC.
31. Extract this folder somewhere convenient, and remember the location. This will be the folder where all of the files and plots created for this experiment are saved.

3 Experimental Procedures

The exercises in this section will demonstrate how to simulate the magnetic leviation dynamic system and compare the simulation results with the experimental system. First the open-loop response will be investigated and the results will be analysed. In the open-loop response the skyline function is used real time to generate pulses with random width and height. The sensor reading can be filtered or smoothen in the open-loop repose experiment. In this part of experiment we will try to fine tune the model in order to get the simulation model follow the experimental results.
Second the close loop response will be discussed. Since in the open loop response model is created in the pervious experiment the classical controller can be designed and tested on both simulation and experiments. The results will be investigated.
Finally, the we will use the open loop response reading to collect data for our NARX model. We will train the NARX model then we will design a MRC for the magnetic levitation system. The result of classical control and neural network controller can be compared for the efficiency.

3.1 Exercise 1: Open-Loop Response

In this exercise we will work on to build the Simulink model of magnetic levitation based the system equation of motion. Then we fine tune the theoretical model to match up. This step will help us in the other experiments to design our closed loop system.

β	α	g	M	$i(t)$	$SamplingInterval$
12	15	$9.8(\frac{m}{s^2})$	$3(Kg)$	-1 to $4(A)$	0.010

Table 3.1: Simulation Parameters for the Magnetic Levitation

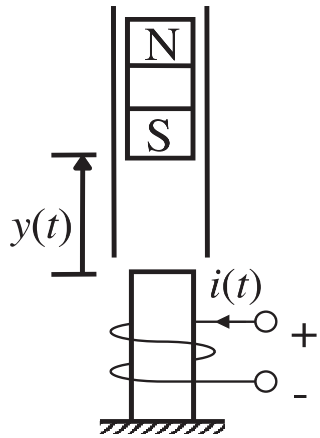


Figure 3.1: Magnetic levitation system

3.1.1 Simulation: Open-Loop Response

In our simulated magnetic levitation system system, we will suspend a magnet above an electromagnet. A magnetic levitation train works in a similar manner. The purpose and goal of this magnetic levitation system is to control the position of a magnet above an electromagnet.

Figure 3.1 shows the magnetic levitation system, which consists of a magnet suspended above an electromagnet, where the magnet is constrained so that it can only move in the vertical direction. The equation of motion of the magnet is

$$\frac{d^2y(t)}{dt^2} = -g + \frac{\alpha}{M} \times \frac{i^2(t)sgn[i(t)]}{y(t)} - \frac{\beta}{M} \times \frac{dy(t)}{dt} \tag{3.1}$$

where $y(t)$ is the distance of the magnet above the electromagnet, $i(t)$ is the current in the electromagnet, M is the mass of the magnet, g is the gravitational constant, β is a viscous friction coefficient and α is a field strength constant. Table 3.1 shows the simulation parameters.

You need to open a Simulink file and draw model the equation 3.1 in the Simulink. The input is current and the output is distance of magnet.

3.1.2 Experimental: Open-Loop Response

32. Check step 28 29 and 30 and download the open loop software code and extract it.

33. Now you should be able to see the following blocks in your Simulink file.

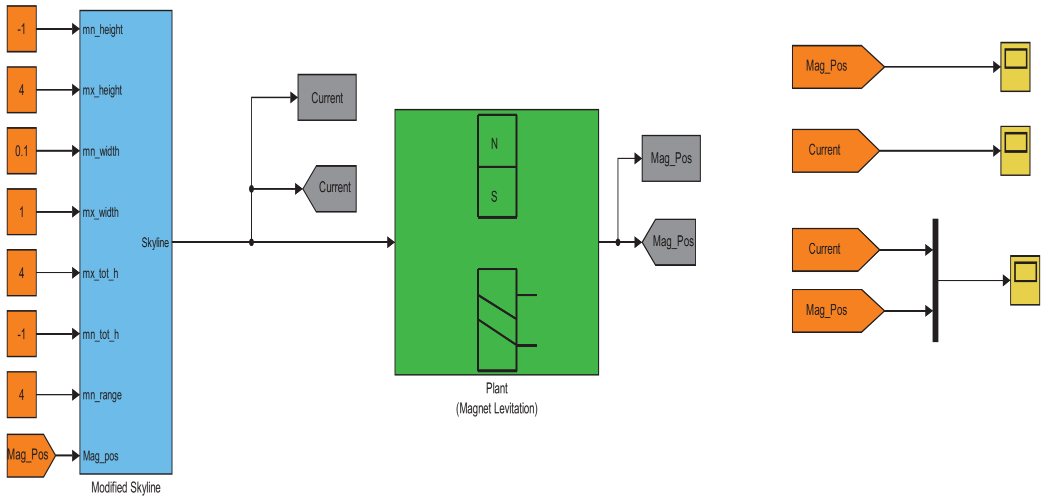


Figure 3.2: Experimental Open Loop Simulink File

Now, by connecting Arduino to the Experimental setup (Be sure you have correct port number), you should be able to collect data in Normal mode by clicking on Plot Data 'single'. Please if you are not able to get the data check the sampling experiment and be sure you completed that experiment beforehand.

34. Fine tune the Simulation model with the experimental model to match up your results. You can change the height and width of skyline function in both cases and make in reasonable for real application. Find the differences and explain your findings.

3.1.3 Experimental: Sensor Flittering

35. Collect the data of Magnet portion in real time. Plot the reading and see if there is any spikes in the results.

36. If there is any spikes in the results, find a discrete filter block in the Simulink reposited and then add it into your open-loop system.

37. Compare the filter and unfiltered results. Explain your findings.

3.2 Exercise 2: Closed-Loop Response

In this exercise we will work on to build the controller in Simulink for magnetic levitation system. The simulated results and experimental results will be compared.

3.2.1 Simulation: Closed-Loop Response

38. Check the root locus experiment and design of a P and PID controller.

39. Design a PID controller based on the model that we built the Exercise 1.

3.2.2 Experimental: Closed-Loop Response

40. Check step 28 29 and 30 and download the closed loop software code and extract it.

41. Now you should be able to see the following blocks in your Simulink file.

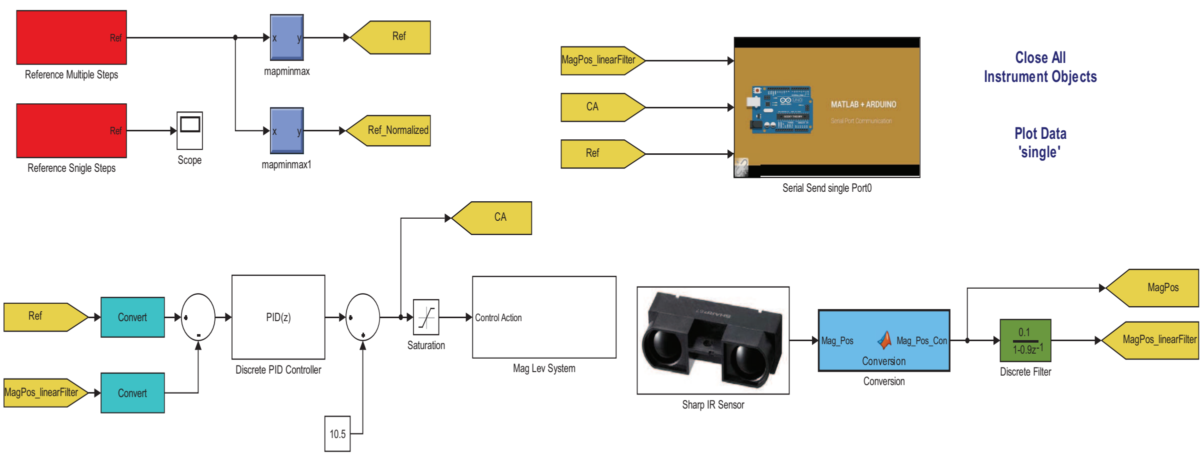


Figure 3.3: Experimental Closed Loop Simulink File

Now, by connecting Arduino to the Experimental setup (Be sure you have correct port number), you should be able to collect data in Normal mode by clicking on Plot Data 'single'. Please if you are not able to get the data check the sampling experiment and be sure you completed that experiment beforehand.

42. Check the gains that you find in the Simulation and verify it with experimental results. Explain your findings.

3.3 Exercise 3: Neural Network Model

In this exercise we will work on to build a neural network model of magnetic levitation system.

3.3.1 Simulation: NARX Model and MRC

43. Follow chapter 7 of "Enhanced Recurrent Network Training".

44. Redo all those works which explained the modeling in details and compare your results.

3.3.2 Experimental: NARX Model and MRC

45. Follow chapter 8 of "Enhanced Recurrent Network Training"

46. Redo all those works which explained the modeling in details and compare your results.

4 Conclusion

The simulated and experimental open loop and closed system repose are investigated in this experiment. The simulation experimental differences are discussed. The advance controller and modeling (Neural Network) is investigated in this experiment.