Victor Garcia Flores
Jessica Jiang

# Lab 4 Report

## 1. Introduction

This lab introduced the use of three phase active bridges on a three phase squirrel-cage induction machine to create a variable frequency drive (VFD). This lab builds on the knowledge and schematics obtained from the previous labs. To start off, there will be a mini lab exercise to familiarize with the functionality of sine and half-bridge functions before building the VFD. Aside from introducing everyone to three phase motor implementation, it also demonstrated the effect frequency has on rotation speed. As earlier mentioned, blocks have been used from previous labs because only the inputs to the H bridge have changed. Here, the PWM signal is set by a three phase signal, each offset by 120 degrees, at an adjustable frequency in dSPACE.

## 2. Design Procedure

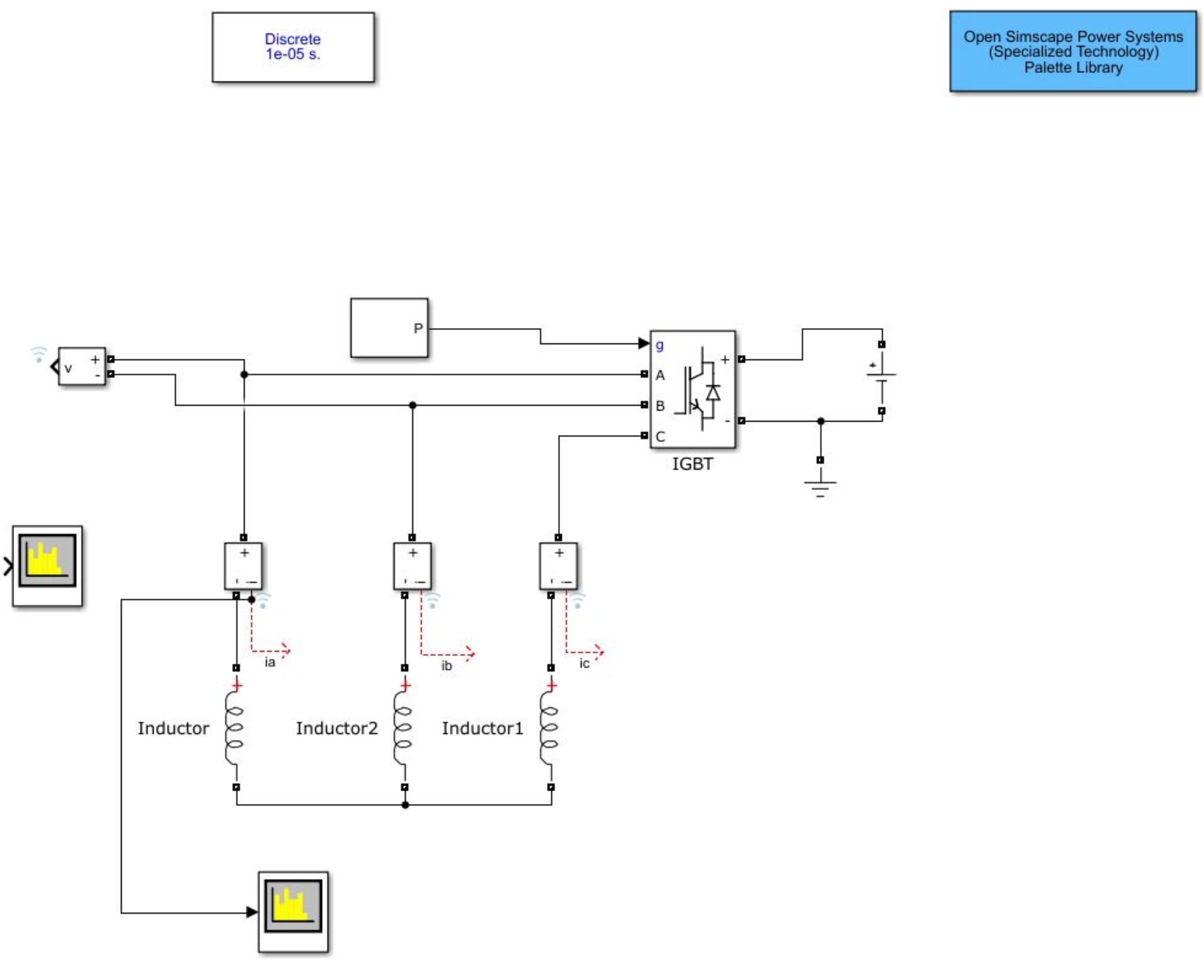
### 2.1 Mini Exercise

The mini exercise will be primarily done in Simulink to show how half-bridge wave rectifiers work. To start, open a simspace power space template in simulink and insert a sine wave block with a frequency of 1Hz (6.28 RPS). Then insert a two level PWM generator block. Double click the block and under "Set Carrier", set the frequency to 10 Hz and the initial phase to 0. Then move on to the "Set Reference Signal" block and check the box "Internal generation of reference signal" and set the frequency to 1 Hz. Save and go to *Gear > Configuration > Solver > Fixed-Step > ODE1(Euler)* and set the fix step to 1x10^-5. Run the design for 1 second to see the sine wave pulse once. This shows how the sine wave function and the PWM generator block works.

Delete the schematic and start over to see a demonstration on how the IGBT (half bridge) block works. Double click on the block block to find the IGBT block. Insert another 2-level PWM generator and follow the steps listed above. Change the generator reference to 50 Hz and PWM to 100 Hz. Insert a DC voltage source and set the amplitude to 42 volts, then connect the DC voltage source to the outputs of the IGBT.

To measure the values, insert a current measurement and inductor for each output A, B, and C and then connect them together. Be sure to set the inductors to 1mH. To see the signals graphically, right click on the current measurement and click log signal. Don't forget to name the log signals. Insert a voltmeter and connect the volt source to ground. Connect the output of the voltmeter to the spectrum analyzer so that the results can be seen graphically. Set the powerGUI to discreet and the sample time to 1*10^-5. To set up the spectrum, double click on it and go to settings. Under "Trace Options", uncheck two-sided spectrum and under "Main Options" Change the type to RMS, uncheck "Full Frequency Span" and change Span(Hz) to FStart(Hz) and set the range from 0.01 to 10000 Hz. When looking at the plot, there should be a large spike in voltage and then harmonics every 1k. Now change the PWM generator to 5000 and change the spectrum range to 0.01 to 50000. Once the run-time has been changed to 25 seconds, there should be the same power spike near 0 and with harmonics every 5k instead of 1k.

The image below depicts the schematic assembled this mini-exercise.

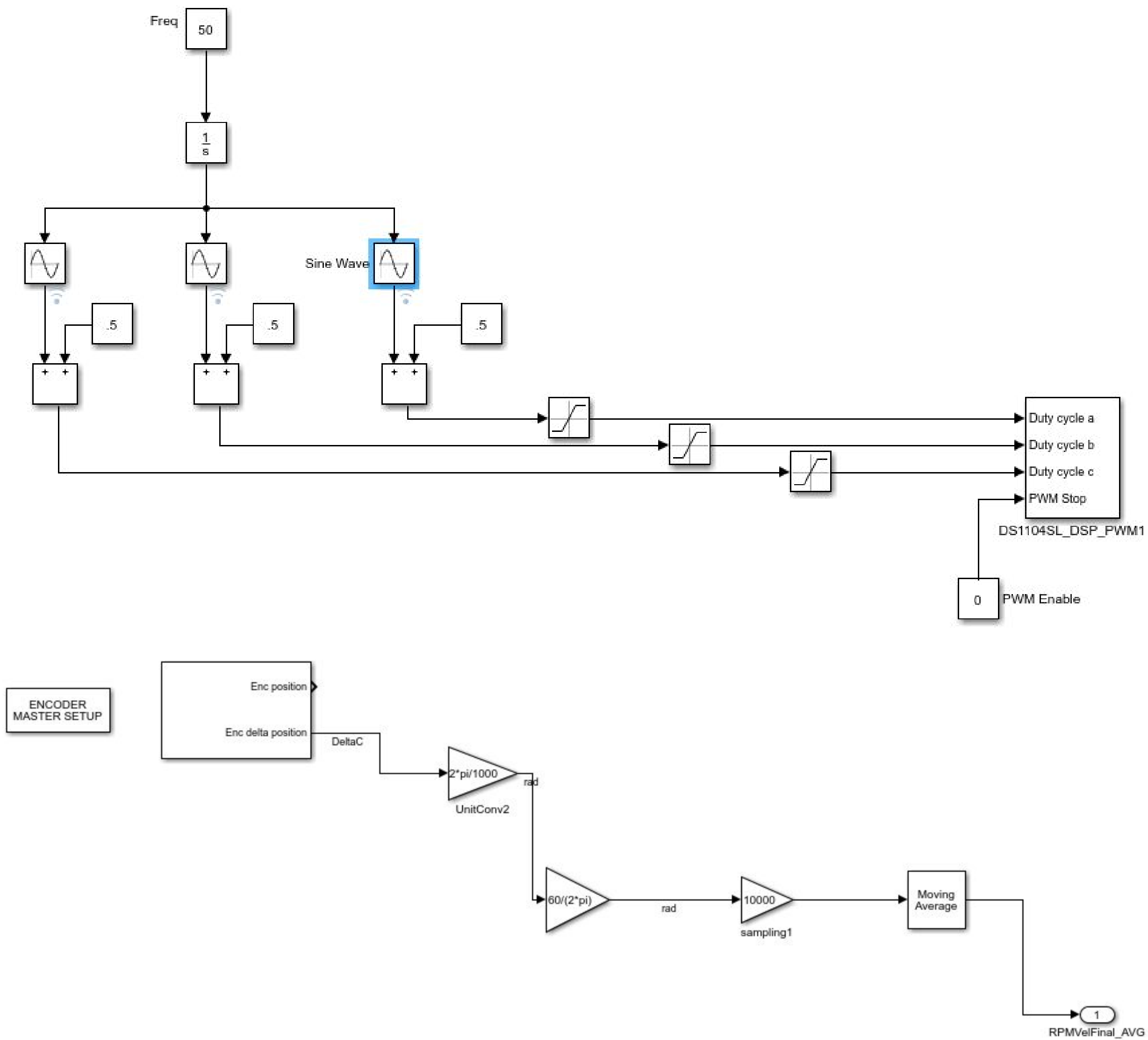



The image above allows one to simulate that behavior of three phase pulse-width modulation in a motor. To be more specific, it depicts how a PWM waveform can be obtained from a sinusoidal waveform.

## 2.2 Lab Procedure

### 2.2.1 Simulink

Copy the schematic from lab 3 into a new folder and remove the old PWM block and insert a new duty cycle block (the same one used in lab 2). Insert three sine wave blocks with the frequency set at 50 Hz (314.16 RPS) and the phase varying from 0, -2,0944,  2,0944. The sine wave blocks will need to be modified to pass an external time signal so that an external frequency input can be received from the dSPACE slider. To ensure that the entire sine wave will be above 0, a constant block of 0.5 will be added to each of the sine waves. Each sine wave will also have their saturation limited from 0 to 1 with saturation blocks to ensure that the motor will not receive inputs beyond 0 to 1 to keep the motor from stalling.




### 2.2.3 dSPACE

Drag and drop a plot, label, display, and slider onto the empty workspace. Label the label under the graph so that it is clear what the graph represents. Link the RPMVelFinal_AVG to the graph and the display and Freq to the slider so the results from the speed of the motor can be checked while it is in motion. The slider should be able to control the speed of the motor through the simulink schematic.

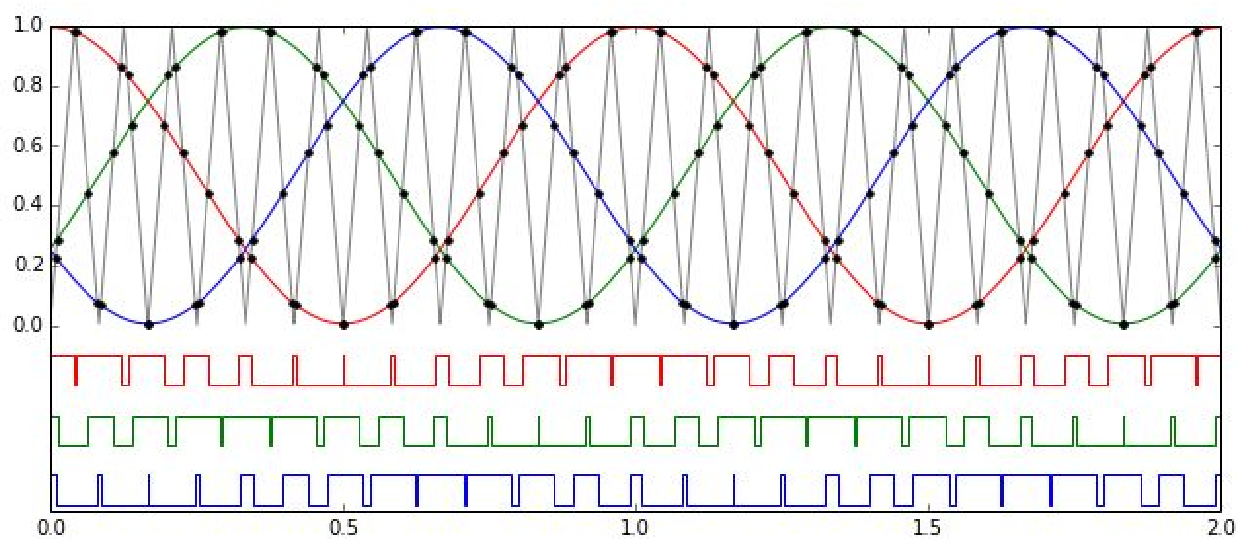
## 2.3 Errors Encountered:

- Very high RPM: Check the sampling time and make sure that it is within range.
- Motor not spinning: This problem occurred when setting the sinusoidal phases going into the PWM module used for the H-bridge. This mistake was easily caught when looking at the properties of each sine wave block. When doing this we noticed that the offset for two waveforms were the same. Due to this, the motor was unable to spin.

# 3. Analysis

### 3.1 Understanding 3-Phase PWM

To understand this lab, it is important to understand how 3-phase signals play roles in PWM. To gain a better understanding of this please refer to the image below.




As one may note above, each colored sinusoidal signal has a corresponding PWM signal. Note that the high/low value and frequency of the PWM signal is set by the input sinusoidal frequency. For example, the closest to the peak leads to longer and positive values in the PWM signal. This is important to understand because this frequency is what's fed into the H-bridge and causes the motor spin. An incorrect offset can cause a wrong PWM, which would lead to odd motor behavior.

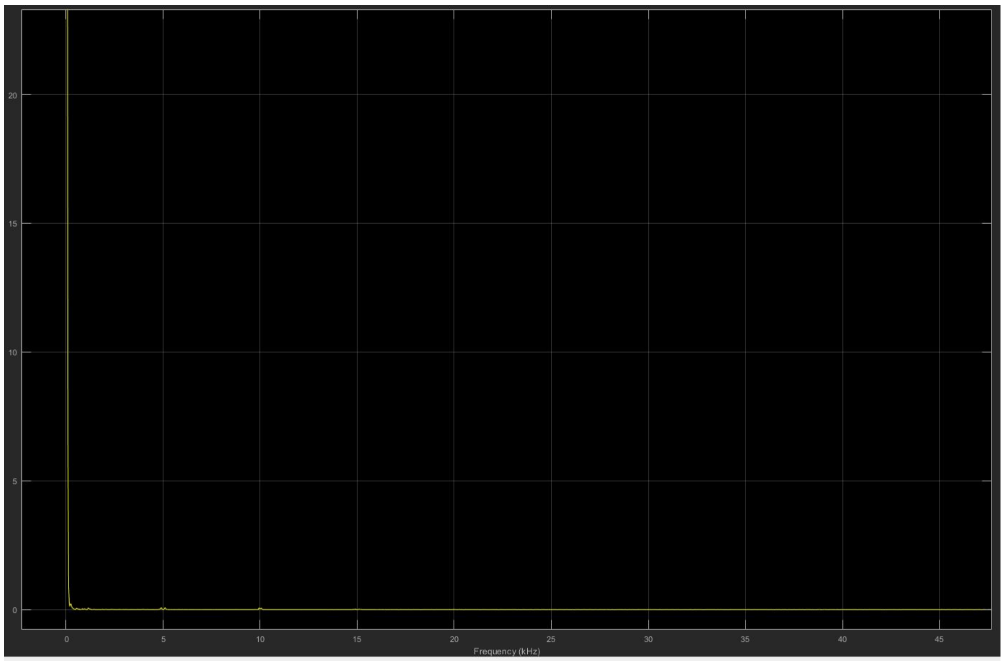
### 3.2 Making Motor Rotate

A rotor will spin the direction dictated by the frequency. To make speed and direction adjustable, dSPACE was used to change the frequency. To do this, implementation from the previous lab was used so that positive and negative rotations is centered around 55 Hz.

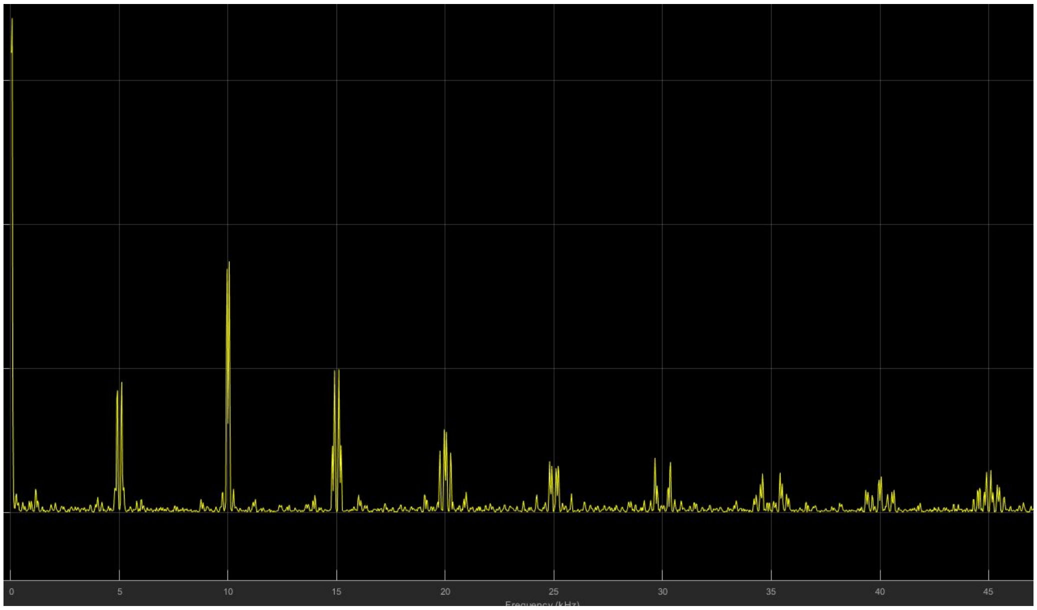
# 4. Simulation Results

## 4.1 Mini-Exercise Results

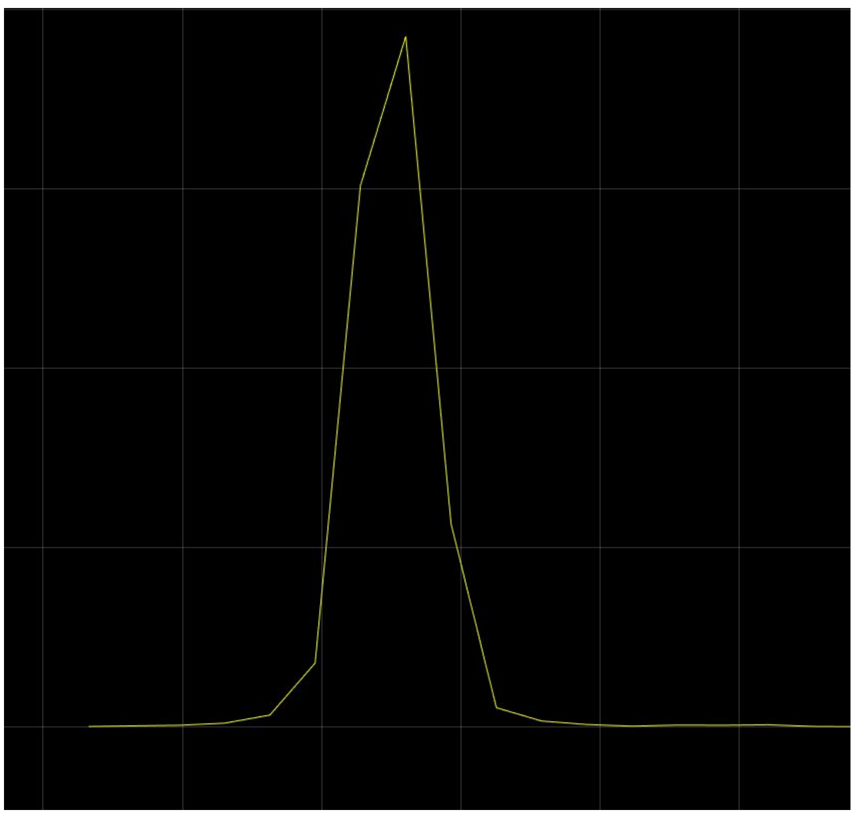
### 4.1.1 5 kHz Spacing w/ 50 Hz Harmonic Current




### 4.1.2 5 kHz Spacing w/ 50 Hz Harmonic Voltage

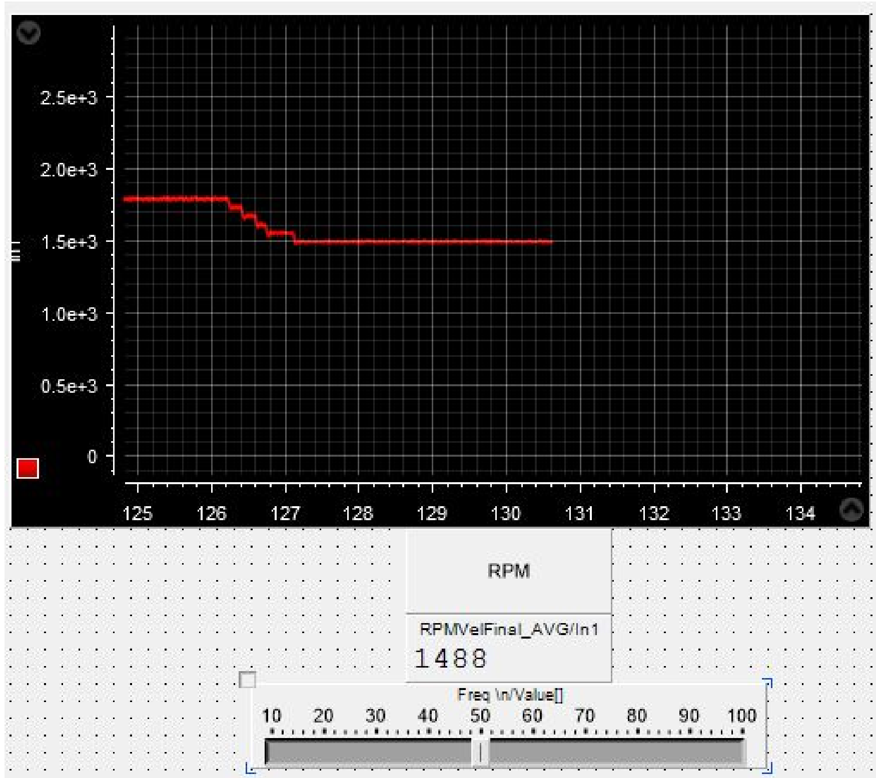



### 4.1.3 10 kHz Spacing w/ 50 Hz Harmonic Voltage

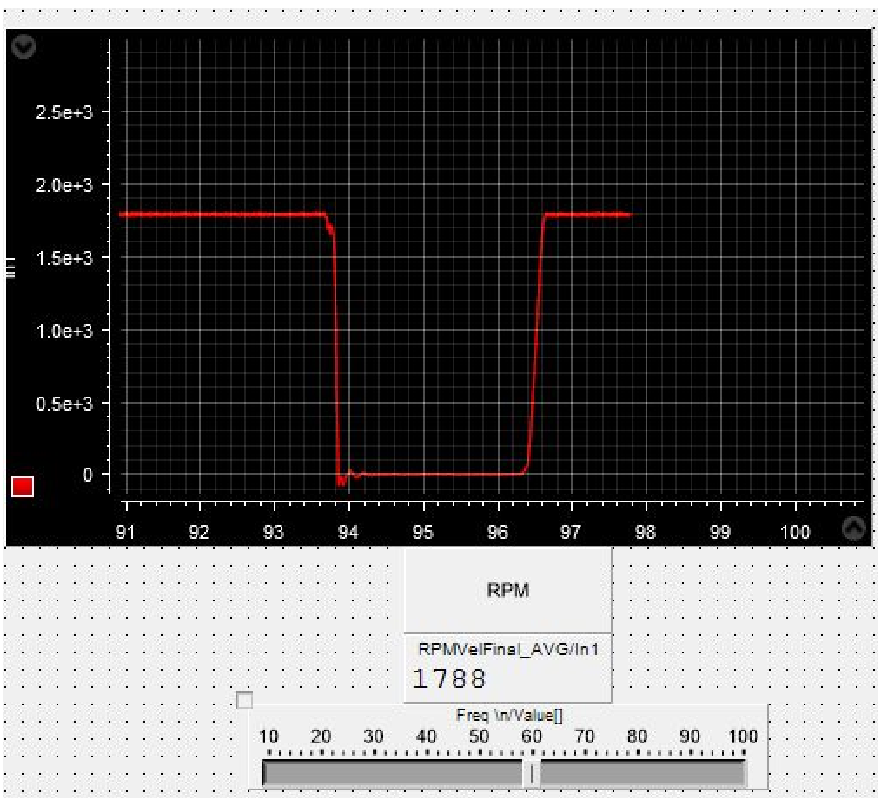


## 4.2 Main Lab Simulations

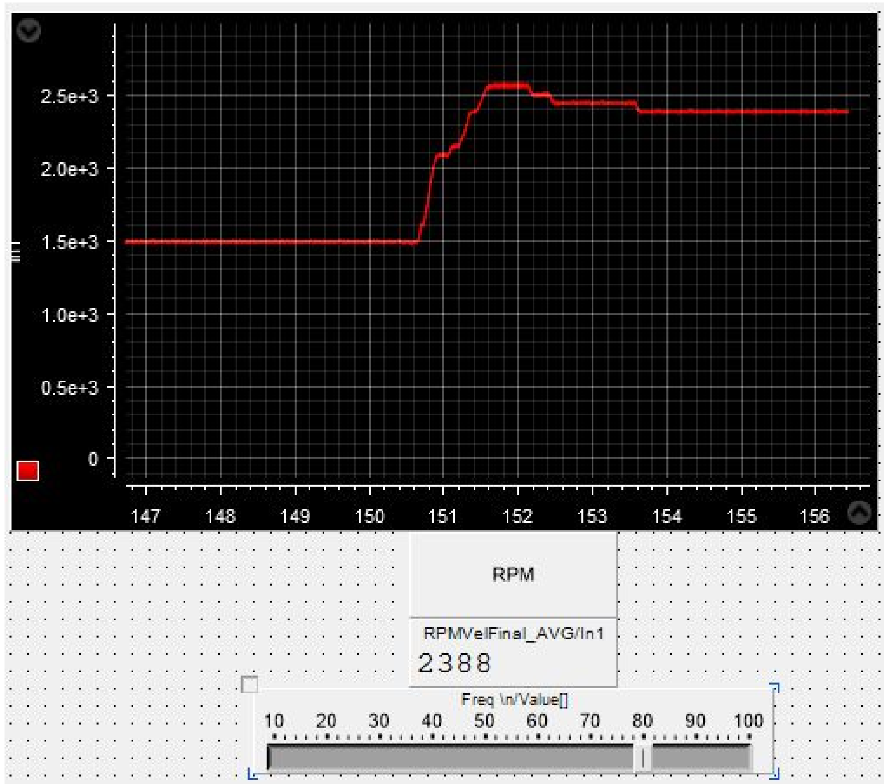
### 4.2.1 Motor Response at 50 Hz




### 4.2.2 Motor Response at 60 Hz



### 4.2.2 Motor Response at 80 Hz




## 5.Conclusion

This lab gave a basic overview of how to manipulate simulink blocks to fit our needs as well as how the sine, half-bridge, amp/voltmeters and scope works in simulink. It also taught how to create a basic VFD to control the motor. In the next lab, the VFD should be a closed loop system that is able to correct itself should the speed of the motor be disrupted. By intuition, one could assume that this autocorrection will involve adjusting frequency by comparing rotor frequency and desired frequency. Since this will be similar to that of Lab 3, implementation of the MatLab block will be necessary.