Erick Pineda
MAE 170
10/23/2023

LAB 3

Q1: Is the variable voltage applied to channel A0 an analog or digital signal?

The applied voltage to channel A0 is an analog signal because we are performing an analog to conversion code on the Ardunio Uno for interpretation.

Q2: What are the minimum and maximum values in the serial stream (first column, in "counts", where counts are the Arduino input channel A/D measurement intervals)? What voltages do these minimum/maximum counts correspond to on your DMM?

MIN: 0931 counts first column DMM: 4.5912V

MAX: 1023 counts first column DMM: 5.0491V

Q3: Given the information in Q2, approximately what is the resolution of your Arduino input channel A0 A/D converter (in volts)?

Resolution: 5.466E-3 V/count

$$\Delta x = \frac{|Xmaz - Xmin|}{2^n} \simeq \frac{|\Delta V|}{Arduino\ counts} = \frac{5.0491V - 4.5912V}{1023-931} = 0.004978\ \frac{Volts}{count}$$

Q4: What does the denominator in Eq. (1) represent?

The Arduino analog input channels on default settings have a range of 0 to 5 V, which corresponds to counts, or of 0 to 1023.

The denominator in Equation (1) represents the counts for the Arduino output which is dependent on the range of voltage Arduino. The value of counts is exponentially dependent on the number of bits, thus the denominator is 2^n counts. Therefore 1 bit corresponds to 2 counts, 4 bits corresponds to 16 counts, 8 bits corresponds to 256 counts.

Q5: What is the number of bits of the Arduino analog input channel A0 A/D converter?

For 0V - 5V, there are 1023 counts. Solving for n bits, we determine the number of bits of the Arduino input channel is 10 bits.

$\Delta x = \frac{|Xmaz - Xmin|}{2^n} \Rightarrow 2^n = 1023$ counts $\Rightarrow n = \log_2(1023) = 10$ bits

Q6: What is the resolution (in volts) of the Arduino analog input channel A0 A/D converter, based on Eq. (1)? How does this compare to what you found in Q4? Discuss any differences and speculate as to potential causes

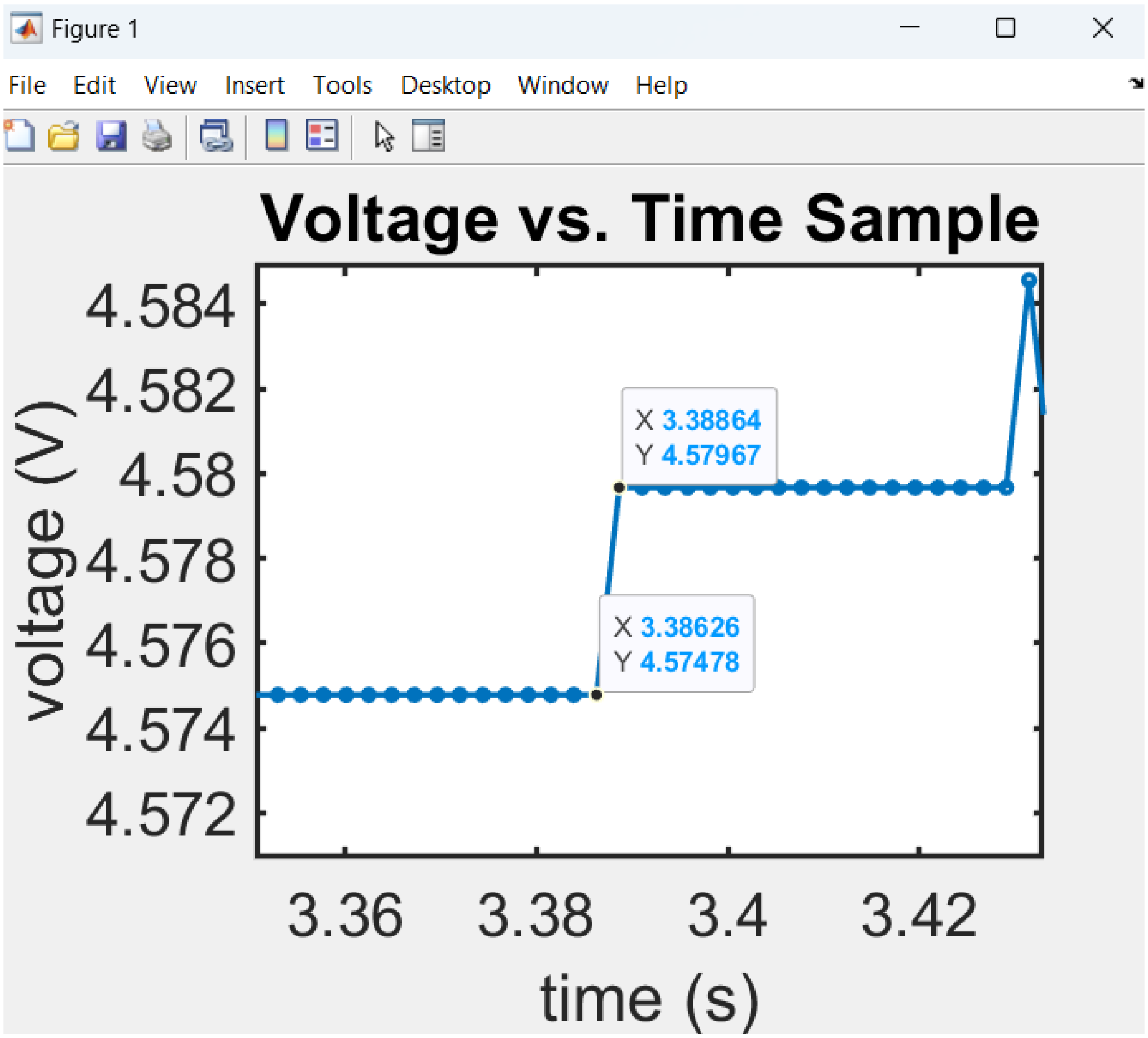
$$\Delta x = \frac{|Xmaz - Xmin|}{2^n} = \frac{5V}{1023} = 0.004888 \text{ Volts}$$

Estimated Resolution Q3 Δx = 5.466E-3 V/count

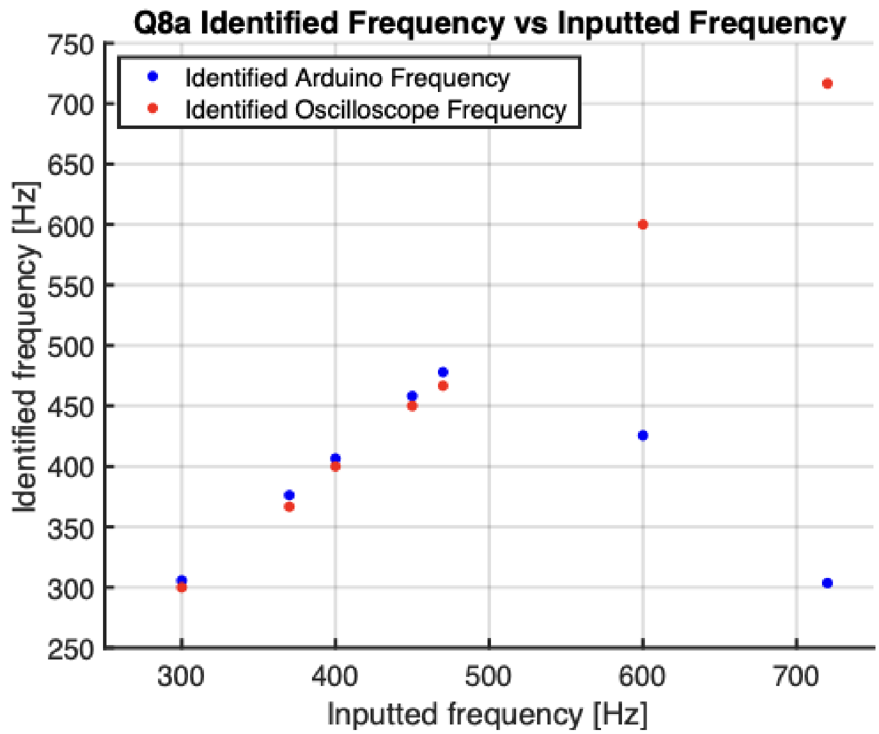
$$\%\text{Error} = \frac{|0.004888 - 0.004978|}{0.004888} * 100\% = 1.824\%$$

The existing percent error of 1.82% demonstrates that there was little discrepancy between the results of Q3 and Q6. Potential errors could exist from the rounding errors from the DMM, thereby leading to different values due to ‘chopping off’ significant figures in measurement Voltage maximum and Voltage minimum. This is demonstrated in the different counts of the Arduino in Q3 and Q6. Another area of potential error is demonstrated in different resistance measured with DMM. As we first tested the resistor, the DMM measured a resistance slightly different from the labeled on the resistor (by about 1kΩ). This slight error may be responsible for our small percent error.

Q7: Resave the figure file that you generated (zooming in until you can show the discrete steps induced by finite, digital resolution) as a .jpg image, and upload it with your lab assignment submission, as an answer to this question.



PART II


Q8a Identified Frequency vs Inputted Frequency
Identified Arduino Frequency
Identified Oscilloscope Frequency
Identified frequency [Hz]
750
700
650
600
550
500
450
400
350
300
250
300
400
500
600
700
Inputted frequency [Hz]

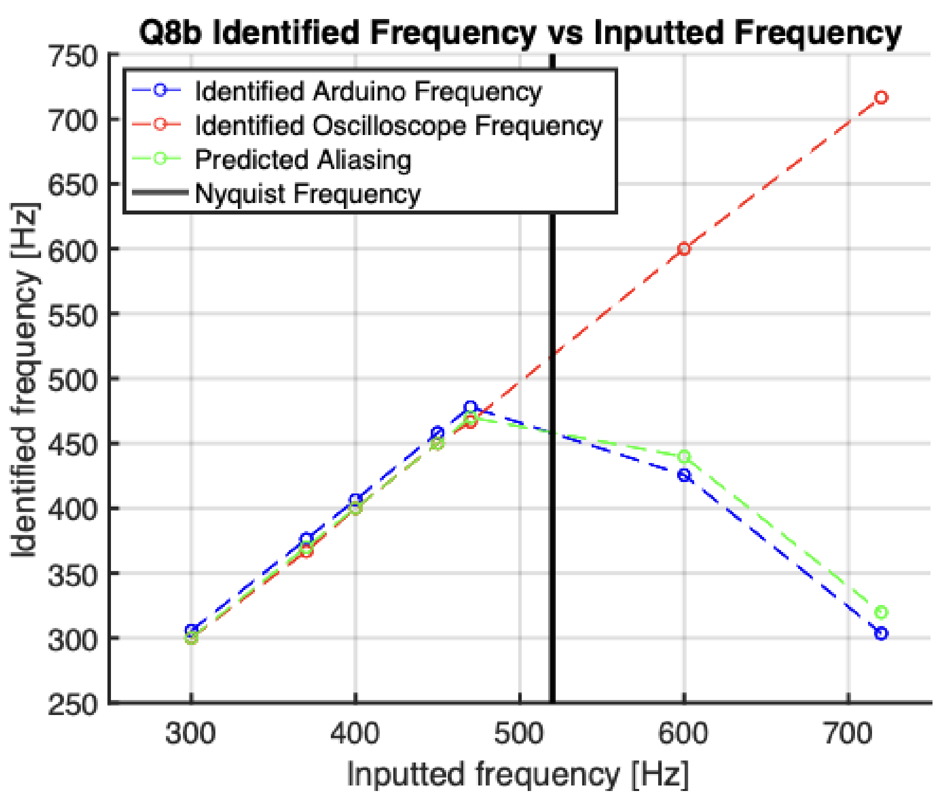

Q8b Identified Frequency vs Inputted Frequency
Identified Arduino Frequency
Identified Oscilloscope Frequency
Predicted Aliasing
Nyquist Frequency
Identified frequency [Hz]
750
700
650
600
550
500
450
400
350
300
250
300
400
500
600
700
Inputted frequency [Hz]

Figure 1 (a) Identified Frequancies from sampling via Arduino (blue dots) and Oscilloscope (red dots) from given inputted **(b)** Now compared with predicted values from f_{alias} (Apprendix) and approximate Nyquist frequency.

Q9: What happens to the measured or aliased frequency when the input frequency crosses the dashed line corresponding to that group of datasets? Describe your answer in 1 to 3 sentences.

As the input frequency approaches about a critical frequency 520 Hz it begins to diverge suddenly from its previous linear relationship with input relationship. Therefore, any data measured after this critical frequency is now an artifact measurement. This critical frequency is known as the Nyquist frequency for Arduino Uno and any sampled data or signal is too high to be sampled because of the existing aliasing.

Q10: One way to detect if an observed signal or frequency component is aliased, is to change the sampling frequency and repeat the measurement. What would happen to the measured frequency, if you do this, and the sample is (or is not) aliased?

By changing the sampling frequency and repating the measurement, the measurement changes well. If we increase the sampling frequency, the non-aliasing frequency may or may not change much since the sampling frequency was already high enough to evaluate the inputted frequency. However, if the inputted frequency was already aliasing then by increasing the sampling frequency, the aliasing frequency may most likely increase and may become a non-aliased if the sampling frequency has increased enough so that the inputted frequency will fall within the nyquist frequency range.

Q11: (BONUS): When analyzing the data there is a large peak around 0 Hz, what is the reason for this?

The reason for the large peak 0Hz is corresponding to the amplitudes of the fourier tfransform. When $f = 0$, then $w = 2\pi f(i) = 0$, thus the fourier transform becomes the average of the DC voltage. Thus a DC signal, a signal with 0 oscillation, results in a four transform of 0, a sine wave with zero frequency.

Part III

Q12: This question pertains to WLO1: Be able to make observations and provide supported interpretations useful to others in the scientific and engineering community. Fig. 3 shows the data similar to what you will collect in Part II of this lab. Describe what was done to acquire this data and what can be observed in this figure, making sure to keep in mind the (WLO1) dimensions discussed in class (and listed previously at the end of lab 1). Note: Here you are essentially writing a portion of the "Results" section of a lab report or scientific manuscript (it is not intended to include the "Discussion" section components).

In the first graph of figure 3, the input frequency is significantly less than the Nyquist frequency (about 450 Hz). We observe 2 sets of peaks, Arduino and Oscilloscope both measure a peak at 0 Hz and again share a peak at about 200Hz. The frequency that occurs at 200 Hz is our input signal frequency for the top graph's dataset. The 0Hz peak exists due the mean value of sine signal derived for Fourier transform derived when w = 0. The Oscilloscope and Arduino both demonstrate similar results on in the first graph |FT| vs frequency diagram. Since the input frequency is less than the nyquist frequency then the signal not aliased thus the signal is correct for this dataset.

Now for the second graph of figure 3, the input frequency is greater than the Nyquist frequency of the Ardunio. Two peaks at 0Hz, another at 300 Hz, and one more at 600 Hz. Similar to the first, there exists a double peak at 0Hz because of the mean value of the signal. We observed that 0Hz may be standard for both aliasing and non-aliasing signals. Both Aliasing and non-Aliasing signals have a significant dip at 350Hz identified by the Arduino. It can be determined that the identified frequencies in graph 2 are different because 600Hz is above the Nyquist frequency of the Arduino resulting in aliasing. However, 600Hz is not aliasing with the Oscilloscope since it is well below its Nyquist frequency.

Q13: This question pertains to WLO2: Be able to present data visually in an accessible and information dense manner. In Q9, you created a figure. Write a caption for this figure, and ensure both the figure and the caption satisfy the dimensions of WLO2 provided below.

Figure 1 (a) Identified Frequancies from sampling via Arduino (blue dots) and Oscilloscope (red dots) from given inputted **(b)** Now compared with predicted values from f_{alias} (Apprendix) and approximate Nyquist frequency.