Instrument Calibration – Lab 2:

Date Performed: 02/22/2023

Lab Instructor's name: Mark Vanpoppelen

Honor Statement:

An essential feature of the University of Tennessee, Knoxville, is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.

I understand that inappropriate assistance includes:

- Using past lab data
- Using lab data from another section (unless approved by your instructor)
- Using the text from past lab reports
- Using text from another student's lab report

Name: (Printed)
Will Buziak

Signature:

Lab Report #2 – Signal Analysis

Will Buziak

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ABSTRACT

The Signals Analysis Lab sought to familiarize students with measuring different frequencies. The layout of the experiments lead students to read different waveforms, frequencies and amplitudes with an Oscilloscope to get a visual representation of oscillatory motion. The intent is for students to have a more integrated understanding of how signals are used in the modern day to run many of the tools around us everyday as engineers and how they transmit and receive signals.

I. Introduction

The first experiment primarily demonstrated different waveforms, frequencies and amplitudes to the students using the oscilloscope and and Signal Generator. While the second experiment sought to show students how signals are used in everyday life. After the first experiment, the students should be able to recognize the different waveforms and predict the frequency of certain digit keys in a given pattern.

A. Theory

The signal generator produces the desired frequencies, amplitudes and waveforms to be read by the oscilloscope. The principles demonstrated by these two pieces of equipment range far beyond measuring phone frequencies and understanding it's characteristics, however. Frequencies, and different waveforms are how most of modern day's technology communicates and operates in space. This technology only continues to develop in beautifully intricate ways that, as the engineer, it is important to be able to understand how and why they work. Understanding these properties can give insight to physical properties as well. For example, the refraction of light of a given material can be understood, or perhaps modeled by understanding the waveforms that are produced from the white light reflecting off the material. The most popular tool for tasks like this is the Fourier Series which allows series of sin and cos waves to model the behavior of any virtually any system.

B. Procedure

Begin the first experiment by verifying that all equipment is turned on and all electrical connections are secure. Log in to the computer and open the oscilloscope Matlab shortcut. After verifying the Oscilloscope, Matlab script and Signal generator are connected and working the first experiment may begin. The first experiment guided the understanding of the signal generator's controls and ability to generally recognize different waveforms and frequencies. The students are to navigate the signal generator and create the inputs given in the Data Sheet (Appendix C). The students are to then report the changes made between each iteration and note the output differences on the oscilloscope. It is suggested that the students collaborate and report their observations between each iteration.

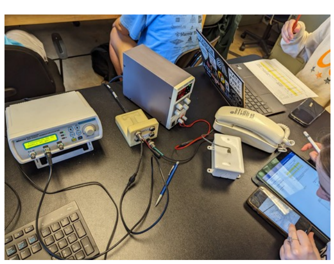


Figure 1
Original lab setup

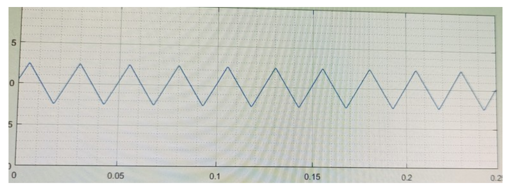


Figure 2

The wave form above can be replicated by creating the "Triangle" wave type with a 5 V amplitude and 2000 Hz sampling frequency

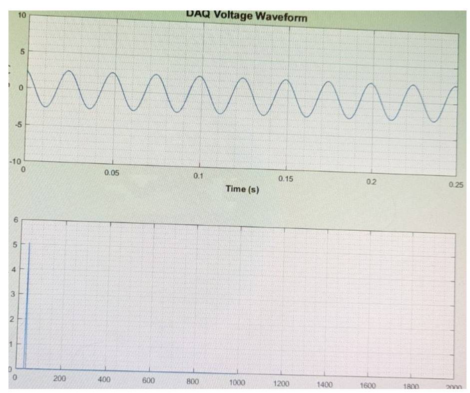


Figure 3

Changing the wave type to a sine wave will produce a graph similar to the one above. The graphical differences are obvious and give rise to the nomenclature of the waveform naming schemes. This pattern will generally stay consistent and can be used as a sanity check as the student attempts to reproduce more graphs.

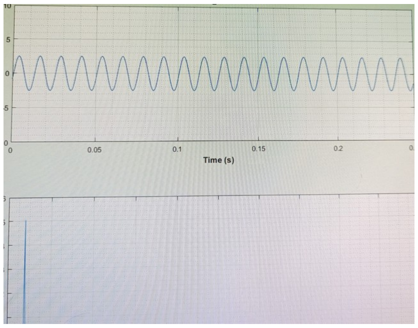


Figure 4

Decreasing the sampling frequency to 250 will appear to shorten the wavelength. The only difference in this figure to Figure 3 is the sampling frequency. However, due to the appearance of a shortened wavelength it is easy to mistake the amplitude to be shorter as well. In reality, a shorter sampling frequency means only that there are less measurements per time step than before, producing a lower resolution picture which gives the appearance of being more erratic.

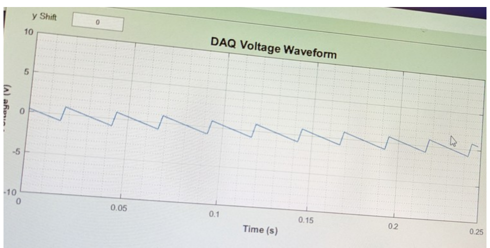
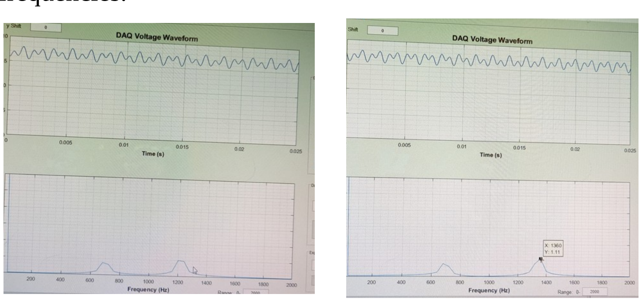
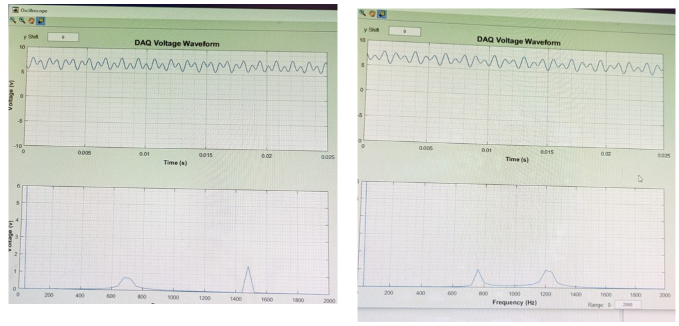


Figure 5

The final graph produced in the first experiment is to be created by the students performing the lab in an attempt to promote exploration of otherwise undefined input settings. Table 2 decided to produce a sawtooth graph and was delighted to see the consistency in what visually represented a sawtooth pattern.

To begin the second experiment, ensure that the phone is connected properly and a noticeable tone can be heard when pressing any of the digit keys. Traverse the digit pad and record the respective frequencies in two patterns, traversing by rows and traversing by columns. The frequencies produced should resemble a pattern and can be approximated once recognized. Verify the approximation with the recorded frequencies.





Figure(s) 6-9

These figures depict the oscilloscope outputs for some of the digit keys during the second experiment. Note the two peaks in the lower half of each figure. The two peaks can be used to both read the value and predict the opposing key in the pattern.

C. Data Reduction

The frequencies seen above can all be modeled with Fourier Series.

Table 1
Equations

$$\sin\left(\tfrac{\pi}{2}-\theta\right)=\cos(\theta) \qquad 1.$$

$$\cos\left(\tfrac{\pi}{2}-\theta\right)=\sin(\theta) \qquad 2.$$

$$y(t) = A_0 + \sum_{n=1}^{\infty}(A_n cos(nwt) + B_n sin(nwt)) \qquad 3.$$

$$A_0 = \frac{1}{T}\int_{\frac{-T}{2}}^{\frac{T}{2}} y(t)dt \qquad 4.$$

$$A_n = \frac{2}{T}\int_{\frac{-T}{2}}^{\frac{T}{2}} y(t)\cos(nwt)dt \qquad 5.$$

$$B_n = \frac{2}{T}\int_{\frac{-T}{2}}^{\frac{T}{2}} y(t)\sin(nwt)dt \qquad 6.$$

Equations 1 and 2 are simply helpful trigonometric relations, with theta relating to the unit circle. Equation 3 is a Fourier Series with the following equations relating to it’s unknown coefficient parameters. [2]

II. Results and Discussion

The *Signals Analysis* Lab was all done electrically, which produces it's own plethora of opportunity for error. The first and most obvious error is an incorrect connection of wires. Although this lab is rather low on wired connections, it is always a potential weak point when dealing with electrical components. Another potential point of error would be from the operation of the software or electrical machinery. Although the Oscilloscope runs as a Matlab script, the signal generator is an exterior component that has it's own native operation techniques that require specific key combinations to access certain input areas. If not used properly it may not be apparent that the current parameters are incorrect.

The first experiment's secret intent was not to merely familiarize students with different waveforms and the ability to recognize different traits of oscillatory motion. Rather to show the student the ability to recreate these given frequencies and to beg, Why is this of use?

Table 2
Digit Pad
(Appendix C)

Number Pad		**Column Frequency 1 (Hz)**	**Column Frequenc y 2 (Hz)**	**Column Frequency 3 (Hz)**
		1240	1360	1480
Row Frequency 1 (Hz)	660	**1**	**2**	**3**
Row Frequency 2 (Hz)	760	**4**	**5**	**6**
Row Frequency 3 (Hz)	840	**7**	**8**	**9**
Row Frequency 4 (Hz)	960	*****	**0**	**#**

The Results of the second experiment suggest a pattern between the traversing patterns of rows and columns. As you traverse a row it will be similar to the row before and vice versa for columns. This gives some hints to how phones operate and key digits are transmitted and recorded. It can also give some explanation to why different key combinations have certain tones that don't entirely seem to relate to the key being pressed.

III. Conclusion

The *Signals Analysis* Lab walked students through the impacts that certain inputs such as amplitude, frequency, sampling frequency and waveforms have on signals. The impact of all of these variations allows equipment to recognize and use these signals in fantastic applications. Coupled with the use of Fourier Transforms to understand, model and replicate these signal transmissions is easily the most revolutionary technology that humanity has ever had the fortune to discover. The mathematics behind Fourier Transforms transcend anything that Fourier himself could have ever imagined.

In a more complicated, but similar vain, Bluetooth sends and receives frequencies or "packets" of information between the paired devices thousands or even millions of times a second in order to create an exclusive channel in which only the connected devices are affected by the signal transmission.

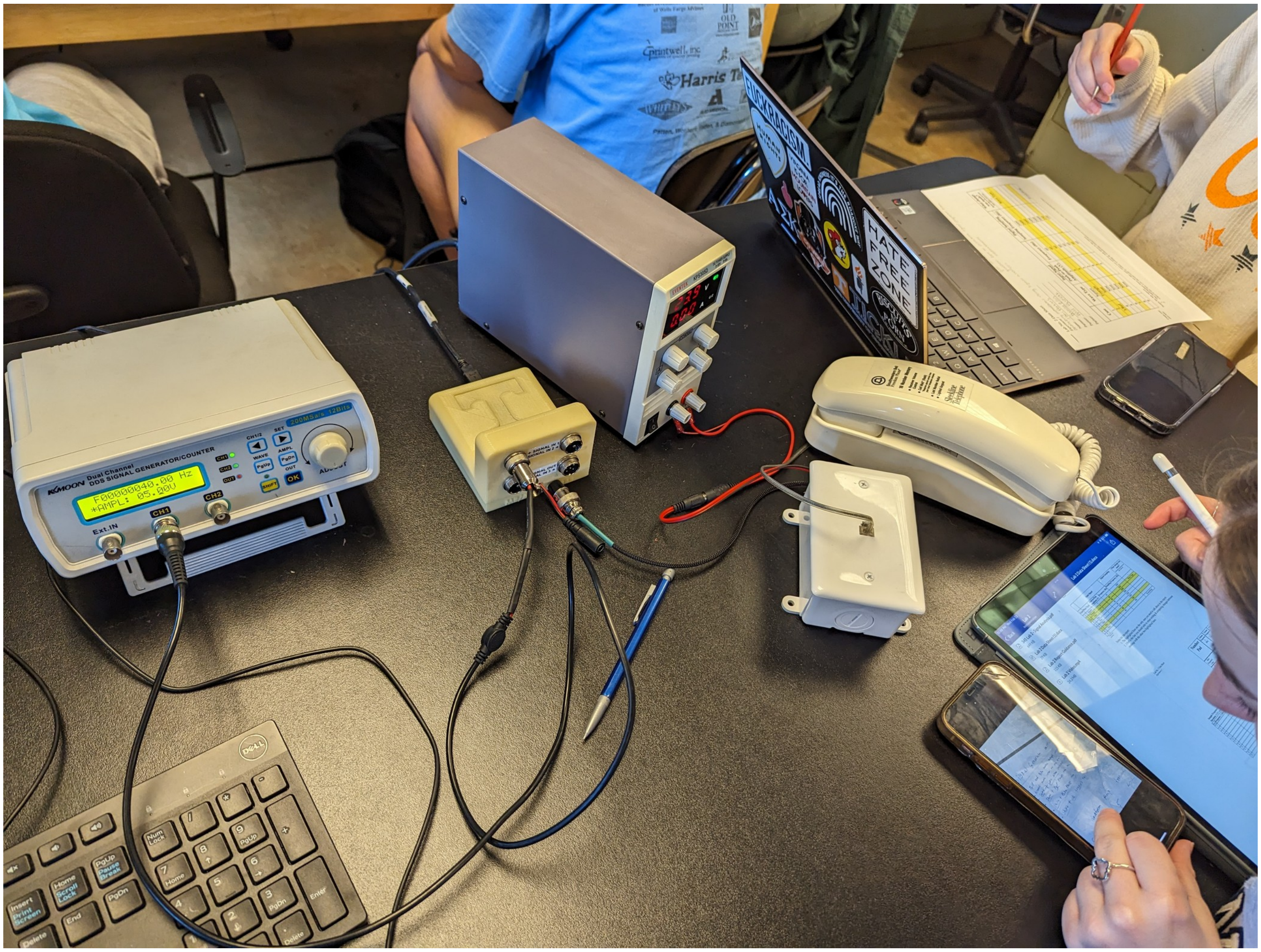
References

[1] M. Vanpoppelen, "MABE 345 Lab Report Required Sections.docx" U.S., Knoxville, TN, 2023.

[2] V. Aloi. (2023, February). ME/AE/BME 345 Instrumentation and Measurements class notes. [Online]. Available e-mail: valoi@utk.edu

Appendix A: Equipment Information

1. Oscilliscope
2. Lab computer (Matlab)
3. telephone
4. Signal Generator
5. DAQ (Signal In)



6.

Appendix B: Hand Calculations

Appendix C: Complete Data Sheet

Lab No. 2 Data Sheet
Experiment 1

Name: Will Buzick
Partner: Brodon Ellis
Partner: Toni Perkins
Partner: ____________________

B

	Input Signal			Digital Sampling	What change
Case	Wave Type	Peak-to-Peak Amplitude (V)	Frequency (Hz)	Sampling Frequency (Hz)	was made? Referring to the previous case above each one.
1	Square	5	40	2000	--
2	Triangle	5	40	2000	Wave Type
3/Ref	Sine	5	40	2000	
4	Sine	5	80	2000	Wave Type
5	Sine	2	40	2000	Frequency
6	Sine	8	40	2000	Amplitude
7	Sine	5	40	250	
8	Sine	5	60	100	[illegible]
9	Sawtooth	2	100	500	[illegible] Everything

Notes for lab report:
1. The highlighted lines are the only ones you need to talk about in the report.
2. 3/Ref is the line you should refer to when writing & comparing changes between readings with the other two highlighted lines.

Create your

Lab No. 2 Data Sheet
Experiment 2

Sample Frequency Used: 50,000 Hz

Duration: 0.025 seconds

Key	Frequency 1 (Hz)	Frequency 2 (Hz)
1	690	1240
2	690	1360
3	690	1490
4	760	1200
5	760	1340
6	980	1490
7	840	1200
8	840	1360
9	840	1460
*	960	1240
0	960	1360
#	960	1480

Number Pad		Column Frequency 1 (Hz)	Column Frequency 2 (Hz)	Column Frequency 3 (Hz)
		1240	1360	1490
Row Frequency 1 (Hz)	660	1	2	3
Row Frequency 2 (Hz)	760	4	5	6
Row Frequency 3 (Hz)	840	7	8	9
Row Frequency 4 (Hz)	960	*	0	#

Lab Instructor's Signature: [signature] 2/23/23 10/04/2022

Figure D
Experiment 2.
Mass Measurements