LabView and Data Acquisition for Mechanical Engineering Measurements

Deep Patel*, Nick Dillon, Ian Gallagher, Glenn Clayton,
Department of Mechanical and Aerospace Engineering
Rutgers University, Piscataway, New Jersey 08854

Analog signals are converted to digital representations using computer hardware and software. A DAQ board and PC is used with LabView to record sine waves and triangular waves at different frequencies. We see that the shapes of the digital signals are greatly dependent on the sampling rate relative to the input frequency. If the sampling rate is not double the input frequency, the wrong frequency is recorded in the digital signal due to aliasing. If the sampling rate is not many times more than twice the input frequency then the amplitude of the digital signal is not consistent with the analog signal. A thermocouple is also used to measure the temperature of the room and the change in temperature from room temperature to when the thermocouple is pinched by 2 fingers. The dynamic graph of the change in temperature from room temperature to finger temperature shows how instantly the temperature changes when the fingers pinch the thermocouple. This shows the instant response of the thermocouple and the great precision with which the DAQ board, circuitry and computer all work together to get a very accurate digital representation.

INTRODUCTION

In today's day, the use of computers and complimentary instrumentation has revolutionized the precision at which measurements can be taken along with the amount of data that can be stored. This allows for faster, easier, and more accurate experimentation.

The main ways in which computers talk to instruments is through serial communication (like USB, Firewire, RS-232), parallel communication, and through a data acquisition board (DAQ) that we will be using. We use this DAQ board to measure an analog signal and convert it to a storable digital signal using a device called an A/D converter. The difference between the analog input and digital conversion is made clear in Figure 1. The A/D converter has a specified finite resolution, which is used to approximate the voltage at each data point, which occurs at the sampling rate of the measurement, the frequency at which digital data points of the signal are acquired.

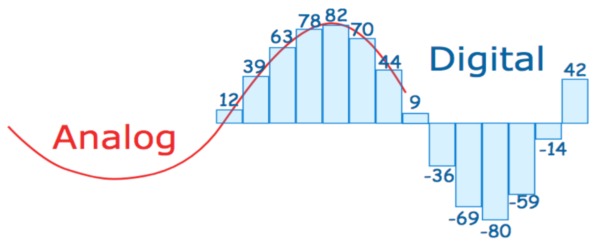

Figure 1. Analog vs. Digital Signal

A crucial element of measuring an analog signal is the frequency at which it is sampled. Pioneers like Harry Nyquist have shown that the sampling frequency must be at least twice the frequency of the signal being measured to ensure that data points are not missed and so that frequency of the sampled data matches the actual frequency of the analog signal. This relation is shown in Equation 1 where F_N is the Nyquist Frequency and Δt is the time between successive measurement data points. This criterion of twice the actual frequency does not, unfortunately, ensure that amplitude of the signal is preserved. For this to occur even higher sampling rates may be needed.

$$F_N = \frac{1}{2\Delta t} \qquad [1]$$

In this experiment, we use a personal computer running the Windows 7 operating system, a National Instruments DAQ board (installed in an empty PCI slot in the computer), cable, National Instruments BNC terminal block, and a miniature thermocouple probe. The software that we use to analyze the data is LabView. We make a block diagram like the one shown in Figure 2 to obtain the

* Corresponding Author

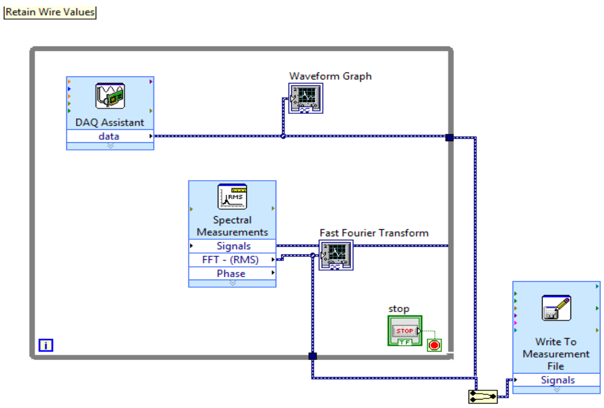

Figure 2. LabView Block Diagram

signal waves at different wave frequencies and sampling rates along with the frequency response of the signal. The frequency response is done using a Fast Fourier Transform function in LabView as shown in the block diagram and is displayed on the front panel of LabView as shown in Figure 3 as a frequency vs. amplitude graph with the peak in frequency tweaked to be at around 500 Hz. The time vs. amplitude of the waveform graph is also displayed in LabView, shown in the same Figure 3 of the 500 Hz sine input with an amplitude set to around 1.

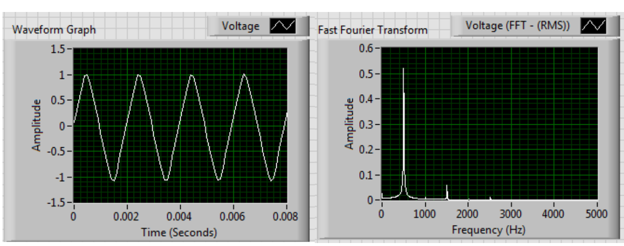

Figure 3. LabView Front Panel

RESULTS AND DISCUSSION

We begin the lab by setting up the necessary settings and block diagram to record the data of the sine and triangle waves that will be measured like shown in Figure 2. We set the amplitude so that the peaks of the sine graph are at 1 and set the frequency of the sine wave by using the frequency response graph and rotating the frequency knob until the peak of the frequency graph is at the desired frequency. Three sine waves were obtained with

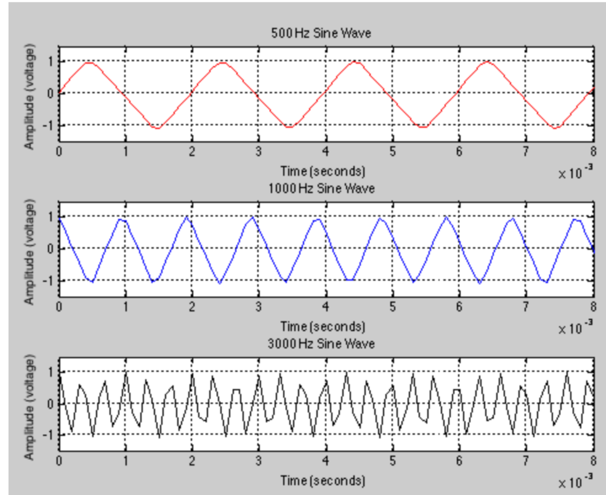

Figure 4. Sine Wave Graphs

frequencies of 500, 1000, and 3000 Hz as shown in Figure 4. The sampling rate used for this procedure is 10,000 Hz.

As you can see from the recorded results in Figure 4, the shape of the waveform of the 500 Hz sine wave is curvy and represents what we are used to seeing in a sinusoidal wave. As the frequency of the wave increases to 1000 Hz, the wave seems more pointed at the peaks and troughs, resembling something closer to a triangular graph. The bottom graph, with a frequency of 3000 Hz is the most abnormally shaped. The trough and peak amplitudes are not consistent throughout the wave and the shape is not as sinusoidal as before. The curves have a lagging effect such that the waves are not symmetric and not repetitive, probably due to an overlapping or minor aliasing effect. This is forced because the sampling frequency is not high enough to properly capture the input data frequency. This is consistent with our predilection of the sampling rate sometimes needing to be more than twice the wave frequency to preserve signal amplitude. In this case, at 3000 Hz wave frequency and 10,000 samples/sec sampling rate, the ratio is 10/3 which is greater than 2, so it satisfies the Nyquist criterion. It shows exactly how the frequency of the signal is preserved, but the amplitude consistency is not.

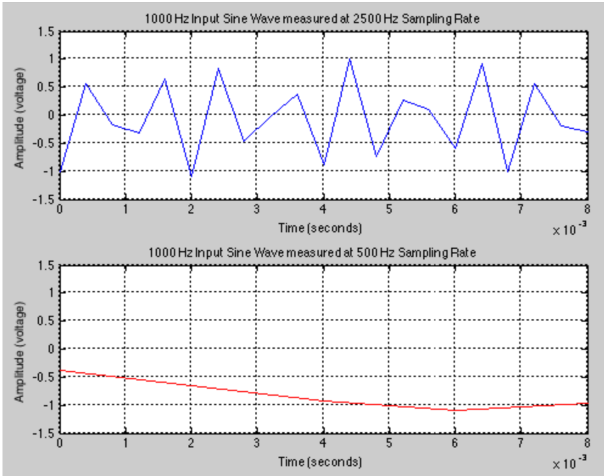

Figure 5. 1000 Hz Sine Wave Graphs at Sampling Rates 2500 Hz and 500 Hz

As you can see in Figure 5, the frequency of graph sampled at 2500 Hz is correct, with one full wave length covered in the span of 0.001 seconds which is the reciprocal of 1000 Hz (or 1/seconds). Yet, the shape of the graph is not accurate because of the still low sampling rate. Below this is the 1000 Hz sine wave sampled at 500 Hz. Because of this extremely low sampling rate (half of the sample frequency) the frequency of the sample is not even detected because the data points between the successive measurements are the rapidly changing ones. There is definitely aliasing occurring, obvious from the difference in the two graphs in Figure 5. This is confirmed by looking at a zoomed out graph shown in Figure 6. This shows that the

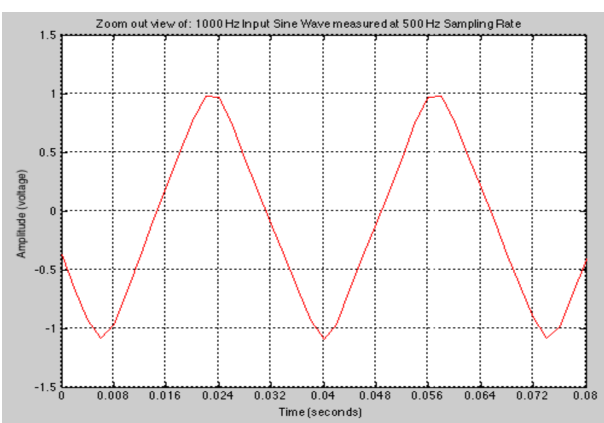

Figure 6. Zoom out View of Figure 5, bottom

aliased frequency holds a much higher value than the actual frequency of the sine wave.

Next, we sampled a 1000 Hz triangular wave at a sampling rate of 10,000 samples/sec which is shown in Figure 7. The shape is quite good considering the frequency is only 1/10 of the sampling rate, so it is quite accurate. As the frequency of the triangle wave would increase, it would start to deform in shape by symmetry and amplitude very similarly to what happened to the 3000 Hz sine wave discussed earlier. At an amply under-sampled frequency the triangular signal will start to alias and a triangular wave of incorrect frequency will result.

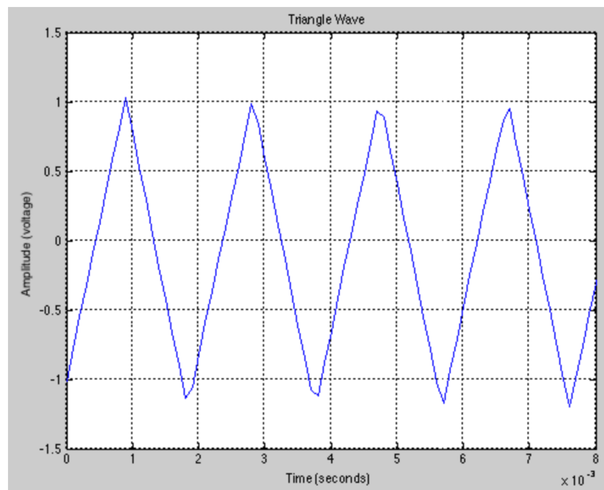

Figure 7. Triangular Wave Graph

The next part of the lab involved attaching a thermocouple to the DAQ board and setting up LabView to measure the temperature through it. Figure 8 shows the block diagram used for this measurement.

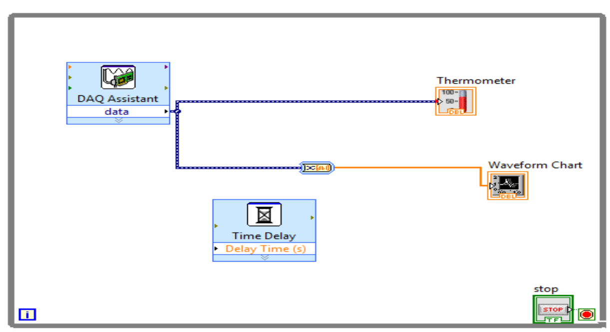

Figure 8. Thermocouple Block Diagram

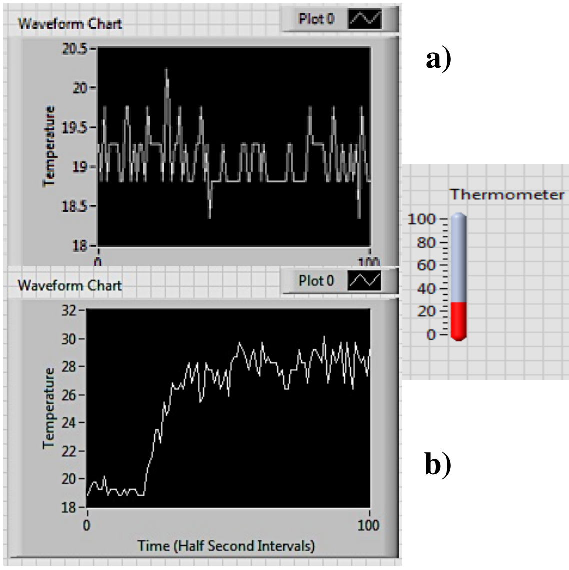

Figure 9. Thermocouple Front Panel of a) Room Temperature b) Thermocouple between Fingers

We first do a measurement of the still room temperature to see its stability and ensure that the set up is working properly. In Figure 9 shows the front panel of LabView for a measurement of 100 seconds. We then move on to something more dynamic. We start the measurement with the thermocouple of the room temperature and after 0 seconds passes, I pinch the thermocouple tip with my thumb and index finger, which transfers heat into the thermocouple in a nonlinear way. This measurement is shown in Figure 10.

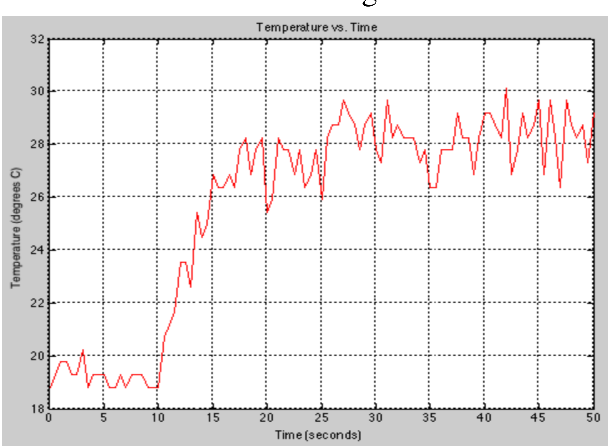

Figure 10. Thermocouple Dynamic Results

The thermocouple data for both the room temperature and the temperature with my fingers placed on the thermocouple fluctuate between a given range. The room temperature fluctuates around the approximate temperature of 19.2 °C by a degree or two. This is usually due to the electrical noise that easily disturbs the thermocouple measurement because it is measured in microvolts and any interference from an external electric field can disturb the signal. Also, the long leads of the thermocouple are often susceptible to noise because they often run through electrically noisy environments.

CONCLUSIONS

In this lab we learn how to program with LabView to make meaningful and accurate measurements of analog signals or different frequencies and learned how to set those frequencies. We see that the Nyquist frequency is an important value to consider when setting sampling rate of a measurement. We also see that even when the sampling frequency meets the Nyquist criterion, namely, that the sampling rate is twice the input frequency, it only assures that the frequency of the measured discrete signal is correct and matches the input frequency. It does not, though maintain amplitude symmetry and consistency with the analog signal. For this, it is seen that a much larger sampling rate relative to the input frequency is needed. We see that a triangular waves is similar to a sine wave at the same frequency and predict its digitally converted behavior as its frequency increases keeping sampling rate constant. Lastly, we conclude the experiment with temperature measurements using a thermocouple. We find that there are slight variations in the thermocouple measurements and hypothesize that this is due to noise in the highly sensitive measuring device that is a thermocouple.

REFERENCES

[1] Figliola, Richard S., *Theory and Design of Mechanical Measurements*, 5th ed, John Wiley and Sons, Danvers MA, 2011.

[2] Drazer, German, *LabView and Data Acquisition Manual*, Rutgers University, New Brunswick, 2017