

BioE 101 – Lab 2

Objectives:

- Learn how to program with Labview
- Build a Labview GUI to plot signals in the time and frequency domain
- Observe aliasing, harmonic distortion, and quantization error in sampled data
- Connect a microphone to your MyDAQ
- Estimate noise and SNR from microphone recordings
- Build an algorithm with Labview to distinguish you and your partner's voice

Teams will each turn in one list of answers to the questions in this lab. List all partners' names and section numbers.

1. Pre-Lab

Before your lab, watch all of the videos under "Labview Basic Concepts" and watch the "Taking a Measurement" video under "Labview Basic Tasks" here:

<http://www.ni.com/academic/students/learnlabview/>

This will take you about 45 minutes.

2. Setup

- a. Your group will need the following items: microphone, BNC cable, BNC-to-binding post adapter, small screwdriver, short pieces of wire, two banana cables, a MyDAQ, and USB cable.
- b. Startup LabView and load a new "Blank VI". "VI" stands for "Virtual Instrument". Note that this creates a new blank front panel (gray screen) and blank block diagram (white screen)
- c. Right clicking in either the front panel or block diagram will bring up the toolbox of elements that you can add to your VI. Take a moment to browse through these.

3. Displaying signals in time and frequency domain with Labview

(2 students, requires function generator and MyDAQ)

- a. Connect your function generator to the MyDAQ analog input 0. Make sure the ground wire is connected to ground on your MyDAQ. You will need to use the BNC binding post adapters and two pieces of wire.
- b. Add a "DAQ Assist" block to your block diagram. Configure this block to acquire voltage signals from analog input 0. Use the appropriate settings to record waveforms with a maximum frequency of 500Hz (Nyquist) and 10Vpp. The samples to read buffer should be set up so that the buffer will span a half second.

- i. Labview will automatically place your DAQ Assist block inside a while loop to enable continuous acquisition. It will not, however, enclose the rest of the components you create below in a while loop. You should create a single while loop now to enclose everything created below.
- c. Once your DAQ Assistant is set up, add a waveform graph to your front panel (note: don't use a waveform "chart" ...it's behavior is slightly different)
- d. Connect the "data" output of your DAQ Assistant block to the input of your Waveform Graph. Make sure the Graph is located within the while loop on your block diagram so that it gets updated every time the loop executes.
- e. Set your function generator to output a sinusoid at 100Hz, 2Vpp.
- f. Run your Labview VI and verify that you can see the signal from the function generator. Do this with a waveform graph, not waveform chart. By default, the axes autoscale. You can manually adjust the X/Y scale of the graph by right clicking on the axes and turning off autoscale and then clicking on the labels and changing them yourself, or by right clicking on the graph and editing the property pages. Experiment with it until you get a comfortable view of your waveform.
- g. Now add a "Spectral Measurement" block from the list of Express VIs. Configure it with the following parameters:
 - i. Magnitude RMS, dB
 - ii. Hanning window
- h. Connect the "data" output of the DAQ Assistant to the "Signals" input of the Spectral Measurements.
- i. Connect the "FFT (RMS)" output to another waveform graph (again, not chart). Note that by default the X axis is "time", so you should change this to "frequency" by double-clicking on the text and renaming it. FFT stands for "Fast Fourier Transform" and it is a computationally efficient algorithm for computing a Fourier transform.
- j. Set your function generator to a 100 Hz, 1V sine wave. Run your VI and verify that you observe a peak in the frequency domain corresponding to the frequency of your function generator. Note that the frequency span is set to 0-500 Hz automatically, based on your sampling rate of 1 kHz.

Question 1: Based on your frequency domain plot, what is the RMS magnitude of your signal in dB? What is the RMS magnitude of your noise floor, approximately? What is your SNR (in dB)? Keep in mind that dB is logarithmic, so even though noise and signal are both clearly visible on this plot, they're really several orders of magnitude apart.

Question 2: Increase the frequency of the function generator to 500 Hz in steps of 100 Hz. What do you see? What happens in the time and frequency domain when you are above this frequency? What do you observe at 490 Hz and 510 Hz?

Question 3: Switch the input waveform between a 50 Hz square wave and a 50 Hz sine wave. How does the frequency spectrum change between the square and sine wave?

Question 4: What would you expect to see if you increased amplitude of the signal beyond what the myDAQ can acquire? Does this phenomenon occur because of a violation of bandwidth, dynamic range, or sensitivity?

Question 5: What is the magnitude of the 100 Hz peak at 1V in dB? What is it at 10V? Why?

4. Observing noise using the oscilloscope

(2 students, requires oscilloscope)

- a. You can disconnect your function generator and turn it off. Stop your LabView program from running and remove all wires connected to your MyDAQ, but keep the LabView program you created open or save it.
- b. The next set of questions uses the HP oscilloscope at your lab station.

Question 6: What is the RMS noise voltage that the oscilloscope sees without anything connected (no probe, no cables)? You may need to increase the Volts/div significantly to see this, and you will want to use “Auto” triggering. Remember that you can make this measurement by pressing the “Measure” button.

- c. Connect the BNC binding post adapter and connect the banana wires to the binding posts.

Question 7: What is the RMS noise voltage now? Why did it change?

Question 8: Hold the positive/negative banana wires straight, parallel, and close together. Observe the RMS noise. Then spread them apart. What happens to the RMS noise? What happens when you touch the positive terminal? Why is the noise changing in these cases?

Question 9: Move the positive wire around. What happens when you place it near fans or power cables behind the computer?

5. Measuring signals from a microphone using the MyDAQ

(2 students, requires MyDAQ and microphone)

- a. The microphones you have are known as “electret” condenser microphones. The sensing element can be thought of as a small capacitor that changes its capacitance as a function of acoustic pressure. The sensing element is then connected to a transistor, which converts the capacitance into a voltage signal. Transistors are active, meaning they need to be powered by an external

voltage with a series resistor. Hence, in your microphone assemblies, there are several leads—two short wires (one with a resistor, one without) which should be connected to analog input 0+ and 0- on your MyDAQ, respectively, and two long wires which should be connected to +5V (red) and DGND (black). Check out this Wikipedia entry:

http://en.wikipedia.org/wiki/Electret_microphone.

- b. Once the microphone is properly connected, start the same LabView program you had running earlier. It will be helpful for the following questions to turn off X- and Y-axis scaling—play around with the scaling to get the best view.

Question 10: What function do you think the serial resistor serves? Remember, the resistor is hooked up between 5V and the output signal.

Question 11: What is the RMS noise voltage (in dB) with the microphone connected (without anyone talking into the microphone - make sure to connect 5V power)?

Question 12: Talk into the microphone at a comfortable level. What is the approximate RMS voltage that you generate while talking? What is your SNR (in dB)?

6. **Processing audio signals using Labview**
(2 students, requires MyDAQ and microphone)

- a. Modify the VI you created earlier by changing the sampling rate to 10k. Change the buffer size to store $1/10^{\text{th}}$ of a second. Verify that you can see signals from your microphone and that your frequency display now shows appropriate values.

Question 13: Use the x-axis scale to zoom in on a very small time/voltage window of your signal, so you're only looking at noise. Notice the quantization error. Can you estimate the voltage step size of the ADC (i.e., the voltage increment corresponding to the least significant bit)? Compare this to the RMS noise voltage of the microphone that you measured with the scope and comment on whether it is a problem or not. How many bits of noise do you have?

Question 14: Pick the best singer in your team and have that person try to hum a pure tone. Observe the time/frequency plots. What is the range of frequencies that you can hum? How close are these to pure tones (i.e. single frequency sinusoids)? If you're musically inclined, try humming a scale and observing how the frequency spectrum changes.

- b. Add a numeric indicator on your GUI that displays the total RMS signal amplitude in volts. You may find the "Amplitude and Level Measurements" express VI handy.
- c. Add another numeric indicator that displays the fundamental frequency. You may want to use the "Tone Measurements" express VI.

- d. Do you notice any differences between the spectrum of you and your partner's voice? These should be particularly apparent if you have a male-female team. For the remainder of the lab, try to use the toolboxes available to you in LabView to develop an algorithm to distinguish the two of you using the data in the frequency or time domain. Check out the blocks under "Signal Processing->Waveform Measurement". The algorithm should output two Boolean values: one for each of you. These should light up LED indicators on your GUI. There are many approaches to this, so be creative. Here are some ideas:
- i. Make a decision using the power and fundamental frequency that you calculate for (c) and (d), with appropriate thresholds for each. If power is over a certain amount, assume that someone is talking. If the peak frequency is above/below a certain amount select one person or the other.
 - ii. Record two waveforms of you and your partner saying the same thing. Store these two waveforms in a local variable. Then use a cross-correlation block to compare the sampled waveform with these saved waveforms. If the cross-correlation is particularly high, consider it as a match.

Question 15: Write out your approach (even if you don't get it to work) and take a screenshot of your block diagram and GUI and paste them in your report.

Bonus Question! If you chose a method that involves a threshold (either on frequency or RMS), try varying the threshold and seeing how many times your classifier gives true/false positives and true/false negatives. Build a ROC curve for your method!