

WESTERN WASHINGTON UNIVERSITY

DEPARTMENT OF ENGINEERING TECHNOLOGY

(Now Changed to DEPARTMENT OF ENGINEERING AND DESIGN)

526 High Street, Bellingham, WA 98225

PROJECT REPORT FOR THE ECETDHA MINIGRANT (02/13/2013 – 08/31/2014)

Project Title:

“Development of Real-Time Real-Life Signal Acquisition, Analysis, and Processing Lab Modules”

Project Director:

Ying Lin

Assistant Professor

Email: ying.lin@wwu.edu

Phone: 360-650-2703

Fax: 360-650-4847

Project Team Members:

Ying Lin, Faculty, EE (EET) program

Aaron Cramer, Instructor/Classroom Support Technician, EE (EET) program

Isaiah Ryan, Students, EET program

Abstract:

In this project, we have developed a sequence of engaging lab demos and lab exercises that implement **real-time real-life** signal/data acquisition, analysis, and processing using Matlab, Labview, and NI myDAQ. Examples of these signals include real-time human voice or music signals. These lab modules are designed to enhance the existing lab components in the signal processing area in the Electrical Engineering (EE) program and/or the Electronic Engineering Technology (EET) program at WWU. The lab topics cover fundamentals of digital signal processing (DSP) such as real-time data acquisition, sampling, time-domain and frequency-domain analysis, a variety of audio signal processing techniques, and different digital filtering methods. In addition, noise analysis and removal examples have been introduced in the lab modules as well.

Besides serving as part of the EE/EET curriculum, the labs developed from this project can be used as effective outreach tools. Since 2011, we have opened our DSP lab sessions to participants (5th graders) of the annual WWU Compass to Campus program (For the program scope and details, please refer to: <http://www.wce.wvu.edu/c2c/>) to promote engineering and technology to young minds. We believe that these newly developed engaging lab demos will help to further attract and spark young students' interests in engineering and technology.

I: Introduction

Digital signal processing (DSP), an important field in Electrical engineering, embraces a broad spectrum of applications, ranging from speech encoding, synthesis, and recognition, image processing, wireless communication systems, radar and sonar systems, control systems, to name a few. Most modern electronic gadgets use some DSP techniques. For instance, the “SURI” function in iPhone 4 uses DSP-based speech recognition algorithms. High quality headphones employ DSP-based noise cancellation techniques.

DSP has become an integral part of EE and Electronic Engineering Technology (EET) curricula at higher institutions worldwide. To fulfill a successful DSP curriculum, it is critical to complement lectures with well-designed hands-on laboratory exercises. The labs facilitate students to achieve the following outcomes, but not limited to:

- Enhancing students’ understanding of DSP fundamentals;
- Connecting theories learned in class to practice;
- Accumulating hands-on skills in practicing and implementing commonly used DSP algorithms;
- Getting familiar with popular software and hardware tools adopted in the DSP field.

Project Objectives:

In this project, our goal is to develop a series of fun and engaging hands-on DSP laboratory exercises that embrace **real-time real-life signal** processing. We strive to relate the DSP theories to real-life examples and make better connections between theory and practice.

Topics Covered:

These labs cover key topics in DSP fundamentals such as period sampling, time-domain analysis, frequency domain (spectrum) analysis, digital filtering, and noise analysis and removal. Details of these topics will be presented in the later sections.

Signals Adopted:

Different from our existing Matlab-based lab exercises where signals are either pre-recorded or generated in Matlab. The signals adopted in the newly developed labs are real-time and real-life signals, such as human voice input from a microphone.

Recently, there has been an increasing need of introducing **real-time** data acquisition and measurements and processing into the curriculum. According to a recent senior student survey, interest in this area of study has greatly increased. Members of the EET Industry Advisory Board from local industry have suggested this area to be considered in our curriculum as well.

Software and Hardware Tools:

A number of software and hardware tools have been selected in developing these hands-on labs. The software tools include MatLab and Labview, respectively. We also incorporate Matlab with Labview to accomplish some lab exercise tasks.

MatLab, a powerful computing and simulation tool, has been widely used in DSP labs and projects. It serves well as a simulation tool for DSP algorithms. In this project, we have used MatLab for multiple tasks:

- To design filters and simulate the filter response.
- To realize math script within a Labview VI program.

On the other hand, Labview, a popular platform used in industry for real-time measurement and testing applications, is a suitable tool to accomplish real-time signal acquisition, analysis, and processing tasks. Due to these features, we have adopted Labview as the major software platform in developing these lab exercises. Other benefits of using Labview include that students get exposed to such a useful tool and have opportunities to build up their experience and skills which prepare them for their future career in this area.

The major hardware components used in these lab modules are data acquisition units such as NI myDAQ and a microphone.

II: Laboratory Modules

In this project, we have developed two main Labview-based lab modules and each consists of a number of tasks or a sequence of lab exercises. Both Modules use a data acquisition unit (DAQ) for real-time signal acquisition. In particular, we have used a Vernier DAQ and a NI myDAQ. The key topics covered in these lab modules are summarized in Table 1.

Table 1: summary of lab module topics

Lab Module	Topics (Tools used)
Lab Module #1	Signal time-domain analysis (Labview)
	Signal frequency-domain analysis (Labview)
	Noise analysis and removal through digital filtering (Labview)
	Digital filter design and simulation (Matlab)
	Sound recording and replay (Labview)
	Various sound effect such as echo (Matlab and Labview)
Lab Module #2	Speech recognition (Microsoft windows API and Labview)
	Voiced-controlled fan system (Labview)

In the following sections, we present detailed lab tasks and snapshots of corresponding lab results.

A. Lab Module #1

This module focuses on fundamental topics in DSP and consists of the following lab exercises:

A1: time-domain analysis of a single tone signal

Tasks:

- The input can be either a sine signal generated from a physical function generator that connects to Labview through a DAQ or a sine signal created by the corresponding Labview palette.
- Provide the time-domain plot and frequency spectrum plot, respectively. Verify the signal from both plots.

Lab results:

Figure 1 shows the snapshots of the two plots for a sine signal with frequency of 1k. As clearly demonstrated from the spectrum graph, the signal indeed is a 1k Hz sine signal given that it has one peak at 1000 Hz.

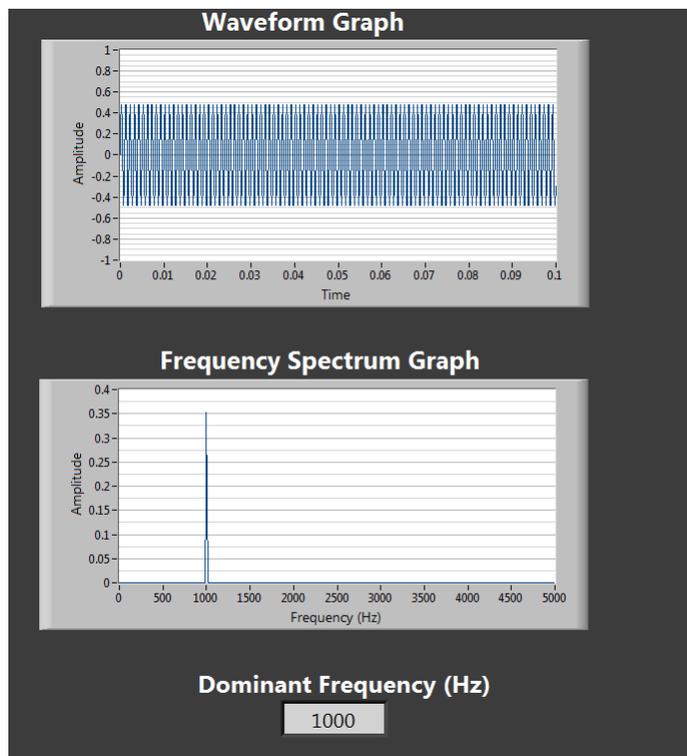


Figure 1: snapshot of the time-domain plot and frequency spectrum plot for A1.

The corresponding Labview GUI snapshot is provided in Figure 2.

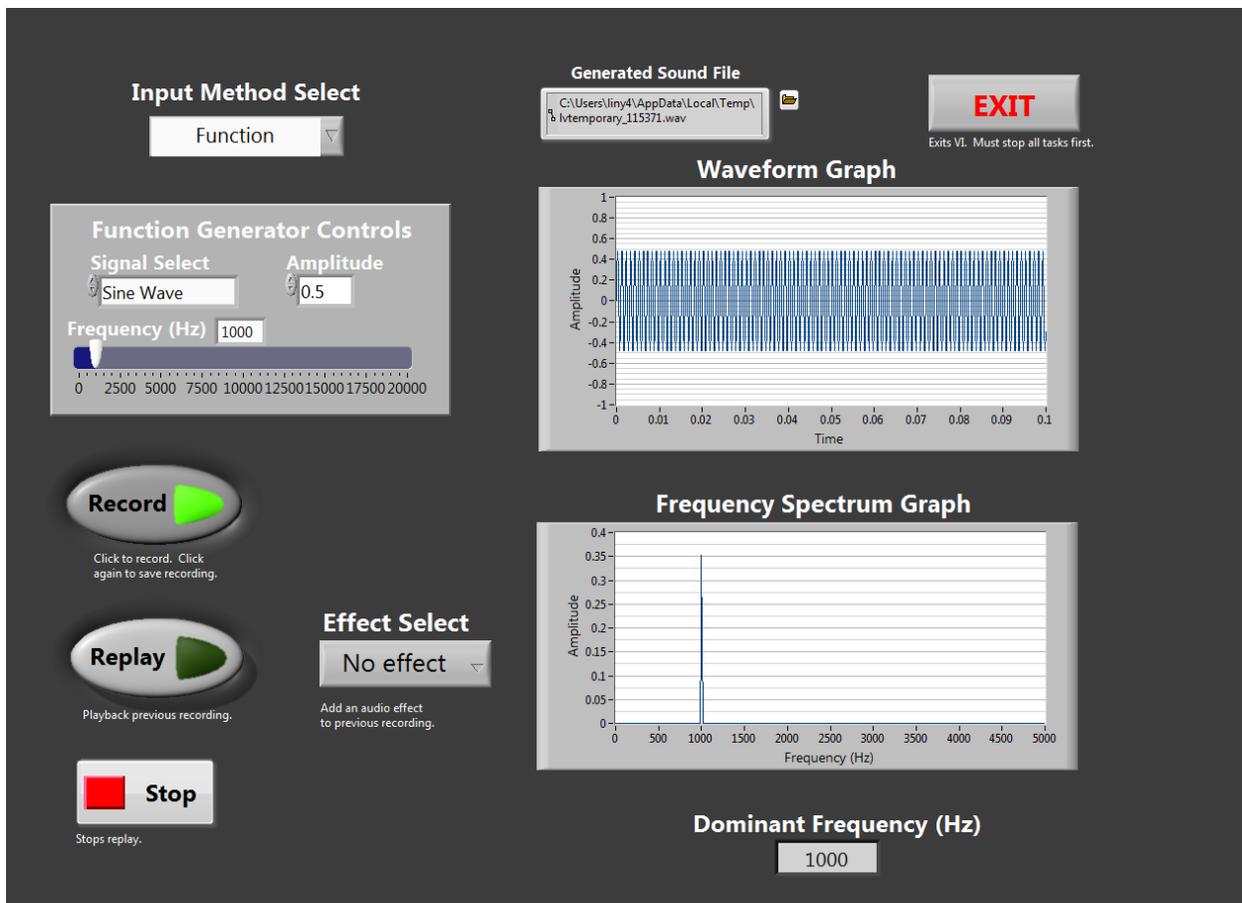


Figure 2: snapshot of the Labview GUI block diagram for A1 with the selected input method as “function generator from a Labview palette”.

A2: time-domain analysis and frequency-domain analysis of human voice/music

Tasks:

- The input can be either human voice or a piece of music taken from a microphone that connects to the PC running Labview.
- Provide the time-domain plot and frequency spectrum plot, respectively. Analyze what major frequency components are included in the input signal.

Lab results:

Figure 3 shows the snapshots of the two plots for a clip of human voice. As predicted, it is difficult to tell the frequency information from the time-domain plot, however, from the frequency spectrum plot, it is clear that human voice typically consists of lower frequency components. This is consistent with theory.

Specifically, for this particular user, the major components are below or around 500 Hz.

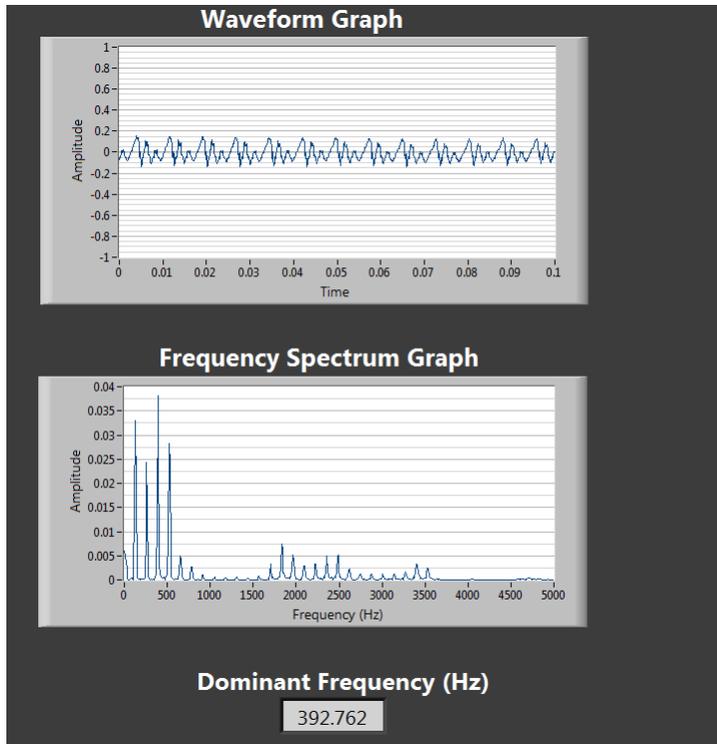


Figure 3: snapshot of the time-domain plot and frequency-spectrum plot of human voice.

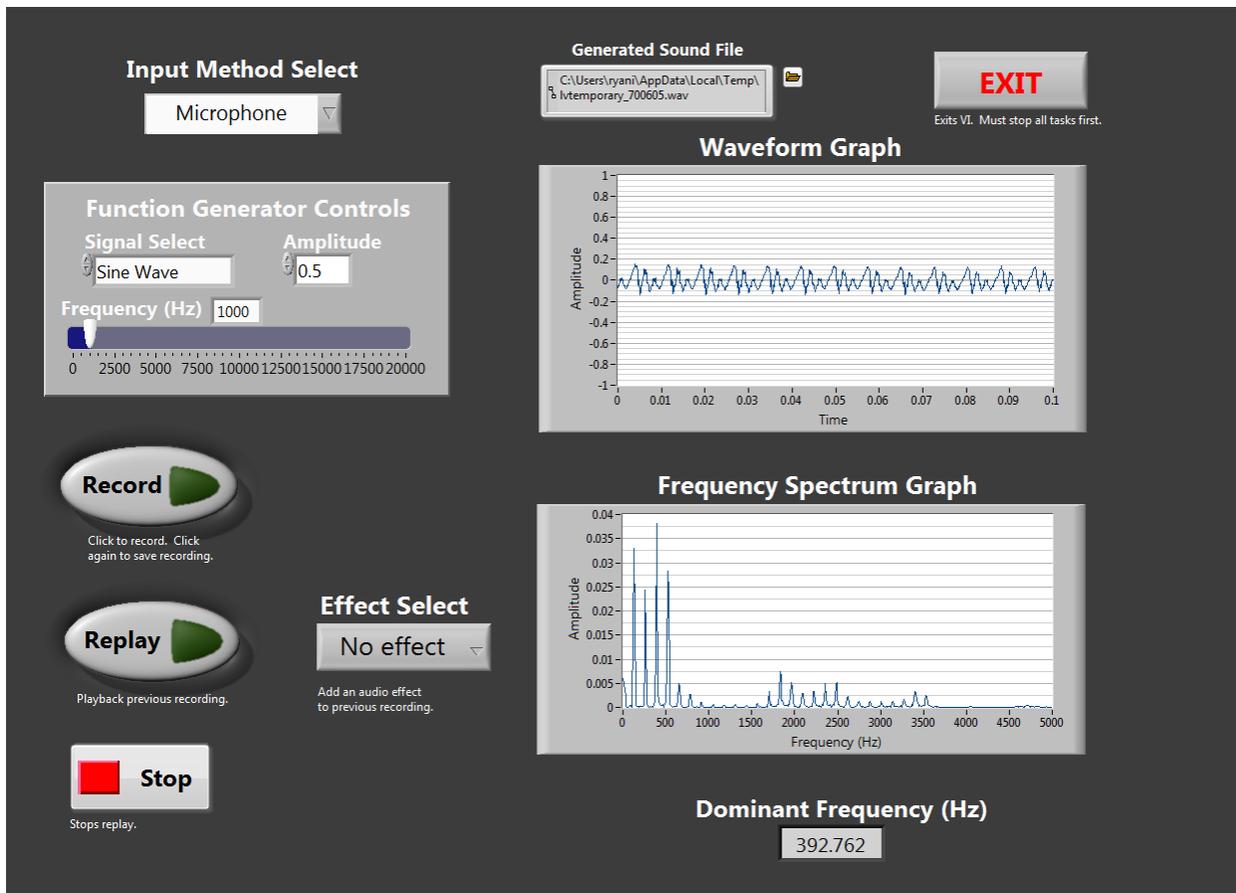


Figure 4 shows the Labview GUI block diagram with the selected input method as “Microphone”.

A3: Noise analysis and removal through digital filtering

Tasks:

- Create the desired (wanted) signal. It can be from any of aforementioned input sources such as either human voice or a piece of music taken from a microphone or a sine tone from a function generator.
- Create the noise signal which is a single tone signal. It can be generated from a physical function generator or from a Labview palette.
- Mix the desired signal with the noise signal.
- Plot the time-domain plot and frequency-spectrum plot, respectively.
- Analyze the frequency components of the mixed signal and design a digital filter to remove the noise.
- Display the filter frequency response.
- Apply the filter and provide the recovered signal time-domain plot and frequency spectrum plot.

- Analyze the quality of the recovered signal after filtering.

Lab results:

Figure 5 shows the snapshots of the time-domain and frequency spectrum plot for the mixture signal of human voice and the noise signal of a 1k Hz.

As predicted, from the time-domain analysis, it is difficult to tell the frequency information and differentiate between the desired signal and the noise signal in the time-domain plot, however, useful information may be obtained through conducting the frequency-domain analysis.

In this particular example, it appears that the 1k hz noise is dominant with a large peak on the spectrum plot. Again the human voice occupies mostly the lower frequency range (below 500 Hz). Such difference provides a good mechanism for possible noise removal.

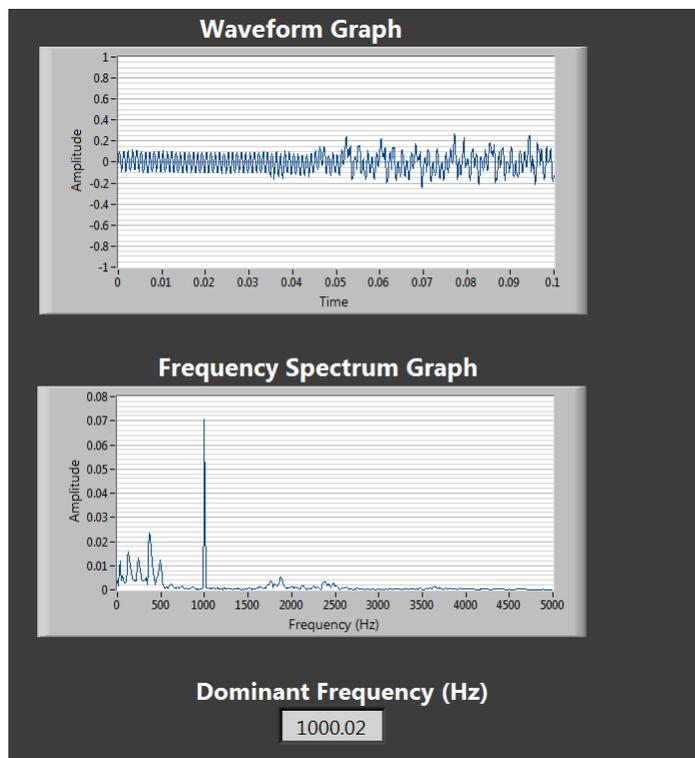


Figure 5: time-domain plot and frequency-spectrum of the mixture of human voice and a 1k Hz single tone noise signal.

To remove the noise signal, a notch filter centered at 1k Hz can be applied to the mixture signal.

In this project, we have used Matlab to design and simulate the digital filter. The corresponding frequency response is shown in Figure 6.

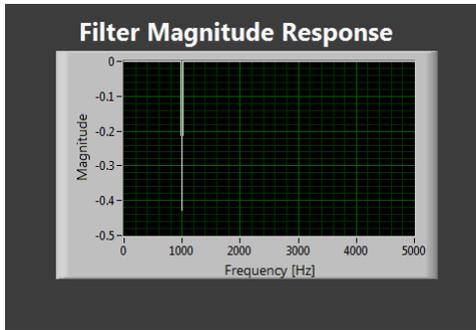


Figure 6: the frequency response of a notched filter with notched frequency of 1k Hz.

The recovered signal after the notched filter is applied is shown in Figure 7. Clearly, the 1k Hz noise signal has been successfully removed as shown from the spectrum plot in Figure 7. The sound quality is comparable to the original sound signal and is thus acceptable as well.

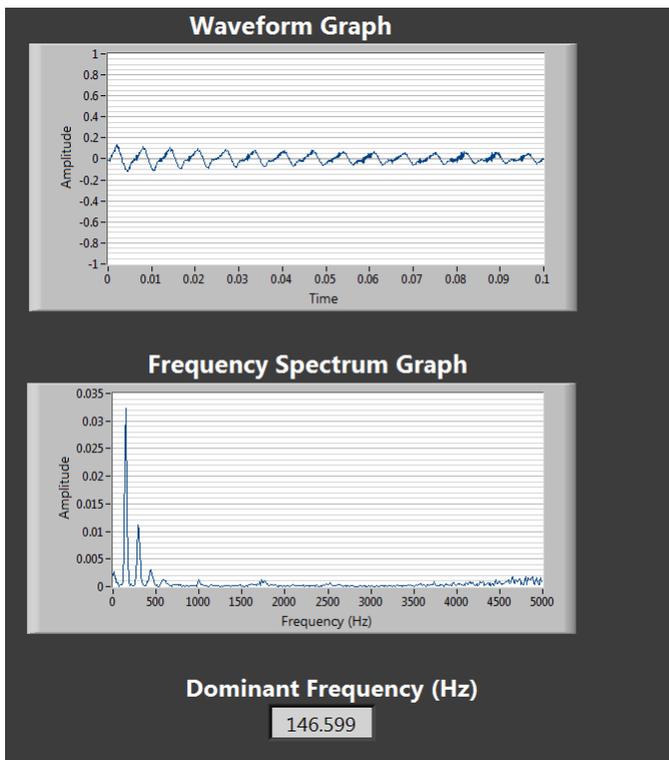


Figure 7: snapshot of the time-domain plot and frequency spectrum of the recovered signal after filtering.

Figure 8 shows the snapshot of the complete Labview GUI block diagram for the noise and filter operations described above.

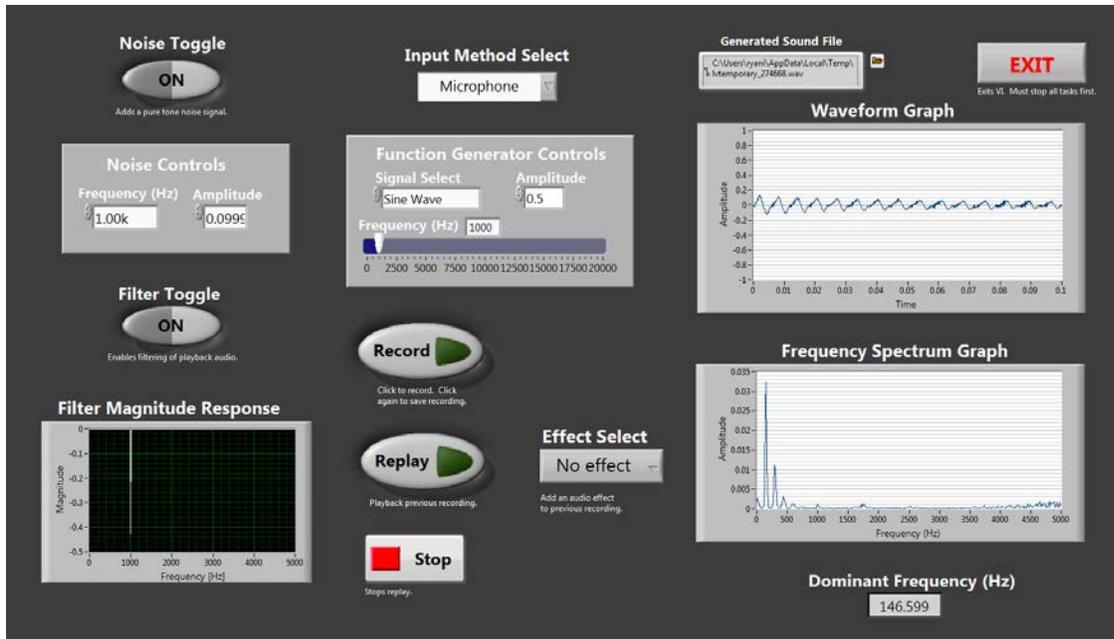


Figure 8: snapshot of the Labview GUI block diagram for noise removal

A4: Record and replay in Labview

Tasks:

- Create a sound recorder function. The input can be any of the input methods. Save the recorded sound to a file.
- Implement the sound replay function.

Lab results:

Figure 8 also shows the snapshots of these two functions realized in Labview.

A5: Various sound effects

Tasks:

- Create an echo effect. The input signal can be from any of the three input methods.
- Create a higher pitch doubling effect.

Lab results:

The echo effect has been created according the block diagram depicted in Figure 9. An example videos (“video_echo.mov”) are available to demonstrate these effects.

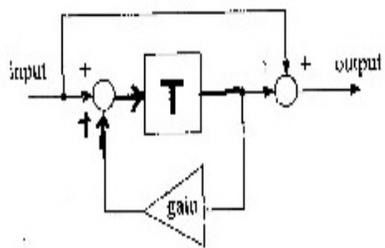


Figure 9: block diagram of an echo system

The complete Labview vi program structure for lab module #1 is shown in Figure 10.

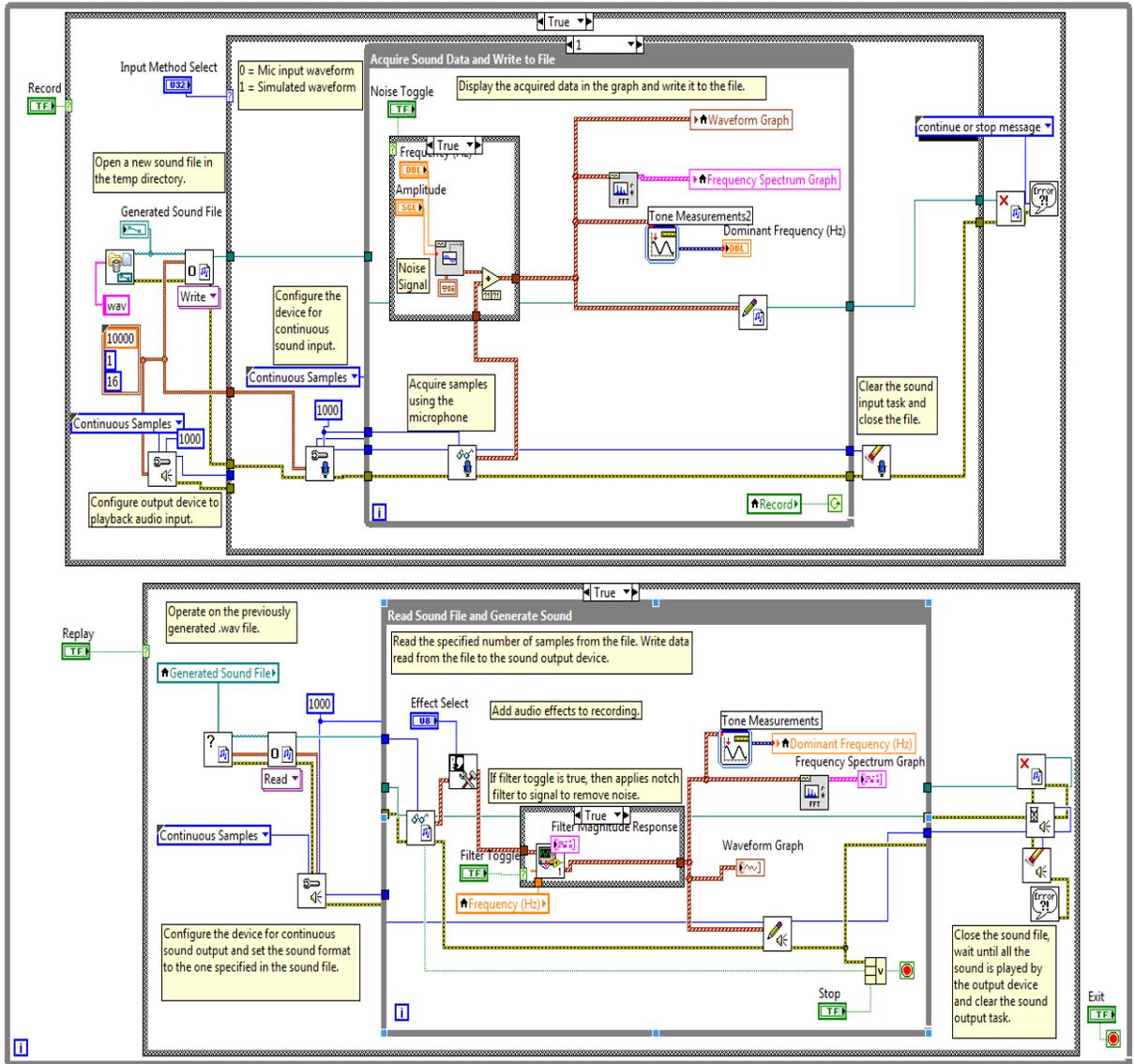


Figure 10: complete Labview vi program structure for lab module #1.

When a user speaks “fan”, the fan will start to operate; it will stop working when a user speaks “stop”. Testing results from a group of students who took the “digital communications” course in spring 2014 have indicated that the correct recognition rate is high and the system works as designed.

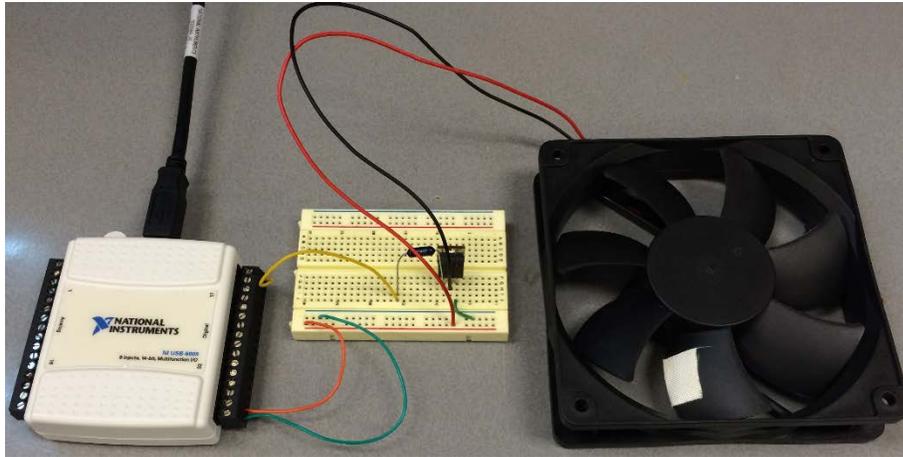


Figure 12: a photo of component connections for the voice-controlled fan system.

III: Conclusion

In this project, we have successfully developed a number of hands-on laboratory exercises for digital signal processing curriculum using Labview, Matlab, and data acquisition units. These labs offers students opportunities to practice DSP fundamentals with real-time real-life DSP applications in speech/audio/music. The resulting labs are fun and engaging.

In addition to the academic impact, the labs developed in this project will also benefit an outreach effort to inspire interests from younger students (e.g., 5th graders who participate in the annual WWU Compass to Campus program) in Engineering and STEM education. These labs will also serve as demos to showcase Engineering and Technology to prospective students, visitors, and guests.

Moreover, the lab modules, the software, and hardware employed to complete this project can be adapted to future laboratory and project developments in other areas such as *Instrumentation*, *Digital Communications*, and *Digital Control Systems* curricula.

Appendix A: source code and video clips

List of source code: (the source code files are available upon request)

VoiceRead.lvproj

VoiceRead.vi

VoiceRead.lvproj

VoiceRead.aliases

NoiseFilter.vi

AudioEffects.vi

Speech setup.vi

Speech check.vi

Speech test.vi

Filterdesign.m

List of example videos: (will be available publically on youtube.com)

video_echo.mov

Video_noise_mix.mov

Video_fiter.mov

Appendix B: timeline and budget information:

Timeline:

Tasks	Completion time
Research on components, hardware ordering, and testing; Brainstorm lab topics	March - July 2013
NI/Vernier DAQ interfacing and testing with Labview	August – October 2013
Lab modules development and testing	November 2013 – July 2014
Project report preparation	July - August 2014

Actual Budget:

Software and/or Hardware	Provider and Model	Cost
Matlab	Mathworks	Provided by WWU
Labview	National Instruments	Provided by WWU
Data acquisition evaluation unit	National Instruments and Vernier.com	\$250/unit * 4 unit
Other hardware components (Microphone, speakers, MOSFET, fan, etc.)	Miscellaneous	Provided by WWU
Total cost:		\$ 1000

Note:

The cost was covered equally through the ECETDHA MINIGRANT of \$500 and the WWU new faculty start-up fund of \$500.