

DEVELOPMENT OF THE DIGITAL COMMUNICATIONS LABORATORY EXPERIMENTS USING LABVIEW SOFTWARE WITH DATA ACQUISITION FUNCTIONS

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ABSTRACT

This study focuses on implementing the Digital Communications Laboratory to the LabVIEW software with data acquisition functions. The current software being used in this laboratory course is MATLAB SIMULINK 2010 which is outdated software. This research intends to take advantage of LabVIEW's graphical programming library to construct virtual trainers that will help the students to understand the fundamentals of digital communications along with the CHED Memorandum Order for Digital Communications Laboratory.

Keywords: *ICT for Engineering Education, Digital Communications, Experiments, LabVIEW, NI USB 6001.*

I. INTRODUCTION

LabVIEW, Laboratory Virtual Instrument Engineering Workbench, is a programming tool commonly used in the industry like C++ but it programs using icons or graphical notations instead of lines of text. Programming languages such as C++ can take programmers weeks or months to create a program, however, with LabVIEW, this can be completed in just hours because of its versatile interface and is very user friendly. It is used in applications of data acquisition, signal processing, telephone line encoder and decoder, analog to digital converters, and hardware control. The most common use for

LabVIEW is for hardware interface and data acquisition [1].

This study aims to implement LabVIEW in the LBYEC38 – Digital Communications Laboratory experiments while introducing the data acquisition device in some of the experiments. In doing so, a hardware component comprising of training module will be present in the output experiments of this study where LabVIEW will be used as an interface. LabVIEW was chosen to be the software for this study because it provides hands-on experiments to the students and it can help the students to understand the theories in digital communications and apply them in real life applications.

The current software used in Digital Communications Laboratory is MATLAB r2010a, this application provides limited tools to be used since it is an outdated version. In addition, the manual for the experiments used in this laboratory has narrow discussions of topics which results to questions that cannot be easily understood.

This research intends to modify everything from the software to be implemented, the

topics to be discussed, and the laboratory manual to be used by the students. The course outline to be applied to the experiments will only be based on the memorandum order for Digital Communications given by CHED. Replacing the old curriculum of Digital Communications Laboratory with a new set of experiments using the LabVIEW software, will enable the next batch of students who would take up the course to understand the fundamental theoretical aspects of digital communications.

The scope of this study is focused on the topics based on the CHED Memorandum Order for Digital Communications Laboratory which are the following [2]:

1. Introduction to Digital Communications
2. Noise Analysis in Digital Communication Systems
3. Sampling Theory and Analog to Digital Conversion
4. Digital Data Formatting and PCM Encoding
5. Amplitude Shift Keying
6. Frequency Shift Keying
7. Phase Shift Keying
8. Error Detection and Correction

These topics, however, were altered by the researchers since the current topics of the Digital Communications Laboratory needs to be integrated within the topics set by CHED and prompted the students to implement some of the experiments using the current software

used, SIMULINK. The inclusion of the data acquisition device are applied in at least two experiments. The data acquisition device that is used in this research is the NI USB 6001 Low-Cost Multifunction Device [3]. It has 8 analog inputs with a 14-bit resolution and 20 KS/s, 2 analog outputs, 13 digital I/O lines, and one 32-bit counter. It is connected to the PC through a USB port and it is portable. This device will be sufficient for the new sets of experiments since it will only be applied to simple signals in the experiments to which they are included [4].

The researchers' final set of experiments that has integrated the current course outline with the CHED Memorandum Order for Digital Communications Laboratory are the following:

1. Introduction to Digital Communications
2. Noise Analysis in Digital Communication Systems
3. Sampling Theory and Analog to Digital Conversion
4. Digital Data Formatting and Pulse Code Modulation
5. Amplitude Shift Keying
6. Frequency Shift Keying
7. Phase Shift Keying and Quadrature Phase Shift Keying
8. Error Detection
9. Error Correction
10. Baseband Communication

II. RESULTS AND DISCUSSION

A. Sampling Frequency Testing of the Data Acquisition Device

The specifications of the data acquisition device, USB 6001, says the maximum frequency of sampling that the device is capable of is 20kSamples/second. In testing the USB 6001's sampling rate, the researchers applied an analog input signal while increasing the frequency of the signal. Nyquist theorem suggested that the sampling frequency be at least twice the maximum frequency component of a signal to be sampled [5]. Since the USB 6001 is limited to a frequency of 20 kHz, the maximum allowable frequency, in theory, should be 10 kHz.

The testing included several trials of varying the input signal's frequency to the following values: 60 Hz, 100 Hz, 500 Hz, 1 kHz, 2 kHz, 5 kHz, 7.5 kHz, and 10 kHz.

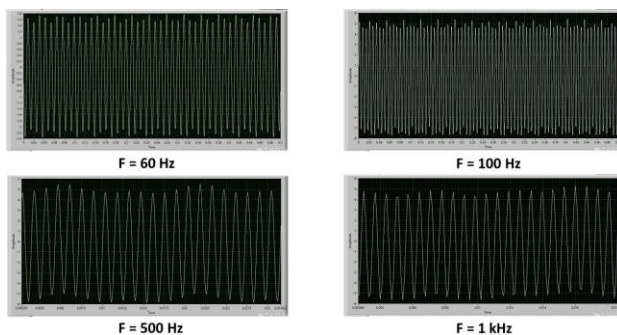


Fig 1. Sampling Frequencies: 60 Hz to 1 kHz

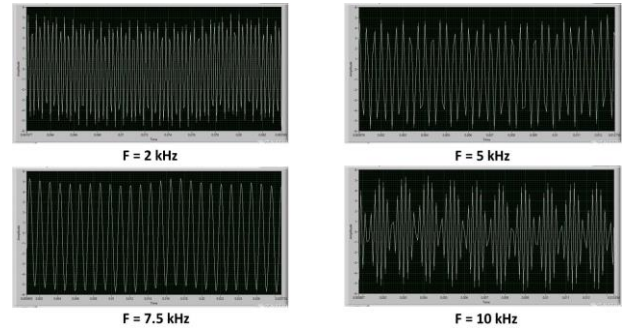


Fig 2. Sampling Frequencies: 2 kHz to 10 kHz

The results of the testing for every frequency can be seen in Fig. 1 and Fig. 2. As the results show, the sampled frequency at 60 to 500 Hz shows no aliasing yet. The signal at 1 kHz to 5 kHz show a signal that is deformed which suggests under-sampling. At 7.5 kHz to 10 kHz, the signal clearly showed that aliasing is taking place.

B. Results of Experiments

1. Experiment 1 – Introduction to Digital Communications

a. Simulation and Visualization

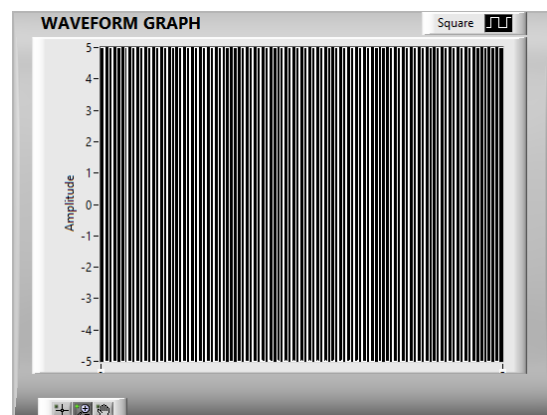


Fig 3. Square Wave with an amplitude of 5 and a frequency of 10

The first part of the first experiment focuses on the simulation and visualization of input signals in digital communication systems. The users can control the parameters of the signal during run time.

b. Telephone Signal – DTMF

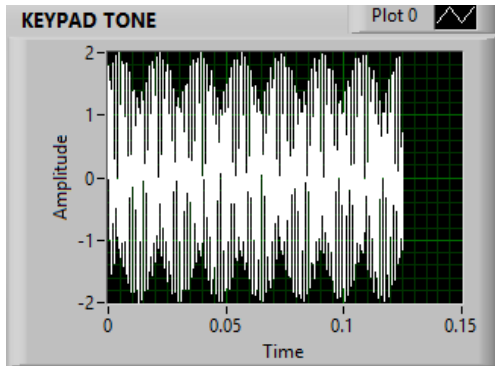


Fig 4. Waveform of Key = 2

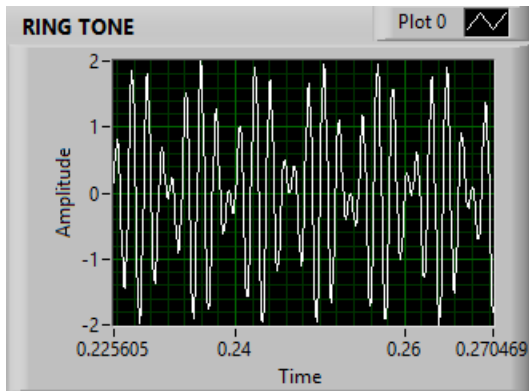


Fig 5. Waveform of Busy Tone

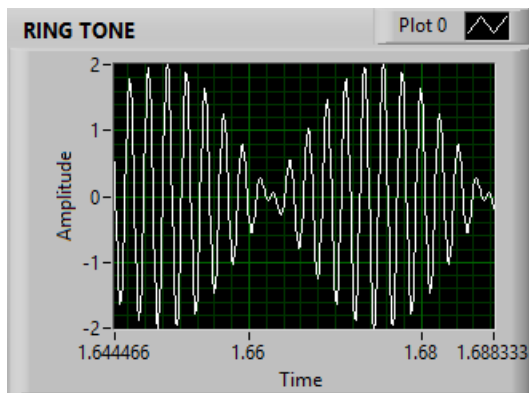


Fig 6. Waveform of Ringing Tone

Telephone tones are also part of the first experiment as part of the users' introduction to digital communications and the software, LabVIEW. The users will analyze the tones of each key in a DTMF keypad. Also, the tones when the line is busy and when it is ringing.

c. Data Acquisition

The data acquisitions introduction includes the USB 6001, and the researchers' I/O module [6]. This introduction is for the students to observe the link between the signals in the physical world and LabVIEW.

2. Experiment 2 – Noise Analysis in Digital Communication Systems

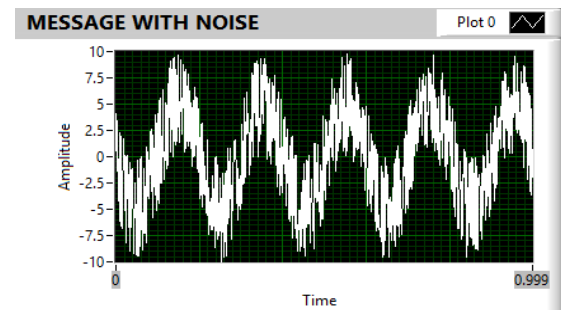


Fig 7. Message with Noise Waveform for Analog Signal

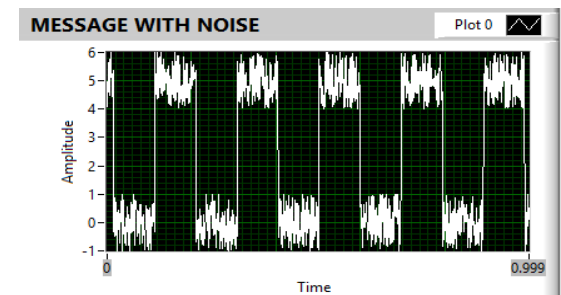


Fig 8. Message with Noise Waveform for Digital Signal

Experiment 2 focuses on how signals are affected by noise when transmitted through a

channel. During transmission is where signals are usually contaminated with noise [7]. Users are to analyze the effects of noise to the Signal to Noise Ratio.

3. Experiment 3 – Sampling Theory and Analog to Digital Conversion

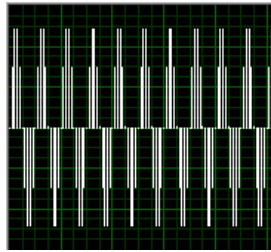


Fig 9. Sampled Signal

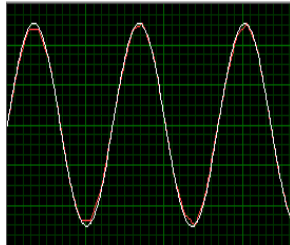


Fig 10. Reconstructed Signal

Experiment 3 focuses on the conversion of analog signals to digital signals. Figure 9 shows a sampled signal with a certain sampling frequency. Figure 10 is the reconstructed signal where the samples taken from sampling are approximated in amplitude levels wherein the number of amplitude levels are determined by the quantization level. The final output of this is the digital bit-stream. This experiment lets the students vary the sampling frequency and the levels of quantization to observe the process.

4. Experiment 4 – Digital Data Formatting and Pulse Code Modulation

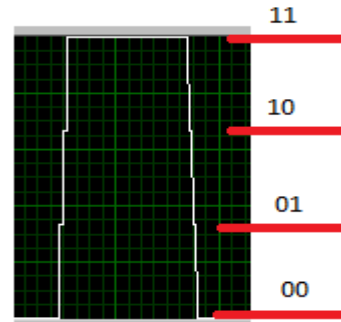


Fig 11. PCM

Figure 11 shows a PCM waveform with a bit length of 2. This means that there are 4 levels of amplitudes. Each are assigned their corresponding codewords.

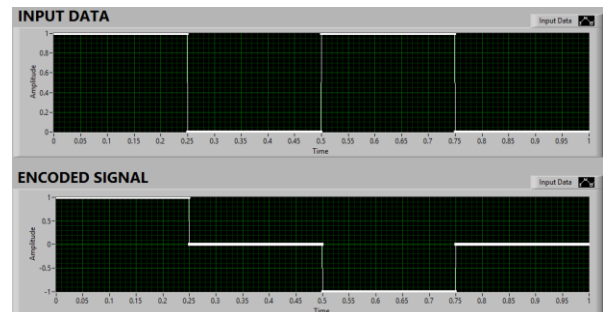


Fig 12. Bipolar NRZ

Figure 12 shows a bipolar line encoding scheme. This part of experiment 4 lets the users analyze the different line coding schemes such as the unipolar, bipolar, and the manchester.

5. Experiment 5 – Amplitude Shift Keying

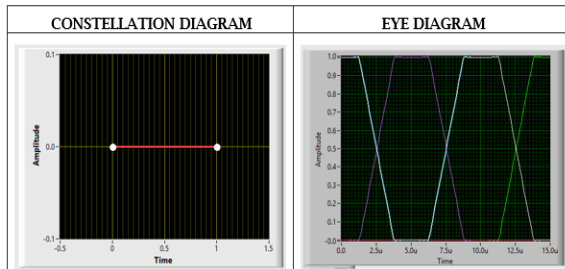


Fig 13. Constellation Diagram and Eye Diagram without Noise ($E_b/N_0 = 100$ dB)

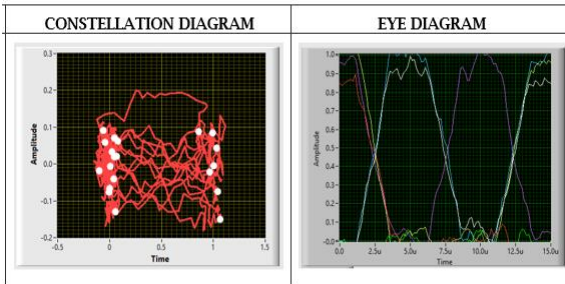


Fig 14. Constellation Diagram and Eye Diagram with Noise ($E_b/N_0 = 20$ dB)

This experiment will enable the students to simulate an M-ary ASK signal while observing and analyzing the Constellation Diagram, Eye Diagram, and Modulated Signal. It will also be demonstrated in this experiment on how noise affects the ASK signal. Fig 13. Shows the output of the Constellation and Eye Diagrams when there is an absence of noise. When noise is added to the modulated signal, the distortions can be seen on the Constellation and Eye Diagrams [8]. The value of the E_b/N_0 (bit energy to noise spectral density ratio) is inversely proportional to the visible distortions on the Constellation and Eye Diagrams [9]. It

was shown on the outputs of the Constellation and Eye Diagrams when the value of the E_b/N_0 is changed to 20, 40, 60, and 80 dB. When the $E_b/N_0 = 20$ dB, as seen in Fig. 14, the modulated signal becomes noisy and the receiver side may not recognize the high and low values of the original message. Thus, adding noise to the signal may cause the receiver side to obtain the wrong message/data. The students will also analyze how different user-defined variables such as the M-ary, carrier frequency, and eye length affect the outputs.

6. Experiment 6 – Frequency Shift Keying

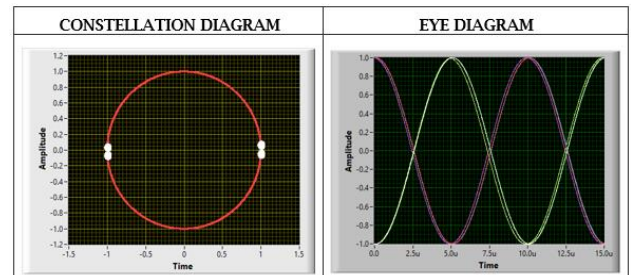


Fig 15. Constellation Diagram and Eye Diagram without Noise ($E_b/N_0 = 100$ dB)

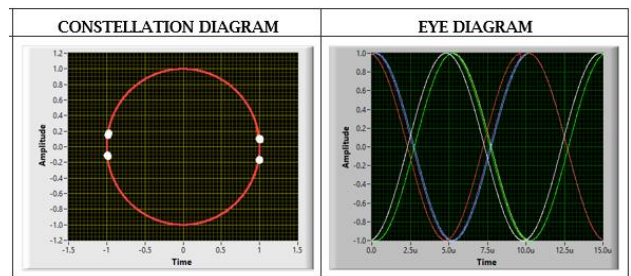


Fig 16. Constellation Diagram and Eye Diagram with Noise ($E_b/N_0 = 40$ dB)

In this experiment, the students will analyze an FSK signal through its Constellation

Diagram and Eye Diagram. The values of M-ary, carrier frequency, frequency deviation, eye length, and Eb/No (bit energy to noise spectral density ratio) may be varied in order to analyze how these variables affect the output. Unlike in ASK, there is no visible distortion in the Constellation and Eye Diagrams for FSK since the phase and amplitude of the signal is constant [10]. However, the distortion due to noise can be seen at the Modulated Signal waveform.

7. Experiment 7 – Phase Shift Keying

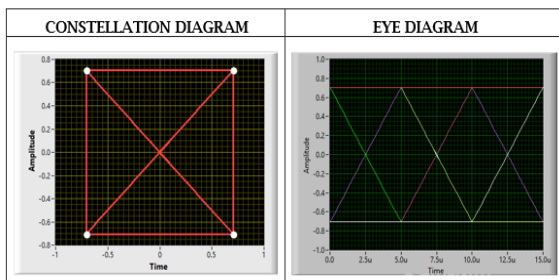


Fig 17. Constellation Diagram and Eye Diagram without Noise (Eb/No = 100 dB)

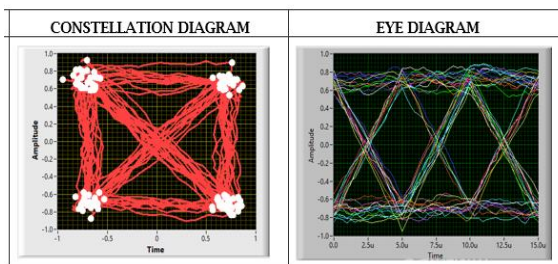


Fig 18. Constellation Diagram and Eye Diagram with Noise (Eb/No = 20 dB)

This experiment enables the student to simulate an M-ary PSK signal and observe their Constellation Diagram and Eye Diagram. The students may vary the values of M-ary,

carrier frequency, eye length, and Eb/No (bit energy to noise spectral density ratio) in order to analyze how they affect the outputs. Similar with the ASK signal, the distortions can be seen on the Constellation and Eye Diagrams when noise is added to the modulated signal. Adding noise to the signal may cause the receiver side to obtain the wrong message/data. Unlike in ASK and FSK, the Constellation and Eye Diagrams of PSK only showed distortion when the value of Eb/No = 20 to 40 dB [11]. Through the three experiments for digital modulation schemes, it can be observed that the most efficient digital modulation technique is Phase Shift Keying. It can be seen clearly in the Constellation and Eye Diagrams that PSK has a very low noise interference. Even though there are distortions in the Constellation and Eye Diagrams, the transmitted signal is still visible.

8. Experiment 8 – Error Detection

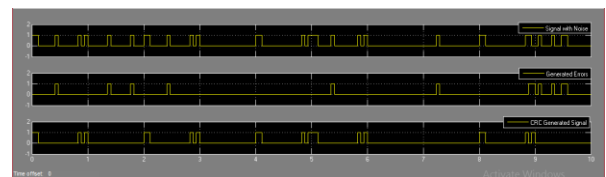


Fig 19. CRC Signal and Noise

Experiment 8 focuses on the error detection algorithm, Cyclic Redundancy Check. When an error is detected at the CRC syndrome detector, the system will prompt a message that requests the transmitter to retransmit the signal.

9. Experiment 9 – Error Correction

Error correction is the focus of Experiment 9. The two algorithms used in this experiment are the convolutional codes and the hamming codes.

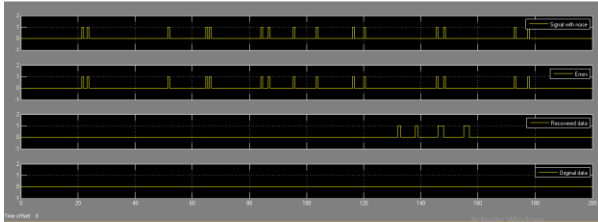


Fig 20. Convolutional Codes

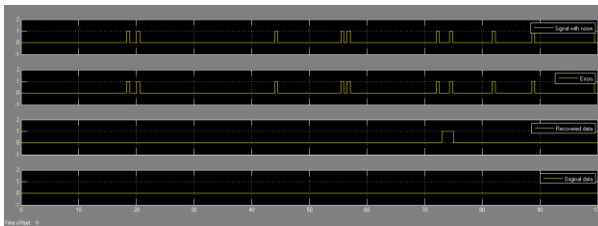


Fig 21. Hamming Codes

Fig 20 shows the effects of using the Convolutional Codes algorithm in correcting errors. The signal recovered showed fewer errors compared to the signal that went through the channel with the noise. For the Hamming Code, the same observation can be made however, the error rate of Hamming Codes show that it is more efficient in correcting data [12].

10. Experiment 10 – Baseband Communication

This experiment shows baseband communications using the digital modulation scheme, Quadrature Amplitude Modulation.

This modulation technique modulates the signal's phase and amplitude which has an improved data rate compared to the ASK, PSK, and FSK. This demonstration will show the systems operation and analyzing the results with noise added in the channel.

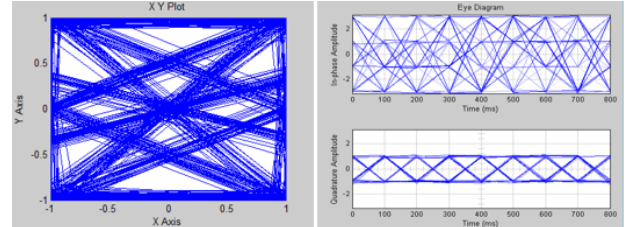


Fig 22. Constellation and Eye Diagram of QAM with $E_s/N_o = 20$ dB

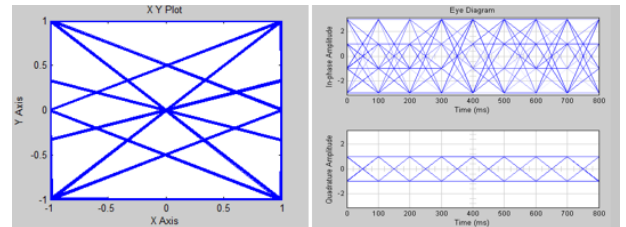


Fig 22. Constellation and Eye Diagram of QAM with $E_s/N_o = 40$ dB

Fig 22 shows the constellation and eye diagram for QAM with bit energy over noise ratio (E_s/N_o) of 20 dB. The graphs are contaminated by noise. Fig 23, however, showed a more stable graph with an E_s/N_o value of 40 dB.

C. Analysis and Results of Survey

TABLE I
 UNITS FOR MAGNETIC PROPERTIES

Questions	Mean
The laboratory manual has sufficient information to support the experimentation.	4.62
The block diagram designed showed the process clearly.	4.8
The results were clear and showed no ambiguity.	4.73
The procedure is easy to understand.	4.62
The guide questions are relevant to the topic and experimental procedures.	4.84

Questions	Mean
The concept theory is thoroughly discussed.	4.524
The procedures are clear and easy to follow.	4.476
The results were clear and showed no ambiguity.	4.667
The guide questions are significant to the topic.	4.524
The experiment is relevant and allowed a deeper understanding of the topic.	4.619
LabVIEW is a user-friendly software.	4.095
LabVIEW allows the student to analyze the data extensively.	4.476
The graphical user interface (GUI) allows the student to view live data efficiently and visualize analyzed results in a faster way.	4.333
LabVIEW has sufficient functions/tools/blocks/VIs which allow further exploration of the experiment.	4.667
LabVIEW allows seamless integration with instruments/equipment commonly found in laboratories and easily integrate them in virtual instrumentation system.	4.429

Each experiment designed by the researchers were tested by at least three students and were required to answer survey questions regarding the effectivity and clarity of each experiment.

Based on the results of the survey, the criteria with the lowest mean is LabVIEW's user-friendliness. The students thought that LabVIEW was very complicated. The results of the other survey questions ranged from 4.333 to 4.667. The interview answers of the interviewees showed positive results. The new

software offers a lot more than the previous software and that it is more interesting.

III. CONCLUSION AND RECOMMENDATION

This research sets a new standard for software experimentation. The key components that the students who tested the experiments admired are the Front Panel which served as the Graphical User Interface (GUI), the controls, the vast number of functions, and the hardware integration for a software-based experimentation. Comparing the experiments designed by the researchers with the previous experiments of the University, the students appreciated the interactive environment that the LabVIEW and MATLAB Simulink offer because the experiments provide a better observation and a deeper analysis into the results and processes. This is mainly because of the parameter controls that the user can set in LabVIEW while the program is running. The students were able to apply the theories in the lecture component of this laboratory course to the experiments since the topics of the experiments were synchronous with the lecture. Thus, the theories taught in the lecture class work hand-in-hand with the researchers' new set of experiments.

For those who are considering to continue to develop this research the researchers would like to recommend to add more DAQ functions focusing more on digital communication applications rather than using

the DAQ only as an I/O device for simple signals such as sinusoids and digital pulses. The researchers recommend synchronizing with the lecture class and provide some real-world applications to the topics discussed in the lecture component. This will significantly drive the students to appreciate and understand the fundamental principles of each topic.

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