

Utilizing LabVIEW™ for data acquisition and analysis for a 13 weeks undergraduate course

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Abstract

Second year Mechatronics undergraduates, in the year 2003 at Monash University Malaysia (MUM) were taking a subject module known as Project and Practise GSE2800. The concept of computer based data acquisition instrumentation was introduced to them. They had been presented with an engineering problem to utilize a data acquisition system to acquire real time, electrical signals with varying voltage as a function of time. Students were required to design and build a simple signal generator, capable of generating a periodically square waveform with frequency less than 1 kHz. At the same time, they were exposed to National Instrument's LabVIEW™ software and hardware for the first time. Each year, students who enroll for GSE2800 module, are required to complete a given project in only 13 weeks. In the year 2003, a team of 3 students was put together to design, develop and test a software program that they had coded in LabVIEW™, which is a graphical programming language. The main aim of this project design was to allow students to write codes in LabVIEW™ software for data acquisition, signal measurements and perform some fundamental Digital Signal Processing (DSP), namely the FFT (Fast Fourier Transform).

This paper reports that LabVIEW™ software may be employed as a useful tool for practical teaching and learning some DSP fundamentals to engineering undergraduates. A National Instruments PCI (Personal Computer Interface) 6036 E series DAQ (Data Acquisition) device and a Connector terminal Block, CB 68LP were provided to the students for this work.

This paper illustrates the gain of knowledge by the students who had worked on this project. Students had appreciated the DAQ functions to perform data acquisition, measurements and basic signal processing using LabVIEW version 6.1 in only 13 weeks.

1. Introduction

Signal processing is often perceived as a complex subject for many undergraduate students. As postulated by Garner and Downing¹, a subject such as Digital Signal Processing (DSP) cannot be learned through the medium of the blackboard or textbook. There are two different approaches for teaching DSP. The theoretical way or a practical approach may be

employed for teaching DSP to students. Undoubtedly, if the theoretical approach alone is used, the teaching of DSP tended to become algorithmically very mathematical². The theoretical concepts of signal processing are difficult to understand for students and even professionals without formal engineering training³. The theoretical approach for teaching DSP has one main drawback, which was suggested by Garner and Downing¹. The in-depth mathematical proofs of DSP theory often make most engineering students lose interest/motivation in the topic. Students often find it difficult to understand and appreciate the fundamentals of DSP. Therefore it will be challenging to see the practical approach to teaching, learning and appreciating the fundamentals of DSP to engineering undergraduates. Much work in this subject had been reported with regard to the teaching of DSP to students. However, the teaching of DSP was mainly devoted to ECE (Electrical and Computer Engineering) students⁴⁻⁶. For mechatronics students, it was believed that giving them some insight to the fundamentals of DSP and data acquisition would benefit them in this advance computer era.

This paper describes the work produced by a team of 3 students. They were put together for a hands-on learning experience in Mechatronics engineering. The rationale for hands-on learning in engineering had been widely studied by many researchers and in one particular study conducted by Ferguson and Hegarty⁷, they carried out an experiment and investigated on how college students learned the mechanics of pulley systems. Their study showed that students with hands-on equipment demonstrated a significant enhancement in their abilities to solve practical problems related to the real-engineering world, as compared to students who learned with diagrams. A graphical programming language, LabVIEW (Laboratory Virtual Instrument Engineering Workbench) had been chosen for this implementation. LabVIEWTM software has been well-recognised as a very powerful tool for data acquisition in test and measurement environment.

2.0 Project and practise module for students

Second year mechatronics students at Monash University Malaysia are required to enroll for a module known as the Project and Practice, GSE2800. This subject is compulsory for all mechatronics students in their second year. This subject is targeted at students with main intentions of allowing students to develop and build both 'soft' and 'hard' skills through a hands-on approach. The term 'soft' is used in this context, because students are required to write up reports and do their presentations about their project work. Students have the opportunities to practise their report writing skill and verbal communication skill through such training. On the other hand, the 'hard' skills are basically the technical know-how acquired during the project. It is strongly believed that students will develop skills, knowledge and confidence by investigating a given engineering project. This module comprises of 1-hour lecture and 3- hours of laboratory work per week. This module of the course lasts for 13 weeks in the second semester of each year. The actual available duration for students to work on the project is only *11 weeks* with the final 13th week reserved for project presentation and report writing. The first week of each semester is normally catered for students' orientation and administration matters. Therefore, the total number of scheduled laboratory duration is 33 hours. Students write a preliminary report on the 2nd

week and submit a mid-semester progress report of their work on the 6th week of every second semester.

Last year, there were 12 students taking this Project and Practice module. They were divided into four groups, and each group was presented with a project that was different from the rest. The main intention of this paper is to present the work done by a group of three students. Their project was to develop a real-time data acquisition system with signal processing capability namely the FFT. They utilized the National instruments data acquisition card (DAQ) and LabVIEWTM 6.1 software.

3.0 Software choice

A suitable software was required for this group of student project and was carefully considered. This software should support the following

- Real-time data acquisition
- Signal analysis
- Data visualization/presentation

One of the main criteria for the choice of software was the ease of interfacing and communicating with data acquisition hardwares. The duration for this project was only 13-weeks, careful decision on the choice of software had to be made prior to the start of the course.

To reiterate, one of the main objectives of this project design was to allow students to write software codes for data acquisition, measurements and perform some fundamental signal processing, namely the FFT etc. The students were expected to have a hands-on learning experience with regard to issues such as A/D conversion, sampling, signal processing implementation etc and a firm grasp of those mentioned. It was *not* the intention to enable this group of students to write complicated software codes such as instrument drivers etc. It was *not* the intention that students were allowed to use Digital Storage Oscilloscope (DSO) with signal processing capability to carry out this work. If the latter was done, it is believed that students at this level would simply regard the DSO as a “black box” performing the required measurement and analysis without thorough understanding for the principles behind its operation.

LabVIEWTM software was developed by National Instruments Corporation in the year 1986⁸. Developments and applications, specifically in LabVIEWTM based applications have shown very promising results. This can be seen in a survey paper reported by Nesimi Ertugul⁹. Custom-written virtual instrumentation (VI) can be easily delivered by relatively low-cost personal computers (PC). With the use of LabVIEWTM software, it instantaneously transforms the PC into a virtual instrument. It is believed that software is the most important component of a virtual instrument¹⁰. Table 3.1 shows some comparisons between traditional and virtual instruments. As mentioned in¹⁰, LabVIEWTM software is an integral part of virtual instrumentation because it provides an easy-to-use application development environment designed specifically to meet the needs of engineers and scientists. The ease of using LabVIEWTM and rapid prototyping were the key factors why this software was chosen for students’ project. From the author’s

personal experiences with LabVIEW™ software, he believes that students can learn and implement fundamental signal processing through LabVIEW™ software quite quickly. This is all the more true if the student has already had some background knowledge in computer programming, e.g. Java, C++, basic or others programming languages.

National Instruments supplies a wide variety of hardwares to complement her software. This has made LabVIEW™ software a very attractive and a good choice. In this work, the National Instrument's MAX (Measurement & Automation eXplorer), which is a configuration utility software was utilized. LabVIEW™ version 6.1 was used for this particular application.

Traditional Instruments	Virtual Instruments
<ul style="list-style-type: none"> • Vendor-defined 	<ul style="list-style-type: none"> • User-defined
<ul style="list-style-type: none"> • Function-specific, stand-alone with limited connectivity to outside world 	<ul style="list-style-type: none"> • Application-oriented system with connectivity to networks, peripherals and others
<ul style="list-style-type: none"> • Hardware is the key 	<ul style="list-style-type: none"> • Software is the key
<ul style="list-style-type: none"> • Can be expensive 	<ul style="list-style-type: none"> • Lower cost in the long run
<ul style="list-style-type: none"> • Closed, fixed functionality 	<ul style="list-style-type: none"> • Open architecture, flexible functionality leveraging on familiar computer technology. In short, reusable and reprogrammable or reconfigurable.
<ul style="list-style-type: none"> • Can be bulky and takes up a lot of laboratory space 	<ul style="list-style-type: none"> • Usually are plug-in boards into PC, do not take up laboratory space outside of the PC.
<ul style="list-style-type: none"> • Frequently lack portability 	<ul style="list-style-type: none"> • Highly portable in nature

Table 3.1 shows some comparisons between traditional instruments and virtual instruments

4.0 Hardware requirements

The main hardware used was the National instruments PCI-6036E series DAQ card, which comprises of a 16 analogue inputs, 2 analogue outputs channels. The sampling rate of this card is up to 200 kSamples/s. A Connector terminal Block, CB 68LP was used for interfacing purpose. A Pentium 2 personal computer was used for this application.

5.0 Data acquisition testing using DAQ board

Students were given the opportunity to perform the installation of both the hardware and the LabVIEW™ software onto a Lab PC. After successful installation, they proceeded to

utilize the MAX for configuration and testing. They were able to verify that the DAQ board is working properly through the use of MAX.

5.1 Using MAX (Measurement & Automation Explorer)

Figure 5.1.1 shows a typical window view of MAX after it has been launched. It allows self-test of device resources. Testing of the functionality of the DAQ device can be achieved, by clicking on the test panel menu as shown in figure 5.1.2

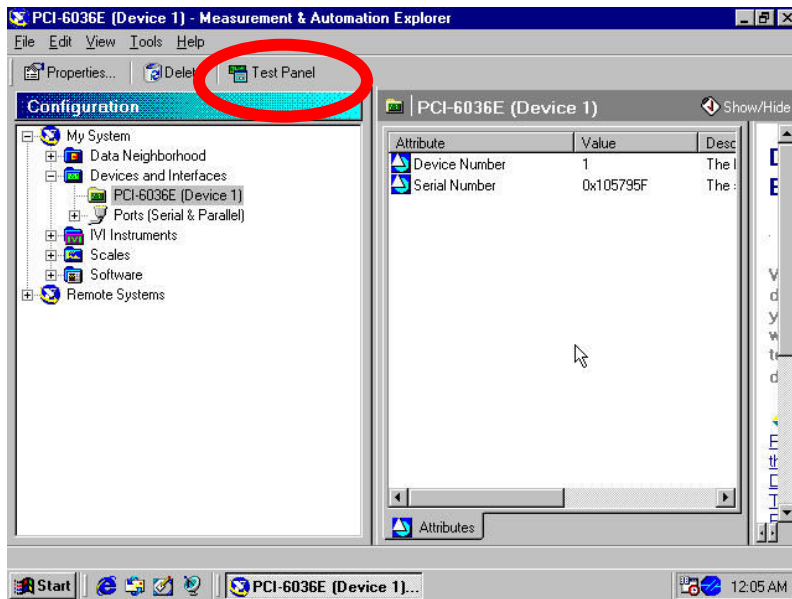


Figure 5.1.1 shows the National Instruments MAX configuration program. The PCI-6036E DAQ card is shown as device number 1. The test panel can be launched by simply depressing the test panel function bar that is circled as shown in the figure.

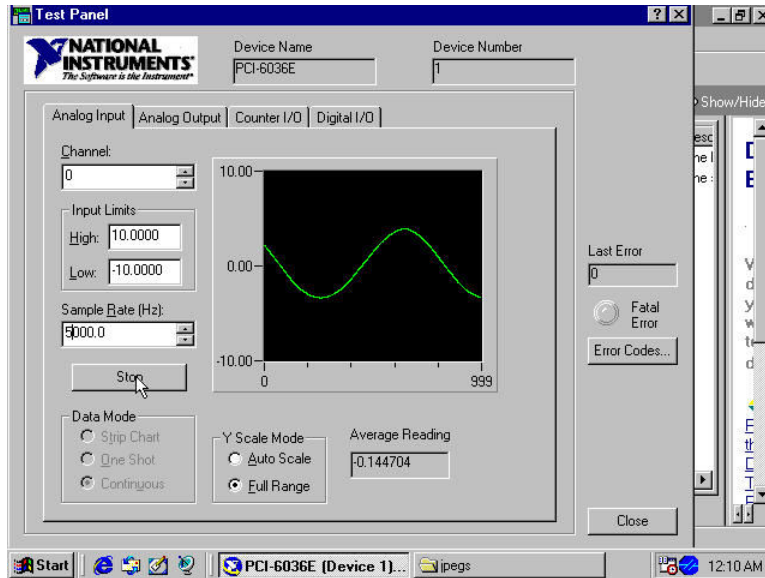


Figure 5.1.2 shows the NI MAX's test panel. The test panel allows user to test the various functionality of the DAQ board, such as Analog Input and Output, Counter and Digital I/O (Input/Output).

The NI MAX configuration utility is a very useful tool. Students were able to verify correctly and quickly that the DAQ board was functioning properly or not at that time.

5.2 Waveform generator constructed by the students

The students had constructed a simple square wave generator using a 555 timer operating as an astable multivibrator or so called a free running oscillator. This square wave generator was capable of generating a square wave with a frequency in a range from 100 Hz to 1 kHz. Subsequently, the square wave signal was applied to the analog input channel of the data acquisition system.

6.0 LAVINST project overview & labview programming

Mechatronics is often perceived as a synergistic integration of mechanical, electrical & electronics and computing engineering disciplines. However, in this work, students were mainly focusing on only two out of the three engineering disciplines. The students have codenamed their project as LAVINST. The simplified block diagram for the students' project LAVINST is shown in figure 6.0.1.

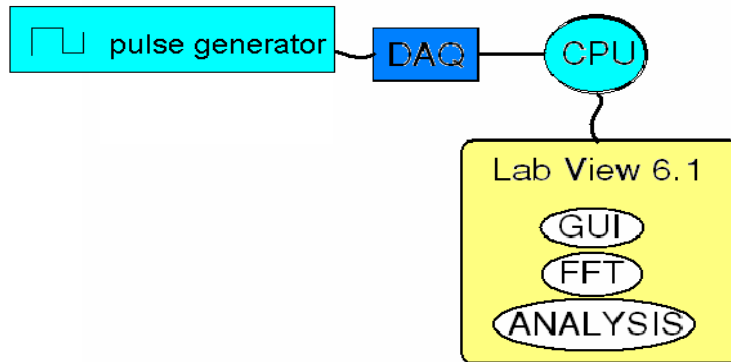


Figure 6.0.1 shows the simplified block diagram for this project LAVINST. It encompasses a complete virtual instrumentation.

Generally speaking, a virtual instrument consists of an industry/standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-in boards, and driver software. Virtual instrument performs similar functions to that of traditional instruments⁷. In this work, students had developed and customized a virtual instrument of their own to perform data acquisition, measurements and fundamental signal processing to meet the aim of the project.

This section describes briefly how the students were introduced to LabVIEWTM. The students were given copies of the following manuals namely as follows:

- LabVIEWTM Basics 1 Introduction course manual¹¹
- LabVIEWTM User manual¹²
- Hands-On Introduction to LabVIEWTM Graphical Development Environment Seminar¹³
- Data Acquisition and Signal Conditioning course manual¹⁴
- LabVIEW for measurement and Data Analysis¹⁵
- A Survey of Modern computer-based experiments¹⁶

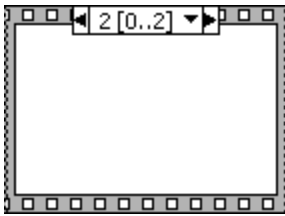
They were given the LabVIEWTM evaluation CD-ROM so that they were able to try this software at their own free time.

6.1 Students exposure to LABVIEW for the first time

These students had no knowledge or experience in LabVIEWTM prior to this course. During the course, students would have a chance to understand the nature of LabVIEWTM programming through a scheduled 4 hours intensive lecture. During the lecture, LabVIEWTM environment, including windows, menus, tools, front panels, block diagrams,

dataflow programming and various tools palette available in LabVIEW™ software were shown to students to enhance their learning.

Generally, students were taught about the commonly used structures in programming like the 'WHILE', 'FOR', 'CASE' structures, 'SEQUENCE' that are available in the function palette at the block diagram level. Adequate time was required by the instructor to explain to the students the main functionality and features in the LabVIEW™ environment. As examples, the following 'SEQUENCE' and 'WHILE' Loop structures are briefly explained.



Sequence Structure. It may consist of one or more subdiagrams, or frames, that execute sequentially. The top of the sequence structure is a sequence selector identifier. It consists of the current frame number and the range of the frames in the center and decrement and increment arrows on each side. These arrows can be clicked to scroll through the available frames. There is a down arrow next to the frame number, a frame can be selected from the pull-down menu when clicked. Right click on the structure border to add and delete frames, or to create sequence locals to pass data between frames. The frame number cannot be assigned manually. LabVIEW™ will automatically adjust the numbers in the frame selector identifier. In this case, the sequence structure executes frame 0 first, then frame 1 and followed by the last frame, which is frame 2.



While loop structure. The while loop is similar in the text-based programming to execute a sub diagram continuously until a condition is met. There is a conditional terminal or an input terminal on the right end corner of the loop. It only receives a specific Boolean value. The default behavior of the conditional terminal is Continue If True. The loop will be continuously executed as long as the input value is TRUE. In other words, the loop will be terminated until the conditional terminal receives FALSE. The behavior can be changed by right-click on the terminal or the border of the While loop and selecting Stop If True. When it has been changed to this behavior, the loop executes its sub diagram until the terminal receives a TRUE value. Because the VI checks the conditional terminal at the end of each iteration, the while loop always executes at least one time.

As a matter of fact, it was impossible for the instructor to explain and cover all the functionality in LabVIEW™ to the students in such a short span of allocated time. Students were encouraged to spend time on their own to explore in more details about LabVIEW™.

6.2 Single-sided Fast Fourier Transform & programming details

The pedagogical approach was to allow students to develop fundamental concepts first through the investigation of the single-sided FFT. This was achieved through the use of LabVIEW™ but not with the DAQ board initially. Once the students were confident and understood the fundamentals of FFT, they were allowed to proceed with data acquisition, measurements and others.

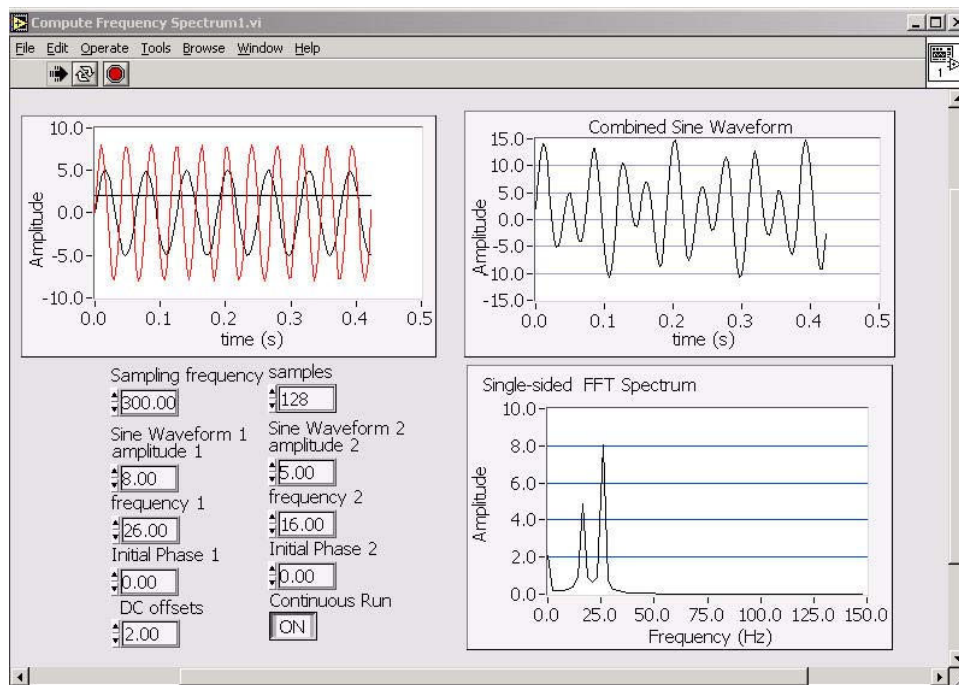


Figure 6.2.1 LabVIEW™ front panel development for the display of both the time and frequency domains of waveforms. The front panels are distributed into 4 quadrants as shown. Going clockwise, the 1st quadrant on the top left hand side displays the individual signal profile. The 2nd quadrant shows the summation of the three-signal profiles. The 3rd quadrant shows the single-sided FFT profile. The 4th quadrant shows various controls for making adjustments to input signals.

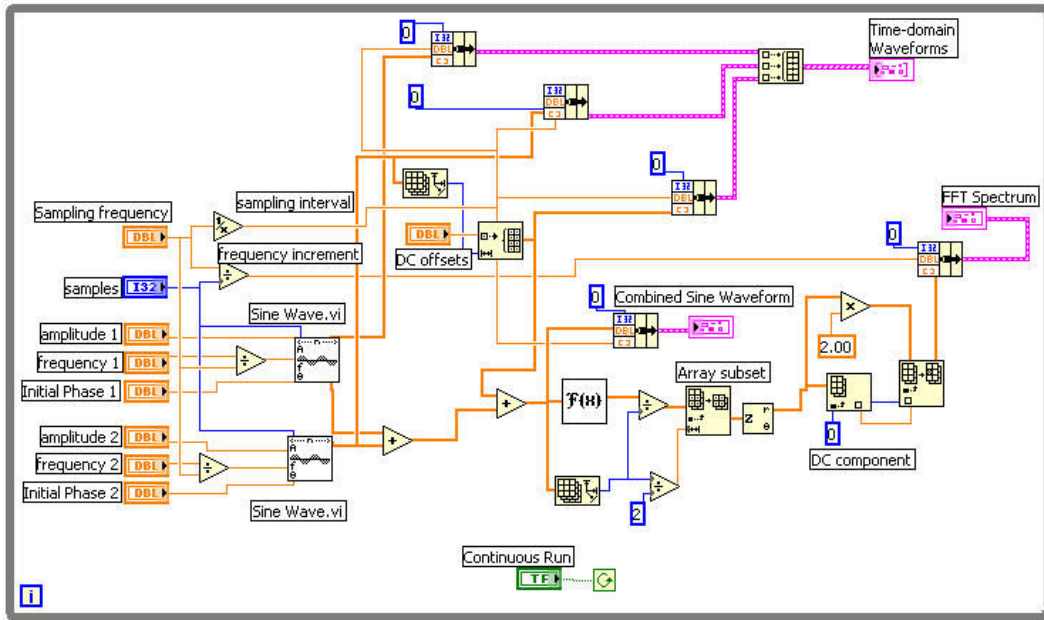


Figure 6.2.2 LabVIEW™ block diagram development by the students. This particular VI can generate three different types of signals, namely a DC offset, and two Sine Wave signals, which are user-defined. The addition of the three signals profiles is shown as a combined Sine waveform. The Single-Sided FFT profile is shown at the end as a FFT spectrum.

The students designed their VI such that it allowed the user to vary three different signals via the control as shown in figure 6.2.1. The three different signals profiles were subsequently summed up and displayed. Single-sided FFT shows the positive frequency components that are displayed in figure 6.2.1.

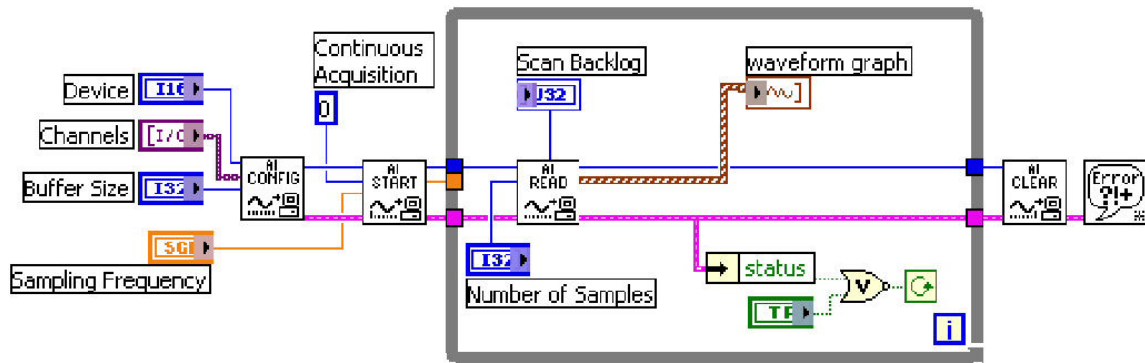


Figure 6.2.3 The VI students used for continuous data acquisition using the PCI 6036E series plug-in board

This paragraph discusses about the figure 6.2.3, the VI that was used for data acquisition. An acquisition can be started by configuring the device number, channels, buffer size with the AI Config VI. The AI Start VI will set the sampling frequency and start the acquisition. A constant zero is assigned to enable the AI Start VI to start a continuous buffered acquisition. The AI Read VI, which is located inside the While loop, will read the data from the buffer with the specified number of samples. The acquired data will be plotted on the waveform graph. To prevent buffer overflow, the number of samples cannot be set equal to the buffer size. Normally, the number of samples is set to one-fourth or one-half the buffer size for a continuous acquisition. If the scan backlog increases steadily, the buffer might overflow and generate an error.

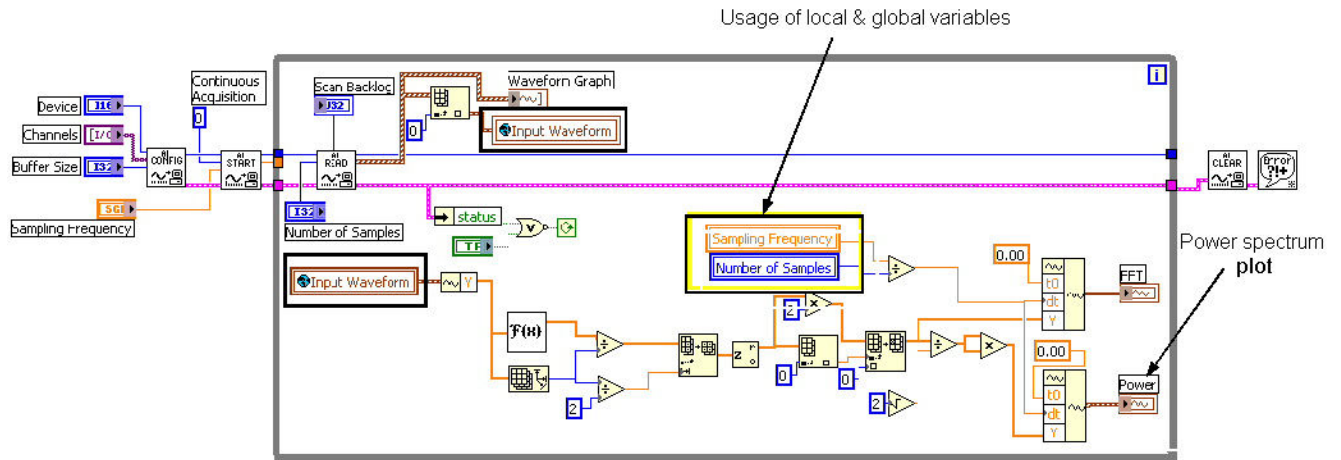


Figure 6.2.4 The VI students used for continuous data acquisition with the integration of the FFT and power spectrum into their block diagram. The usages of local and global variables are highlighted as shown. They were used mainly to eliminate very messy diagram wiring.

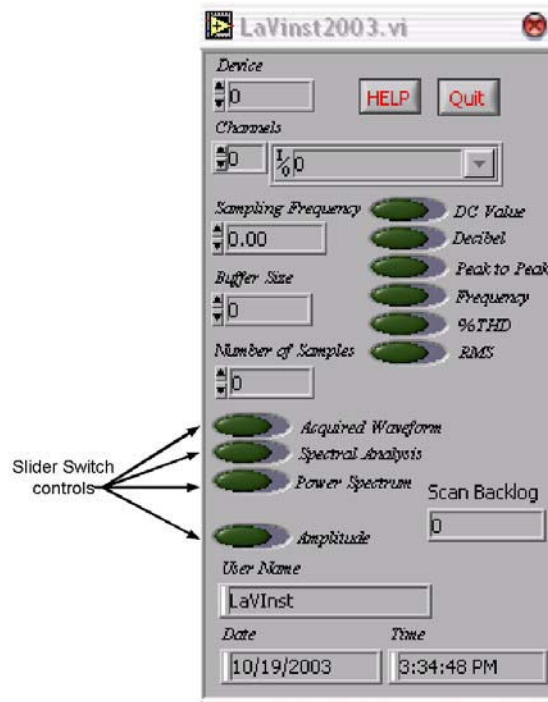


Figure 6.2.5 Student's final LAVINST project front panel as shown above. There are various slider switch controls as highlighted in the figure. When this program is running, enabling the desired slider switch control will launch a popup window for its specified function.

LAVINST project front panel is shown in figure 6.2.5. In this program coded by students, it can be seen that various measurements are catered for after real-time data acquisition of an input analog signal. The measurements include the following:

- DC Value
- Decibel
- Peak to Peak
- Fundamental frequency
- % of total harmonic distortion
- RMS

The acquisition of the real time signal can be viewed by clicking on the slider switch control and will launch a popup window. Similarly, the spectral analysis (Single-sided FFT) and the power spectrum can be viewed by clicking the appropriate slider switch controls.

7.0 Student response to this hands-on session

Initially, students were quite intimidated and they found LabVIEW™ software quite daunting and overwhelming due to unfamiliarity. However, getting accustomed to LabVIEW™ software, they were impressed by the functionality of LabVIEW™ and virtual instrumentation. They had expressed their thoughts that learning and appreciating the fundamentals of signal processing, data acquisition and measurement. They had compared this hands-on approach with the theoretical mathematically method. They gave a remark “LabVIEW™ is easy to learn and a very useful tool for learning FFT indeed”. This seems to support the findings by Ferguson and Hegarty ⁷. They found students’ learning and understanding improved through a hands-on learning approach.

8.0 Concluding remarks

In this paper, the hands-on learning and implementing using LabVIEW™ for undergraduates have been demonstrated successfully. Students were able to perform real-time data acquisition, measurements and fundamental signal processing using LabVIEW™ software. The students had no previous experiences in LabVIEW™ before and it has to be noted that rapid prototyping and software development by the students was made possible through the use of LabVIEW™. The students had acquired a better understanding of the fundamentals of signal processing and data acquisition. The use of LabVIEW™ in this project and practise, GSE2800 subject is an effective way for hands-on learning for this group of mechatronics students. LabVIEW™’s ease of use, coupled with its power and flexibility, are noteworthy advantages in the development of hands-on learning experiences for students. It is noted that students with some basic background knowledge and experience with programming language, in this case, Java programming are at advantage. Students are quicker to pick up another programming language such as LabVIEW™. The

graphical approach, or icon based LabVIEW™ software programming seems to be an effective way for students' learning in particular the data acquisition, measurements and fundamental signal processing.

5.0 Acknowledgement

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Biography

Alex See obtained his Bachelor degree (Hons) in Electrical and Electronics Engineering from University of Leicester, UK in 1998. He was given a fee waiver scholarship at University of Leicester to pursue his PhD in the area of high voltage engineering immediately after his graduation. He had obtained his PhD in the year 2001. He had worked with the Defense Science Organisation (Singapore) as an engineer for one year. He is currently an Engineering lecturer at Monash University at Malaysia campus.