AC 2008-922: INCORPORATING LABVIEW TO ENHANCE THE LEARNING EXPERIENCE IN THE ELECTROMECHANICAL ANALYSIS LABORATORY

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Incorporating LabVIEW to enhance the learning experience in the Electromechanical Analysis Laboratory

Abstract

This paper describes our experiences in incorporating data acquisition and virtual instruments in the Electromechanical Analysis Laboratory to promote hands-on and real-world experiences to students enrolled in the mechanical and the electromechanical engineering technology programs at the State University of New York, Alfred. Because the students taking this course come from two different backgrounds, mechanical engineering technology and electrical engineering technology, the incorporation of virtual instruments has helped to balance the difference in the backgrounds. The paper describes in detail how the experiments have been organized to ensure that students from both backgrounds acquire the knowledge and skills in the mechanical and the electrical components of the course.

Introduction

The present work describes our experiences in incorporating LabVIEW® in laboratory experiments to help enhance the learning experience for the Electromechanical Analysis (EMA) course in the Engineering Technology Department. The EMA course is a sophomore level course, required for students enrolled in both the Mechanical Engineering Technology and the Electromechanical Engineering Technology programs at the State University of New York, Alfred. The EMA course presents an integrating experience of mechanisms and instrumentation. This course emphasizes applications of material learned in courses involving statics, dynamics and strength of materials and introduces students to vibrations. The integration of these subjects is enhanced through laboratory experiments where students study different mechanisms with the aid of transducers and electronic instrumentation. The material covered in the lectures include the study of levers, links, slide mechanisms, cams, scotch yoke and the principles of force, torque, velocity, acceleration, inertia and friction. The laboratory covers techniques of instrumentation for research and development and automation including set-up and calibration of transducers, readouts of electrical signals and data acquisition.

Since the Mechanical Engineering Technology program is offered by the Mechanical Engineering Technology (MET) Department, and the Electromechanical Engineering Technology program is offered by the Electrical Engineering Technology (EET) Department, students taking the EMA course come from two very different backgrounds. Because of this, students from the MET department have little or no knowledge and skills in measurement of electrical signals, however, they have a more solid background in statics, dynamics and strength of materials. On the other hand, students from the EET department lack knowledge and skills in statics, dynamics and strength of materials, but are skillful in the measurement and principles of electrical signals.

To balance this difference, the lectures and laboratory material have been carefully planned. To enhance the learning process, the EMA course is a team taught course where the lecture is taught by a MET faculty member, and the laboratory is taught by an EET faculty member. The laboratory experience has been organized in such a way that students from both backgrounds will share strengths and experiences that will help each other to better learn the subject. As part of these changes, data acquisition boards and LabVIEW® software have been incorporated in the EMA laboratory, substituting the traditional electronic equipment, such as, oscilloscopes, digital multimeters, signal generators and signal conditioning circuits (such as electronic amplifiers and filters). This change has been greatly welcomed by the MET students, who find the virtual instruments more appealing to their knowledge and skills. On the other hand, the EET students have also received very well the use of data acquisition and virtual instruments, since it offers a new and interesting way of doing measurement of electrical signals.

Importance of Virtual Instruments.

Virtual instruments are flexible tools that promote hands-on and real-world experiences to engineering students. Nowadays, virtual instruments are common in industry, and many companies continue to invest in the virtual instrument concept because the cost of laboratory equipment is significantly reduced with virtual instruments. By using virtual instruments, companies easily modify testing, measurement, and control procedures without the need for purchasing additional equipment. Therefore, students with skills in virtual instruments are better prepared to meet the demands of industry [1,2,3].

Virtual instruments can help to enhance engineering education in a variety of undergraduate laboratory settings and can be adapted for different learning levels and environments. As reported in the literature [4,5,6], virtual instruments offer versatility in measurement and the development of laboratory procedures as well as emulate industry standard practices. A virtual instrument can be easily modified to create an individualized laboratory experience based on the skills and knowledge of students while maintaining the fundamentals of the experiments. One of the most desirable technical skills of engineering technology graduates is the ability to conduct and design experiments (ABET Engineering Criteria c) .

Course Format and Description

The Electromechanical Analysis course is a four-credit course that meets for three one-hour lectures and one two-hour laboratory per week. The course learning objectives are shown in Table 1. The EMA course is team taught, the lectures are taught by a MET faculty member and the laboratory is taught by an EET faculty member. The topics covered in the lectures mainly involve theoretical analysis of statics, dynamics, and strength of materials. A summary of the topics covered in the lectures is given in Table 2.

Course Learning Objectives
• Apply basic methods of statics, dynamics and kinematic analysis • Analyze the characteristics of common mechanisms • Be able to work with, describe and use the common types of mechanical to electrical transducers used in this course • Be familiar with signal conditioning concepts, data acquisition, collection, and interpretation from different transducer sources

Table 1. Course Learning Objectives

Lecture Topics
• Static equilibrium. Free Body Diagrams. Elasticity • Mechanics of materials. Rotation about a fixed axis. • Mass moment of inertia • Kinematics. Geometry of motion • Position, velocity and acceleration • Work and Kinetic Energy • Vibrations

Table 2. Lecture Topics

The electrical aspects of the course are completely covered in the laboratory sessions. The topics covered in the laboratory are related to instrumentation, transducers, electrical measurements and data acquisition. Table 3 shows a list of typical laboratory experiments.

Introductory Labs	**5 Weeks**
Introduction to Electrical Measurements	7 basic stations
Introduction to Signal Conditioning Circuits	7 basic stations
Introduction to LabVIEW & Data Acquisition	7 basic stations
Lab Rotation A – Basic Applications	**3 Weeks**
Static Weight Scale Measurements	2 stations
Force Measurements	2 stations
Angular Displacement Measurements	2 stations
Lab Rotation B – Advanced Applications	**6 Weeks**
Flywheel Characteristics	1 station
Scotch Yoke Analysis	1 station
Center of Percussion	1 station
Punch Press Analysis	1 station
Linear Vibration Analysis	1 station
Cam Analysis	1 station

Table 3. EMA Laboratory Experiments

Details of the course topics, including laboratory handouts are linked to the course website [7].

The Electromechanical Analysis Laboratory

As mentioned before, the EMA course is a required course for students enrolled in both, the Mechanical Engineering Technology (MET) and the Electromechanical Engineering Technology programs (the latter being part of the Electrical Engineering Technology, EET, Department). Usually the number of MET students is significantly larger than the EET students (80% or more are MET students), therefore to ensure some heterogeneity in the laboratory teams, the lab instructor assigns each student to a team (two to three students per team). Furthermore, to expose students more to team setups, the instructor will reassign teams two or three times during the semester.

The EMA Laboratory has seven basic stations to accommodate 14 to 16 students. Students work in groups of two or three. Each basic station is equipped with a PC, digital oscilloscope, digital multimeter, power supply, function generator and data acquisition board. The data acquisition hardware and software is the NI PCI-6024E from National Instruments (200kS/s, 12 bit, 16-Analog-Input, 8 digital I/O lines, two 24-bit counters) and LabVIEW® 7.1. Figure 1 shows a basic EMA Lab station.

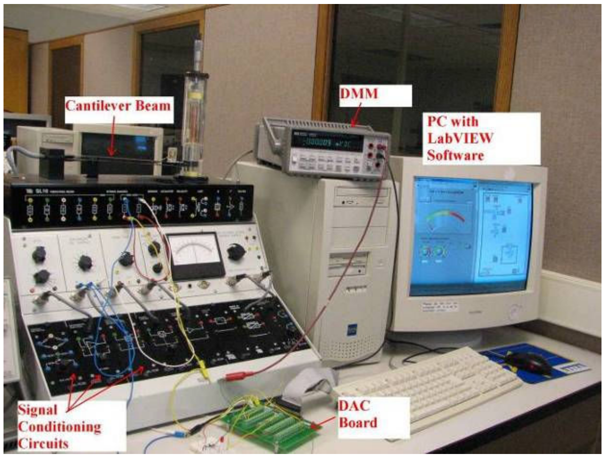

Figure 1 - Basic Electromechanical Analysis Lab Station

Besides these basic stations, the EMA laboratory is equipped with nine stations for application specific experiments (Table 3). These application specific stations include a press punch with a large flywheel and a crank and slider mechanism. To characterize the flywheel (angular velocity and acceleration) a DC motor generator is attached to the wheel (Fig.2). A linear potentiometer and a linear velocity transducer (LVT) are attached to characterize the crank and slider mechanism (Fig 2).

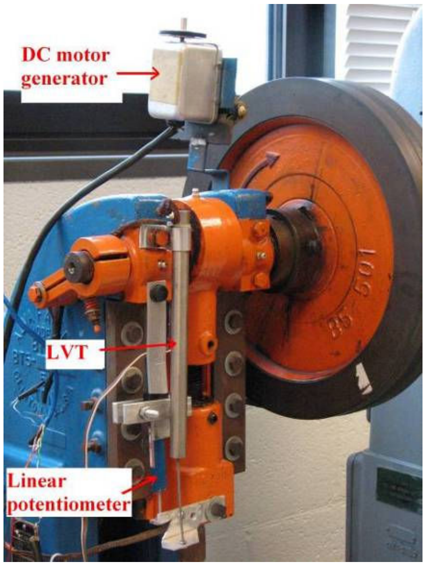

Figure 2- Press Punch Station

The force measurement station consists of a platform with an aluminum bar that is setup as a cantilever beam. A stain gage is mounted on one end. Different weights can be hung on the other end (Fig 3).

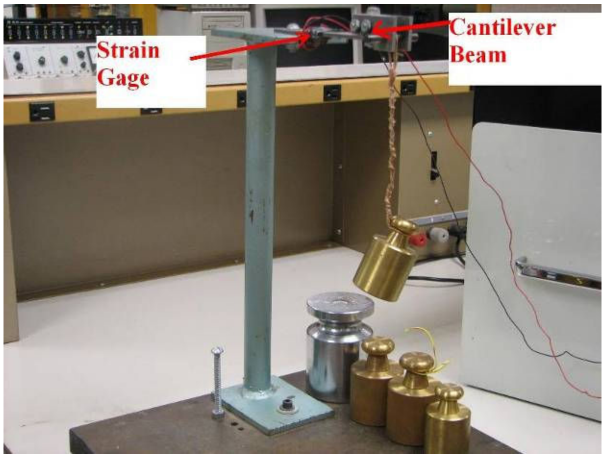

Figure 3 - Force Measurement Station

The static weight station consists of a metallic frame where load cells are placed to measure the force at different position in the weight structure (Fig. 4).

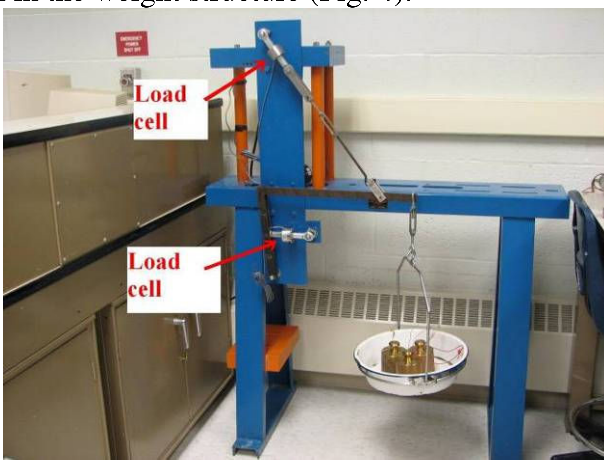

Figure 4 - Static Weight measurement Station

A Scotch Yoke mechanism is provided with a linear potentiometer and a linear velocity transducer (LVT) to characterize the displacement and velocity of the mechanism (Fig. 5).

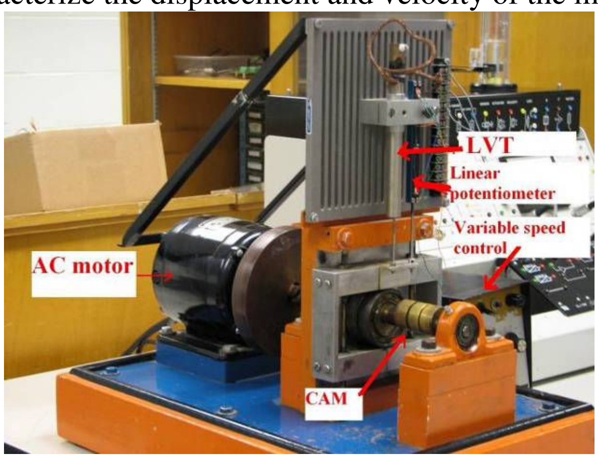

Figure 5 - Scotch Yoke Station

The center of percussion station is a metallic structure with a free-swing beam (a strain gage is mounted on the beam to measure the pin reaction force at the fixed end). This structure has an adjustable stop bar that allows the study and characterization of the center of percussion (Fig. 6).

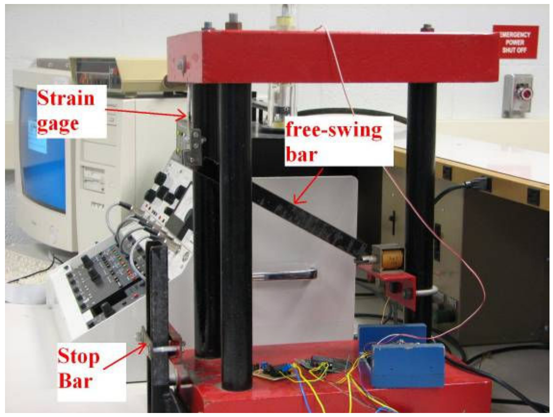

Figure 6 - Center of Percussion Station

The Cam station consists of an engine camshaft mounted on a Lathe. A linear variable differential transformer (LVDT) and a linear velocity transducer are mounted to allow the students to analyze the lobe characteristics of the Cam (Fig.7). The vibration station consists of a brass beam mounted as a cantilever beam with a fixed weight mounted on its free end to provide beam vibration. A strain gage is mounted on the beam to measure and analyze the beam vibration.

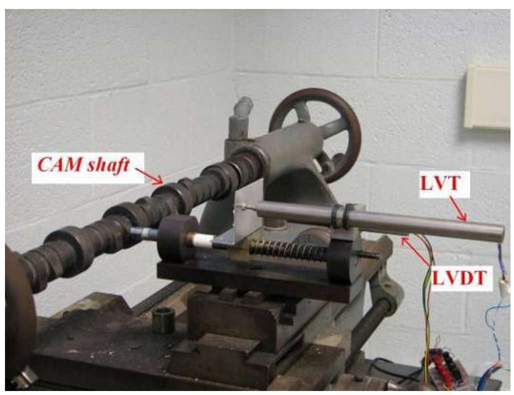

Figure 7 - Cam Analysis Station

Description of the Lab Experiments

The laboratory is divided into three groups as shown in Table 3. Students spend the first 5 weeks of the semester working on the introductory lab experiments. After that, students progress through the basic application experiments, which is a group of three different lab experiments. Finally, students spend the last six weeks working on the advanced application experiments. The last introductory lab is an introduction to LabVIEW®. All the rest of the lab experiments have LabVIEW® incorporated into them.

The introductory lab experiments begin with the measurements of AC & DC signals using digital multimeters and oscilloscopes. Ohm's law and the voltage divider applications are also covered as well as the characteristics of analog and digital signals. In the last introductory lab experiment, LabVIEW® is introduced. A working LabVIEW® "shell" file has been developed for students to learn from. The "shell file" virtual instrument, or "VI" for short, is illustrated in Figure 8.

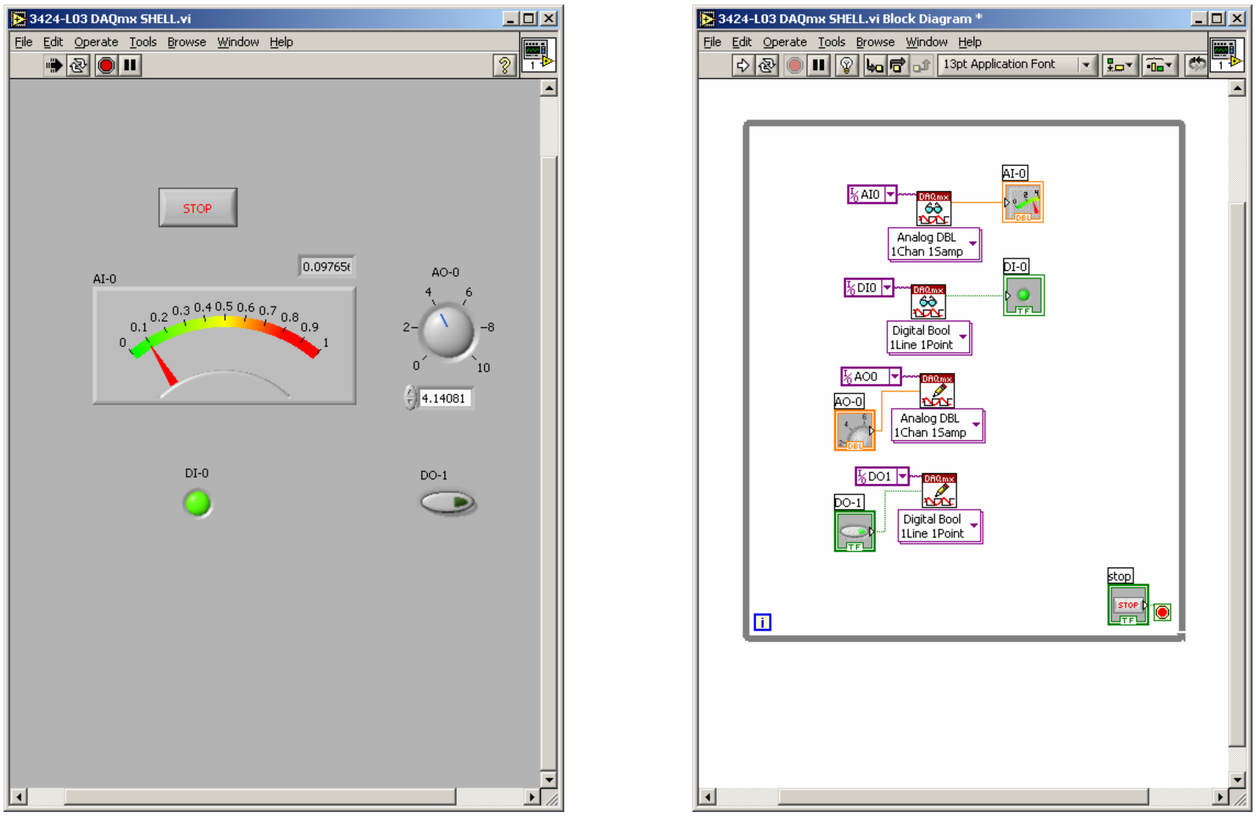

Figure 8 - LabVIEW® "Shell" VI

For this lab experiment, students experiment with one analog input, one digital input, one analog output, and one digital output. Students connect their I/O signals into the DAQ terminal block to an external breadboard. The DAQ pin-out is given in Figure 9 and the wiring diagram for this lab experiment is illustrated in Figure 10. The analog voltage signal is generated from a strain gage mounted on a cantilever beam. The strain gage is wired into a voltage divider circuit, and the output signal is fed into the DAQ terminal block. The analog voltage generated is proportional to the deflection or displacement of the cantilever beam. A micrometer is used to measure the beam deflection. The digital input comes from a momentary pushbutton with a pull-up resistor wired on an external breadboard. The +5V supply from the DAQ board is used for the supply voltage. The digital signal from the push button is wired into the digital channel 0 (DIO-0) on the DAQ terminal block. The digital output is wired from the digital channel 1 (DIO-1) on the DAQ board to an LED through a current limiting resistor. For the analog output, a digital multimeter is used to monitor the voltage on the analog output channel 0 of the DAQ terminal block.

Figure 2. NI 6024E Pinout

Figure 9 - DAQ Pin-out for PCI-6024E

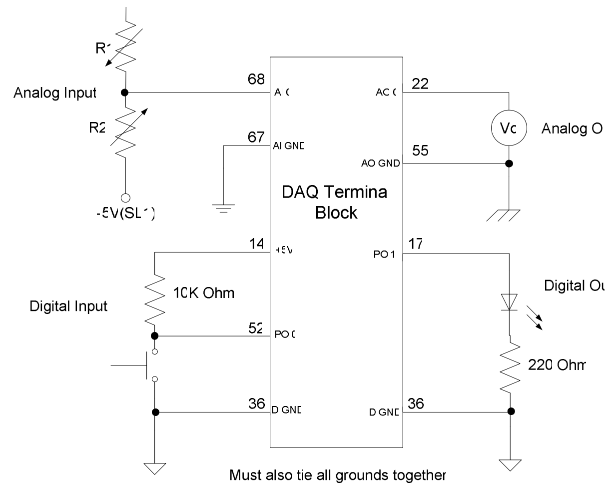

Figure 10- DAQ Wiring Diagram

Students modify the "shell" file so that the analog voltage represents displacement in mm. The calibrated voltage is then output to the analog output channel, which is monitored with a digital multimeter. A high limit knob is added so the user can set a high limit for the beam. When the beam limit is reached, the external LED (digital output) is turned on. When the momentary push button is pressed (digital input), the units are converted from mm to inches. The completed VI is shown in Figure 11.

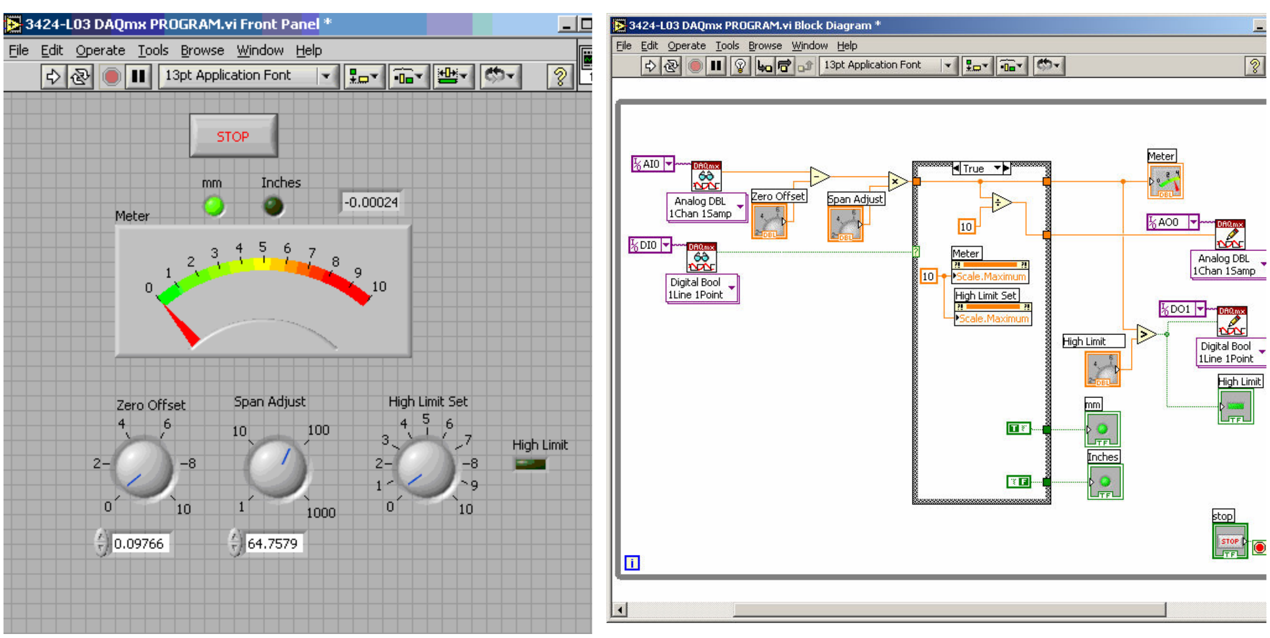

Figure 11 - Completed VI for Experiment # 3

In the set of advanced application experiments, students perform the theoretical analysis of the mechanisms under study and then, using the appropriate transducers and instrumentation tools acquire the necessary data to perform an experimental analysis of the mechanism. Finally students use Microsoft Excel™ to plot a series of theoretical and measured parameters associated with the mechanisms under study. Conclusions from the analysis of the plots are derived. As an example of this type of experiment, the Punch Press (Figure 2) experiment is described below.

The Punch Press Experiment

In the Press Punch experiment, students analyze the crank & slider mechanism of the punch press. First, the critical dimensions such as the punch travel, link arms, and flywheel speed are all measured. Students are then able to calculate the punch press displacement and velocity as a function of the flywheel input angle [8]. Students utilize Microsoft Excel™ to plot the displacement vs. time and velocity vs. time plots. Next, students capture the displacement and velocity data and compare their measurements to the calculated data.

The punch press is equipped with a linear potentiometer for measuring punch displacement and a linear velocity transducer (LVT) for measuring punch velocity. For this particular lab, the LabVIEW® VI has already been developed. As illustrated in Figure 12, the font panel of the LabVIEW® display consists of a waveform chart displaying both the displacement and velocity waveforms simultaneously.

The student specifies a filename path to save the data. Once a path has been specified, then the student captures the data by pressing the "acquire data" button. The data is then saved to an Excel file at this point. Next, the students copy the displacement and velocity data into their own Excel spreadsheet for further analysis. The block diagram for this VI is given in Figure 13 and Figure 14. The VI converts the raw voltages so the displacement data is in inches and the velocity data is in in/s. The calibrated displacement and velocity data is then copied to a spreadsheet file. Calculated and measured data for both displacement and velocity are given in Figure 15.

Figure 12 – LabVIEW® Front Panel Display for the Punch Press Experiment

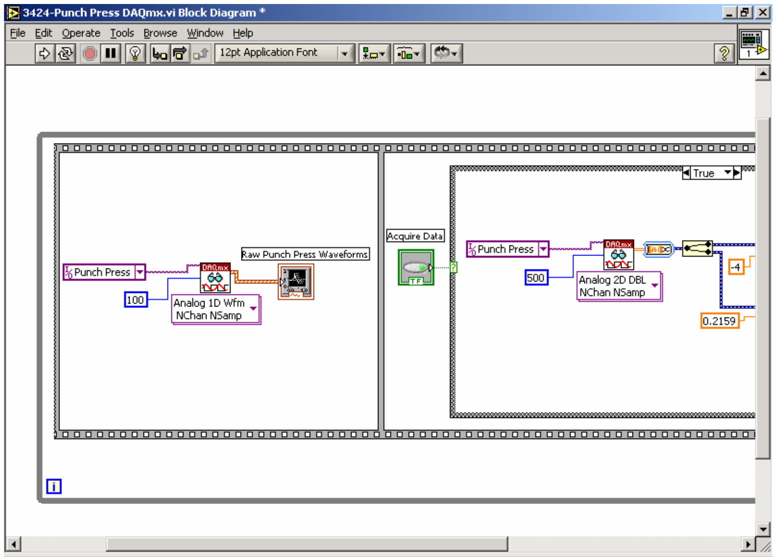

Figure 13 – Block Diagram for Punch Press Experiment Part I

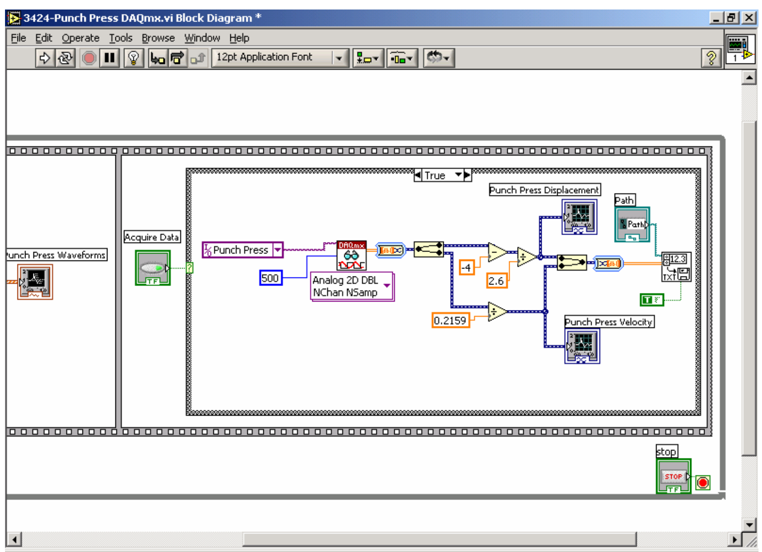

Figure 14 – Block Diagram for Punch Press Experiment Part II

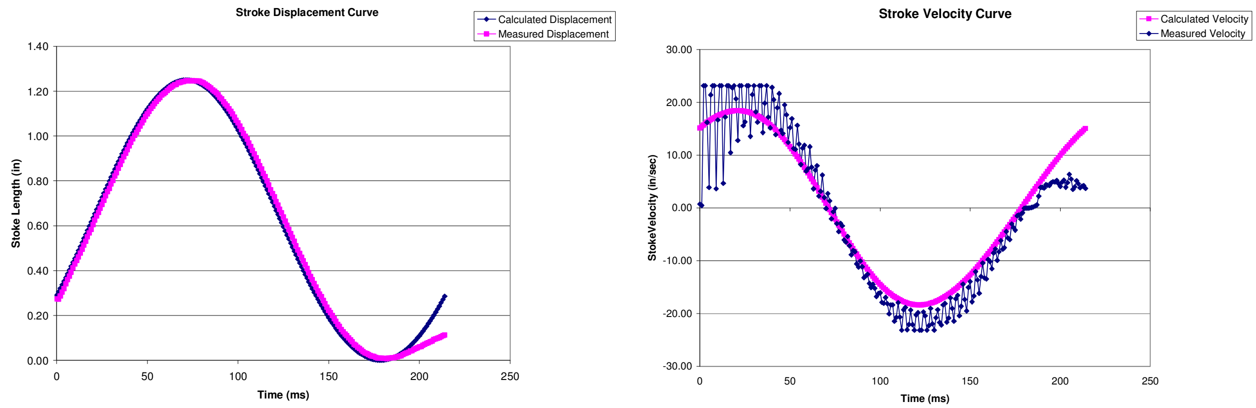

Figure 15 – Calculated & Measured Data for Punch Press Displacement & Velocity

For more details about the experiments, the reader is encouraged to refer to the course website [7].

Conclusions

Incorporating data acquisition boards and LabVIEW® in the EMA laboratory to substitute the traditional electronic equipment (oscilloscopes, multimeters, signal generators, signal conditioning circuits) has helped to make the learning of electrical measurements and instrumentation more appealing to the MET students, and offers a new and interesting way of doing electrical measurements to the EET students. The use of virtual instruments is viewed as a solution for enhancing education principles in a laboratory setting, promoting the understanding of theoretical concepts. Furthermore, for students to be prepared for the real world they need to be proficient in virtual instrumentation.

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