Integrating LabVIEW® into Engineering Technology Curricula

Wes Stone[1]*, Aaron Ball*[2]*, and Brian Howell*[3]

Abstract –Today's global economy requires a rapid time-to-market, placing heavier demands on design, prototyping, testing. and production. Those demands have challenged scientists and engineers to master new tools in the form of computers and software. One software package that has provided the ability to merge the virtual and real worlds has been LabVIEW® by National Instruments. This paper describes how LabVIEW® is being integrated into the Engineering Technology (ET) and Electrical and Computer Engineering Technology (ECET) curricula at Western Carolina University in an attempt to address some of the challenges facing its graduates. Background objectives are presented along with descriptions and examples of activities for courses in automated systems, instrumentation, and engineering analysis at the undergraduate level along with implementation for a graduate level automation course. Background objectives are presented along with descriptions and examples of learning modules and applications. Instructional methods, student performance, and educational merit are also presented.

Keywords: LabVIEW, Engineering Technology, hands-on, visual, graphical

INTRODUCTION

Western Carolina University offers undergraduate programs in Engineering Technology (ET) and Electrical and Computer Engineering Technology (ECET). To fulfil each program's goal of nurturing technical professionals with strong experiential skills, the focus is on applied scientific knowledge and engineering principles rather than traditional engineering theory and engineering design [Kumar, 7], [Grinberg, 4]. To achieve a balance of fundamentals and applications, laboratory instruction and commonly used standard software is integrated in several courses. With continued widespread use of LabView® and the growing need of industry to have personnel with a working knowledge of systems characterization through Data AcQuisition (DAQ), analysis, and control, the software is being integrated in courses such as engineering analysis, instrumentation, and automated systems. LabVIEW® is also being used to support graduate courses in automation systems and directed projects.

Due to various mathematical backgrounds and different abilities among students, traditional theory-oriented instructional methods for teaching engineering principles have not adequately equipped graduates with necessary skills for continued advancement in technical careers. Intuitively, a more effective method should combine theories, hands-on experiences, and applications of theory and skills. This is the foundational core of Engineering Technology as a discipline. This applied approach at Western Carolina University focuses on this core concept, and enhances students' theoretical understanding by using computer software packages and improves their application capabilities through applied projects in common industrial systems. The following sections will discuss the implementation of this applied approach in terms of course structure, LabVIEW® applications, and applied projects.

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THEORETICAL FOUNDATIONS

The reliance on more advanced computer systems and software is evident in all areas of our economy, and it is critical that we equip our engineering and technology students with the skills necessary to meet tomorrow's challenge. National Instruments has demonstrated the commitment to advancing technology for supporting engineering and engineering education. The Austin, Texas based firm just celebrated 25 years of success with LabVIEW®, and the software is now in worldwide prolific use. During recent years LabVIEW® has seen a significant increase in industry, as well as academia with applications ranging from hands-on [Kiritsis, 5] to simulation [Neuman, 9].

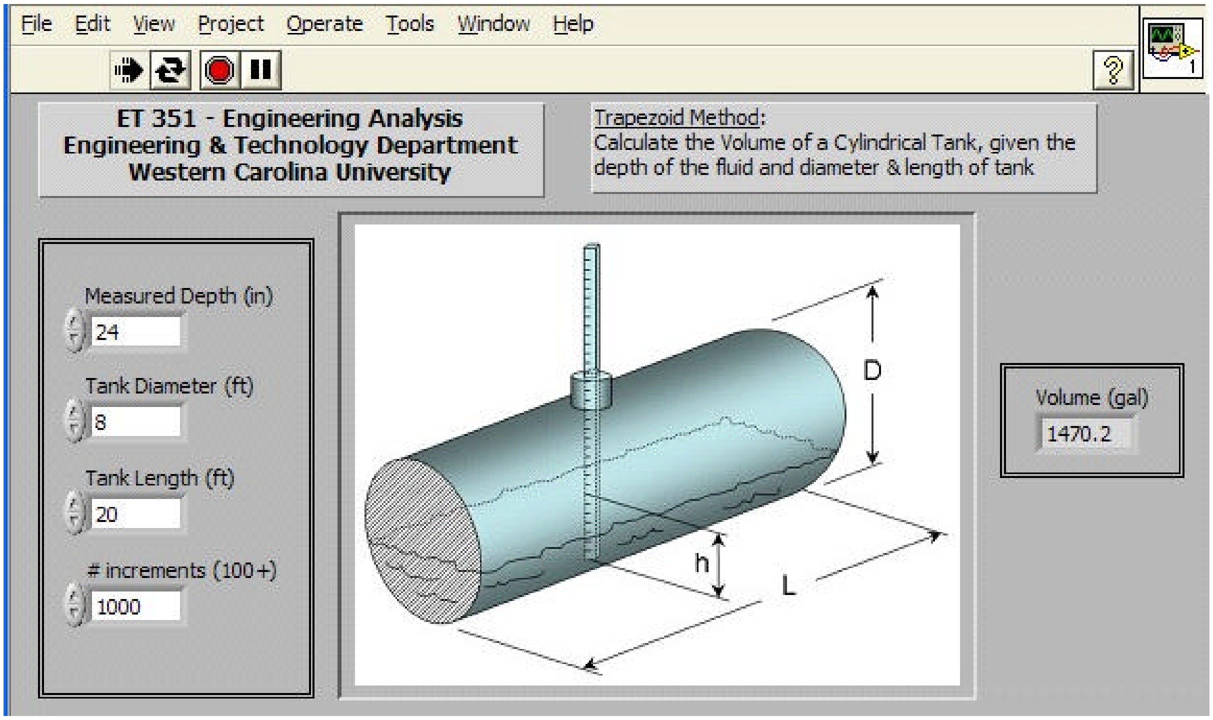
Modern computer tools such as LabVIEW® have become an integral component of engineering curricula and provide efficient methods of blending theory into practice. However, this common use has also contributed to differences between the practicing engineer and technologist becoming more clouded [Ball, 2]. Commercial software packages can enable students to rapidly perform calculations with relative ease and efficiency. Similarly, electrical circuits can be created and simulated with only a modest knowledge of background theory. However, without adequate knowledge of fundamental laws and theory, this approach may give a false impression as to the ease of engineering design, component selection, and circuit analysis. This virtual approach does not always reflect characterization of actual circuit performance. Knowledge of basic laws and fundamental theory remains essential for understanding industrial systems.

Wingo suggested that effective course design strategies implement instructional methodologies that affect multiple dimensions of learning [Wingo, 10]. Students who prefer abstract conceptualization with concrete answers would likely benefit from solving theoretical problems in a more traditional manner [Kolb, 6]. However, more positive learning outcomes may be achieved through active experimentation using a hands-on approach. Computer-based programs can be used to promote a better understanding of systems and component functions, and they provide an excellent method of reinforcing learning through feedback [Marsh, 8].

This logical approach to enhancing learning has been integrated in the engineering technology programs at Western Carolina University. In the following sections, the structure and approach, laboratory examples, and projects will be presented relative to undergraduate and graduate courses in automated systems and undergraduate courses in engineering analysis and instrumentation.

Engineering Analysis Undergraduate Course, ET 351

Undergraduate students majoring in Engineering Technology take Engineering Analysis (ET 351) in their junior or senior year—a course focusing on numerical methods. Students learn techniques in numerical integration and differentiation, fixed point iteration, Gaussian elimination, matrix manipulation, among other related topics. Historically, this course had used Microsoft Excel® and Matlab® as the tools to perform the programming. Beginning with the Spring 2007 semester, LabVIEW® was introduced to replace Matlab for two reasons: to complement other courses in the curriculum using LabVIEW®, and to take advantage of LabVIEW's graphical interface. The incorporation of LabVIEW® included the basics of using front panels and block diagrams, writing in "G" language (graphical), and creating virtual instruments (VIs) and sub-VIs. One sample application, shown in Figures 1 and 2, illustrates the use of the Trapezoid Method of numerical integration to find the volume of liquid in a partially filled cylindrical tank, by measuring the depth with a dip stick. The controls on the left side of the front panel in Figure 1 allow the user to access the for-loop using Mathscript in the block diagram in Figure 2, arriving at the volume shown by the indicator on the right side of Figure 1.

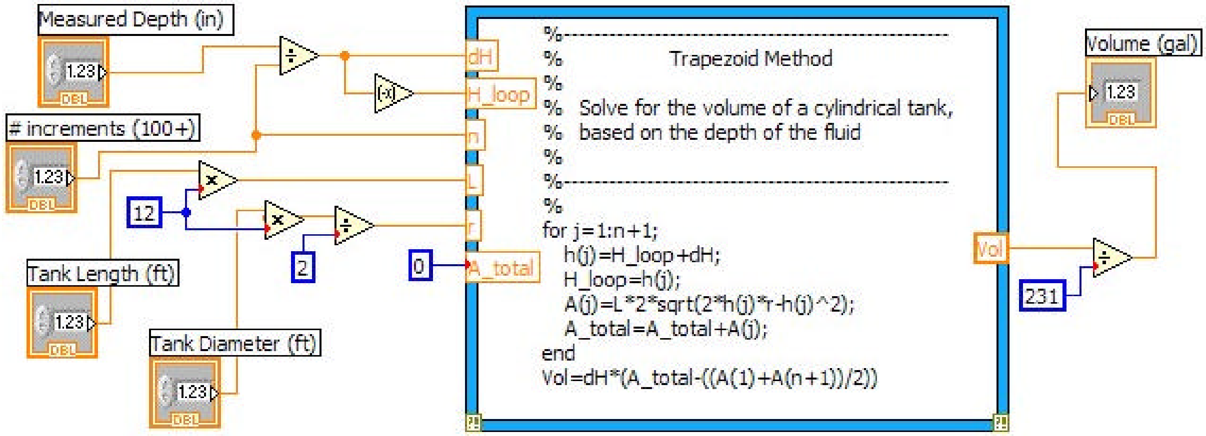


ET 351 - Engineering Analysis
Engineering & Technology Department
Western Carolina University

Trapezoid Method:
Calculate the Volume of a Cylindrical Tank, given the depth of the fluid and diameter & length of tank

Measured Depth (in): 24
Tank Diameter (ft): 8
Tank Length (ft): 20
increments (100+): 1000
Volume (gal): 1470.2

Figure 1: Front Panel for VI to calculate volume of liquid in a cylindrical tank



```
%-----------------------------------------------
%                Trapezoid Method
%
% Solve for the volume of a cylindrical tank,
% based on the depth of the fluid
%
%-----------------------------------------------
%
for j=1:n+1;
   h(j)=H_loop+dH;
   H_loop=h(j);
   A(j)=L*2*sqrt(2*h(j)*r-h(j)^2);
   A_total=A_total+A(j);
end
Vol=dH*(A_total-((A(1)+A(n+1))/2))
```

Figure 2: Block Diagram for VI to calculate volume of liquid in a cylindrical tank

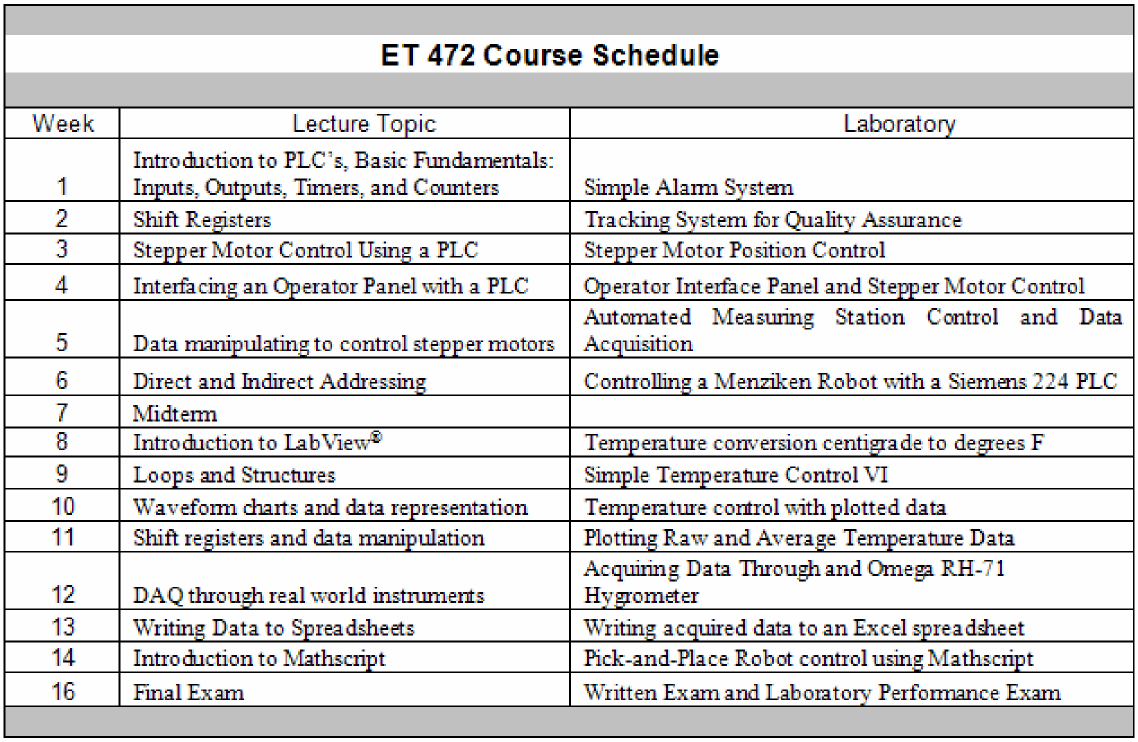
This graphical mode of operation allows the user to work within an uncluttered environment in the front panel, while accessing the intricate details in the block diagram. The block diagram provides a visual interpretation of the program execution. The Mathscript structure allows the user to merge any Matlab® code previously written, or to program in C.

Automated Systems Undergraduate Course, ET472

The Engineering and Technology (E&T) Department offers an undergraduate course in Automated Systems (ET 472) which has traditionally focused on Programmable Logic Controllers (PLCs) and industrial control systems. Similarly, a graduate course is also offered in Automation Systems (ET 642). During the spring and fall semesters of 2007, LabVIEW® was integrated into both courses due to the growing demand for graduates having related skills. LabVIEW® has been in existence for over 25 years and has grown to become a standard in Data AcQuisition (DAQ) and control across many fields. While PLCs continue to dominate industrial control applications, LabVIEW® is being used more and more for monitoring and data acquisition. Object linking and embedding for Process Control (OPC) capabilities have also made the software package more attractive to users who wish to integrate DAQ with PLC control. The E&T Department at WCU recognized the need to integrate more modern controls approaches into the curriculum, and version LabVIEW® 8.2 was procured to support instruction in these courses. The following section presents the logical sequence of tutorials and laboratory exercises for the undergraduate ET 472 automation course.

The ET 472 course consists of 6 week coverage of PLCs followed by 6 weeks of LabVIEW® instruction and applications. Specific topics by week are shown in Table 1.

Table 1: ET 472 Course Schedule



ET 472 Course Schedule

Week	Lecture Topic	Laboratory
1	Introduction to PLC's, Basic Fundamentals: Inputs, Outputs, Timers, and Counters	Simple Alarm System
2	Shift Registers	Tracking System for Quality Assurance
3	Stepper Motor Control Using a PLC	Stepper Motor Position Control
4	Interfacing an Operator Panel with a PLC	Operator Interface Panel and Stepper Motor Control
5	Data manipulating to control stepper motors	Automated Measuring Station Control and Data Acquisition
6	Direct and Indirect Addressing	Controlling a Menziken Robot with a Siemens 224 PLC
7	Midterm	
8	Introduction to LabView®	Temperature conversion centigrade to degrees F
9	Loops and Structures	Simple Temperature Control VI
10	Waveform charts and data representation	Temperature control with plotted data
11	Shift registers and data manipulation	Plotting Raw and Average Temperature Data
12	DAQ through real world instruments	Acquiring Data Through and Omega RH-71 Hygrometer
13	Writing Data to Spreadsheets	Writing acquired data to an Excel spreadsheet
14	Introduction to Mathscript	Pick-and-Place Robot control using Mathscript
16	Final Exam	Written Exam and Laboratory Performance Exam

During the second phase of the course, general tutorials were developed allowing students to work independently on the first three LabVIEW exercises. The following are examples of exercises completed by undergraduate students following the tutorial exercises. The fourth exercise introduced Measurement and Automation (MAX) and configuring real world devices. An Omega RH71 hygrometer was implemented into a real time data acquisition exercise. The Omega RH71 unit provided a general method of calibration and verification of the developed VIs and Sub-VIs by comparing LabVIEW data to the LCD display.

Figure 3: Temperature DAQ Laboratory System Diagram

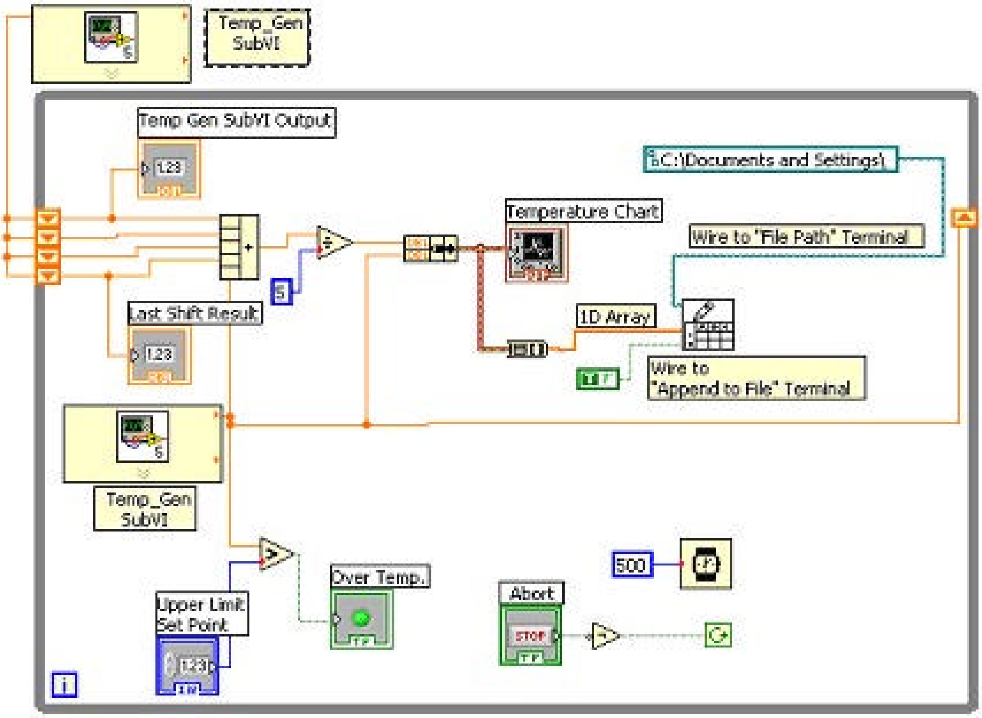


Figure 4: Temperature Acquisition and Write to Spreadsheet File (Block Diagram)

The final LabVIEW exercise for the ET 472 automation course consisted of controlling a pick-and-place robot using Mathscript. Students were required to develop both control and monitoring capabilities and integrate an embedded Mathscript program. The VI was set up to read inputs from proximity switches, compare current states to the next sequence, and write outputs to solenoid valves for positional control. Illustrations of the system along with the front panel and block diagram are shown in Figures 5, 6, and 7.

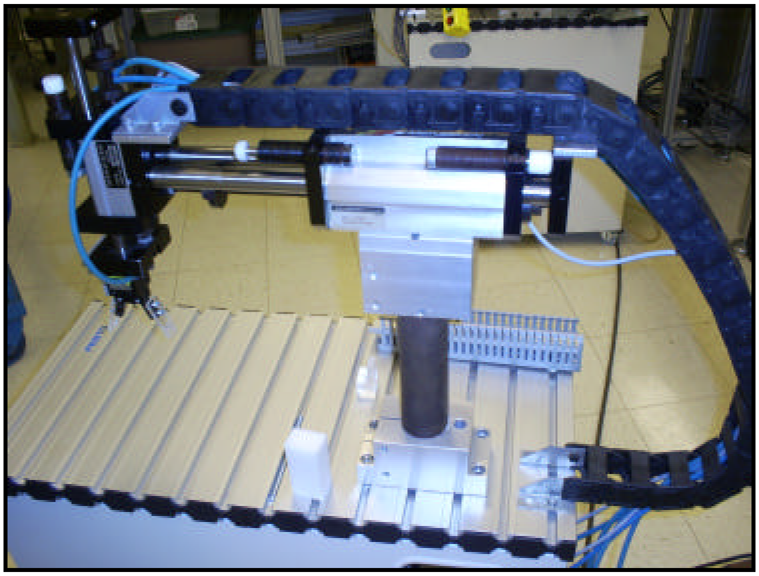
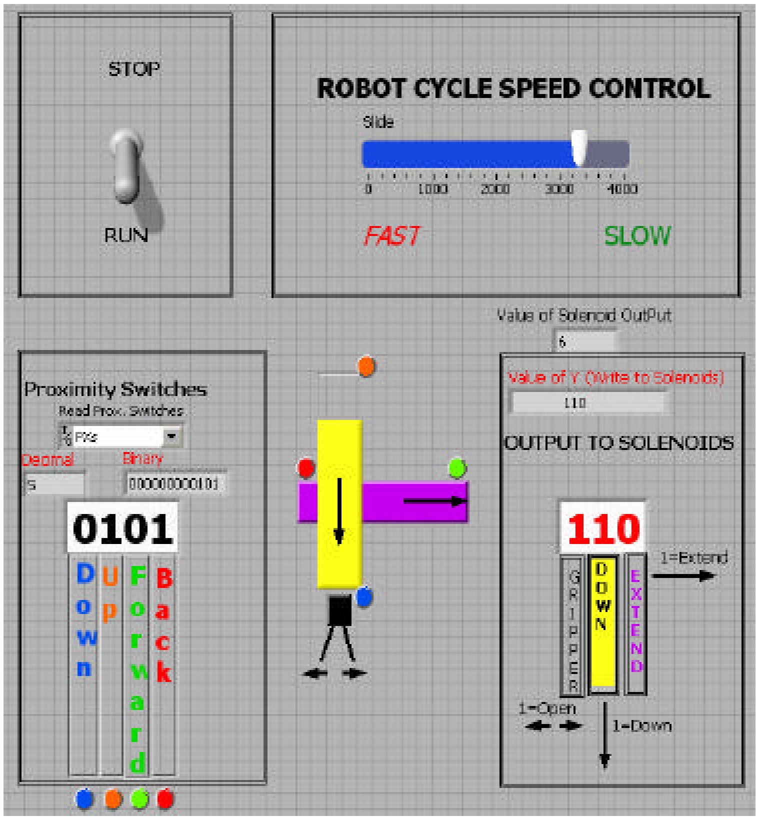


Figure 5: Menziken Pick-and-Place Robot



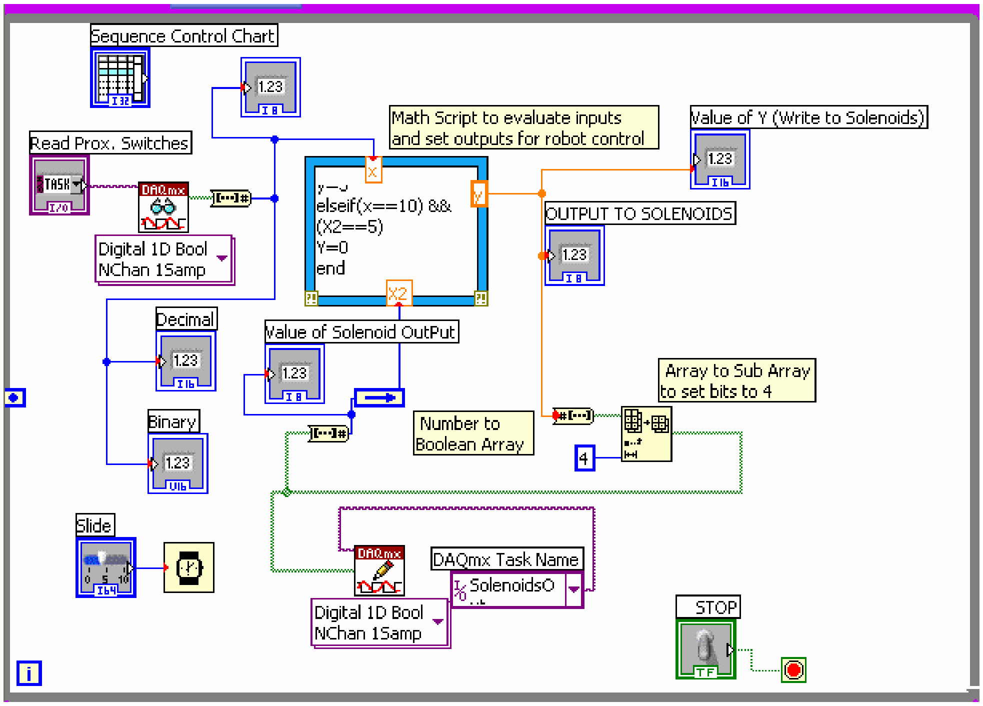
Value of Solenoid OutPut: 6

Decimal: 5

Binary: 0000000000101

Value of Y (Write to Solenoids): 110

Figure 6: Front Panel for Robot Control Laboratory Exercise



```
elseif(x==10) &&
(X2==5)
Y=0
end
```

Figure 7: Block Diagram for Robot Control Laboratory Exercise

LabVIEW® in the Electrical and Computer Engineering Technology Program

LabVIEW® has several primary strengths which make it attractive for integration into the Electrical and Computer Engineering Technology (ECET) Program. First, the programming environment has a soft learning curve which allows students who understand basic computing concepts to engage the tool rapidly in their design process for PC based automation systems. Secondly, the National Instruments strategic partnerships with Lego, Tufts University, and Carnegie Mellon have resulted in the Mindstorms® NXT® software which allows young students to learn the basics of robotics and more importantly, structured design. This has resulted in an ability to reach out to the middle and secondary schools for student engagement projects using the same programming paradigm as the professional engineering package. As a bonus benefit, this effort also has allowed the LabVIEW® tool to be applied to embedded applications such as the ARM7 processor. Thirdly, the software tool allows the teacher and students to isolate the computing skills form the other circuit analysis and testing skills. Lastly, the graphical programming paradigm forces students to think in a flow chart paradigm which is one of the core skills required for graduation in ECET. This has been problematic to force this discipline on students using procedural languages such as C or Basic. The combination of these strengths has been to develop a continuous, multiple contact point with the ECET program for students from middle school to graduate school.

ECET Program Context

In this context, the students are expected to master the design of automated systems for medical, transportation, robotics, manufacturing, and network applications. In addition, they are expected to demonstrate skills in a senior capstone design activity. The skill set focuses on the student having the ability to design an automation system based on PCs, microcontroller embedded processors, or both. They are also taught to separately analyze non computer portions of the automation system (sensors and actuators) and to address non idealities of those portions of the system. LabVIEW® is integrated in the curriculum at two places. Students are engaged using the tool in the senior year in the Instrumentation course, ECET 464. Soon, the problem solving skills will be pushed down to the first ECET class, Computer Engineering Fundamentals course, ECET 290. LabVIEW® is not taught as a standalone tool, but rather as a support tool to easily implement the other concepts being taught.

Instrumentation Undergraduate Course, ECET 464

ECET 464 is a senior course in overall instrumentation design. In 2005, LabVIEW® was introduced as the tool for the course. In that first experience with 6 students in the class, the LabVIEW® textbook, "LabVIEW 7 Express" [Bishop, 3] was used as the primary textbook and homework and labs were pulled from the material. While successful, it was noticed that students became bored with the homework assignments and were in fact "learning past the book" due to the way in which the software invites an individual to experiment with software modules or "blocks."

For the next two semesters, the course was taught with the book as a supplementary text used only for the first four lab exercises, focusing on software competency; students were expected to read and master the remaining material on their own. The focus of the class returned to more traditional topics, that of sensors, non-ideal amplification, signal conditioning, actuators, statistical methods, and optical systems. LabVIEW® was then required as the interface for delving into these concepts.

Outreach

The advent of the LEGO Mindstorms NXT® product in 2006 adds a new dimension for both teaching and community outreach. A group of seniors from the WCU ECET program during 2006-2007 were engaged by local middle schools to develop a curriculum package not for middle school students but for their teachers. In summer 2007, a "Camp Robot" one-week experience for teachers was implemented where the primary focus again was not on the tool, but instead on problem solving and scientific inquiry. Teachers from three local counties arrived with weak technology backgrounds. After two days of interactive training, the basics of the NXT® software was acquired and the teachers were challenged to create curriculum and projects appropriate to their classroom settings and to the North Carolina State teaching curriculum requirements. Initially, many of the participants expressed reservations about implementing any new technological component to an already overburdened curriculum setting. By Fall 2007, all three counties had not only exposed 6-8 graders with the graphical programming paradigm, but also had fielded their first teams to the North Carolina State First Lego League Competition. For future student development, the LabVIEW® software has specific blocks for use with the Lego Mindstorms® such that these middle school students will see a smooth progression from Lego NXT-G® software to LabVIEW® for Mindstorms®, finally to full LabVIEW® as shown in Figures 8 and 9.

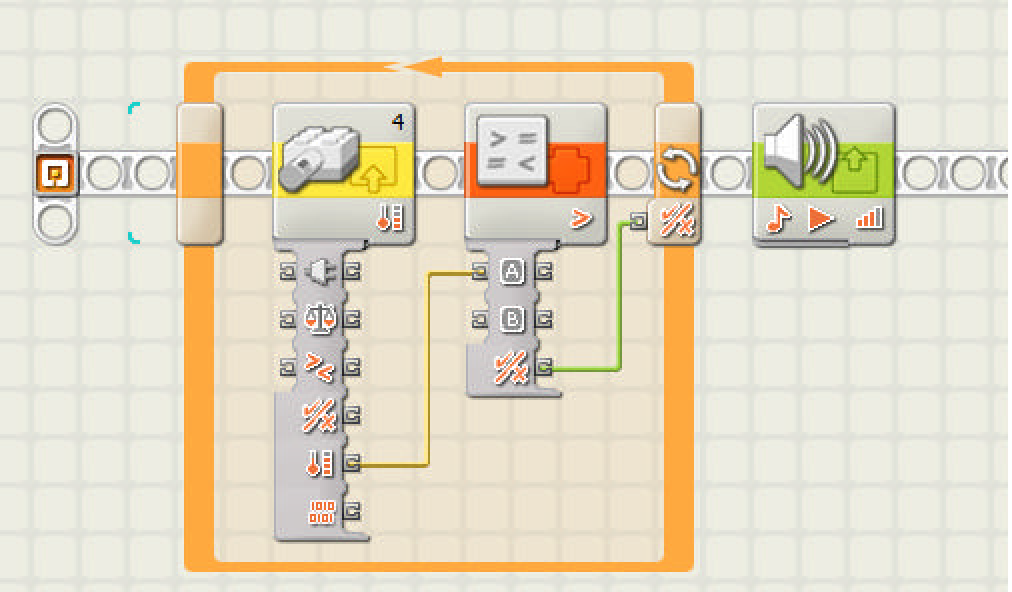


Figure 8: Lego Mindstorms NXT-G Code for Temp Alarm

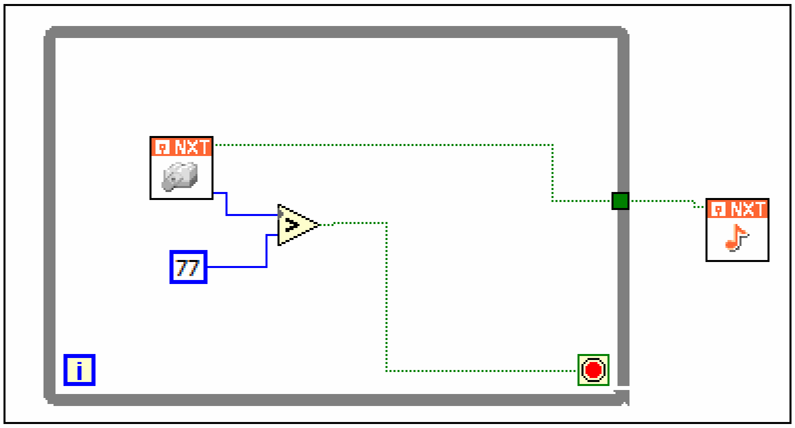


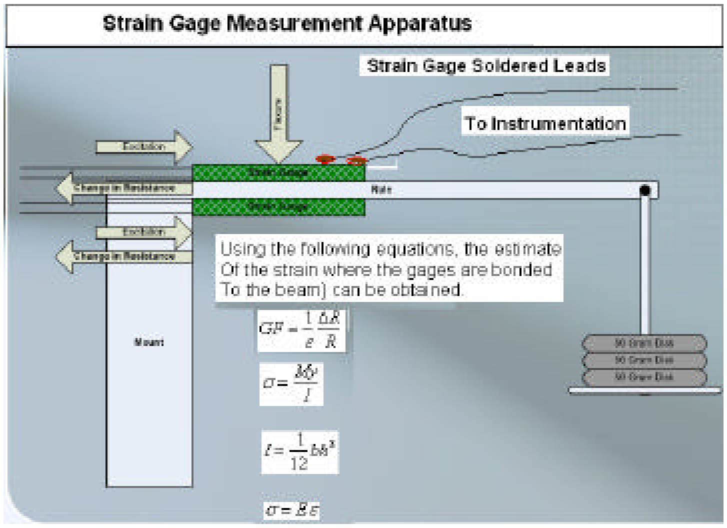
Figure 9: "Full" Labview VI Code for Temp Alarm

Automation Systems Graduate Course, ET 642

As part of the partial fulfillments for a graduate level ET 642 class, graduate student groups were required to develop training sessions in four different areas including the following

1. Strain gages
2. Pressure Transducers
3. Flow Meters
4. Thermocouples

Each group was charged with presenting the theory of operation, theory of application, and comparison of at least two instrumentation methods. Additionally, groups were required to evaluate the success of their training exercises through tests and/or laboratory exercises. The developed exercises will be used and integrated into the ET 472 undergraduate course. An example training session and laboratory exercise consisted of strain gage theory and application. Further, the team compared the results of three methods of monitoring strain including: 1) a "bread-boarded" quarter-bridge circuit with operational amplifier; 2) a National Instruments strain gage module with integrated amplification and signal conditioning; and 3) a Vishay Strain gage indicator. Examples showing the methods and applications of strain gages employed by the team are shown in Figures 10, 11, and 12.


Strain Gage Measurement Apparatus

Using the following equations, the estimate Of the strain where the gages are bonded To the beam) can be obtained.

$$GF = \frac{1}{\varepsilon}\frac{\Delta R}{R}$$

$$\sigma = \frac{My}{I}$$

$$I = \frac{1}{12}bh^3$$

$$\sigma = E\varepsilon$$

Figure 10: Diagram Apparatus Setup for Strain Gage Exercise

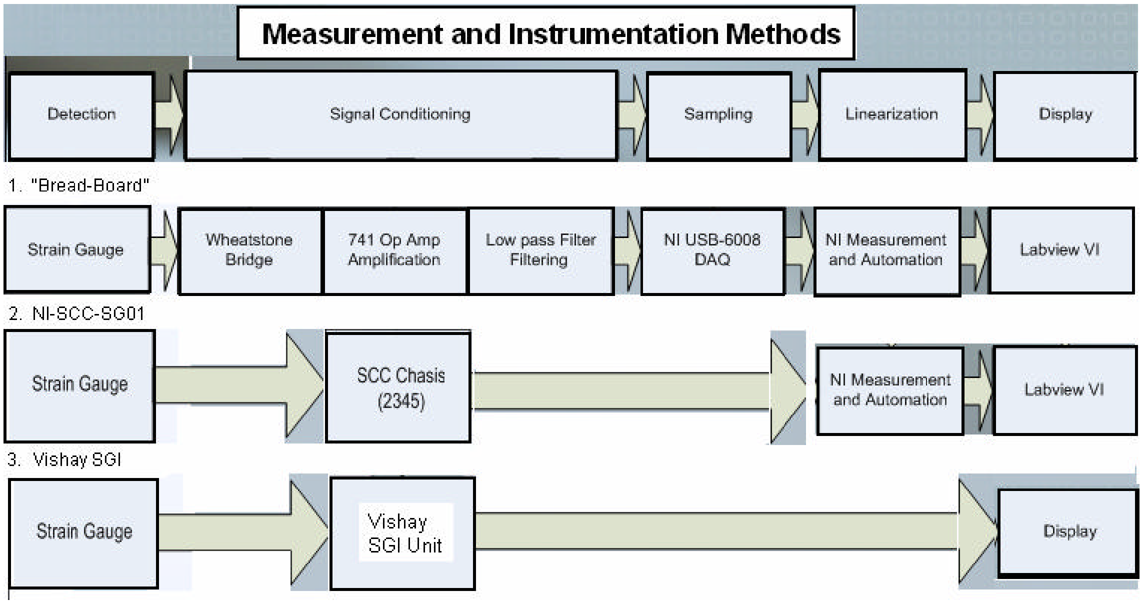


Figure 11: Diagram of Three Measurement Methods for Reading Strain Gages

Weights were added to the setup as shown in Figure 10 in increments of 50 grams, and strain was recorded as a function of voltage. A comparison of the three methods yielded the plot shown in Figure 12. The results demonstrated the increasing sensitivity and accuracy of measured strain.

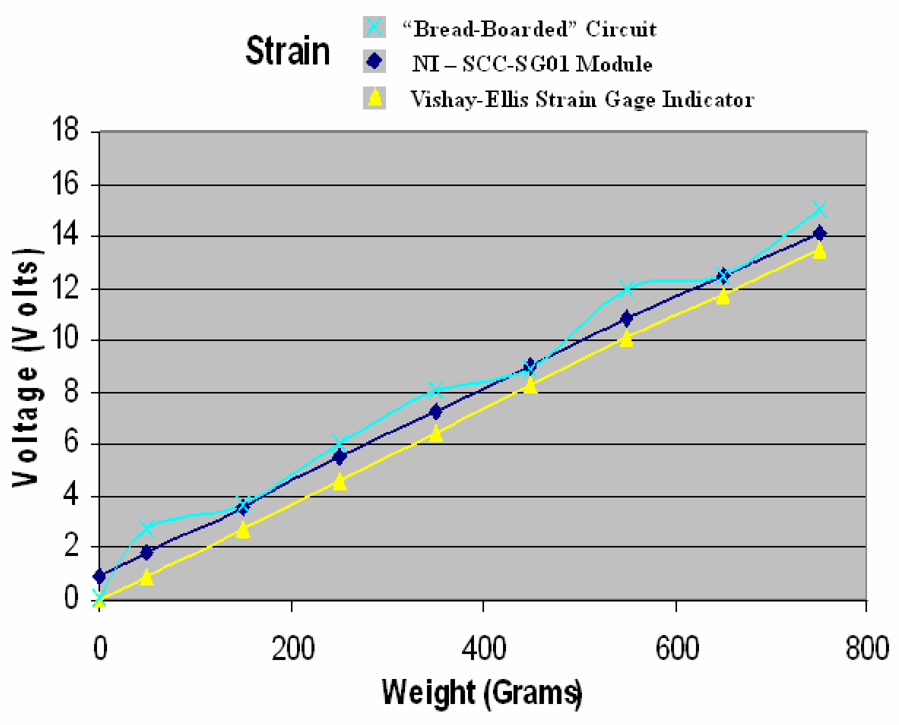


Figure 12: Plot Showing Three Measurement Methods for Reading Strain Gages

Student Learning Outcomes

The Engineering Analysis course (ET 351) introduced numerical methods to ET students using Excel® and LabVIEW®, simplifying calculus techniques that are often too cumbersome to solve in closed form. Student response to LabVIEW® was very positive, much more so than with Matlab®. Having grown up in a more visual environment than previous generations, they gravitate toward this graphical platform, achieving a genuine sense of accomplishment when they see the program laid out and working properly.

ET students often struggle with control theory and abstract concepts. This was observed during the first 6 weeks of ET 472, which focused on the PLCs. However, students demonstrated fundamental understanding of basic numbering systems, I/O, addressing, ladder logic, registers and shift registers, data manipulation, and control through live laboratory exercises. Interestingly, the same concepts were covered during the second 6 weeks using LabVIEW® with a much more positive outcome. Students struggling with subroutines and timing functions were able to better grasp the concept using the graphical "G" language in LabVIEW®. Similarly, a much quicker understanding of functions was grasped by students using graphical icons as opposed to the standard symbols used for PLC programming. Perhaps this phenomenon is due to exposure to the graphical world at younger ages through video games and other interactive graphical stimuli. The difference in student response and performance was significant, and demonstrated a sound case for increased use of LabVIEW® to supplement teaching.

In the Instrumentation course (ECET 464), it was discovered that the software itself became subordinate to the subject material and the students readily used the software to design their own tools for tasks such as photodiode characterization, temperature data-logging, and linearization. With both student groups of 5 and 19 in two classes, the majority of students worked beyond class and lab times in order to perfect the virtual instrument design by choice. Many students also began to update their projects to attempt to exceed initial specifications.

Lastly, from a teaching perspective, it became possible to lecture using LabVIEW® in real time. For example, in automation, the controller is discussed as being built up of sensors, actuators, processing elements and feedback. As these elements are discussed there is a one-to-one correspondence with the related LabVIEW® block. Even such advanced concepts as linearization by algorithm versus look-up tables were demonstrated with live, active demonstration in a 1-hour 15-minute class.

EDUCATIONAL MERIT

The educational merits of this approach are abundant and significant. First, students grasped the foundations and control methods that were intended to be conveyed by these courses. This was evidenced by their improved capabilities when using LabVIEW® over more traditional methods. Second, the students learned hands-on problem solving and analysis skills much faster using the LabVIEW® approach. This was demonstrated by their capabilities of developing and using computer tools to analyze variables, as well as determining logical parameters for system control. Thirdly, graduate students developed their abilities to apply methods and skills learned to conduct applied research in their fields. As shown in the examples, students were able to transfer knowledge from courses to successfully solve problems in different engineering disciplines.

Educational merit was also shown by the uniqueness of this approach. It is worth noting that these skills are not always explicitly taught in engineering curricula where the focus has been on content and analytical skills of specific engineering disciplines. Industry and the Accreditation Board for Engineering and Technology (ABET) nonetheless expect engineering graduates to have well developed computer skills [ABET, 1]. The approach implemented in the ET and ECET programs at Western Carolina University provides a logical and systematic method for building on theory and developing essential computer skills. Through immediate feedback, students can gain a better understanding of variables in equations and the impact of change with respect to independent variables to response variables. Further, as evidenced by student projects, the ability to apply theory and knowledge gained from lectures was demonstrated in a more positive manner when compared to traditional methods.

CONCLUSIONS AND FUTURE WORK

Positive results of the applied approach have been observed through student feedback and performance, and integrated projects have provided a vehicle for transferring theoretical knowledge to practical, systematic application. This practical approach has resulted in improved collaboration among students from various disciplines and has provided more continuity within the ET and ECET curricula at Western Carolina University. Ongoing program assessment will continue to provide feedback on the effectiveness of the methods implemented with the goal of continued class improvement.

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