Implementing the Design-Build-Instrument-Test Approach for Curriculum Integration in Engineering Technology

Paul M. Yanik[1], Aaron K. Ball[2]

Abstract – With rapid changes in technology impacting engineering design and instrumentation requirements for adaptive systems, engineering technology programs must constantly look for innovative methods to deliver quality education that provide students with the skills necessary to enter engineering careers. Engineering technology programs historically have taken the direction of engineering applications as opposed to engineering science in traditional undergraduate programs. This approach has tended to create *islands* of applications for new technology within the curriculum. Western Carolina University has long sought to provide a more integrated approach to provide continuity across targeted subject areas within the engineering technology program. The purpose of this paper is to describe a method that cuts across subject areas and provides opportunities for students to apply the design-build-instrument-test approach. Specifically, a project integrated in an undergraduate industrial automation class will be presented. Curriculum integration approaches and laboratory exercises will be covered along with benefits and obstacles encountered. Instrumentation for a pneumatic driven engine using LabVIEW® for monitoring and data analysis will be emphasized. The goal of the paper is to share experience with other colleagues who may wish to take similar paths with their engineering technology programs and to learn from our experiences.

Keywords: Engineering Technology, curriculum integration, design, fabrication, instrumentation

INTRODUCTION

Engineering Technology programs typically focus on applied scientific knowledge and engineering principles while engineering programs emphasize the theoretical aspects of the discipline [1] [2]. Modern computer tools have become an integral component of engineering technology curricula and provide efficient methods of blending theory into practice. However, without adequate knowledge of application, this approach may give a false impression of the ease of engineering design and product development. Application of basic engineering skills is often fragmented as students progress through an engineering or technology program. Many engineering curriculums do not require students to use the skills learned in the freshman year until the senior design course three or more years later [3]. In a report entitled "Making Quality Count in Undergraduate Education," the Education Commission of the States presents a number of characteristics related to a quality undergraduate experience [4]. One prevalent characteristic is the "ongoing practice of learned skills." The report makes a strong point that if opportunities to use basic skills are not continuously presented, those skills erode quickly for many students. Thus, for an undergraduate in a four-year program of study, many skills learned in the freshman year will likely be forgotten or at best seriously diminished by

---

[1] Western Carolina University, Department of Engineering and Technology, Cullowhee, N.C. 28723, pyanik@wcu.edu.

[2] Western Carolina University, Department of Engineering and Technology, Cullowhee, N.C. 28723, ballaaron@wcu.edu.

graduation unless they are applied in other courses [4]. Therefore, a strong case can be built for curriculum integration.

Research examining integration in practice is still relatively rare [5]. Further, effective integration is not easy problem to solve [6] due to the diversity of approaches that currently exist. These authors do suggest that key features of a well-planned and integrated curriculum include:

- investigations drawing on several discipline areas,
- flexible timetables,
- team teaching,
- student-centered learning and
- high levels of interaction between students, between students and teachers, and between teachers.

Using a curriculum integration approach to teach engineering applications focusing on design-build-test-analyze provides an opportunity for students to gain a better understanding of modern manufacturing methods. This paper will present such an approach that was implemented in the Engineering Technology program at Western Carolina University. A unique curriculum integration project involving the design, fabrication, and testing of a working steam engine is presented in the following section. A description of how the project has been implemented in two specific courses including Rapid Tooling and Prototyping (implementing CAM and CNC), and Industrial Automation is presented. The emphasis will be on testing and analysis using LabVIEW® in a senior level automation course.

INSTRUCTIONAL APPROACH

Modeling and Fabrication

Students enrolled in a junior-level Engineering Technology course entitled Rapid Tooling and Prototyping were responsible for redesigning and creating 3D constraint-based models of a unique reciprocating and rotating piston steam engine. The original design was developed in the 1800s and is depicted in Figure 1. Copies of original drawings as presented by [7] were provided to students working in teams. Students were responsible for recreating a scale model and developing executable CNC programs using OneCNC® CAM software that were compatible with HAAS milling and turning centers. The instructor coordinated and sequenced the lecture and laboratory activities to correspond with the progression of tasks necessary for student teams to complete their projects. Student teams worked collectively to produce Pro/Engineer® 3D solid computer models. The best model and engineering drawings were selected as a master for teams to use during fabrication. Examples of components modeled in Pro/Engineer are shown in Figure 2. Students in each team produce components using HAAS CNC machines that were later assembled as a functional pneumatically powered engine. A completed project is show in Figure 3.

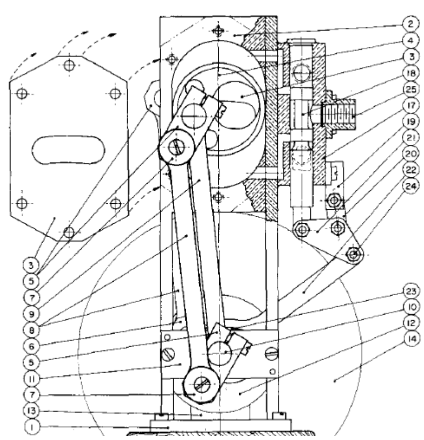

Figure 1: Illustrated Assembly View of an Antique Engine Named “An Unusual Steam Engine” [7].

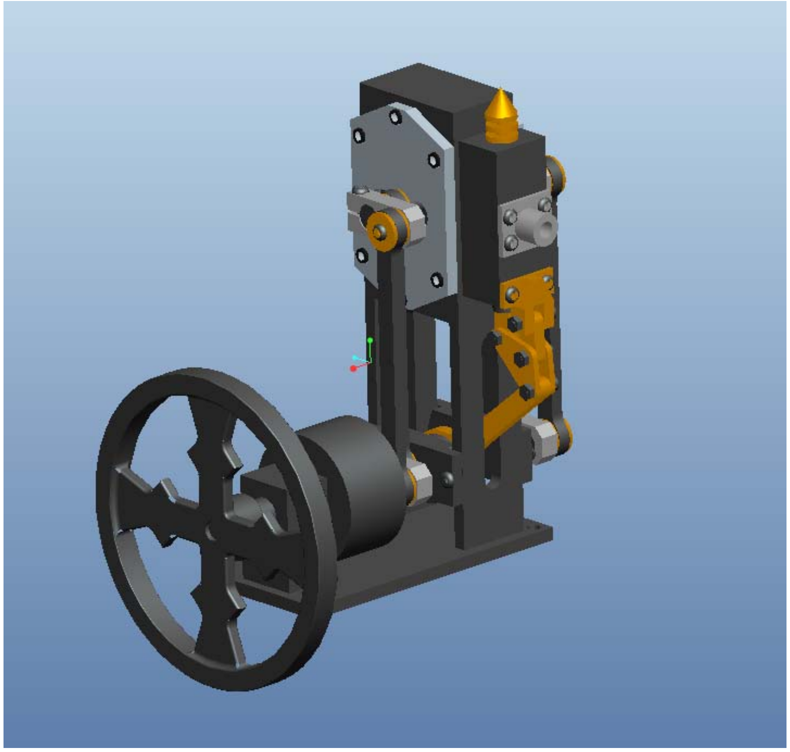

Figure 2: 3D Computer Model of Assembled Engine

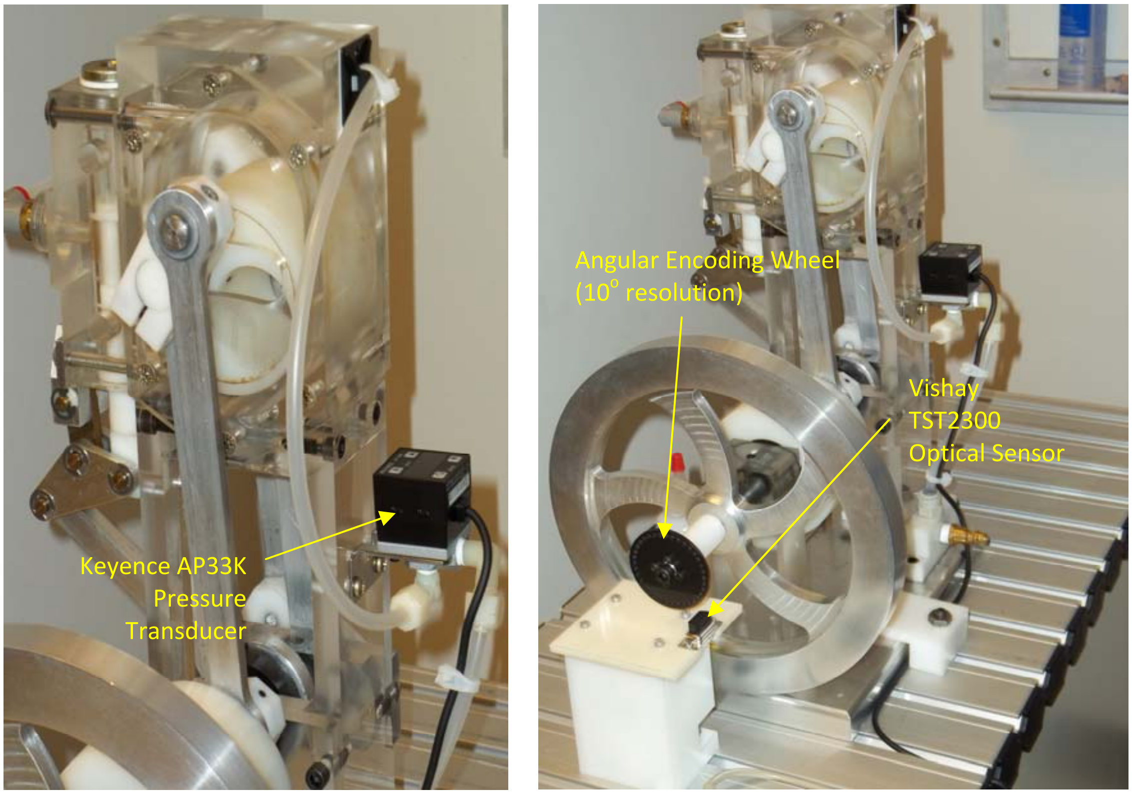

Figure 3: Photographs of Fabricated Engine and Instrumentation

Integrating the Product as a Test Station for Teaching LabVIEW®

In the spring semester of 2012, the previously fabricated pneumatic engine was integrated as a test station in a senior level automation course. The main goal of this approach was to use the engine as a test station to support a novel way of teaching instrumentation and analysis using LabVIEW®. A brief description of the automation course curriculum and sequence is provided in the succeeding section followed by a more detailed description of how LabVIEW® was integrated to acquire data for engine analysis.

Automation and Instrumentation

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. LabVIEW® has been in existence for over thirty years and has emerged as 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 LabVIEW® was procured to support instruction in this effort. The ET 472 course consists of six weeks covering PLCs followed by six weeks of LabVIEW® instruction and applications. Using the pneumatic engine as a test station, a mini-project was implemented that required students to develop Virtual Instruments (VIs) in LabVIEW that acquired pressure and angular position data for analysis of engine performance.

A Vishay TST2300 optical sensor and an acrylic encoding disk, fabricated in the machining lab of WCU, were used to detect pulses for determining angular position of the engine's crankshaft. Similarly, to monitor changes in system pressure during engine operation, a Keyence AP33K pressure transducer was wired to a NI-6008 USB DAQ for monitoring and analysis using LabVIEW® as shown on the wiring diagram in Figure 4.

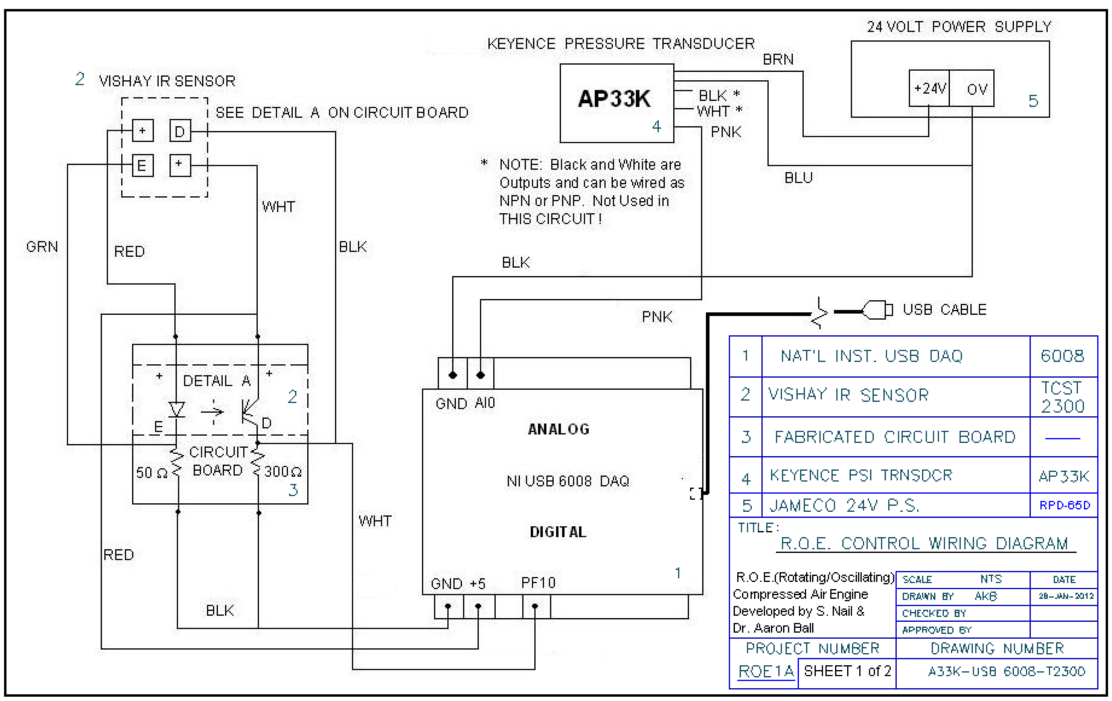

Figure 4: Wiring Diagram Showing Optical Sensor, Pressure Transducer, and DAQ

Pressure data was averaged and graphically displayed simultaneously while angular crankshaft position was acquired and dynamically displayed for monitoring. Typical front panel and block diagram VIs are show in Figures 5 and 6 respectively. Engine data was also written to a spread sheet file for archiving and analysis.

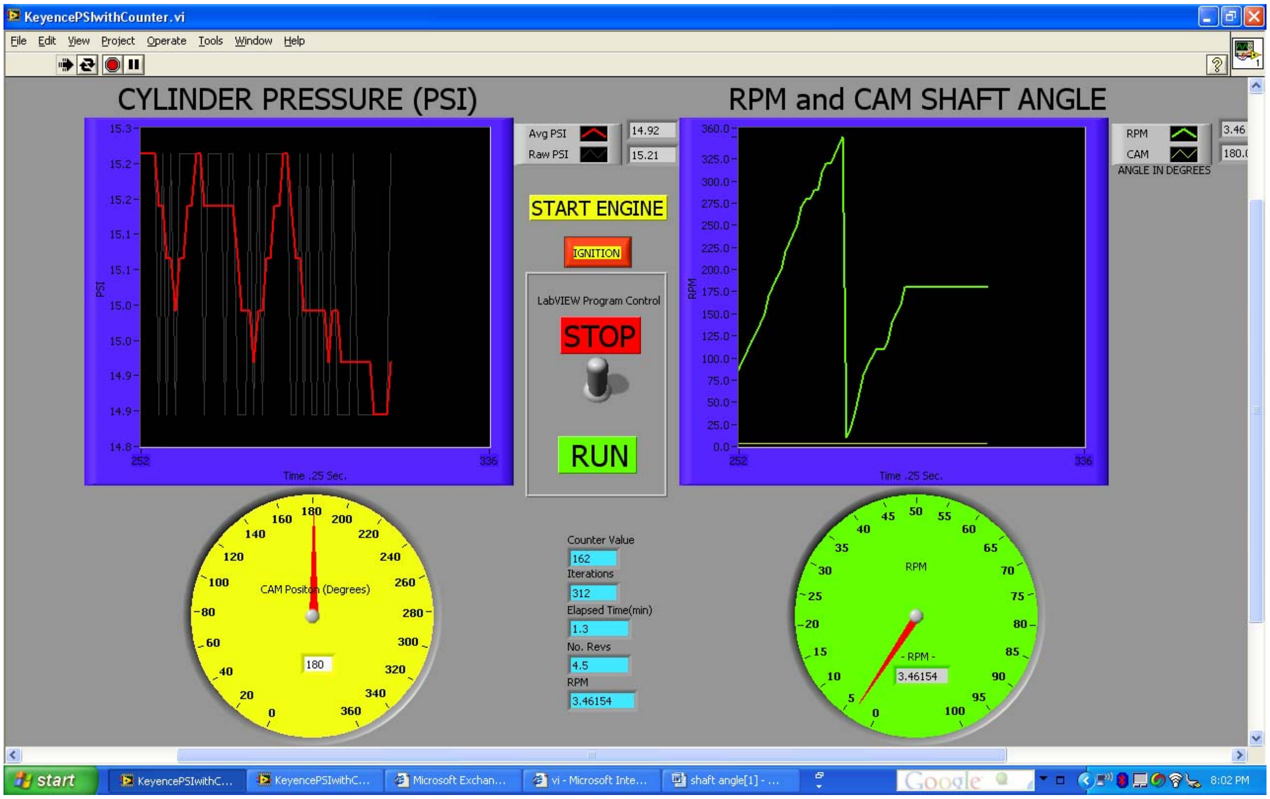

Figure 5: Front Panel of LabVIEW® Monitoring VI

Students were required to analyze data relative to sampling rate, changes in pressure due to valve position actuated by a cam mechanism from the crankshaft, and crankshaft angular position. By increasing the sampling rate, the pressure changes related to valve position were discovered and noted. Accuracy was reported and discussed by each team since the positional resolution was limited to ten degree increments (restricted by the thirty-six holes in the encoder disk).

Overall, students came away with a sense of accomplishment and understanding of basic mechanisms, importance of quality and fits in fabrication and assembly. Further, they obtained a practical understanding of LabVIEW® programming fundamentals for instrumentation, data acquisition, monitoring and analysis.

Uniqueness of the Approach, Benefits, and Obstacles

The uniqueness of this approach can be seen in the students' need to address the design-build-test-analyze cycle from end to end and across multiple courses. Students were required to redesign an existing set of engineering drawings, develop ProE 3-D models, create the CAM applications to generate CNC code, machine and assemble a working model, and finally, to test the model's performance by instrumenting with infrared sensors using LabVIEW. In this way, students were afforded a comprehensive view of the design-build-test-analyze cycle which was supported in practice by carrying the project from one Engineering Technology course to another.

Similarly, faculty gained a better understanding of the curriculum effectiveness based on continuity of course outcomes to reinforce learning across different course subjects. Further, the concepts of Design for Assembly (DFA), Computer Aided Manufacturing (CAM), Quality Assurance (QA), and performance testing were more tangibly experienced in contrast to the traditional stand-alone academic exercises that existed before.

The primary obstacles encountered in this approach were related to student time management and to implementing the project across courses which necessitated review of past semesters' material. While these obstacles hindered the rate of progress, they also provided opportunities for faculty to reinforce the importance of meeting deadlines and the steps of the design to test cycle. In the future, a more structured timeline of milestones with specific outcomes for each phase should lead to improvements in implementing interdisciplinary projects across ET courses.

SUMMARY AND CONCLUSIONS

Using the curriculum integration approach to teach engineering applications focusing on design-build-test and analyze provides an opportunity for students to gain a better understanding of both modern manufacturing and control methods. Knowledge gained in individual courses is carried forward and applied in a logical sequence to enable a more concrete understanding of concepts, while building quality into the Engineering Technology curriculum.

A project of the nature described in this paper meets the student on a number of levels which help to bring classroom theory to the fore in a manner that might be encountered in the student's early professional life. Students are asked to incorporate multiple facets of their degree program including concepts in design, fits and materials selection, CAM, CNC, and tooling applications. Using an industry standard tool, LabVIEW®, students experience the value of instrumentation, monitoring, and analysis to quantitatively assess the effectiveness of their work.

Collectively, these factors traverse the Engineering Technology curriculum in both time and subject matter. In this way, the approach should improve long term student learning. And, by making courses more keyed to tangible, rewarding outcomes, student retention and long term student success may be improved.

REFERENCES

[1] Wingo, O. G., "Analysis of Learning Style Preferences in Adult Learners." Doctoral Dissertation, University of Florida, 1992. (Dissertation Abstracts International, Publication no. AAI 9304072*).*

[2] Kolb, D. A., *Experiential learning*. Englewood Cliffs, NJ: Prentice-Hall, 1984.

[3] Coe, W.E. "Incorporating CAD Analysis Tools into the Mechanical Engineering Technology Curriculum, *"The Technology Interface*, Vol. 3 No. 3, Fall, 1999.

[4] AAHE, *Making Quality Count in Undergraduate Education*, American Association of Higher Education, 1996.

[5] Wallace, J., Rennie, L., Malone, J., & Venville, G., 'What We Know and What We Need to Know about Curriculum Integration in Science, Mathematics and Technology,' paper presented at *National Association for Research in Science Teaching*, New Orleans, April 2000.

[6] Venville, G. and Dawson, V., 'Integration of Science with Other Learning Areas,' *The Art of Teaching Science*, Allen & Unwin, Crows Nest, New South Wales, Australia, 2000, pp146-161.

[7] Fitt, W.C., *Steam and Stirling: Engines You Can Build*, Traverse City, Mich: Village Press, 2006.

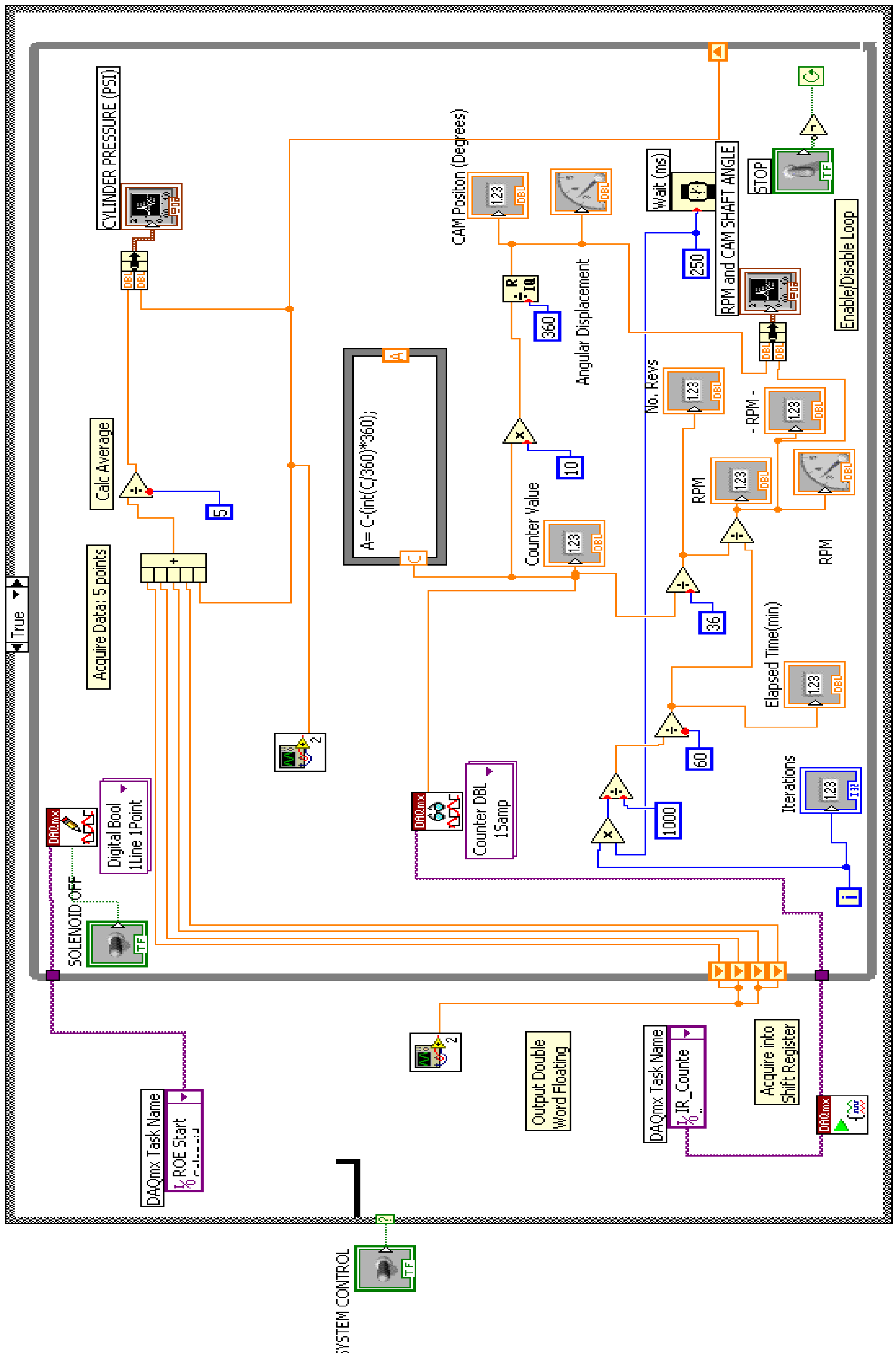

Figure 6: Block Diagram of the LabVIEW® Monitoring VI.

Mr. Paul M. Yanik

Mr. Paul M. Yanik is an Assistant Professor in the Electrical and Computer Engineering Technology program at Western Carolina University, Cullowhee, North Carolina. He holds a B.S. in Electrical Engineering and an M.S in Computer Engineering, both from North Carolina State University. He is currently a Ph.D. candidate in Computer Engineering at Clemson University. His industrial experience includes fifteen years in the design of complex digital systems for telecommunications and microprocessor applications. His research interests include intelligent systems, machine learning, robotics, and electronics design automation.

Dr. Aaron K. Ball

Dr. Aaron K. Ball is a full professor of Engineering and Technology at Western Carolina University, Cullowhee, North Carolina. He holds a B.S. and M.S. from Appalachian State University, and earned his doctorate from Virginia Polytechnic Institute and State University. Prior to his arrival at Western Carolina University, Dr. Ball worked in production engineering at Chicago Telephone Supply and Vermont American Corporation. His areas of interest include fluid power, advanced machining, prototyping systems, and applied research.