A Low Cost Conveyor System for Teaching Automation to Engineering Technology Students

Aaron K. Ball[1], Johnson S. Busick[2]

Abstract–As a result of a graduate level directed project, a new conveyor system was developed at Western Carolina University that included the integration of a Siemens Programmable Logic Controller (PLC), laser sensors, and a National Instruments Data Acquisition and Control (DAQ) module. Using LabView™ for monitoring and a PLC for control, a relatively low cost but effective conveyor system was developed for supporting laboratory instruction in engineering technology programs. This paper will present a logical approach to developing such a system and describe how applications have been integrated into the curricula of the Engineering Technology Program at Western Carolina University. Emphasis will be placed on system design, fabrication and control methods. Further, the method by which the project was integrated into a valuable learning experience for both graduate and undergraduate students will be presented. Educational merit will be described relative to respective educational levels.

Keywords: Engineering Technology, graduate directed projects, automation, undergraduate laboratory instruction.

Introduction and Background

Western Carolina University (WCU) has continued to provide opportunities for students to engage in real-world projects that not only benefit students, but external constituencies as well. WCU has several mechanisms in place that allow collaboration between the university and industry. The university has developed a Quality Enhancement Plan (QEP) that encourages students to create connections between what they learn inside the classroom and the outside world. Recently, Western Carolina University adopted the Boyer model for engaged teaching which supports the creation of a learning environment of application. The Boyer model focuses on discovery, integration, analysis and application, knowledge transmission and transformation, and the understanding of real world issues. Further, the Engineering Technology Department at WCU stresses Problem Based Learning (PBL) as a concerted effort to employ the Boyer model.

Project Based Learning

The integration of project based learning is certainly not new and has been implemented across an array of varied disciplines. As suggested by Greenburg [3] and Nelson [6], responsibilities of carrying out the project shift to the student while the teacher serves more in a mentor role. Fink [2] further describes the PBL approach as a method that encourages creativity, independent thinking, and proactive self-directed learning. Support for PBL in Engineering Technology include realistic environments that are more similar to those students will encounter when entering the work force. Projects are focused solutions rather that theory focused calculations, and the integration of knowledge from a variety of non-traditional classroom resources. To fulfill the Engineering Technology program 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 as stressed by both Kumar [5] and Grinberg [4]. This approach was implemented using PBL through the development and integration of an automated conveyor system into the Engineering Technology Curriculum at Western Carolina University.

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Scope of the Project

The outcome of this project was intended for supporting the curriculum of the ET-472 automation undergraduate course of study at Western Carolina University. The scope and sequence of the undergraduate course is shown in Table 1. Further, the intention was to provide the students with a real world application for one of the required laboratory experiments for the course. Prior to the development of the conveyor system, the specific laboratory experiment was purely theoretical.

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	**Integrating LabView and PLCs**	**Control and Monitoring of a Conveyor System**
14	Introduction to Mathscript	Pick-and-Place Robot control using Mathscript
16	Final Exam	Written Exam and Laboratory Performance Exam

Table 1: Scope and Sequence Structure for ET 472

The concept of this project was to develop a conveyer system to simulate a processing line made up of five separate work stations. The project consisted of a conveyer belt coupled to a prime mover used to traverse simple parts through the five work stations. Upon entering each work station, the conveyer would halt until the work had been completed. The first station served to inspect parts to determine whether each part was good or bad based on part height. Laser sensors were incorporated to detect height of the parts. The remaining stations only operated if the part was determined to be a good part. The second station simulated a cleaning operation while the third station simulated a spray coating of the part. The forth station simulated heat setting of the coated part to solidify the enamel. Finally, the fifth station was used to divert bad parts off of the conveyor. A concept illustration of the conveyor system is shown in Figure 1.

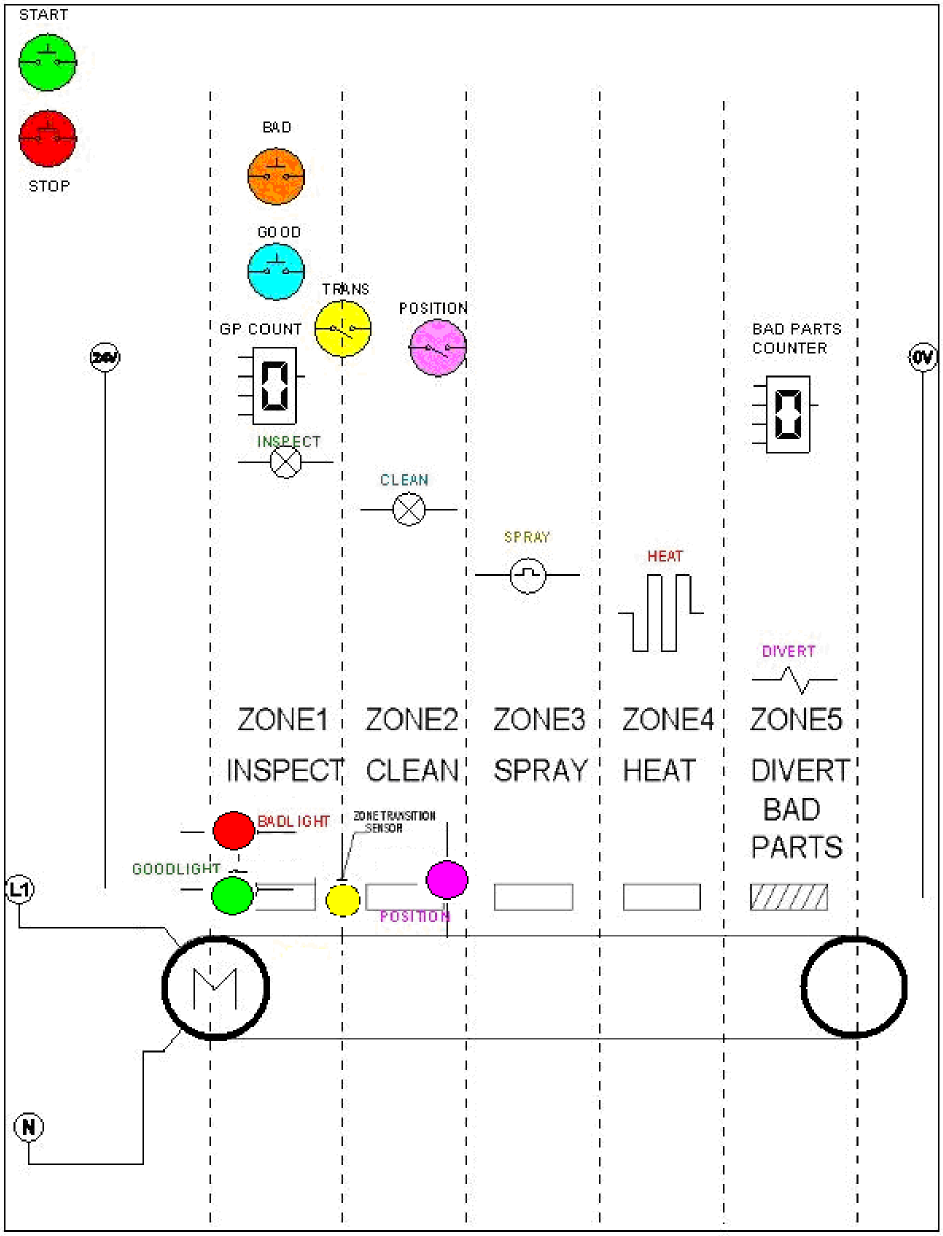

Figure 1: Concept Layout of Conveyor System

Preliminary Design and Approach

As part of the requirements for a graduate level directed project, Mr. Busick chose the conveyor system as a semester project and developed a preliminary design adhering to the scope of the project as shown in the Figures 2 and 3. Many aspects of this project required custom fabrication, which meant utilizing the CNC machining laboratory and the laser laboratory at WCU. The primary materials from which the structural components were fabricated included 6061 T6 aluminum and acetyl. The programming for the system included ladder logic for a Siemens S7-224 PLC and LabVIEW™ 8.2 software with a National Instruments NI-USB-6008 Data Acquisition Device interface. The Virtual Instrument (VI) incorporated the use of a shift register to determine which stations were activated for the corresponding part. Digital I/O ports of the DAQ device were used to control the simulated actuators using 24 volt strobe lights for each station as well as the conveyor itself. A standard 24 volt D.C. power supply was incorporated for both the control and monitoring systems.

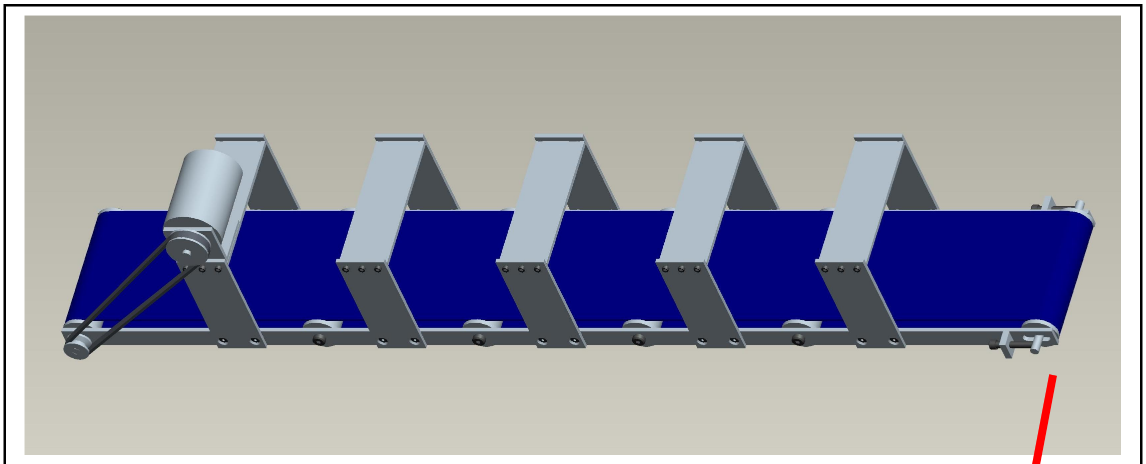

Figure 1: Preliminary Parametric Model

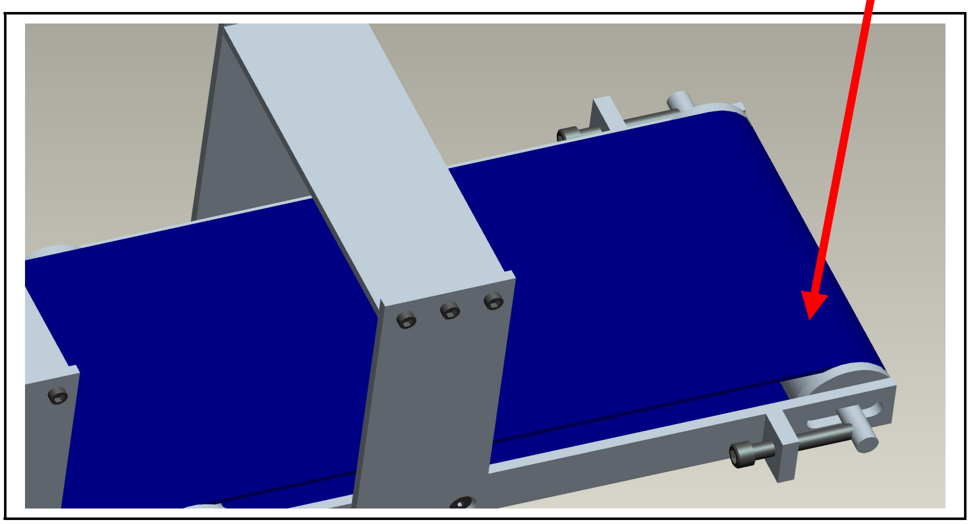

Figure 3: Belt Tensioning Concept Model

Project Results

Several design variations were considered, and final parametric models were developed prior to fabrication of the frame and structural components. Pro-Engineer was used to develop all models and two-dimensional drawings. IGES files were imported into OneCNC CAM software for the development of CNC programs. Simulations were executed prior to the actual machining of components on HAAS vertical CNC milling machines and HAAS horizontal CNC engine lathes. Namely, a VF-3, Super Mini-Mill, Tool Room Mill, and Tool Room Lathe were used. Assembly of the structural frame, motor mounts, conveyor belt, and tension adjuster were completed prior to mounting of electrical components. After a detailed wiring diagram (shown in Figure 4) of all electrical components was completed, final connections were made. The completed conveyor is shown in Figures 5A through Figure 5D.

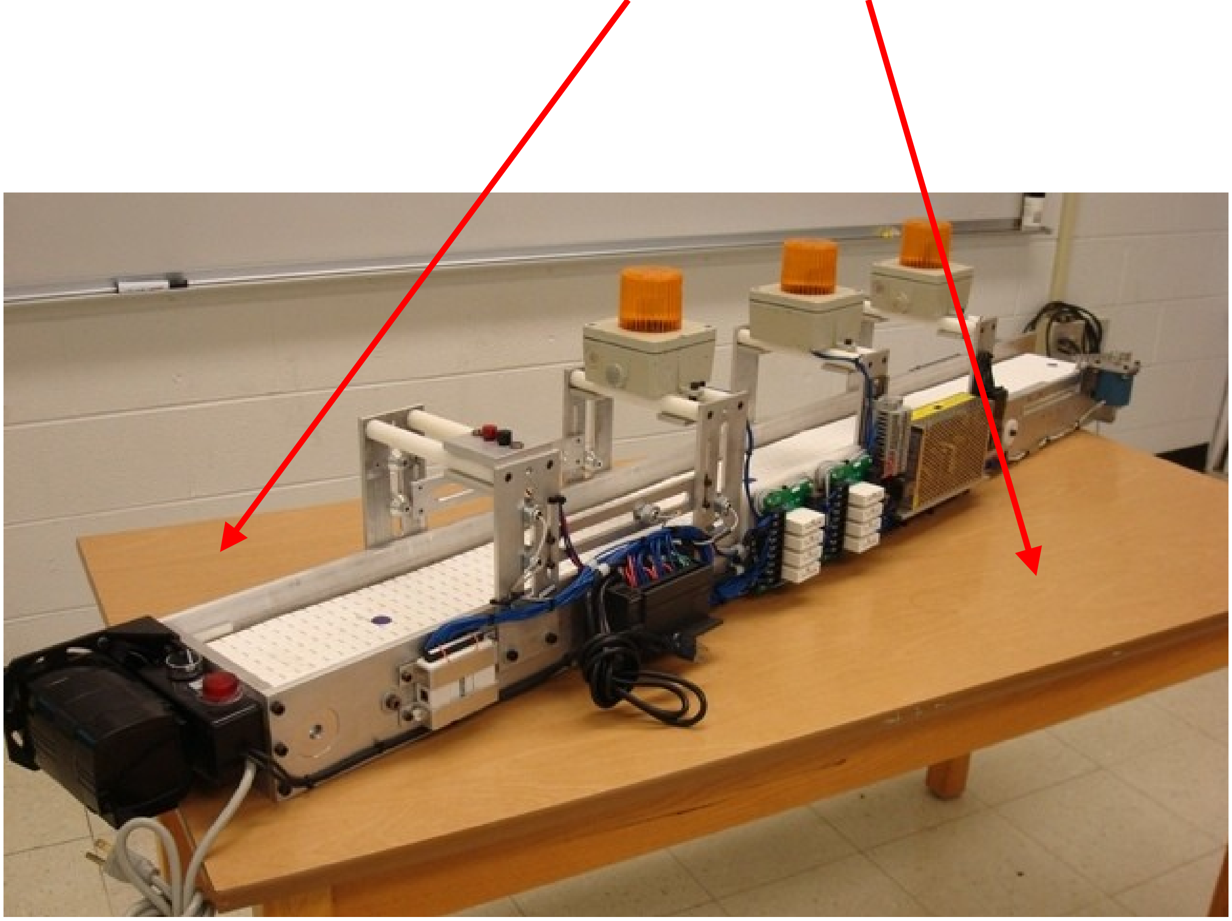

Figure 5-A: Photo of Completed Conveyor Assembly

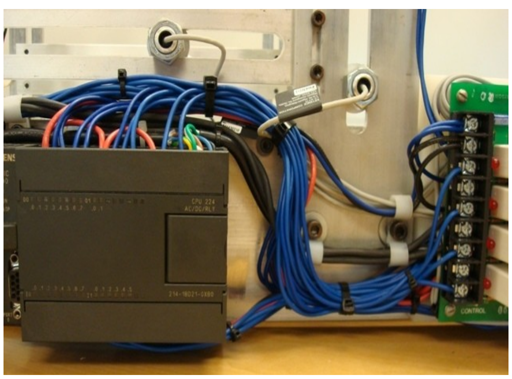

Figure 5-B: Siemens S7-224 PLC

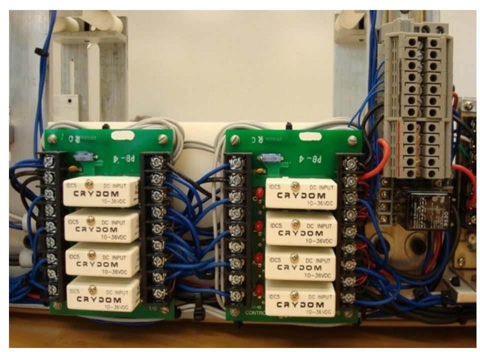

Figure 5-C: Crydom Solid State Relays

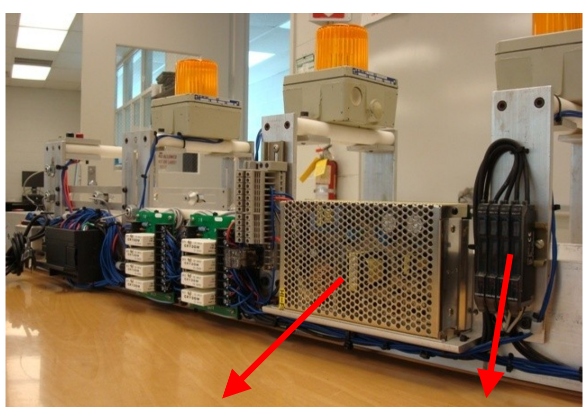

Figure 5-D: Power Supply and Laser Sensors Amplifier.

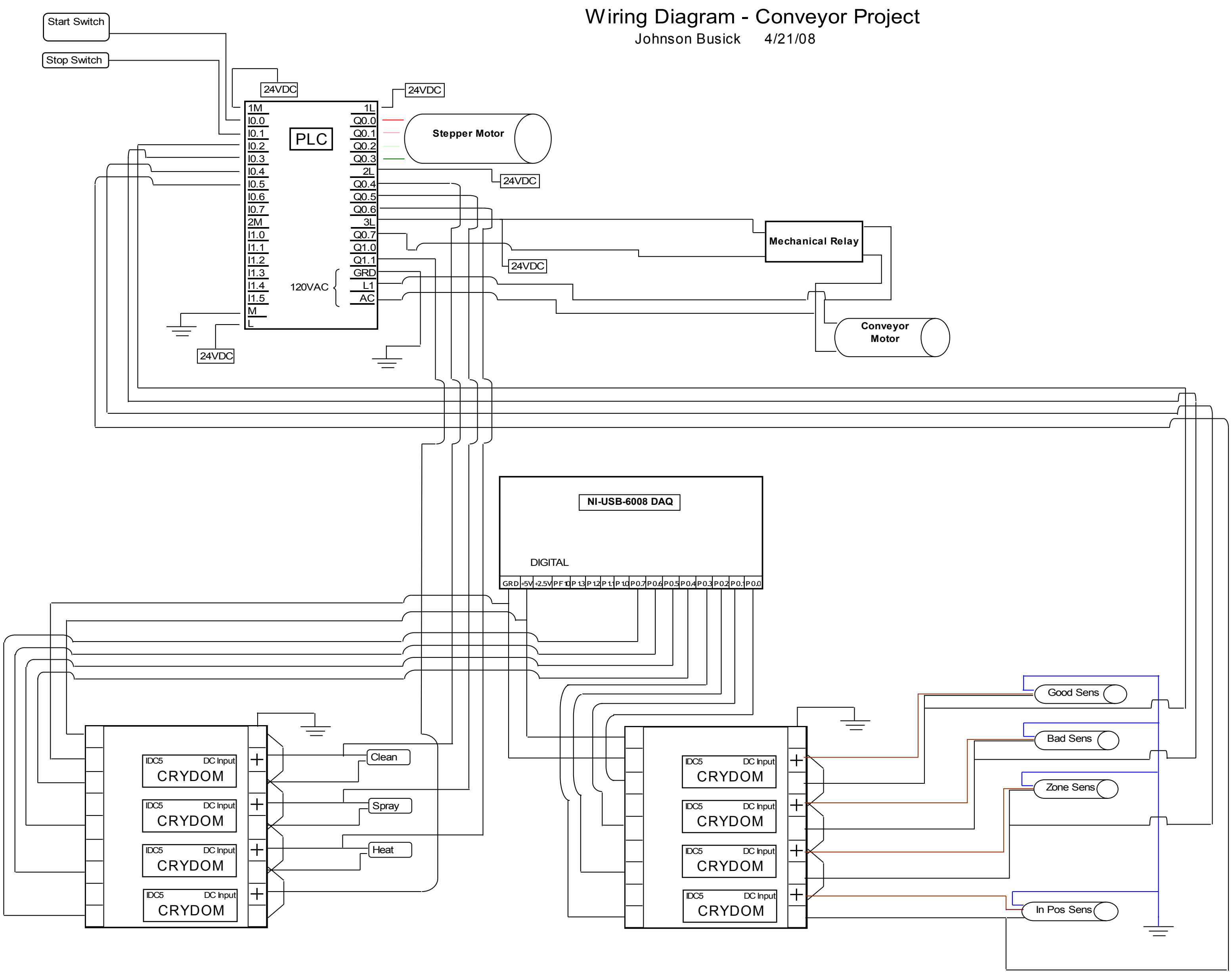

Figure 5: Electrical Wiring Diagram for Conveyor

Student Learning Outcomes

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 laboratory exercises. Interestingly, similar concepts were covered during the second 6 weeks using LabVIEW™ with a much more positive outcome. Further, students struggling with subroutines and timing functions were able to better grasp the concept using the graphical "G" language in LabVIEW™ when provided the opportunity to develop the control and monitoring programs for the automated conveyor system.

To further test the approach of using a live conveyor system and the effects on learning, two different classes were given the same conveyor control problem in the spring semester of 2009. The first group had full access to the previously fabricated system, while the second group was given the assignment to develop a completely virtual system. Both groups completed a PLC control program using the Siemens S7-224 and a system monitoring VI using LabVIEW™ 8.2.

As expected, the first group had significantly less difficulty in completing both the PLC program and the VI. Having full access to the "live" system enabled students to trace wiring, and test the physical connections prior to running the programs. The visual feedback from LED's and laser sensors also enabled students having access to the actual system to demonstrate better organization in their programs as well as better "debugging" techniques. The second group, with the aid only of a virtual system, struggled in how to grasp the solution for sequential control as well as monitoring. A second trial is currently in progress to evaluate these same comparisons for two new groups.

Educational Merit and Conclusions

The educational merits of this approach are abundant and significant. First, students grasped the foundations and control methods that were intended to be taught by implementing the live conveyor system. This was evidenced by their improved capabilities when developing PLC programs and LabVIEW™ VIs compared to students using only virtual systems. Secondly, the students learned problem solving and analysis skills much faster using the live system approach. This was demonstrated by their capabilities for developing and using computer tools to analyze variables, as well as determining logical parameters for system control. Finally, Mr. Busick enhanced his abilities to apply engineering methods and skills learned at the undergraduate level by way of designing, fabricating, and testing the conveyor system. The ability to transfer knowledge from courses to successfully solve problems in different applied engineering areas was effectively demonstrated.

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 [1]. The approach implemented in the ET program at Western Carolina University provides a logical and systematic method for building on theory and effectively implementing project based learning methods. Through immediate feedback, students can gain a better understanding of problem definitions, logical programming solutions, and troubleshooting techniques. 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 and the use of only virtual systems.

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Dr. Aaron K. Ball is full professor in the Engineering and Technology Department at Western Carolina University in Cullowhee, North Carolina. He holds a B.S. and an M.S. from Appalachian State University, and earned his doctorate from Virginia Polytechnic Institute and State University. His areas of interest include automation, fluid power, advanced machining, prototyping systems, applied research, and Design of Experiments (DOE).

Johnson S. Busick

Mr. Busick completed his B.S. in Engineering Technology in May 2007 and his M.S. degree in Technology from Western Carolina University in May, 2009. He served as a graduate teaching assistant in the areas of fluid power and automation, and completed his thesis in the area of organic corn based polymers. Mr. Busick also has experience in the machining and fabrication fields and is currently employed by a fabricator in Kernersville, NC.