AC 2008-607: A PLC PROJECT IN A CONTROL COURSE LABORATORY

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Abstract

This paper describes the design, development, and implementation of an automated labeling process in an undergraduate control course laboratory. This effort provided students with valuable hands–on experience in computer assisted control system. The objective of this project is to design an automated labeling system that would label products on a conveyor belt and counts the total number of parts coming off the conveyor belt for final packaging.

The system consisted of several mechanical, electrical, and pneumatic components that were integrated into a control system: a conveyor, a labeling machine, a double solenoid valve, a pneumatic actuator, a programmable logic controller (PLC), a photoelectric sensor, and relays. The photoelectric sensor, conveyor, relays, and double solenoid valve were connected to the PLC. The PLC was programmed to communicate with these components and control the entire process. All of the components were integrated to perform a task of automated labeling process.

The automated labeling process began with loading parts onto the conveyor belt. The conveyor belt transported parts to the labeling station that was equipped with photoelectric sensor, actuator, and labeling machine. When the part arrived on the station, the photoelectric sensor detected the part and sent a signal to the PLC to stop the conveyor. The time delay at this station allowed the labeling machine to label the part. After the part was labeled, the pneumatic actuator extended and pushed the part into the storage area for packaging process. The actuator retracted before the conveyor motor restarted to carry another part to the labeling station. This is a repetitive process in which, after storing a part, the system will reset itself to label and store other part.

The design of the system involved programming of individual components through extensive circuit wiring, testing, verification and modification. Applying this system required the links and integrations of components that challenged and stimulated the students.

I. Introduction and Background

The PLC and sensors are widely used in industry to control manufacturing process, to increase reliability and flexibility, reduce cost, and increase maintainability. Today, due to competition among manufacturers and suppliers, industries are looking for ways to reduce man-power as well as the cost of operation, and expediting the entire process. There are many companies that utilizing PLC and sensors for automation cell, distribution system, and warehouses. References[1-4] provide some applications of PLC and sensors in dredging, GPS, research laboratories, pharmaceutical and other sector of industries.

As the use of automation increases in the manufacturing industry, as well as the distribution and shipment industry, understanding this technology is critical for technology and engineering technology students who want to be prepared for their first job. The objective of this project was to introduce students to the PLC and sensors in the context of a control system. This introduction was done in a laboratory setting. Several steps were used to expose students to operation of an automated labeling system. First, students received an introduction to operation of PLC, sensors, conveyor, solenoid valve, actuator, and electrical relay. Second, students designed the ladder logic diagram to control each individual component to investigate the response of each component after receiving signal from PLC. Finally students designed a ladder logic diagram to integrate all the components with appropriate wiring connection.

It is clear that the practice of engineering is undergoing significant change some in response to rapidly changing technology and others in reaction to the large social changes. The focus of this project was to adopt the new changes and improve the methods that students practice in a control course laboratory. In the traditional laboratory, students are limited to conducting the experiment, collecting and analyzing data, and generating a report. However, in this lab project, students had to design the system, integrate and wire the electrical and mechanical components, test, troubleshoot, and analyze the system. The project can be used either in a manufacturing laboratory or in a Capstone Project for assessing student learning. It is also a useful method to measure educational outcomes through an effective assessment program to improve program curriculum, course content, and instructional delivery.

II. Methodology

The objective of this project was to design and construct a fully automated labeling system for educational purposes. Several steps were necessary to accomplish the project.

Step one: Identify necessary components with appropriate specifications to design, construct, and simulate the system

The system consists of an Allan Bradley PLC with 120V ac operation[5], conveyor belt that runs by a 120V ac electric motor[6], labeling machine, 24V dc double solenoid valve, double acting pneumatic actuator, 24V dc photoelectric sensor[7], relays, two DC power supplies to power the solenoid valve and the photoelectric sensor, and a storage area for packaging the parts. The chassis of PLC houses a 120V ac power supply, a CPU 5/2, 120V ac four and eight-terminal input modules with 120V ac com terminal connections, and a 120V ac eight-terminal output module with 120V ac terminal connection. The initial design of the project and ways to integrate them were discussed and depicted.

Step two: Design ladder logic program for each individual component and simulate them

Students used their own knowledge to program PLC to control each individual component such as conveyor’s motor, and solenoid valve connected to double acting actuator as well as simulate them through training units. Each ladder logic diagram consists of normally open and normally closed inputs, outputs, and on-delay timer with associated control bits. After creating each PLC ladder program, it was simulated on the training unit to test and troubleshoot the program. Figures1a and 1b show the training units.

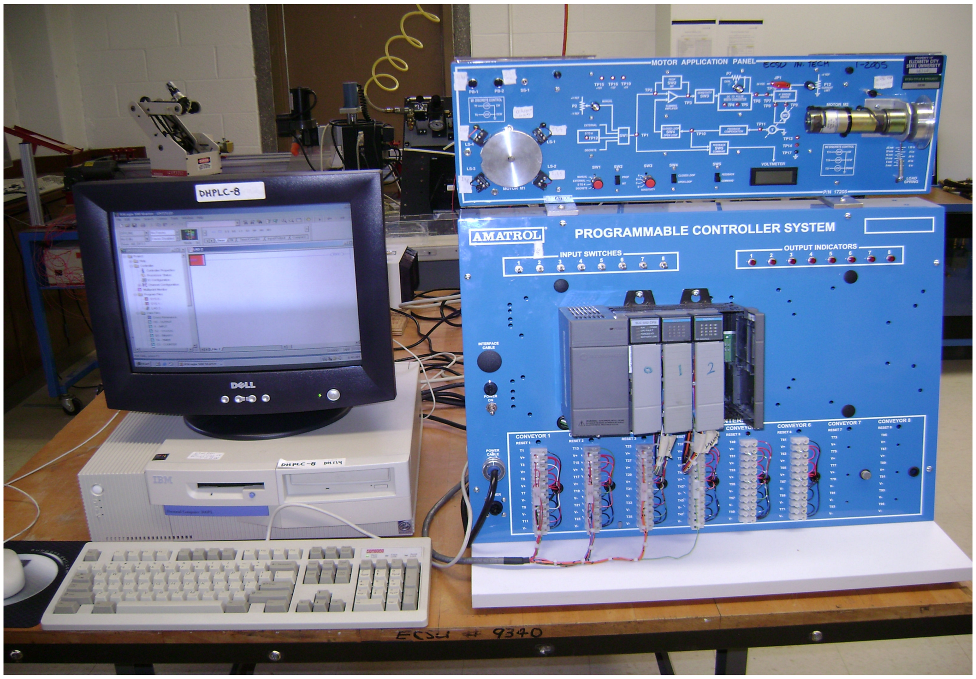

Figure 1a: PLC with Electric Motors Training Unit

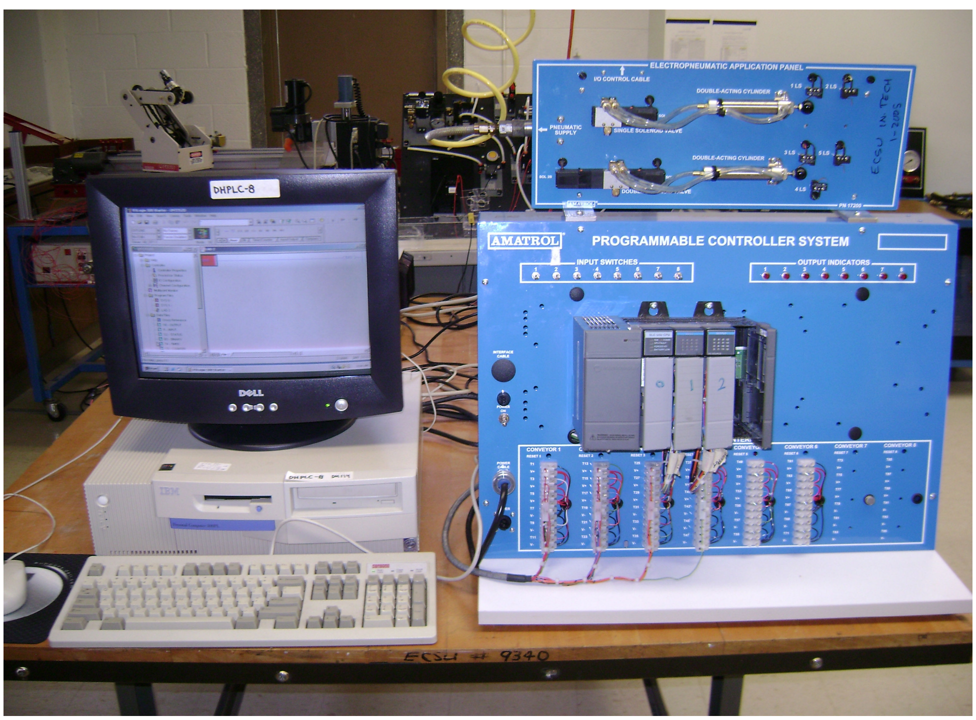

Figure 1b: PLC with Pneumatic Training Unit

Step three: Design a main ladder logic diagram to integrate all the components to work together as a system

Figure 2 shows ladder logic diagram using RSLogix 500[8] software. As depicted in Figure 2, in rung 0, the output O:3/7 (conveyor belt) is tied to a normally closed relay enable bit T4:0/EN and normally closed input I:1/1 (photoelectric sensor). The conveyor belt is latched, in order to stay energized until the photoelectric sensor detects the presence of a part. The part cuts the light beam and causes de-energizing of the normally closed input I:1/1 and conveyor stops for next step of the process that is labeling the part.

In rung 1, I:1/1, which is energized, activates the timer on delay T4:0 presets to 5 seconds. The normally open input enable bit T4:0/EN, which uses for latching the timer on delay T4:0, allows the timer to keep timing for five seconds. The five second time delay will give the labeling machine enough time to label the part at this stage.

In rung 2, the energized input done bit T4:0/DN activates timer on delay T4:3 and timer in turn energizes input timing bit T4:3/TT in rung 3. This allows energizing solenoid A and activating actuator arm to extension position and pushing the part to storage area.

In rung 4, the normally open input done bit T4:3/DN is connected to timer on delay T4:2 preset to 2 seconds. The timer on delay T4:3 is timing until the accumulated time equals the 5; the T4:3/DN is then activates the timer on delay T4:2. This allows energizing solenoid valve B in rung 5 and retracting the actuator arm to its original position.

In rung 6, the normally open input done bit T4:2/DN is connected to an output reset T4:0. After time elapsed two seconds in timer on delay T4:2, the reset re-energizes the input T4:0/EN in rung 0, in order to restart the conveyor belt.

In rung 7, the normally open input I:1/1 is connected to a counter up C5:1 with a preset of 1000 parts. Every time a part breaks the light beam of the photoelectric sensor the counter counts up until the number reaches 1000, which indicate the storage area is full.

Figure 3 shows the sequence of pulses applied to conveyor's motor and double solenoid valve A and B. As depicted in Figure 3, conveyor belt stops when light beam of photoelectric sensor is interrupted by a part and will be restarted after energizing the reset coil.

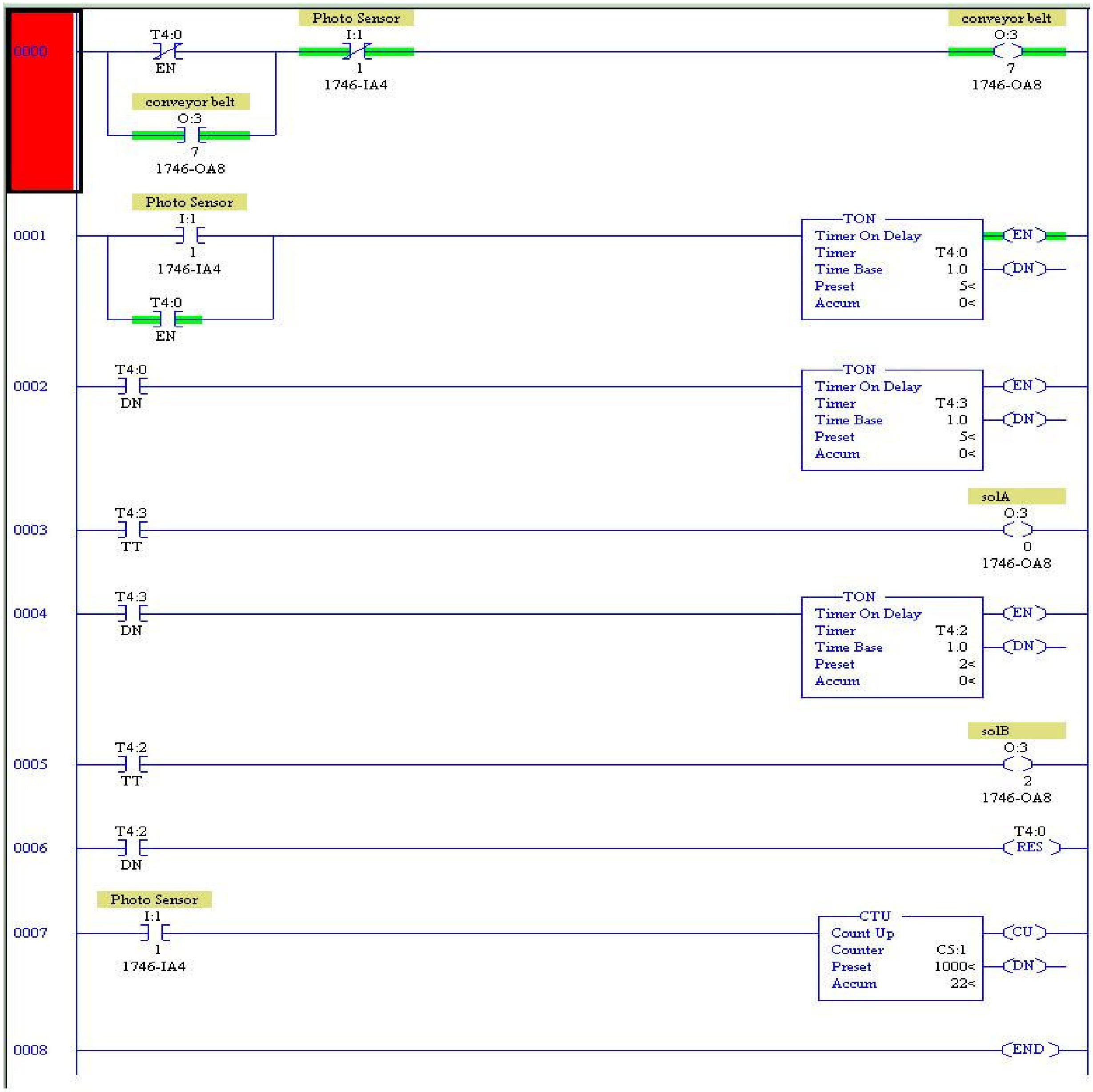

Figure 2: Ladder Logic Diagram

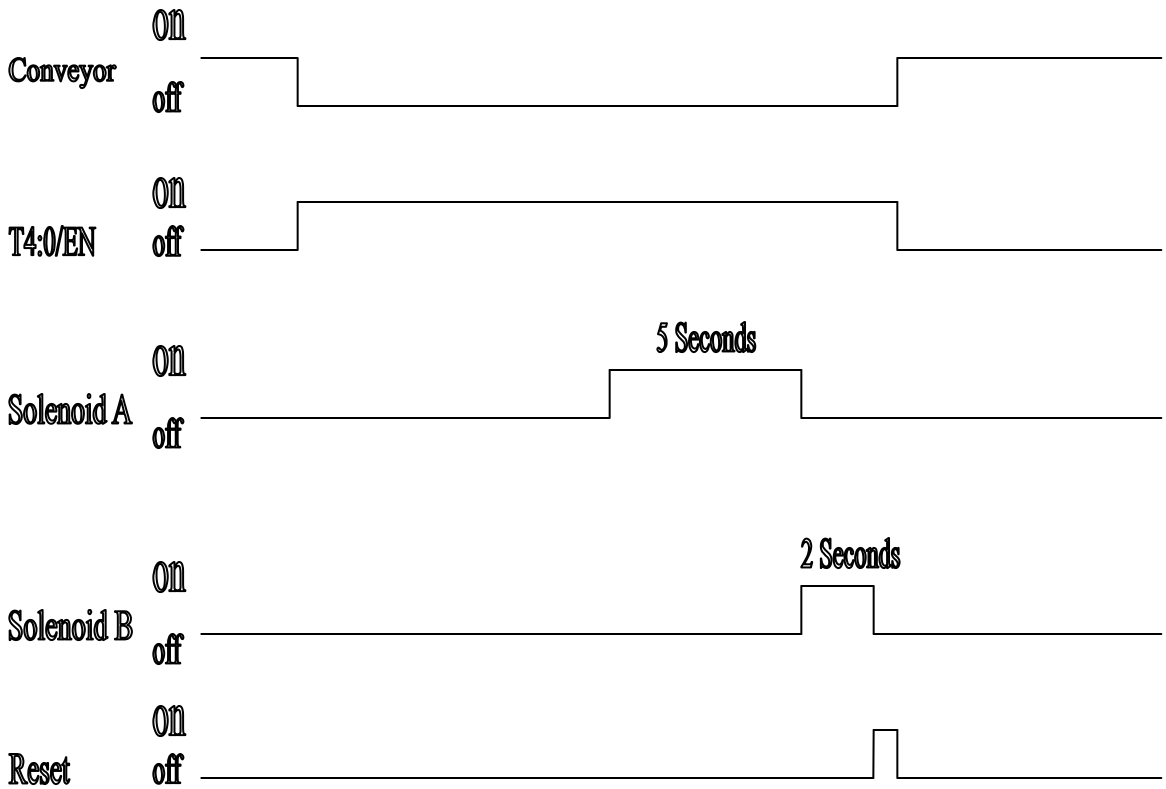

Figure 3: On-Off Sequence Chart

Step four: Wiring the components and simulate the system

This step was a major challenge in the process to integrate the components correctly. Figure 4 shows the components connected by wiring to each others. Also, Figure 5 shows the wiring diagram. As depicted in Figure 5, the wiring starts with connecting the solenoid valve and conveyor's motor to the PLC output module and connecting the photoelectric sensor to the input module of the PLC. The solenoid valve and photoelectric sensor operate with 24V dc voltages. However, the input and output modules of the PLC operate with 120V ac voltages. The two relays with coil of 120V ac and contact of 24V dc are utilized for providing isolation between these circuits. If the coil of relay is energized with external voltages, a magnetic field would be generated and would open or close the contact. A 24V dc power generator and the solenoid valve are wired to the contacts of the relays. The coils of relays are wired to the AC Com terminal, on input module #2, and to the terminals 0 and 2 on output module of the PLC. This allows PLC energizes solenoid valve; the actuator arm then moves forward and backward to push the part into the storage area. A relay with coil of 24V dc and contact of 120V ac is utilized to connect the photoelectric sensor to input module of PLC. The photoelectric sensor and a 24V power supply are wired to coil of relay and one of the terminal contacts is wired to the terminal 1, on the input module, and other terminal contact is wired to 120VAC1 terminal on the output module of PLC. This allows the photoelectric sensor to send the signal to the PLC in order to stop or restart the conveyor belt.

After finishing the wiring and troubleshooting, the labeling system was simulated successfully by labeling the parts and place them into the storage area for packaging process.

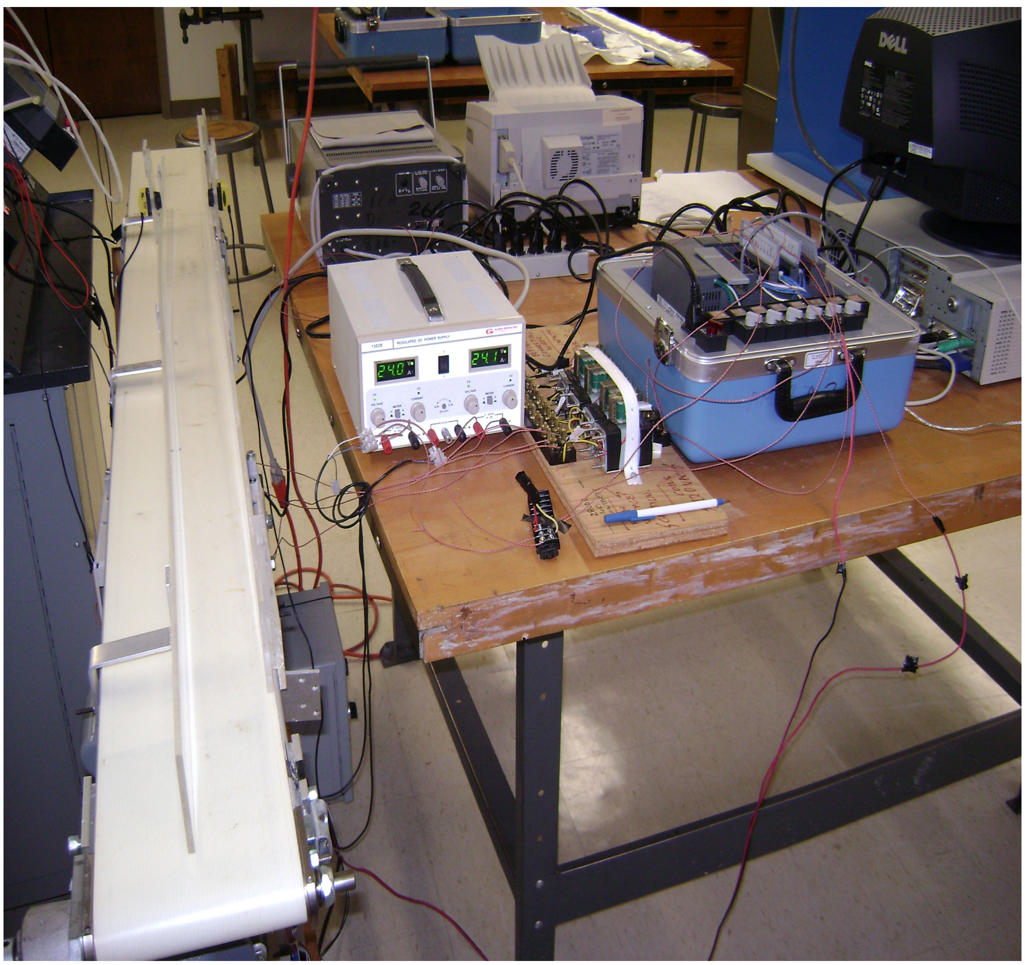

Figure 4: Automated Labeling System

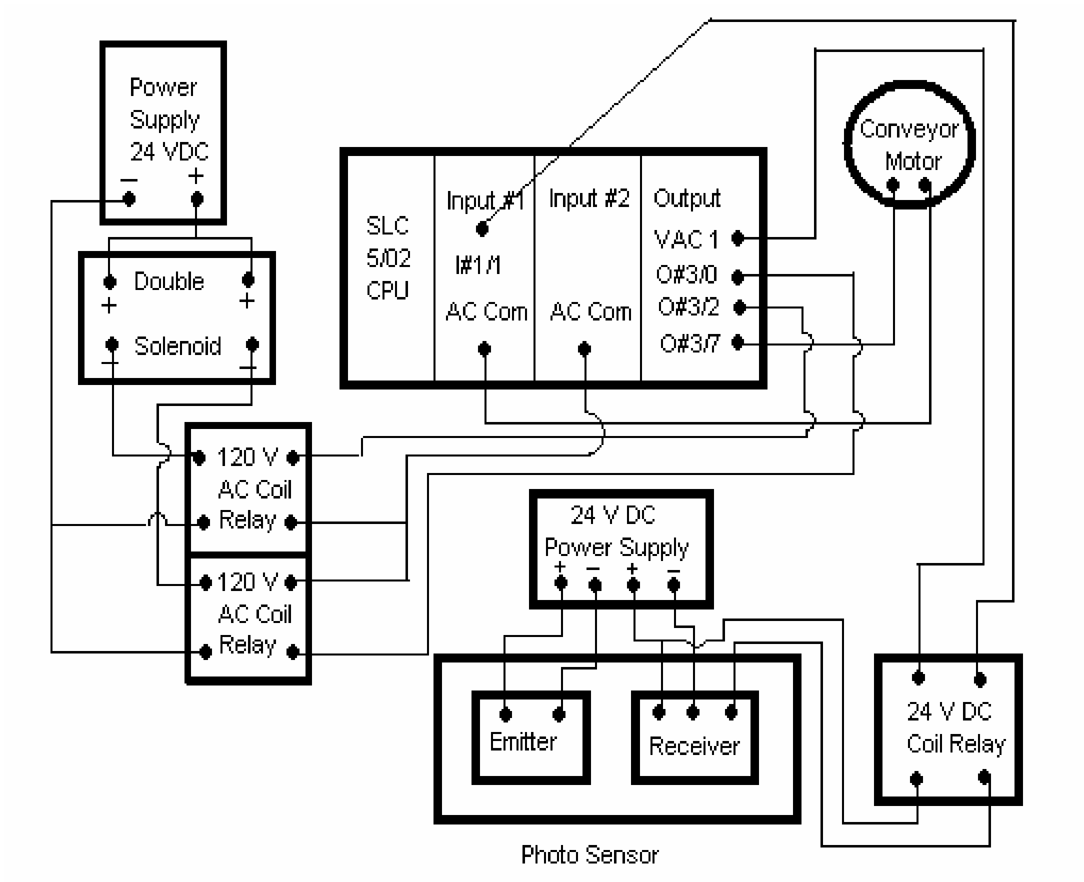

Figure 5: Wiring Diagram of Components of Automated Labeling System

III. Assessment of Students

In this performance assessment project, students were observed working with complex tasks associated with a real world project. The project afforded students an opportunity to put into practice many of the competencies learned in their field of study including design, software simulation, wiring, and system construction. A team of faculty members utilized a capstone project matrix instrument to validate students' competencies in the areas of technical knowledge, problem solving skills, writing, oral presentation, and team work.

Many universities use direct assessment instruments such as written exams, oral exams, embedded questions in exams, certification exams, and other instruments. Traditional teacher-constructed tests and standardized tests yield information about student knowledge and performance. Alternative forms of assessment, such as this constructive project, may also be expanded to examine student development and progress in creativity, design, problem solving, trouble shooting, and approaches in handling real world projects.

IV. Recommendations for Future Research

This system can be improved by utilizing a robotic arm to pick up the parts and palletize them for delivery. The robotic arm would receive the signals from PLC to perform the operation. Further research could be conducted on using the laser beam to mark the part (bar coding) faster and make the labeling process more accurate and precise. Also, adding of a scanning station to the system would provide a scan of the package to detect any illegal object in the package.

V. Conclusion

The objective of this project was to design and test an automated labeling system for a control laboratory class. The PLC, photoelectric sensor, conveyor, relays, and actuator are integrated together to operate the entire system automatically. Each component of the system must rely upon input from another component and provide an appropriate signal that indicates a task is completed. The wiring allows the signals being sent in order to energize or de-energize the components to complete the task. The PLC receives and sends signals to components in order to control the entire system.

In this project, the role of PLC, photoelectric sensor, solenoid valve, pneumatic actuator, conveyor, and relays were examined. The general structures, applications and operation of each individual component were reviewed to gain knowledge of operating the system fully automated. Troubleshooting techniques for each component were also acquired in case of a malfunction in the system. Programming of each individual components, troubleshooting, and integrating of them were a major key to the development of this project. Team work and group dynamics were other important part of this project.

The project is an example of practical application which can be performed in an industrial setting as well as in a control laboratory. This experience develops essential skills and knowledge to design an advanced motion and process control system with practical applications in an industrial setting. Through numerous experiments on the automated labeling process, it was verified that the proposed project is an effective module for an undergraduate control laboratory course.

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