

Final Phase of Design, Test, and Evaluation of a Portable Programmable Logic Controller Trainer

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Abstract:

This paper presents the second and final phase of modifying the design for the Portable Programmable Logic Controller Trainer. The paper will explain the details of adding additional hardware and sensors, CAD drawing and material specifications, and electrical prototype layout schematic diagram. The paper will also discuss potential safety issues and electrical hazards, which were taken into consideration during the final design phase, as well as developing a portable storage cart to for the trainers and discussing the CAD drawing layout. The final trainer designs were tested by students in both the spring and fall semesters of 2017. This paper will also include the students' feedback of the final prototype design. The survey results from the student evaluations of the trainers will be presented and discussed. In addition samples of labs that were conducted using the trainers will also be included in the paper.

Introduction:

The Department of Engineering Technology (ET) at Purdue University Northwest (PNW) offers the Mechatronics Engineering Technology (MET) program. This field of study, which includes mandatory courses that use Programmable Logic Controllers (PLC), includes hands-on laboratories and activities that are essential for all Mechanical Engineering Technology, Electrical Engineering Technology and Mechatronics Engineering Technology students to work on. In order to allow students to work with PLC training units individually or in small groups without requiring a large lab space, portable PLC trainers have been utilized in order to support the laboratory portion of this course for two semesters in 2017. Therefore, portable PLC trainers have been designed and built to replace the out-of-date, rack-mounted PLC trainers. The final design, schematic drawings, sample lab handouts, and results from a survey given to students will be presented in this paper.

Finalized design

This section includes figures demonstrating completed portable PLC trainers that were designed and built by the technology department for students to use during labs. The schematic drawings of wires are also included as seen in **Figures 2&3**. The touch screen, also known as Human Machine Interface (HMI), and controls are mounted on the front of the board. The power supply and input/output modules are connected to the board using DIN rails. The design of the portable PLC trainer includes a metal back board to cover up the wires in order to avoid any electrical hazards during the labs.

Along with the portable PLC trainers, the department has also built an easy to move storage cart so that all the trainers can be stored at curtain place relocated if necessary. The PLC trainer prototype has a front and back panel, both of which are made from 6061 aluminum. This durable frame provides a sturdy mounting surface for the industrial electronics. The front side is shown in the **Figure 1** below. The back side of the trainer is used for both support and to protect the components from any damage in case the PLC trainer is dropped on the ground.

Mechanical Design:

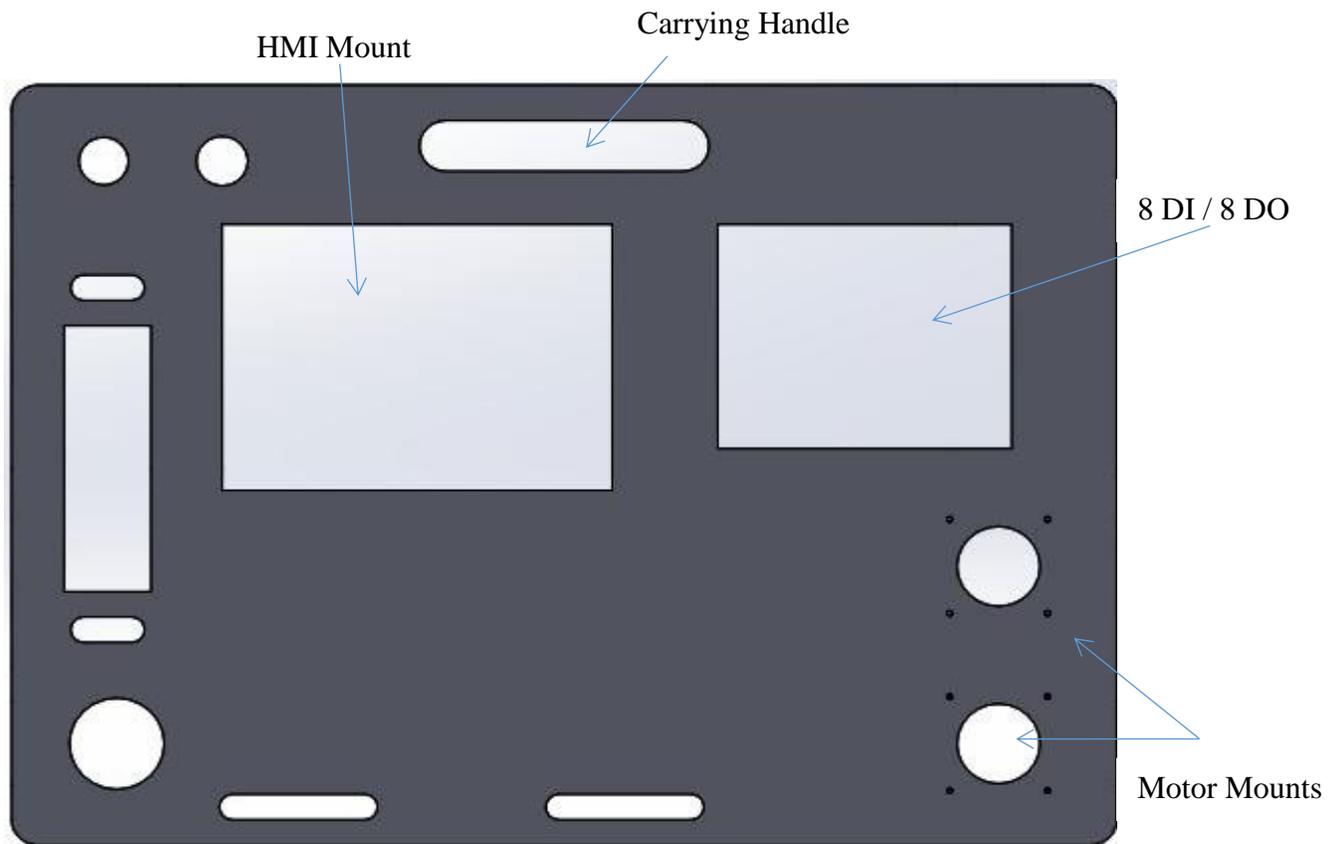


Figure 1: Front Side of the Trainer

The front side has been polished and all the cut parts smoothed and finished. Next the components are configured in the correct layout. Figure 2 below shows the front cover where all the components of trainer are installed. Each component is installed at its position, which are demonstrated in the following figures.

Electrical Design:

The electrical design included all the schematic diagrams drawing for students to follow. The front panel schematic diagram is shown in the Figures 2 and 3 below. The schematic diagram was so helpful for students and give them better understanding about wringing. A wiring diagram is a simple visual representation of the physical connections and physical layout of an electrical circuit. It shows how the electrical wires are interconnected and can also show where fixtures and components may be connected to the system. The front panel schematic drawing is shown in Figure2 including HMI, Main CPU, I/O modules, I/O simulation box, and Motors.

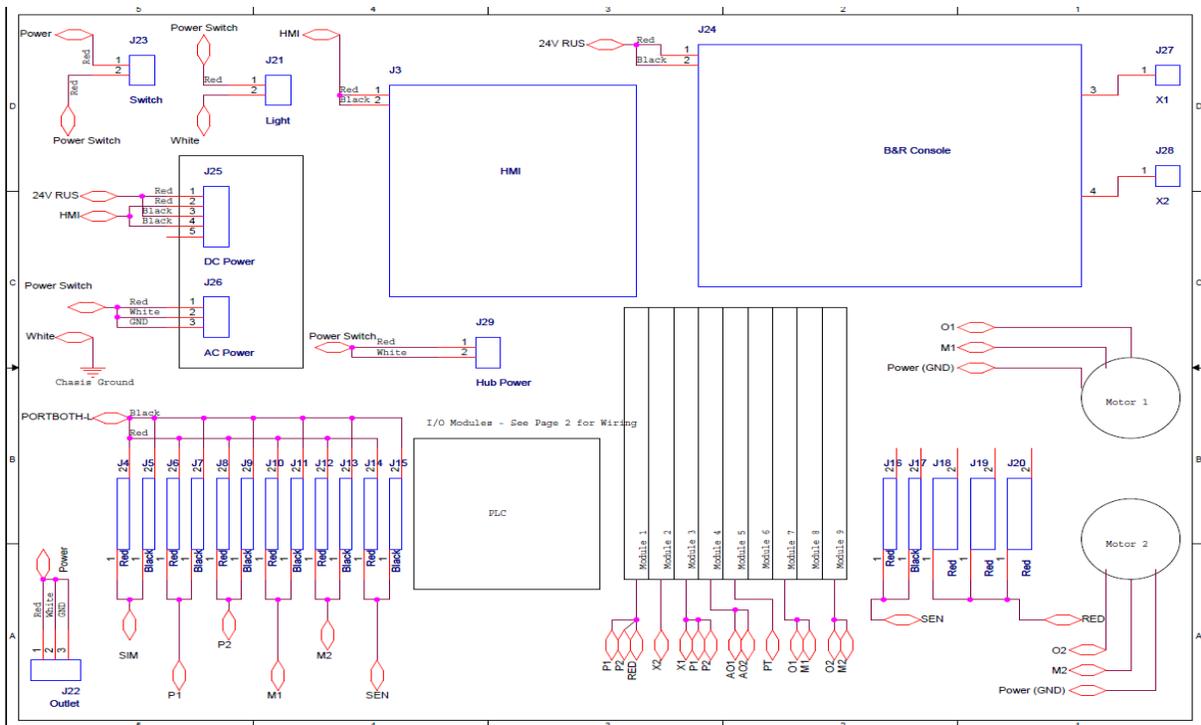


Figure2 Front Panel Schematic Drawing

The back panel schematic diagram is shown in Figure 3.

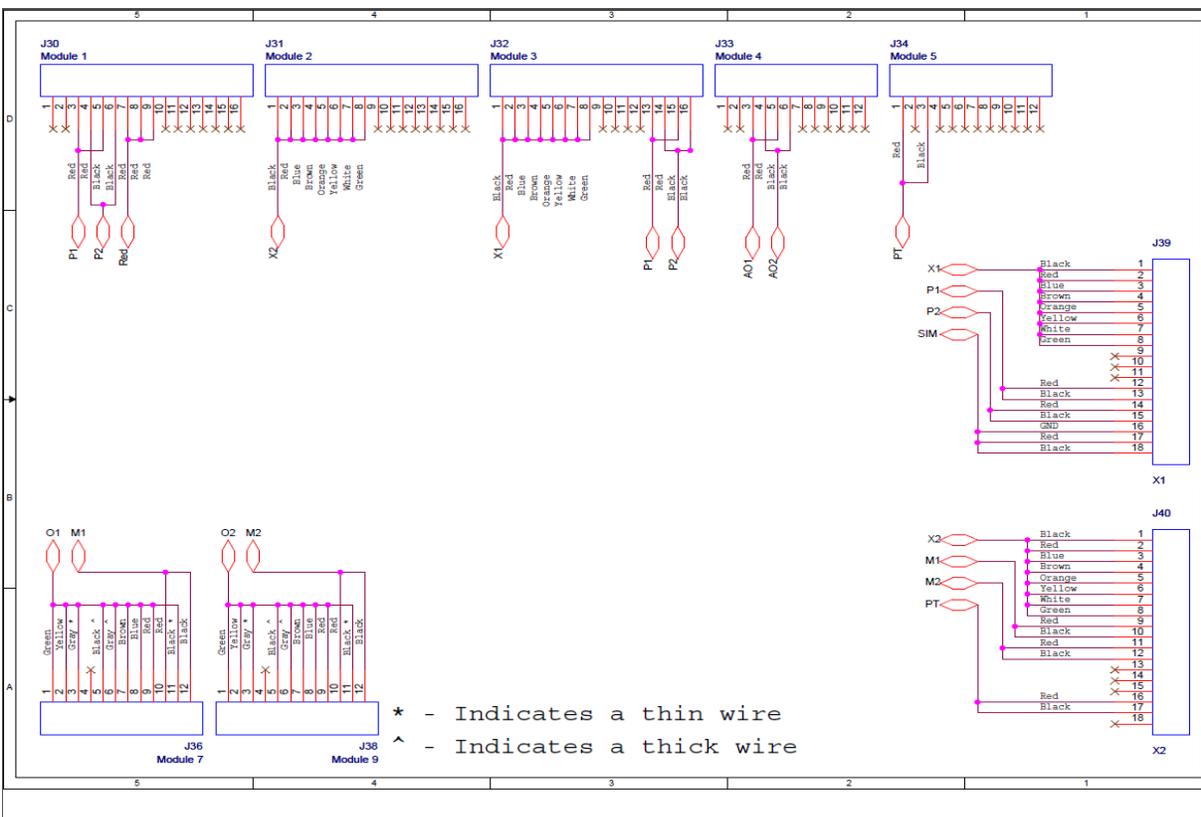


Figure 3 Back Panel Schematic Drawing

Components assembly

In the following steps, students were able to place all components in the right place as shown in **Figure 4**.

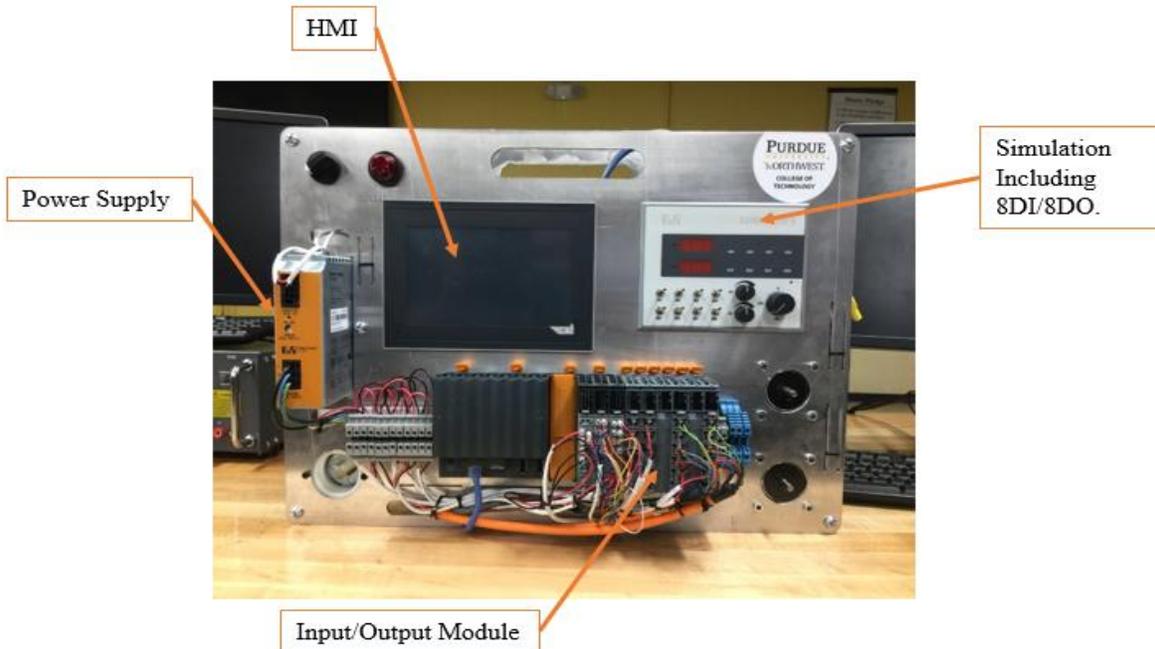


Figure 4: Front View of a Completed Portable PLC Trainer

The back of the trainer is shown in **Figure 5**. After all installing and wiring the trainers, then the cover side placed in the back to protect the trainers.

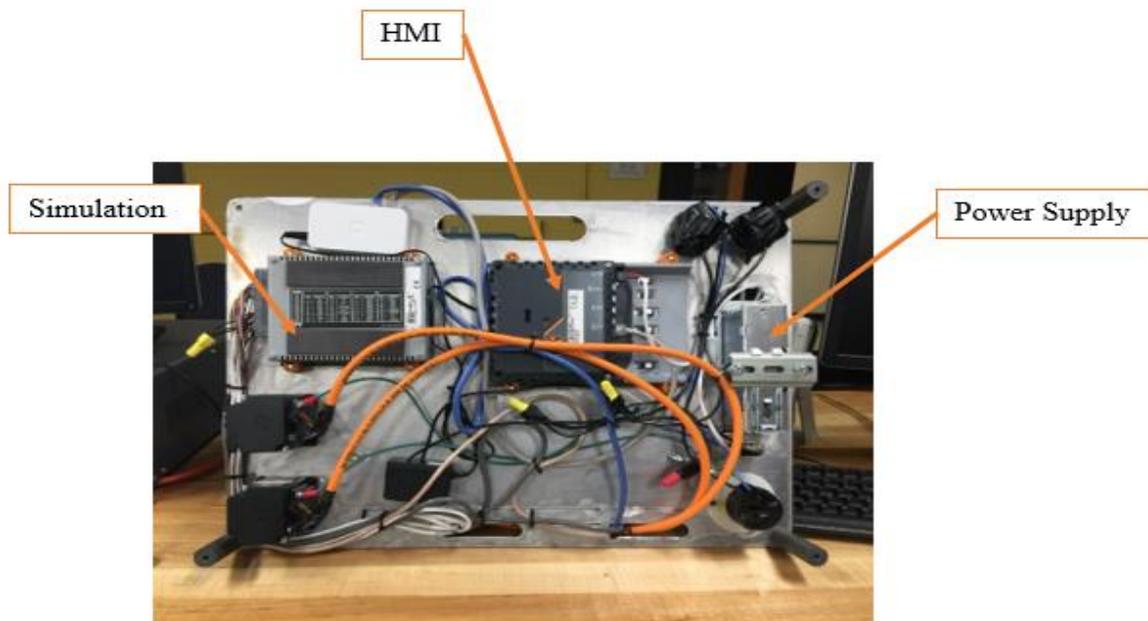


Figure 5: Back View of a Completed Portable PLC Trainer Without the Back Cover

One of the important aspects of the design is safety. Electrical safety hazards were considered. After the PLC trainers had been correctly assembled and wired, the 120 V AC electrical terminals were properly insulated by means of electric tape. All of the trainers were powered up and tested for any type electrical hazard.

Figure 6 shows the trainer's status when it is powered on. The HMI will show programs that are downloaded to the trainer from Automation Studio. The input and output module shows status of eight inputs and outputs.

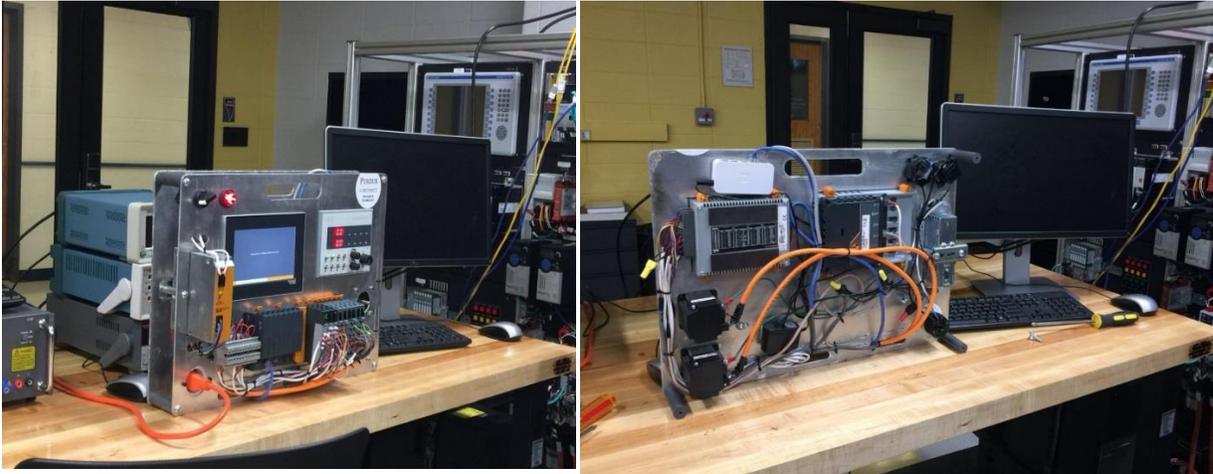


Figure 6: Powered up all Trainers for Safety checks

Storing the final product

The specifically designed storage cart has been assembled to host all the trainers for proper storage as well as ease of use as shown in **Figure7**. This cart utilizes a sturdy steel frame and durable caster wheels that is easy to move from one classroom to another.



Figure 7 PLC Trainer Storage Cart

Survey Results /Trainers Evaluations

This section contains the actual survey that was sent out to students and an overall feedback from the students who took the PLC course and worked with the portable PLC trainers in spring 2017.

PLC trainer Lab Survey

This is a fully anonymous survey over your experience in the ECET 262 lab section at Purdue University Northwest. Please answer the following questions as fully and honestly as possible, as they will be used to improve this lab for future sections. Your answers will NOT affect your grade so please do not enter your name on the survey.

Q (1) what parts of this lab did you struggle with the most and how could it have been improved for future classes?

Uploading the ladder programs to the portable PLC trainers when a pair of students work on the same trainer.

Q (2) what sections of these labs gave you the most trouble? Which labs do you feel were the greatest help to you?

The best two labs were the timer and counter labs.

Q (3) After taking this course would you feel that this lab would benefit from a pre lab lecture in order to recover the lab's material, or would you prefer to begin right away with the labs?

Preferably to begin the actual labs right away.

Q (4) what would be your biggest complaint about the lab, and what would be your biggest complaint about the lab manuals?

The lab room has a time limit and it is not always available. Also, the lab manuals didn't have detailed steps of labs.

Q (5) How well do you feel the B&R trainers fit in with the lab? What PLC features would you have liked to have seen added to this course?

The HMI part should have been introduced earlier during the semester so that the students would have enough time to become familiar with it.

The scale of question 6 through 14 is as following:

Not at all – 0 1 2 3 4 5 6 7 8 9 10 - Extremely well

	Q	Avg.
6	How well did the labs introduce the concepts seen in the lecture?	8.8
7	How well the B&R PLC did provides the ideal environment for Professional learning?	8.9
8	How well the practice questions help me learn the material?	9.3
9	How well the hands-on experience did helps me visualize the process?	9.3
10	How well the Using Portable PLC did is relevant to my education?	9.2
11	How well the challenges questions help me learn the material?	9.3
12	How well the Using Portable B&R PLC did helps me learn more about PLC programming?	9.1
13	How well the layout of Portable B&R PLC trainer design did helps me to work with PLC components easily?	9.3
14	How well the assembly of Portable B&R PLC trainer did helps me to work safely with PLC components?	9.0

Conclusion

This paper has provided a background of the current issues with PLC trainers that are used to teach the programmable logic controller course (ECET 26200). The authors presented the rationale to develop new PLC trainers and to explain the necessary steps to build them. In addition, various advantages and features of the new PLC trainers were explained. The courses in which the trainers will be used has been mentioned with more emphasis on ECET 26200. For this course, the lab activities were also outlined. The authors believe that these PLCs enhancements, when implemented, will benefit students learning and improve the lab's safety. Yet, examining the impact of these trainers on students learning is the subject of a future study. For the future, the authors are planning to conduct a survey to learn about students' feedback on what they think about the new trainers in terms of the design, features, etc. The authors will conduct the study in next fall when the course and the lab will be offered.

Acknowledgement

The authors would like to express their gratitude to B&R B&R Industrial Automation Corporation for their continuous support of the mechatronics program. Also the authors would like to thank Midwest Regional Manager B&R Industrial Automation Corporation, Mr. Patrick McDermott, Chicago office for his continues support.

Reference

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- [2] "B&R," 2009. [Online]. Available: <https://www.br-automation.com/en-us/perfection-inautomation/>. Accessed: Feb. 6, 2017.

Appendix (PLC Lab Manual Sample)

This lab was introduced to the students during the middle of spring 2017 semester when students should have all become familiar with the trainers and Automation Studio software. The lab mainly focuses on applications of timers and counters in real life. Students were asked to complete three given ladder logic diagrams, and then attempt to complete the challenge. After the lab had been completed, students were asked to answer the lab questions listed in the manual.

Description:

Timers and counters are some of the most commonly used instructions in ladder programming and it is extremely common for them to be used together in various programs. Over the course of this lab students will be introduced to more complex programs that utilize both timers and counters. Using the skills they have acquired through the previous labs they will have to modify programs in order to fit certain specifications. This lab will have a more basic focus on the application of these instructions so high speed programs will not be seen in this lab; however high speed operations are still very commonly seen in an industrial environment. High speed operations are very similar to the name all this means is that the programs operations are taking place so fast the

clock cycle of the PLC's processor becomes a serious concern. In these situations there is another commonly used instruction known as one shot. This one shot instruction is used to create only one impulse during a given clock cycle, which will allow for a program to become much more stable when running at high speed. After this lab students will be familiar with the operation and application of timers as well as counters in ladder programming.

Procedure:

Part 1 - Traffic Light

1. Open the Automation Studio software and connect to the PLC.
2. Now in the automation studio software recreate the traffic light program that was seen in the first timer lab and modify it so that it is only able to cycle through each light 3 times. The original traffic light program can be seen on the next page in figure 1. This new modified program should be included in the lab report.

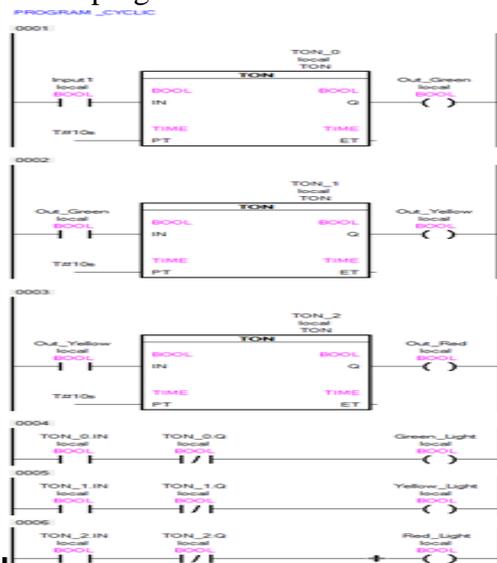


Figure 1.

Part 2 - Blinking Light

1. Create the simple program shown below in figure 2 in order to make a light blink.

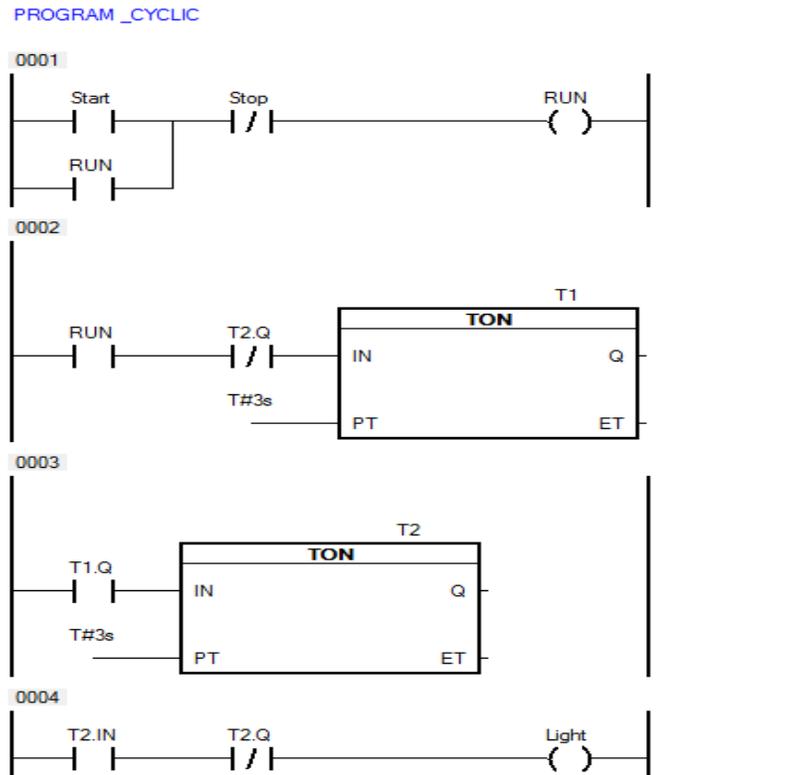


Figure 2.

2. Now after verifying the operation of this simple program on the PLC trainer the next step is to modify it so that the light will only blink only ten times then stop. This new program should be included in the lab report.

Hint: The first step is to determine the coil that will be used to actuate the counter.

3. Now after the new program, created in step 2, has been tested and its operation have been verified the next step is to modify that program so that the light blinks once every 3 seconds and after it blinks the first 4 times it will begin to blink once every 1 second. Then the light will stop blinking after it blinks 5 times at its new speed of 1 blink per second. This means that the light will blink 9 times in total throughout the operation of this program before it turns off entirely.

Hint: You may need to add more timers and counters to your program in order to accomplish this task.

Part 3 - Timer/Counter Application

1. Create the program shown on the next 2 pages in figure 3a and figure 3b. This program will be used to simulate an industrial oven that can hold 5 objects at a time. The program will allow 5 objects into the oven before the doors lock and the oven starts. There will be a 7 second delay before the oven starts after the doors begin to lock, this is done for safety reasons. The objects are being moved by a conveyor at a rate of 1 object every 2 seconds, which is being simulated by the timer in the second rung. After the oven is full the conveyor will stop delivering objects and the door will begin to lock. Then after the 7 second door lock delay the oven will turn on and stay on for 20 seconds, after which a done indicator light will be illuminated. This program will not continue to cycle. It will require a manual reset in order for it to continue the process. Try to determine the actual function of each rung as you are building the program instead of just copying the picture, if necessary don't hesitate to ask the instructor if something is unclear.

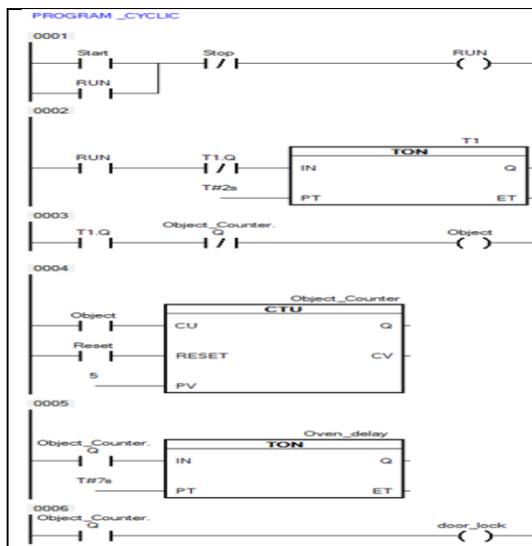


Figure 3a.

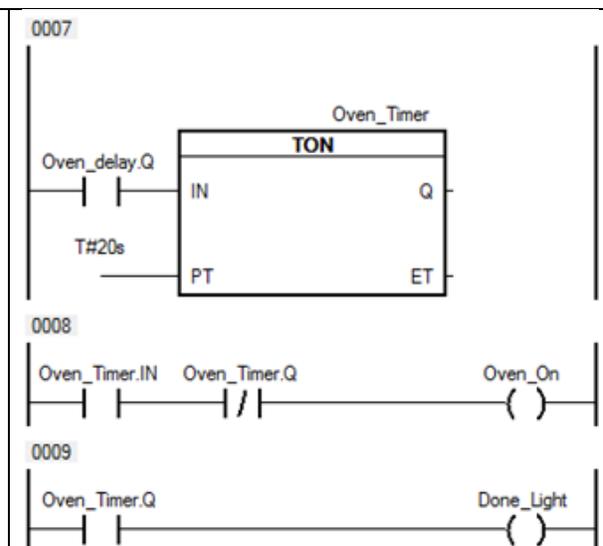


Figure 3b.

Part 4 - Challenge

1. Develop a program for a candy bar packaging line that will control how many candy bars are placed in a wrapper together, how many wrapped candy bars are boxed together, and how many full boxes are placed together on a shipping crate. The program will also keep track of how many full shipping crates were sent out until it is manually reset. The program will allow for 2 candy bars per wrapper, 5 wrapped packs per box, and 2 full boxes for the shipping crate. The candy bars can be represented by your trainer's manual toggle switches.

Lab Questions

- 1. Why are timers and counters so important in industrial PLC programming? Give at least one example of how a timer and counter could be used for an industrial application that was not seen in the lab.*
- 2. Why are reset switches necessary?*
- 3. Describe the one shot instruction and specify why it is beneficial in high speed operations. This instruction was not seen in the procedure of this lab however it is useful to know for future programs.*