Paper ID #21342

Developing PLC-based Pneumatic Lab Activities for an Undergraduate Course on Fluid Power

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Introduction

Fluid power is a sophomore course offered in Mechanical Engineering Technology (MET) at the University. The course includes a lecture section and a lab section that is offered every semester. The lab section includes hydraulic and pneumatic lab activities with the latter being recently developed. However, the pneumatic lab activities are based on prescribed instructions for students to build a circuit and manually operate it to observe certain behavior. With an increase of automation technology applications in industry, students should be able to build and run pneumatic circuits automatically.

This paper reports the results of developing pneumatic lab activities that include the design, simulation, and testing such circuits using Automation Studio software and Programmable Logic Controls (PLC). This serves as the first phase of a two-phase study with the ultimate goal of collecting and incorporating students' feedback on these newly-developed lab activities for course improvement.

Lab activities

The course on fluid power (MET 230) has two components: lectures and lab. Students performed a total number of 10 hydraulic labs, as well as 3 pneumatic labs. Figure 1 shows the trainers used for hydraulic and pneumatic lab activities.

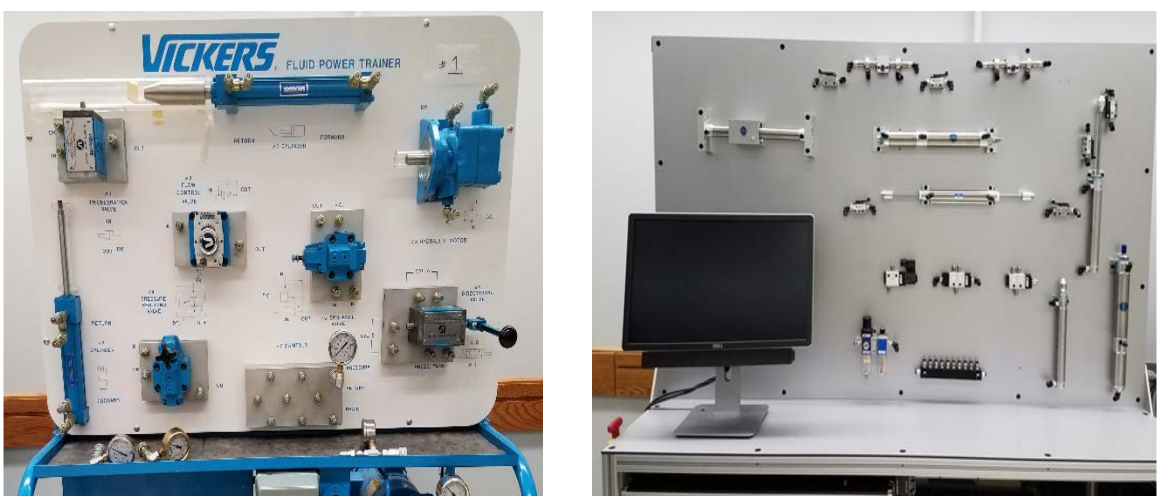

Figure 1. The Hydraulic (left) and pneumatic (right) trainers.

The pneumatic trainers includes various components as well as a dedicated computer on which Automation Studio is being installed. More information on trainers design and development, as well as pneumatic lab activities designed for the course can be found in [1] and [2]. All the pneumatic components and the PLCs were donated to the College by industrial partners. The trainers' frames were ordered and assembled by undergraduate students with a total cost of roughly $25,000 for six trainers.

The author, who also teaches the course, developed a set of 3 new pneumatic lab activities based on previous work discussed in [1]. The new lab activities are on:

1- Design and actuate a double-acting cylinder.
2- Design and run a reciprocating pneumatic circuit
3- Design and run two rotary actuators simultaneously clockwise and counterclockwise.

These lab activities are pure manual; students simply have to connect the components, observe whether the circuit works the way it should, and do some measurement and calculations (i.e., for example, measuring the cycle time for a complete reciprocation in the second lab and calculating the reciprocation frequency).

However, the current trends in industry suggests increasing use of electrical automation and control in pneumatic systems, as was indicated by Department of Engineering Technology's industrial advisory board. Therefore, the authors decided to expand the topics being covered in fluid power course by introducing electrical automation, in particular, PLC-based automation mechanism. To do so, an introduction to PLC programming and automation will be given in the lecture portion of the course. This includes ladder logic, PLC hardware components, and input/output devices. Students are to perform the lab activities in group and to answer discussion questions at the of each lab activity. Finally, each student will submit a lab report in Blackboard.

The lab portion includes the following three lab activities:

- Lab 1: Introducing PLC and input/output modules and how to control a cylinder.
- Lab 2: Doing Lab 1 with two cylinders and a timer
- Lab 3: Operating two cylinder with a limit switch

These three new labs will be added to the existing pneumatic labs which help the instructor teach automation in pneumatics during the lecture portion.

Lab 1: Introducing PLC and input/output modules and how to control a cylinder

The objective of this lab activity is for students to apply what they have learned in the lecture to build a pneumatic circuit using a double-acting cylinder, a PLC, and a control valve. They will learn about how to wire and write a ladder logic program using Automation Studio for a PLC to extend and retract the push rod using one input and one output. For programing purpose, B&R's Automation Studio [3] will be used. The circuit schematic is shown in Figure 2, and Figure 3 shows the circuit built using the schematic diagram and ladder logic program in Automation Studio respectively.

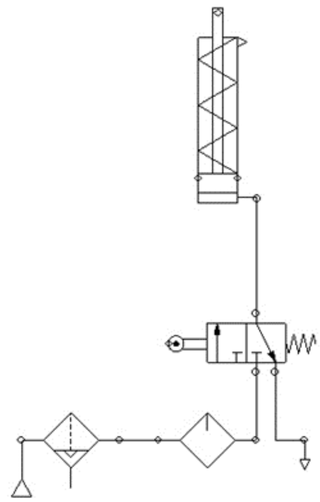

Figure 2. The schematic of Lab 1

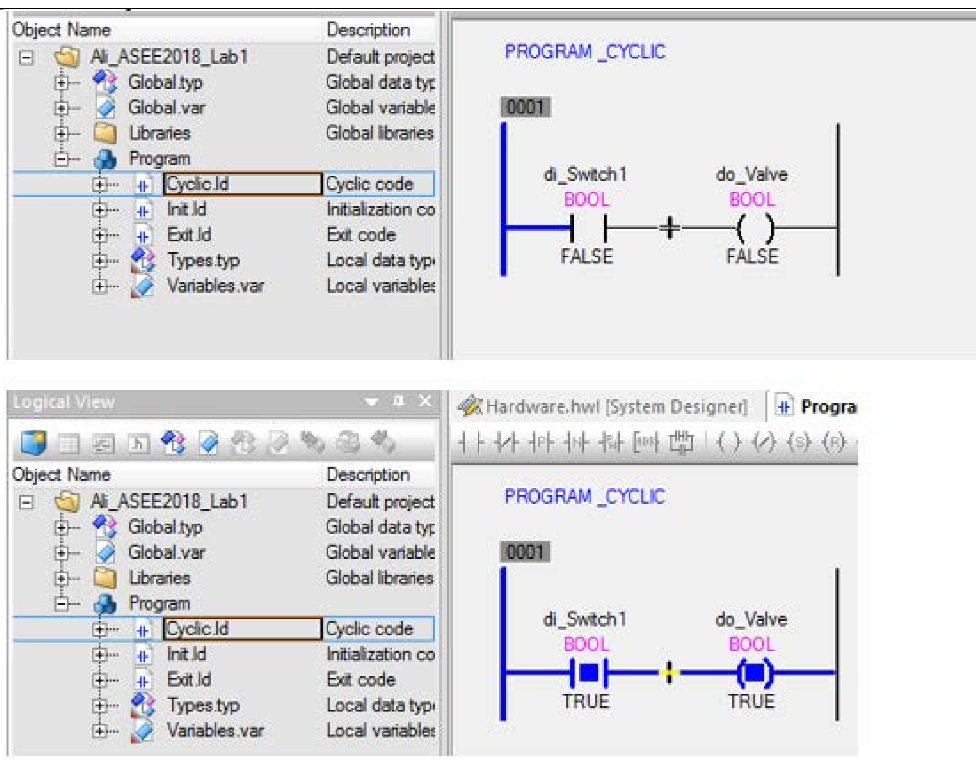

Figure 3. The ladder logic of Lab 1

Lab 2: Two cylinders and a timer

This lab contains two parts that were developed to help students to understand the concept of automations.

Part 1:

This part is an extension of Lab 1 with two double-acting cylinders connecting in parallel as shown in Figure 4.

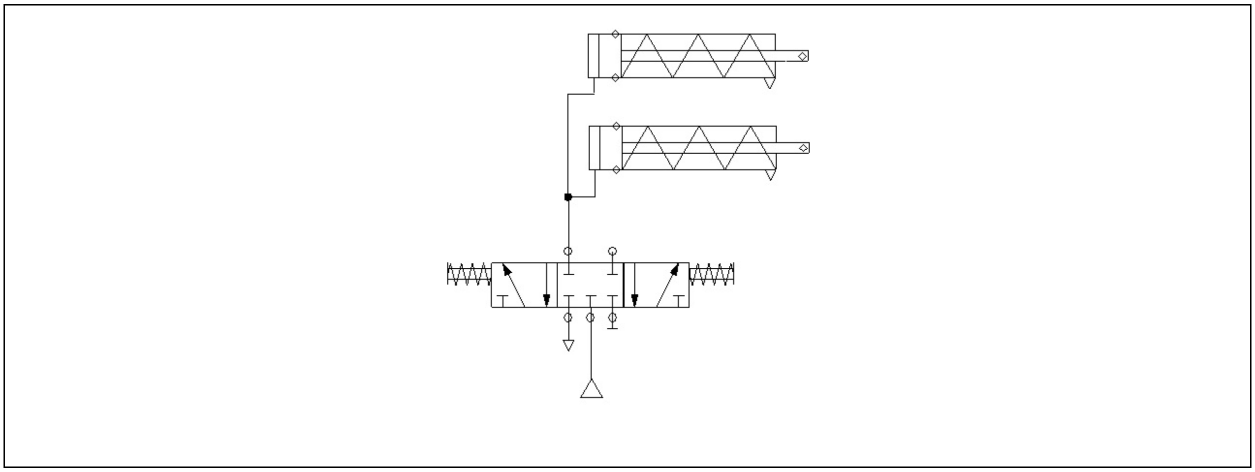

Figure 4. The schematic of Lab 2, part 1: two parallel cylinders

Students will learn to write a PLC code to use cylinders that are connected in parallel. Figure 5 shows the ladder logic for two parallel cylinders.

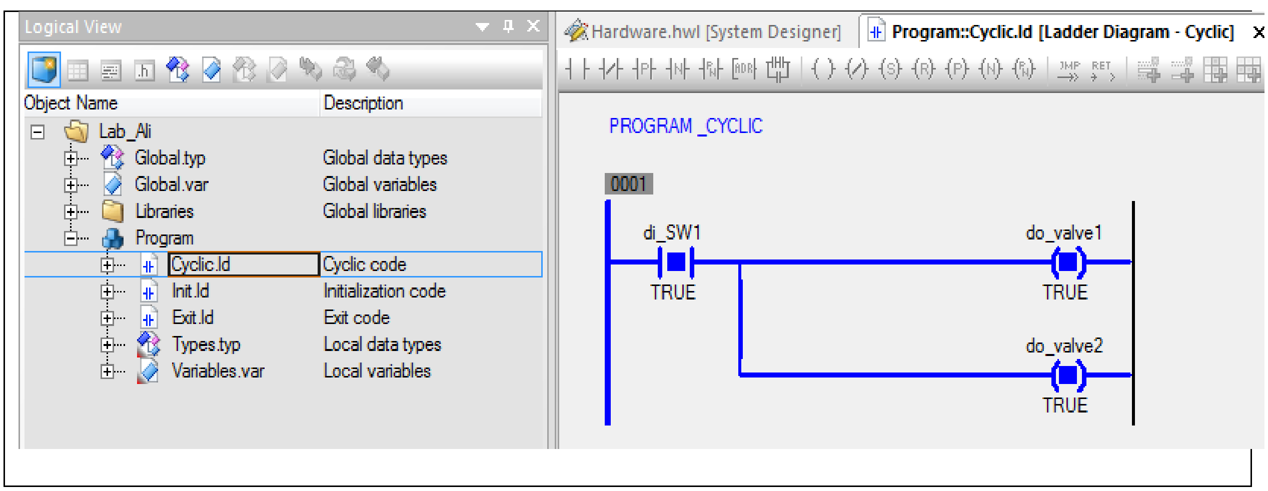

Figure 5. Two Cylinder connected in parallel (Lab 2, part 1)

Part 2:

Students are to use a timer to delay the extension and retraction of the second cylinder after 3 seconds. Both the cylinders are connected in series. Figure 6 shows the ladder logic.

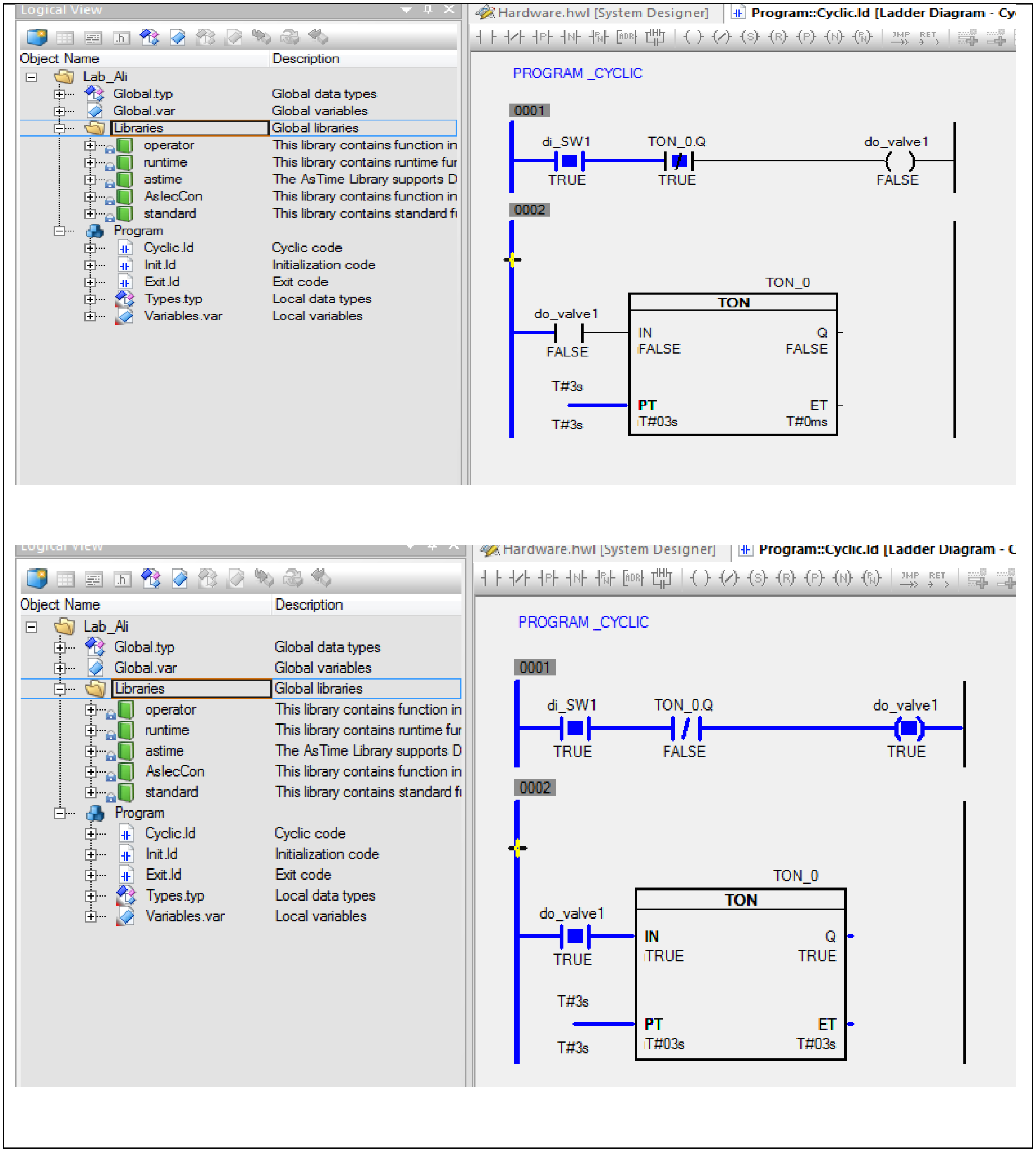

Figure 6. Two Cylinder connected in series using a timer (Lab 2, part 2)

Lab 3: Operating two cylinder with a limit switch

In this lab, students will learn about limit switches and how to build a circuit using them. Similar to Lab 2, they will connect the cylinders in parallel and use the limit switch to extend/retract the cylinders. Figure 7 shows the ladder logic.

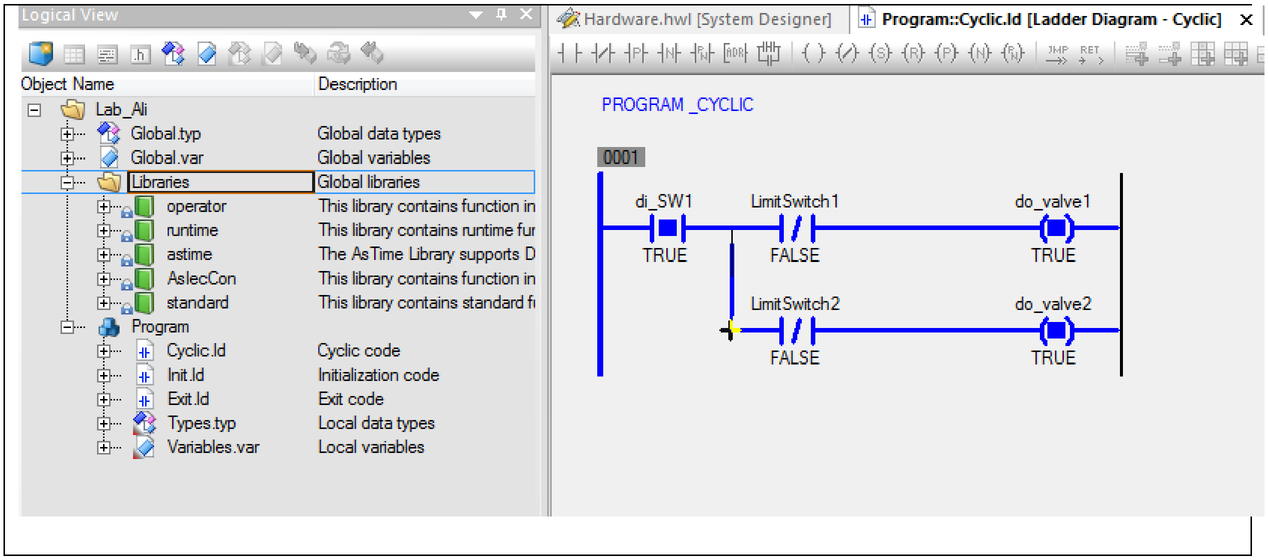

Figure 7. Two cylinder connected in parallel with limit switches (Lab 3)

In this lab students will learn that the limit switch acts as a stop switch. Figure 8-a shows that when LimitSwitch1 is activated it will turn off the do_valve1. The limit switch used as a type of non-servo control or open loop control system. Figure 8-b shows when the two limit switches 1 and 2 are activated so hat then the two cylinders are retracted

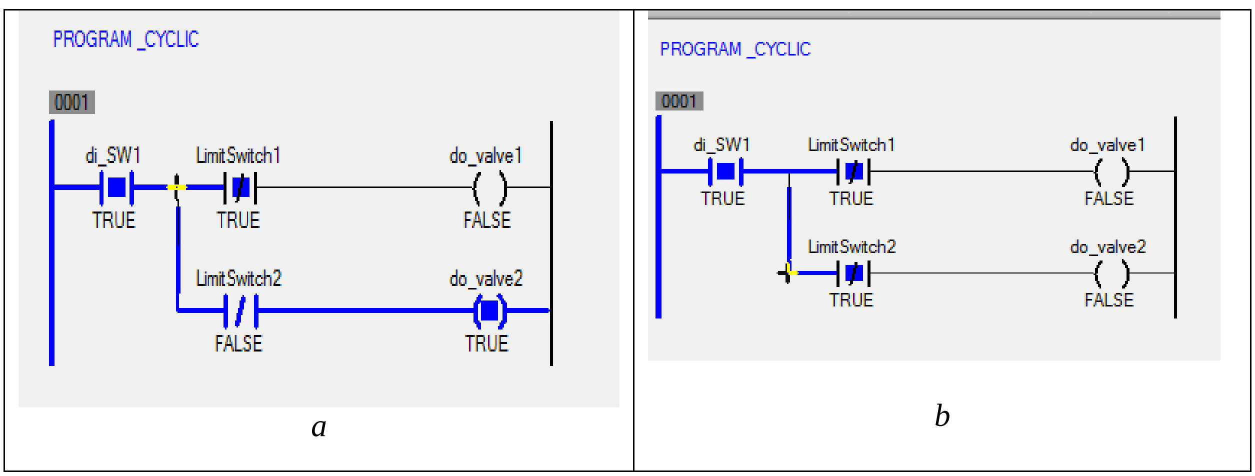

Figure 8. Two Cylinder connected in parallel with limit switches (Lab 3)

Conclusion

In this paper, the authors discussed three basic PLC-based pneumatic lab activities. These labs will be added to the lab portion of the fluid power course. Understanding the relationship between the hardware in term of pneumatic cylinders and the software (i.e., ladder logic) was one of the main goals of these labs. This is the first phase of the study, as the authors are planning to seek students' feedback on the lab activities for course improvement in next academic year.

Acknowledgment

The authors would like to express their gratitude to Bimba for providing necessary pneumatic components and technical supports throughout the design and assembly of the pneumatic trainers. Also, special thanks are expressed to 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

[1] M. R. Verma and A. Alavizadeh, “Design and development of pneumatic lab activities for a course on fluid power,” in *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, 2017, Columbus, Ohio, USA, June 25-28.

[2] A. Alavizadeh and M. Mikhail, “Integrating Measurement Instruments in Pneumatic Lab Activities,” in *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, 2017, Columbus, Ohio, USA, June 25-28.

[3] "B&R," 2009. [Online]. Available: https://www.br-automation.com/en-us/perfection-inautomation/.Accessed: Feb. 2, 2018.