# Design and Development of Portable Pneumatic Trainers to Teach Basic PLC Wiring and Programming

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## Introduction

The Mechanical Engineering Technology (MET) program at the University includes a sophomore course on fluid power with both lecture and lab sessions. The lab section includes hydraulic and pneumatic lab activities, both of which have been recently updated. The authors have already proposed pneumatic lab activities using PLC wherein students would use relevant software packages to design and simulate pneumatic circuits and to build the actual circuit using the pneumatic trainers (Figure 1).

*Figure 1*. The pneumatic trainers

The potential challenge with the current lab setting is twofold: students are all MET majors who do not have background in electricity and PLC, and the hydraulic and pneumatic lac (Figure 2) does not have enough/adequate space conducive to teaching basics of PLC.

*Figure 2.* The hydraulic and pneumatic lab

The solution that the authors devised was to design and build portable pneumatic trainers so that the course instructor could dedicate two lectures on PLC wiring and programing coupled with hands-on experiments. For the experiments, student connect a few pneumatic actuators and operate them using PLC. This paper reports the rationale and the steps in developing a set of portable pneumatic trainers that are to be built and used in the fluid power course.

The course

The lecture portion of the fluid power course includes the principles of both hydraulics and pneumatics. With the current industry interest in automations, at least, in the area of pneumatics and robotics, the authors felt that there should be more emphasis on PLC programming and wiring in pneumatics systems. Therefore, they focused on the pneumatic portion of the course. Table 1 shows the course contents in pneumatics. The third row relates to the design and build of pneumatic circuits, for which the authors have already developed some lab activities [1, 2]. Yet, the developed lab activities revolve around utilizing Automation Studio to design and simulate some circuitries and building them on the pneumatic trainers in the lab (Figure 1).

Table 1. Topics covered in pneumatics.

| | | |
|---|---|---|
| Pneumatics lectures | Principles and Laws | No lab |
| | Cylinders and Valves | Labs 1 - 3 |
| | Circuit design and analysis | No lab |

The authors designed two lectures on the basics of PLC. The first lecture will be merely on the basics of electricity and PLC with one introductory lab activity to PLC, which will be performed on the proposed portable pneumatic trainers. The second lecture will focus more on wiring with intermediate PLC programming. The contents of the lectures are as follows:

1- Wiring

a. Introduction to electricity (voltage, ampere, resistance, etc.)

During this lecture, students will learn about the wiring skills and how they can use the tools and components. Students will been asked to draw electrical schematic diagram for the circuit. Students will learn the skills of how to convert schematic diagram into actual wiring using many components. Students will learn how to select the right tool to perform the task.

b. PLC (its structure and applications, etc.)

A programmable logic controller (PLC) is an electronic device used in many industries to monitor and control construction systems and production processes. Unlike PCs and smartphones, which are designed to perform any number of roles, a PLC is designed to perform a single set of tasks, except in the case of limitations in real time and with superior reliability and performance. To meet the demands of rigorous industrial environments, PLCs are designed to be extremely robust, often capable of withstanding extreme temperatures, humidity, vibration and electrical noise. The logical controllers are commonly responsible for monitoring and controlling a large number of sensors and actuators, and therefore are different from other computer systems in their extensive input / output (I / O) arrangements.

PLC s are used in several industries like petrochemical, biomedical, cement manufacturing, oil and gas sector etc. Because of PLC advantages is using in many applications such: Reliability. Flexibility in programming and reprogramming. Cost effective for controlling complex systems. } Small physical size, shorter project time. High speed of operation. Ability to communicate with computer systems in the plant. Ease of maintenance /troubleshooting. Reduced space. Energy saving.

c. Basic PCL wiring

Students will understand the main components of PLC and the connections between these components as a big pictures. The PLC main components is shown Figure 3.

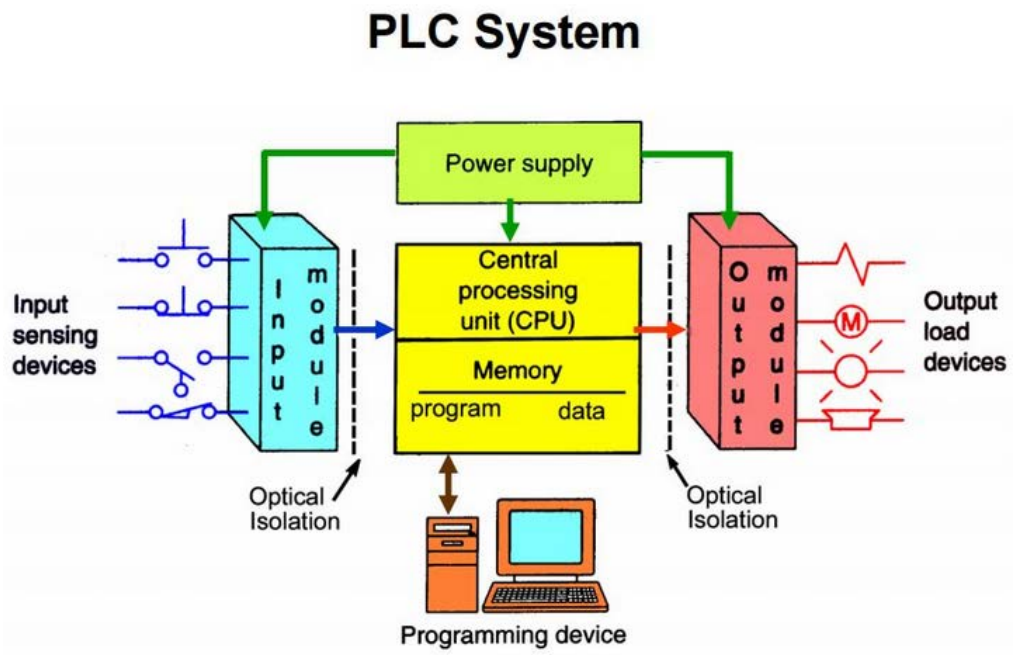



*Figure 3.* A typical PLC system

In the wiring lecture, the goals are for students to:

a- Be able to wire power supply using terminal blocks, fuses, switch, and grounding.
b- Be able to provide a DC power supply to PLC and it's Input and Outputs modules
c- Learn to distinguish between source and sink I/O module
d- Learn how to map the I/O into external Terminal Block
e- Mount all these components on the din rail
f- Learn how to wire the solenoid valve and cylinder
g- Lean how to adjust the PSI for Pump and provide power supply to it.

2- Intermediate PLC wiring

In this lecture students will perform basic troubleshooting for the AC/DC power supply. Ensure that all AC wires terminals are isolated properly and secured. Configure the communication between the PLC and PC. Complete and finish wiring check and test the conductivity before turning the main switch ON.

The objectives of the intermediate PLC wiring are foe students to be able to
a- Write a small PLC program
b- Test the inputs signals and send signal to activate the solenoid valve to extend the stroke.

The fluid power course is offered every semester during regular academic year and the enrollment, though varies, is about 20 to 28 students. The course instructor is planning to have 3 students work on a single portable pneumatic trainer (so, a total number of 10 trainers will be built) and at the end of the lecture, each group is to show how the circuit is working. There will be an assignment on each of these lectures, along with a question or two in the final exam.

Since the lecture time is once a week, these two lectures will take two weeks of the semester. The lab section is in a separate day. It is the authors' goal to utilize two lab sections to implement the PLC-based lab activities, outlined in [1], so that students can continue what they have learned in design and build more challenging pneumatic circuits.

Design Steps

One of the authors had designed and used a portable PLC training for his PLC course in the Mechatronics program (Figure 4). Therefore, it was decided to emulate the same design with proper changes to fit lab activities for PLC programing and pneumatic actuators.

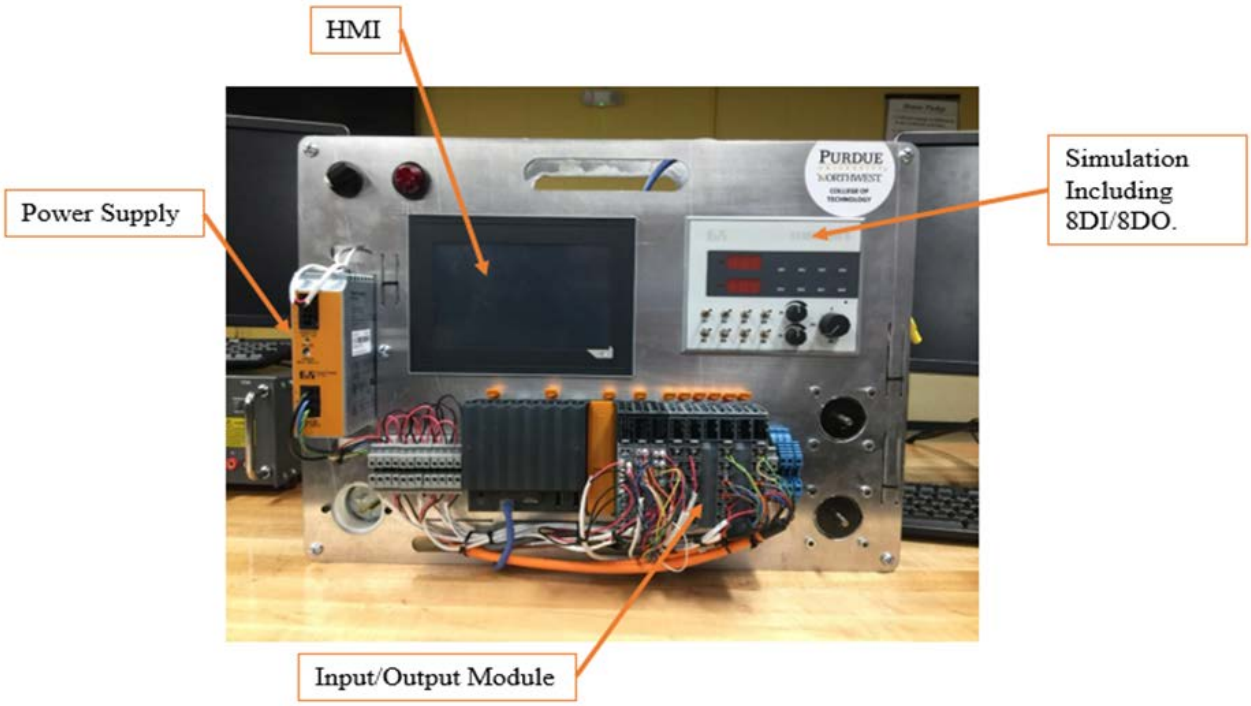



*Figure 4.* The existing PLC trainer used in PLC course.

The board is made of aluminum and will be machined internally in the College's machine shop using the existing inventory. Table 2 includes the list of the components needed to build the portable pneumatic trainers.

Table 2. List of various components needed to build one trainer

| Component | Quantity |
|---|---|
| Double-acting Pneumatic Cylinders | 2 |
| Air Compressor | 1 |
| Power Supply (PS) | 1 |
| Terminal Block (TB) | 4 |
| Limit Switches (LS) | 2 |
| PLC | 1 |
| Solenoid valve | 2 |
| Terminal blocks | 4 |
| Din rail | 1 |
| Mis. (Wires, Input Output ports, etc.) | varies |

Some of the components are available in the lab (for examples, wires). The cylinders, switches, and the solenoids are donated by the industry partner (Bimba Manufacturing). Figure 5 shows a drawing of the cylinder as was being downloaded from the manufacturer's website ([3]).

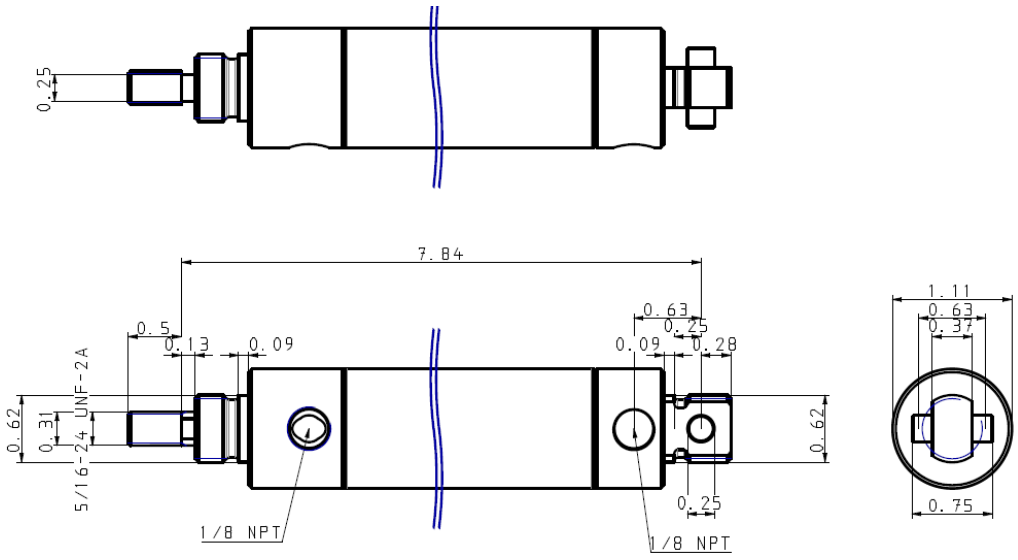
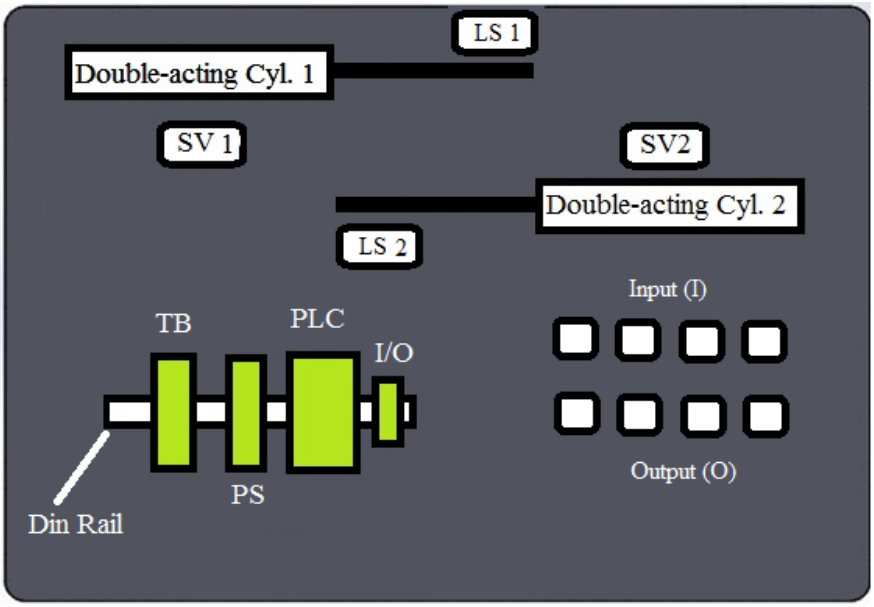



*Figure 5*. The drawings of the double-acting cylinders

Other components, such as the PLC, the switches, the din rail, terminal blocks, and the compressor are to be purchased. Figure 6 includes a picture of these components. The dimension of the board is 20 by 15 inches. Figure 7 shows a drawing of the board with the locations of the components.

*Figure 6.* The electrical components needed for the trainers.




Note: SV: Solenoid Valve, LS: Limit Switch, PS: Powe
Supply, TB: Terminal Block,

*Figure 7.* The drawing of the aluminum board with the locations of the components.

## Conclusion

The goals of the present paper was to discuss the rationale to design and build 10 portable pneumatic trainers that will be used in teaching the application of PLC in operating some basic pneumatic systems. Since the students are all MET majors with limited, if any, background in electricity and PLC, it is imperative that the course instructor includes a few hands-on-based lectures to introduce PLC and how to wire it. It is the authors' goal to build the trainers in summer and to include the lectures in following semesters and to assess students learning using the trainers. This will be the goal of a future pedagogical study.

## Reference

[1] A. Alavizadeh and M. Mikhael, "Developing PLC-based pneumatic lab activities for an undergraduate course on fluid power," in *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, 2018, Salt Lake City, UT, USA, June 24-27.

[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, OH, USA, June 25-28.

[3]. Bimba Manufacturing, Inc. [Online]. Available: https://www.bimba.com/Products-and-Cad/Actuators/Inch/Round-Line/Non-Repairable/Original-Line-Cylinder [Accessed February 1, 2019].