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Programmable Logic Controllers: Essential and Affordable

Dr. John Marshall, University of Southern Maine

John Marshall received his Ph.D. from Texas A&M University and is the Departmental Internship Coordinator at the University of Southern Maine. His areas of specialization include Power and Energy Processing, Applied Process Control Engineering, Automation, Fluid Power, and Facility Planning.

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Introduction

The importance of a programmable logic controller (PLC) component in Engineering Technology curriculums is essential. The cost associated with developing or upgrading this area can range from modest to the extremely expensive. This manuscript will provide individuals with a strategic approach to creating a very workable PLC lab on a less than generous budget.

A review of literature reveals that "PLCs represent one of the fasted growing segments of the industrial electronics industry and have proven to be the solution for a variety of applications which previously relied on electromechanical control systems. A few examples of current PLC applications include the: Manufacturing Industry; Travel Industry; Aerospace; Printing Industry; Food Industry; Textile Industry; Hospitals Film Industry; Corrugating; Plastics Industry; Agriculture; Foundry; and Leisure.[1]

PLCs can be programmed with graphical ladder logic and are unlike a general-purpose computer in that they are environmentally hardened to survive on a manufacturing plant floor.[2] Couple this with the ease of interface to hydraulic, pneumatic, and electronic power systems make PLCs an essential skill for Engineering Technologist.

To achieve this level of familiarization, PLCs can be a dedicated process control course or integrated into an existing course such as fluid power or industrial automation. Budget is often a concern and some programs are choosing to purchase the individual components and fabricate the PLC modules themselves.

This manuscript discusses the need for including PLCs into the curriculum, and how the PLC modus modules discussed here are used in a course entitled Applied Process Control Engineering which can briefly be described as a study of the fundamental concepts, devices, and applications of electronic components and controllers utilized on industrial equipment. Laboratory sessions focus on instrumentation, programming, downloading, and wiring discrete input / output devices.

Specific **Course Competencies** of the course include the ability to:

1. Identify major applications of programmable logic controllers in industry, transportation, construction, and environmental control.

2. Identify, discuss, and describe the purpose and function of the primary components utilized in open and closed loop process control systems. To assist in this outcome, each student will develop an appropriate theoretical base, and a complete comprehension of the associated terminology.

3. Contrast the limitations and capabilities of open and closed loop process control systems.

4. Discuss the important design and maintenance considerations of open and closed loop process control systems.

5. Demonstrate the ability to develop and interpret basic ladder logic controller programs.

6. Demonstrate the ability to wire input and output devices and debug software and hardware problems.

What is a PLC anyway?

"A programmable logic controller (PLC) is a solid state system designed to perform the logic functions previously accomplished by components such as electro-mechanical relays, drum switches, mechanical timers/counters, etc., for the control and operation of manufacturing process equipment and machinery." [2] They are a form of computer that is frequently used in commercial and industrial applications to monitor inputs, make decisions based on a program, and control outputs to automate a process or machine.

Programmable Logic Controllers first came about as a replacement for automatic control systems that used tens and hundreds (maybe even thousands) of hard wired relays, motor driven cam timers and rotary sequencers. More often than not, a single PLC can be programmed to replace thousands of relays and timers. These Programmable Logic Controllers were first befriended by the automotive manufacturing industry, this enabled software revision to replace the laborious re-wiring of control panels when a new production model was introduced. [1]

Also, as a result of their ladder logic and sensors, a PLC is capable of using logic in response to an almost limitless amount of real-time values to determine the sequence of electrical flow to be actuated with or without the presence of a human operator.
PLCs are used in almost every factory setting where there is assembly line technology and automated processes. They are also used to control such things as dishwashers, lighting systems and computer peripherals.[3]

In 1968 General Motors issued a request for proposals for an electronic replacement for hard-wired relay system. The winning proposal came from Bedford Associates [4] who started a new company dedicated to developing, manufacturing, selling, and servicing this new product: Modicon, which stood for **MO**dular **DI**gital **CON**troller. One of the people who worked on that project was Richard E. Morely, who is considered to be the "father" of the PLC.[5]

PLCs are a form of computer that has the specific job of sequencing the steps in a process or the operations of a machine. Like traditional computers, PLCs have an internal memory to store information. Your traditional computer can store hundreds of programs and run many different types of software, each one with the ability to crash the system without warning. The PLC on the other hand is a dedicated computer that runs only the program entered by its user. This dedication results in a much more stable platform for controlling complex machinery and is why industry depends on them to carry out the day to day repetitive tasks.

The PLC is designed to operate in an industrial environment with vibration and a wide range of ambient temperatures and humidity. PLCs are also immune to electrical noise that is present in most industrial applications. Though PLCs and computers differ in many ways, the computer is often used for programming and monitoring when the PLC is first implemented.

Most PLCs use a visual form of programming known as Relay Ladder Logic, which was derived from the days of hardwire design that was referred to as ladder logic. The "ladder" logic diagram consisted of two vertical lines with a series of lines running horizontally connecting each side. It resulted in a drawing that resembles a "ladder", hence the name. Each horizontal line is a separate line of code and is generally referred to as a rung. The vertical lines, or the sides of the ladder, represent the power and the rungs the connections between them.

PLC manufacturers knew that the current electricians and technicians that would be using their products were already familiar with this form of problem solving. So they created a high level, real world, graphics language that could easily be understood (resemble the ladder logic) but in reality was an interface to a programming language that utilizes logic components such as: AND gates, OR gates, NOT gates, Memory Blocks and Counter Blocks.

PLCs consist of four primary components; these components are the processor unit, the power supply, the programming device and the input/output interface. The processor unit houses the processor that is the brain of the PLC. The processor is a microprocessor based system that replaces the counters, timers, sequencers and control relays. The processor has been designed so that the user can enter in the desired program. It then makes all the appropriate decisions necessary to carry out the user program based on the status or values of the inputs and outputs for the control of a machine.

The power supply converts incoming power like 120 volts AC to lower voltage DC that powers most PLC processors. In some instances the power supply also serves as the energy source for the input and output devices. Some PLCs come in a modular setup with separate processor and power supply units while others come together in one package. The format of the PLC will vary by manufacturer, performance and capability, and price range.

Programming devices come in two distinct forms. First is the hand held programming device usually associated with older PLCs. It is a dedicated device that allows you to enter in the appropriate programming code line by line. Although they are still available for many PLCs, they are rarely used for new program development.

These hand held pendants are being replaced with software packages that enable the traditional PC to be utilized to develop the ladder logic and program the PLC. The computer software packages are generally easier to use and allow you to write and edit code much faster. They also provide the user with many more programming and monitoring options. Perhaps the most significant advantages are the abilities to easily view and review the program, and being able to monitor the program while it is actually running. This feature comes in extremely handy in the all-important debugging phase.

The input and output interfaces of the PLC are the means through which the PLC communicates with the real world. The inputs are the eyes and ears of the PLC. They inform the PLCs processors of the exact status of the real world events. Inputs are devices like switches, sensors, and limit switches. The majority of inputs and outputs that are used with PLCs are known as discrete devices. This means that they are either on or off, full speed or stopped. Expansion modules are available for PLCs that enable them to communicate with analog devices that can have varying speed or flow rate.

The most common industrial input device is a limit switch, which reports object positioning. Other forms of switches that frequently serve as input devices include Push Buttons, Selector Switches, Foot Switches, Flow Switches, Float Switches, and Pressure Switches. Sensors may also serve as an input device. Examples of sensors that are frequently interfaced with PLCs include proximity (which can detect objects without contact), photoelectric, encoders (which are used to measure rotational angles, distance, and speed), thermocouples and resistance temperature detectors (which measure temperature), and load cells (which measure weight or force).

The output interface allows the PLC to reach into the real world and actually control a machine or a process. Continuing with the example where the inputs were analogous to the eyes and ears of the PLC, the outputs would be the hands and feet. The central processing unit within the PLC is the "brain" which orchestrates the preprogrammed sequence of events. Examples of output devices include indicating lamps and mimic panels (provide visual and graphical information), relays (to control output loads), electric motors and motor starters (switches heavy loads), and solenoid directional control valves (widely used, controls fluids).

The junior level applied process control engineering course utilizes Allen-Bradley programmable logic controllers and the accompanying RSLogix ® software. A dozen clusters are equipped for the controller programming and wiring. Each cluster is composed of a desktop computer linked to a Micrologix 1000 ® PLC module was also designed and fabricated as a project of this class. An organized kit includes typical industrial inputs such as push button switches, limit switches, and both inductive and capacitive proximity devices. The kit also includes typical industrial outputs including lights, buzzers, motors, and solenoid activated pneumatic directional control valves.

The PLC modules and I/O devices used in this junior level course were specified at the same voltage and have been designed for patch-cord assembly. This allows the students to focus on the job of learning the software and interfacing the I/O devices without the danger of injuring themselves or the components. In the senior level capstone course, this safety net is not present and more time is spent on these concepts.

After the PLC overview, we proceeded to the programming software. Many feel that the best method for teaching the software is via lab activities that require the students to develop ladder logic programs designed to control a process. To begin the activity, the students are given a problem statement that identifies exactly the sequence of events that must occur and what inputs/outputs (I/O) are specified.

From this problem statement, each student develops their own software solution via the scientific problem solving method. Compiling, downloading, wiring I/O and testing their solution takes only a few minutes. This quick feedback is crucial to the learning process. If the program does not work properly, they can modify it and try their new solution without consuming excessive lab time.

Typical process control projects include a traffic intersection where the traffic lights and pedestrian walk signs are accurately sequenced. Another programming and I/O project is a parking garage that tracks vehicles entering and exiting, and illuminates either a “Lot Full” or a “Room Available” sign based on the garage’s capacity.

One of the more challenging problem solving PLC based projects is to develop the logic for a pneumatically powered press. In this safety related scenario, both hands must push separate buttons before the press is allowed to close. The tricky aspect is that if the press operator tapes or ties down one of the buttons, the press will not respond! A small pneumatic cylinder controlled by a solenoid directional control valve simulates the press motions. A total of eleven problem solving projects are utilized in this course.

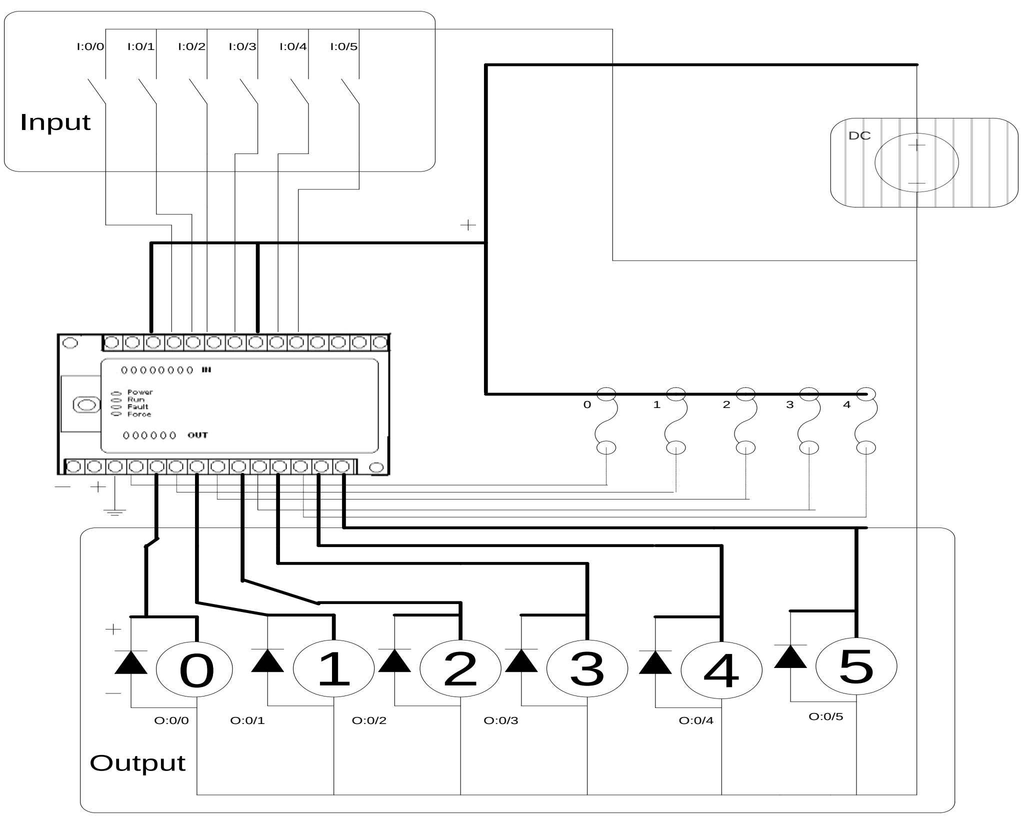
Please find below a description of the components needed to fabricate a PLC module; an image of one of the modules built by our students; the wiring schematic; and, in the appendix, several of the lab activities that the students solve and demonstrate.

Programmable Logic Controller Module Description

> One programmable logic controller (Allen-Bradley MicroLogix 1000) with 6 inputs & 6 outputs; completely wired with a power switch with indicator light, input / output modules. The input module is wired to accommodate six inputs and the output module accommodates six outputs. Components are mounted to a 16” x 16” x ½” piece of high density plastic with machined handle and edges.
>
> Six normally open switches assembled in individual enclosures for a total of six input devices. Four light bulbs, one buzzer, and one electric motor comprise the six output devices. All of the input and output devices are connected to the PLC modules via installed binding post and included patch cords.

Image of Module Fabricated by our Students
They Gained Knowledge and Saved Departmental Funds

Module Wiring Schematic



Conclusion

Engineering technologists are frequently immersed into a PLC intensive environment. More than solely manufacturing, PLCs are everywhere: waste treatment plants; alternate energy generation systems; the military sector, the transportation sector; the construction sector, and the agricultural sector all utilize the environmental hardened PLC.

While digital logic can be learned from intelligent relays (although very limited input/output and display), PLCs advantages are numerous (as described above) and these are the actual devices that will surround our graduates on a daily basis. In fact, many feel that no single invention has had as much impact on the manufacturing sector as the PLC, it changed the way we automate our factories [5] and is widely use today.

PLCs can be a dedicated process control course or integrated into an existing course such as fluid power, electronic control technology, or industrial automation. Regardless of how and when, it is critical that the Engineering Technology graduate have a working understanding of programmable logic controllers.

The above paragraph that begins with the phrase “The junior level applied process control engineering course” pinpoints why the cost savings is significant – the PLC modules were designed and fabricated by the students! While it is important to provide graduates with PLC familiarization, purchasing vendor supplied “training systems” can be financially challenging. The in-text image displays one these modules.

This manuscript has discussed a successful and cost savings method where individual components were purchased and very workable PLC modules were fabricated. The following appendix contains several laboratory activities that can be used to gain experience and insight into the instrumentation, programming, downloading, and wiring of discrete input / output devices.

Appendix

Lab Activities Solved and Demonstrated by Students

Laboratory Activity One - Industrial start cycle with an automated stop function.

The goal of this laboratory activity is to create a program and wire input and output devices that will replicate an industrial start cycle with an automated stop function. The equipment operation specifications for this activity include:

- Use a momentary, normally open switch as a start button.
- When the start button is depressed, a warning light and an electric motor are energized. The motion of the electric motor drives a power take off along a track.
- At the end of the track is a normally closed limit switch that needs to send a feedback signal that will stop the motor and shut off the warning light.
- There also needs to be an emergency stop switch that, at any time, will stop the motor and shut off the warning light.

Procedure for solving this activity:

Step 1: Start by reading the equipment operation specifications very carefully and in your own words, develop a sequence of operations.

Step 2: Using your sequence of operations, develop a flow chart of the events that should occur.

Step 3: Create a symbol table that includes the component's name, address and description.

Step 4: By hand, sketch an input/output drawing that includes the addresses and software that you think will satisfy the flow chart.

Step 5: Once you have solved it on paper, proceed to the computer lab to develop your program.

Step 6: Save your program to a disk (label disk with your name and "PLC labs").

Step 7: Using the computer in the automation lab, download your program to a PLC. Connect the inputs and outputs. Test your program, inputs, and outputs to determine if everything is working properly.

Laboratory Activity Two – Conveyor system with indicating lights.

The goal of this laboratory activity is to create a program and wire input and output devices that will perform the equipment operation specifications below:

- A momentary normally open START button is pressed.
- Conveyor motor is started.
- Package moves until it reaches a limit switch and stops.
- An emergency stop switch that will stop the conveyor for any reason, before the package reaches the limit switch.
- A red light to indicate when the conveyor has stopped after the process has begun.
- A green light to indicate when the conveyor is moving.

Laboratory Activity Three – Timing six sequential outputs.

The goal of this laboratory activity is to create a program and wire input and output devices that will perform the equipment operation specifications below. Timers should be used to turn on lights 1,2,3,4,5, and 6 sequentially in the following manner. Extra credit will be awarded if you make the process repeat itself automatically after 3 seconds.

- Light 1 should turn on when the start button is depressed.
- 3 seconds later 1 should go off and 2 should come on.
- 3 seconds later 2 should go off and 3 should come on.
- Process should continue until light 6 comes on and can remain on.
- Pressing the stop button at any time should turn off all the lights and allow the process to restart with light 1 when the start button is pressed.

Laboratory Activity Four – Automated palletized material handling system.

The goal of this laboratory activity is to create a program and wire input and output devices and assemble a pneumatic circuit that will perform the equipment operation specifications below:

- Use a momentary normally open switch as a start button.
- When the start button is depressed, a warning light and an electric motor is energized. The motion of the electric motor drives a conveyor.
- The conveyor has baskets fixed to the belt that makes contact with a momentary limit switch and stops the conveyor.
- One second after the basket stops a one way piston extends and kicks the part out of the basket.
- One second later the air valve is shut and the spring returns the piston.
- One second later the conveyor begins to move until the next basket strikes the limit switch.
- While the conveyor is moving there needs to be a indicator light on.
- There also needs to be an emergency stop switch that, at any time, will stop the motor and turns on a warning light.

Laboratory Activity Five – Computerized parking garage.

The goal of this laboratory activity is to create a program and wire input and output devices that will perform the equipment operation specifications below:

- Design a system using indicating lights to alert a parking attendant when the parking lot is full. The system needs to be able to handle cars coming and going. It needs to have a light that indicates when the parking lot is full and when it is not full. It does not require any kind of emergency stop command. You will however, need to include a reset command.

Laboratory Activity Six – Vehicle intersection traffic light controller.

The goal of this laboratory activity is to create a program and wire input and output devices that will perform the equipment operation specifications below:

- Use a momentary normally open switch as a start button.
- When the start button is depressed, a vehicle intersection traffic light sequence will begin. Utilize the wiring junction connected to the two actual traffic lights mounted on the lab wall.
- Program five-second traffic cycles.
- There also needs to be a stop switch that, at any time, will turn all lights off.

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