Enticing High School Students into Engineering Technology with a Simple Industrial Process Control Module

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Abstract

Too few high school students understand that a career in Engineering and Engineering Technology can genuinely be exciting and neat. Some have the short-term view that good paying jobs are plentiful, so why take the really difficult courses. Many sell their own abilities short and convince themselves that it is too difficult a career path. And still others conjure up the image of a dirty, dull, dangerous, and demeaning factory floor and run (not walk) in the other direction.

What is needed to turn these impressions around are exciting exposures to engineering topics in existing high school courses such as technology education, science, math and physics. The purpose of this paper is to identify exactly one such exciting module that has been successfully used to build bridges that link high school students to an engineering career path.

Case Study

The University's relationship with a local high school began with a simple invitation to their technology education teacher. When asked if he would be interested in bringing a class to tour our Industrial Power Transmission and Control laboratory, our phone call was answered with a slightly skeptical – perhaps. The teacher wanted to visit us first and determine the usefulness of bringing a class to campus.

His skepticism resulted from a fear that a highly theoretical environment would intimidate and turn-off his students. He was however, searching for a method to motivate and challenge his classes. Immediately upon arriving, he began to see an environment that blended the theory of industrial power and control with "hands-on" fabrication of automated cells. Hydraulic and pneumatic "gadgets" supervised by programmable logic controllers (PLC) were manipulating tennis balls and golf balls in a whirl of motion, noise, and excitement. This was really neat "stuff" that his student's would love!

The subsequent class visit was a huge success. Before the afternoon was over, high school boys and girls were developing ladder logic and programming the PLC to sequence lights, motors, and buzzers. They never imagined that learning could be so much fun or what they could accomplish in a few short hours.

A follow-up phone call a week later led to a successful cooperative venture between the University and the high school. The high school purchased two PLCs and the programming software. Together, we found industrial donations of input and output devices such as switches, motors, valves, and pneumatic cylinders. The high school class returned to campus, this time to develop ideas for their own automated cell to be built from their newly acquired components. Four more visits were strategically planned over the next two months to provide the high school teacher and students with the skill sets needed to replicate our lab on a smaller scale.

In fifteen years of teaching experience, this high school teacher had never seen a more motivated group of students. The demand for his class continually increases and the excitement has become contagious. Two years into this relationship has yielded excellent results with increased retention in the high school program, and a growing stream of new majors for our department.

The design and fabrication of the high school modules was a college-based class activity. The university class made two PLC and pneumatic modules with the high school district paying for all of the components. The secondary educators were thrilled to have a "plug and play" module that genuinely turned-on their students. This is definitely one of those win/win initiatives that can provide an enjoyable, meaningful class project, and at the same time establish a pipeline for recruiting talented incoming majors!

During the first high school visit, we provided the group with a basic overview of programmable logic controllers. We intentionally kept the subject matter simple and clear. The overview began with definitions and an historical perspective.

Programmable Logic Controller Overview

"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" (Richard A. Cox, 1995). 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.

Richard E. Morely who founded the Modicon Corporation, which is still today a large producer of PLCs, invented the first PLC in 1969. During the past several years, they have proven to be the solution for a variety of manufacturing applications, which in the past had relied on electromechanical control systems. Today, PLCs represent one of the fastest growing segments of the industrial electronics industry.

PLCs have many desirable characteristics that have lead to their utilization in every segment of industry where automation is required. On of the primary reasons for their success is that they can be programmed and operated by individuals who do not have strong backgrounds in computers, such as plant engineers and maintenance personnel.

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 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.

Thus, advantages of a PLC include: solid state reliability; lower power consumption; expandability; replaces electromechanical relays, counters, and timers; accepts input data from various sensing devices; immediately executes the stored user program from memory; initiates appropriate output commands; and eliminates much of the hard rewiring that occurs when the process is modified.

PLCs consist of four primary components; these components are the processor unit (CPU), 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 interacts 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).

After the PLC overview, we proceeded to the programming software. 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. The six laboratory activities that we utilized are the: Industrial start cycle with an automated stop function; Conveyor system with indicating lights; Timing six sequential outputs; Automated palletized material handling system; Computerized parking garage; and the Vehicle intersection traffic light controller.

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.

Conclusion

This presentation has identified a successful relationship that was developed between a university and a high school by implementing a simple and exciting industrial process control module. After visiting our university laboratory, the high school obtained industrial power transmission and control components. The university class designed and fabricated PLC and pneumatic modules with the high school's components. Table 1 contains the component list for the PLC modules, complete with vendors and prices. These modules were then utilized by the high school students to learn about pneumatics, PLCs, programming, wiring, input devices, and output devices. The high school students returned to campus for strategically planned instructional visits and to brainstorm designs for their own automated cells.

The design and fabrication of the modules was a college-based class activity, and the secondary educators were thrilled to have a "plug and play" module that genuinely turned-on their students. This is definitely one of those win/win initiatives that can provide an enjoyable, meaningful class project, and at the same time establish a pipeline for recruiting talented incoming majors!

Table 1. Component List For PLC Module

Quantity	Part Number	Description		Cost
Your local Siemens PLC Supplier				
1	6ES72121BA0XB0	Siemens Brick PLC	$	185.00
1		Communication Cable	$	77.00
1		Software	$	137.50
Cadillac Plastic	1-800-274-1000			
0.125	174920	Plastic board	$	27.50
0.125		Shipping	$	8.25
Jameco Electronic	1-800-536-4316			
1	139096	AC/DC table top power supply	$	21.18
3	18921	ABS speedy boxes	$	6.44
1	151554	Power jack for power supply	$	0.87
7	274-661	pack of 4 binding posts	$	20.02
1	150666	DC Motor	$	0.98
1	32601	Audible Signal	$	4.35
4	18921	ABS speedy boxes	$	8.58
3	274-661	pack of 4 binding posts	$	8.58
1	900-7843	switch	$	11.25
Local building supply				
1		Electrical Isolation switch & box	$	16.50
1		Fuse Holder	$	4.95
1		Fasteners	$	5.50
1		Consumables (solder, wire, etc)	$	8.80
Electronix Express	1-800-972-2225			
10	05ALS4	Banana to Banana Lead	$	26.00
Local electrical supply				
3	509 K	GE 24 Volt Lamp	$	3.75
3	267	Leviton Lamp Holder	$	6.60
		TOTAL PRICE	$	589.59

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