

INTEGRATION OF MOTION CONTROL TECHNOLOGIES INTO A PROGRAMMABLE LOGIC CONTROLS COURSE

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Abstract

In this study, the author developed new motion-control teaching components for inclusion in an advanced programmable logic controller (PLC) course. The proposed motion control teaching components consisted of a human-machine interface (HMI) terminal, a commercial industrial control trainer (ICT), a stepper motor drive, and an ac servo motor drive. For the first exercise, a lesson on a PanelView HMI terminal from Rockwell Automation was given to the class. The students practiced with PanelBuilder32 software in order to program the HMI terminal to operate the PLC. Programming with an ICT, from Bytronic Inc., was the second exercise to help students become familiar with various motion control components such as the permanent-magnet dc motor (PMDC) and linear and rotary solenoids. The stepper motor control laboratory assignment was next given to the class. The students learned how to use the special module for the stepper motor drive. Next came the ac servo motor. The Ultraware setup and programming software for Ultra-series ac servo motors was examined. The final design project was given to three student groups of four members each. Each group built a four-level elevator using a stepper motor as the prime mover and any additional sensors as necessary. The main focus of the elevator project were application of the HMI terminal for elevator control and accurate position control of the stepper motor. The assessment method for these motion control components is also presented in the conclusion of this paper.

Introduction

Penn State Berks offers a year-long PLC course for both EET (Electrical Engineering Technology) and EMET (Electro-Mechanical Engineering Technology) students. The fundamentals of PLCs course (EET220) is taught in the spring semester, with the advanced topics course (EMET430) in the fall semester. The fundamentals of PLCs course covers introduction of PLC hardware (SLC500 and I/O modules) and PLC programming, with basic instructions such as bit, timer, counter comparison, arithmetic, move, and logical functions. In this paper, the author introduces the newly developed motion control teaching components for the advanced topics course.

Table 1. Proposed Topics of the Advanced PLC Class and Laboratory

Week	Topics	
	Class	Lab
1	PanelView / Communications	PanelView
2	PanelView / Communications (continue)	PanelView (continue)
3	Motor Drives	Programming with ICT
4	Motor Drives (continue)	Programming with ICT (continue)
5	Motor Drives (continue)	Stepper Motor Drive
6	Motor Drives (continue)	Stepper Motor Drive
7	PID	Stepper Motor Drive (continue)
8	PID (continue)	Oven Temperature Control
9	PID (continue)	Oven Temperature Control (continue)
10	Ultraware	Automated PLC Controlled Lighting
11	Ultraware (continue)	Automated PLC Controlled Lighting (continue)
12	Fuzzy Logic	Motor Control for Waste Water Treatment
13	Fuzzy Logic (continue)	Motor Control for Waste Water Treatment (continue)

The topics of the class and lab are listed in Table 1. The students learn about the PanelView operator terminal and PanelBuilder software to design control panel applications for the PV550 HMI terminal [1], [2]. The laboratory assignments are based on the user manuals from the manufacturer and customized descriptive problems. Four major motor types—the induction motor, brushed/brushless dc motors, and the stepper motor—are included. The characteristics of these motors and application methods are emphasized. The Ultraware class provides an opportunity for students to program and run the digital ac brushless servo system widely used in industry.

The ICT laboratory provides numerous topics that students can apply to real-world problem solving. In order to interface sensors to the PLC, scaling and mechanical adjustment techniques are required. The design of proper timing for overall system control is very important in writing a working ladder logic diagram. The PID concept may be hard for students with lecture only. The newly proposed teaching components help students visualize the effectiveness of the PID function in automation and process control through a series of laboratory exercises. The concept of fuzzy logic is introduced at the end of the semester since advanced PLCs such as ContoLogix offer it. The PLC laboratory at Penn State Berks is equipped with six SLC500 PLC training stations; each station has a 10-slot modular chassis from Rockwell Automation.

PanelView - PV550 HMI Terminal and PanelBuilder32

The main objective of this teaching component is to provide students with the opportunity to learn how to use an HMI terminal. Since the PLC lab at Penn State Berks is equipped with PV550 monochrome terminals, the class focuses on how to use PanelBuilder32 software with the SLC500 PLCs. A couple of exercise problems are given to the class to practice with PanelBuilder32 software. The students learn how to control their ladder logic diagrams through not only I/O devices on the PLC training station, but also the PV550 HMI terminal for future motion control projects.

ICT System

The ICT laboratory exercises provide students with techniques for parts detection, sorting, and assembly. The ICT from Bytronics is designed to sort an aluminum peg from a plastic ring, then assemble these two components and check for correct assembly. These components are initially placed randomly on the chain conveyor. The chain conveyor moves them to the assembly chute. Then, the plastic components are detected by the sort area infrared (IR) sensor and ejected by a linear solenoid down the plastic ring hopper. In the meantime, the aluminum peg remains on the conveyor and goes down to the belt conveyor through the feeder chute. The plastic ring hopper is positioned above the belt conveyor in order to engage the peg with a hole in the ring. The inductive- and capacitive-type proximity sensors and IR sensors are positioned along with the belt conveyor to check for the correct assembly. The properly assembled parts proceed into the finished parts tray, but incomplete assemblies are rejected by a linear solenoid into the recycle bin. A picture of the ICT system connected to a SLC500 PLC is shown in Figure 1.

Two I/O modules, 1746-OW8 and 1746-IB16, are used to control the ICT through the SLC500 PLC. The details of the modules installed are listed in Table 2. The step-by-step laboratory assignments enable students to complete ladder logic programming exercises which control all of the ICT processes such as detection, sorting, queuing, and counting.

Step 1. **Sorting Routine:** Component detection and sorting are common practices in industrial control. First, detect the plastic rings moving along the chain conveyor and redirect them to the plastic ring hopper. Second, detect the metal pegs and lead them to the assembly chute.



Figure 1. Industrial Control Trainer (ICT) from Bytronics

Table 2. Details of SLC500 Ten-Slot Modular System

Chassis Slot Location	Part Number	Description
0	1747-L541	SLC 5/04 CPU – 16K Mem. OS401
1	1746-OA16	16-Input (TRIAC) 100/240 VAC
2	1747-SDN	DeviceNet Scanner
3	1746-IB16	16-Input (SINK) 24 VDC
4	1746-OB16	16-Output (TRANS-SRC) 24 VDC
5	1746-IB16	16-Input (SINK) 24 VDC
6	1746-OB16	16-Output (TRANS-SRC) 24 VDC
7	1746-OW8	8- Output (RLY) 240VAC
8	1746-IB16	16-Input (SINK) 24 VDC
9	1746-NT4	Analog 4 Ch Thermocouple Input

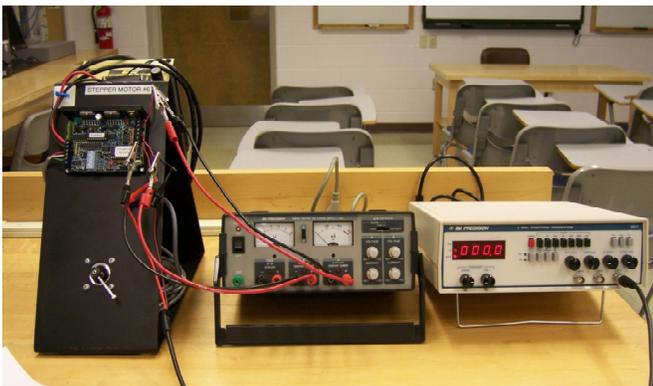
- Step 2. **Queue Counting:** Counting is required in almost all industrial applications. Since the maximum queue length in the assembly chute is five, once the queue has been filled, the chain conveyor should be stopped.
- Step 3. **Operation Timing:** The sort and queue counting routines developed in the previous steps are combined together in this step. The queue count should decrease as the plastic rings are taken into the assembly area.
- Step 4. **Plastic Ring Detection and Sorting:** A single plastic ring is detected and rejected during this stage. The inductive proximity sensor detects the metal peg, and the capacitive proximity sensor detects the presence of a plastic ring assembled onto a metal peg.
- Step 5. **Metal Component Detection and Sorting:** The existence of an aluminum peg is discovered and expelled into the reject bin.

- Step 6. Component and Assembly Detection and Sorting: The single plastic ring, aluminum peg, and assembled parts are identified. Single parts are expelled to the reject bin and assembled parts are accepted.
- Step 7. Complete System Control – Component Queue Handling: A queue of parts travelling along the belt conveyor is identified to complete the system control.

Stepper Motor Drive

There are numerous stepper motor drive applications in the automation and process industries. The shaft of the stepper motor can be held in any fixed position, providing precise positioning control. The stepper motor can rotate in both clockwise (CW) and counter-clockwise (CCW) directions. An electronic circuit, indexer or translator with power amplifier, is inherently required for the stepper motor to drive it.

The objective of this teaching component is to provide students with various real-world techniques to drive a stepper motor. The STP-DRV-4035 micro stepping drive from Automation Direct [3] and the 1746-HSTP1 stepper controller module [4] are used for this lab. The experimental setup of the stepper motor drive and a sample PV550 screen are shown in Figure 2. In order to control the stepper motor properly, the I/O data tables of the stepper controller module must be configured [4]. The module can be configured to determine which inputs are used, the active level of inputs used, and if a quadrature encoder is used. In addition, the module should be configured to select whether the output of the module is a pulse train with direction command or CW and CCW pulse trains, and to select between configuration mode and command mode.



(a) Stepper Motor Drive Setup



(b) Sample PV550 Screen to Control a Stepper Motor

Figure 2. Experimental Setup of the Stepper Motor Drive and PV550 Screen

Ultraware and Ultra3000 Digital Servo Drives

Ultraware is a Windows software application that provides a complete setup and programming environment for the Ultra3000 digital servo drives [5], [6]. The goal of this teaching component is to provide real-world experiences for students by driving and controlling the Ultra3000 digital servo drive with Ultraware setup and programming software. Another goal is to learn about and test the IMC110 termination panel and SLC servo control module [7], [8]. The termination panel provides an easy connection to a user-side dc power supply, emergency stop, drive feedback, and fast I/O to the SLC servo control module in the SLC500 PLC. The basic analog velocity control functions are exercised along with the SLC500 PLC. Sophisticated control functions such as the preset current and position control and the position follower control with encoder and indexing control are skipped in this exercise due to time limitations.

Final Project

At the beginning of the class, the importance of the final project is addressed. In the previous semester, the final project was a group effort with topics proposed by the students and then carefully selected by instructor. Due to the limitation of the hardware availability on the PLC trainer, the previous projects were merely static simulations of various real-world applications. The proposed motion control enhanced teaching components include a final project to design and build a four-story elevator system controlled by an SLC500 PLC. Three groups of four students each build their own four-story elevator system. The prime mover of the elevator system is assigned to the stepper motor. The same types of stepper motor and translator are given to each

group. Each group has the freedom to select the sensor types and the ladder logic program with which to control the elevator system. The requirement of the elevator system is limited to the basic operation of the elevator such as moving up and down, and stopping at each level without the operations of opening and closing the elevator door. In this project, the students learn about group work, project scheduling, selection and interfacing of sensors, scaling and application of stepper motor drives.

Assessment

The assessment of the newly developed motion control teaching components consists of an in-class presentation of each topic and written lab report. Six teams with two students per team select one topic to present the activities. The demonstration of their ladder logic diagram is very important and serves to verify the correctness and effectiveness of the program. The formal laboratory report includes the design approach, the generated report, and the logic diagram from RSLogix500. The assessment rubric is shown in Table 3.

The format of a report of the laboratory project design exercise consists of:

- **Objective** – The objective section should include a brief assertion of the goals of the project design exercise. It should contain the essence of the design and not a sequential list of assigned tasks or requirements.
- **Design Input** – The design input section should summarize all requirements imposed on the design project and any other pertinent data.
- **Design Output** – The discussion should outline how the requirements of the project were met. With it, students should include ladder logic diagrams, ladder logic instructions used, process flow charts, and other pertinent data. They should define what parts (rungs, pages, etc.) of the project design were done by which team members. Students may reference the project handout provided at any point and it will be included with their report in an appendix. Students may also refer to other sources; however, they must be sure to declare them in a reference section.
- **Design Verification** – The design verification section should address how the requirements were verified. It should include information on the process of verification and what equipment was used to test and debug the design. It should include truth tables, field device list, graphs, figures, and/or diagrams.

Table 3. Assessment Rubric

Assessment	Points	
Objective	5	
Design Input	5	
Design Output	5	
Design Verification	10	
Design Validation	10	
Conclusions	15	
References	5	
RSLogix500 Project Report	25	
RSLogix500.rss File	10	
Uniqueness Demonstration	10	
Total	100	

- **Design Validation** – The design validation section should summarize the results from design verification testing and indicate whether all of the requirements were met. If any requirements could not be met, list them in this section. The students should refer the RSLogix500 project report.
- **Conclusions** – The conclusions section should also summarize what students learned by executing the project and should identify problems encountered other than equipment problems during the laboratory session.
- **References** – The references should be any resources relevant to the assigned laboratory topics.
- **RSLogix500 Project Report** – The RSLogix500 report should reflect the following options in the configuration and ladder options dialog, as shown in Figures 3 and 4.

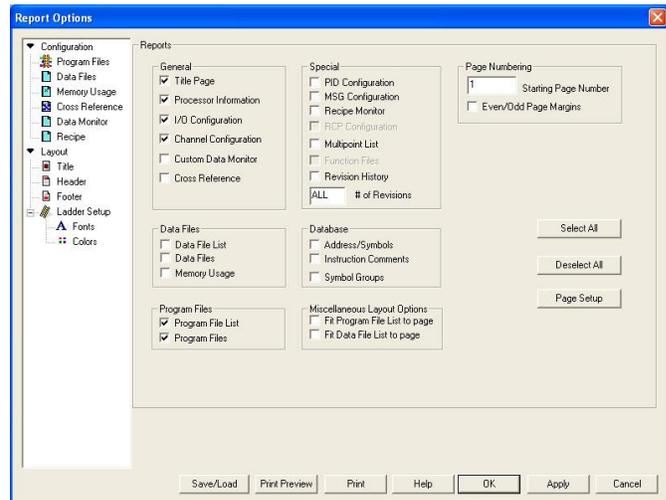


Figure 3. RSLogix500 Project Report Options

- **RSLogix500 File** – The ladder logic diagram should include a title, such as ‘Laboratory #_Your Name .rss’, and as many rung comments as possible. The developed and

tested file should be submitted via ANGEL, the Penn State proprietary course management system.

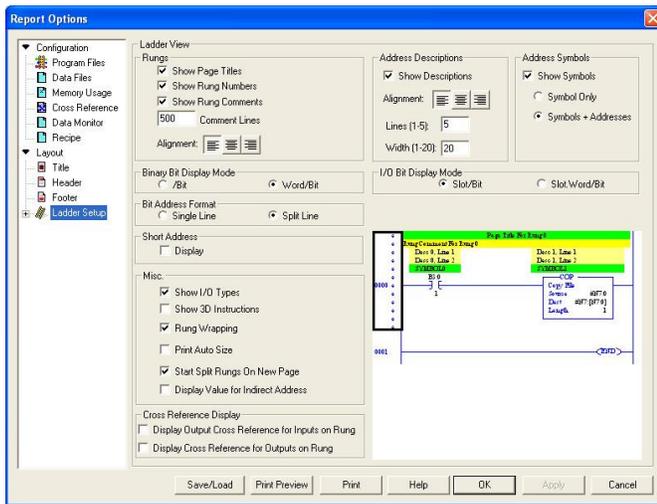


Figure 4. RSLogix500 Ladder Setup Options

- **Uniqueness Demonstration** – The developed and tested ladder logic program should be demonstrated and its operation and uniqueness shown to the instructor during the lab activity.

Conclusion

The newly developed motion control teaching components provide students not only with fundamental theory but also hands-on experience through lab work. The various hands-on laboratories were designed to develop essential technical skills which could apply to real-world motion control applications. The major skills that students can develop through the newly developed advanced PLC course are scaling of analog I/O signals along with the selection of the correct sensors, creation and use of I/O data tables, and use of advanced PLC instructions. Students additionally must acquire team work ethics, time management skills to complete projects, and organizational skills. The students expressed only optimistic opinions on the newly developed motion control teaching components, saying that they enjoyed themselves tackling the challenging assignments.

References

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Biography

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