DESIGN OF A PROGRAMMABLE LOGIC CONTROLLER TRAINER

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Abstract

This paper presents the design of a flexible teaching trainer that has incorporated the Allen Bradley commercial SLC-503 programmable logic controller (PLC) into its system. The system consists of many modules including a digital input/output module, an analog voltage/current input module, and an analog to digital conversion output module.

The trainer has several support materials. It comes with a shielded programming cable which connects the computer's RS-232 port to the trainer's RS-232 port. The user can write a program using the Allen Bradley software. This software is based on the ladder logic diagram. The user gathers information about conditions of various inputs through computer program and then makes decisions based on the information to produce the required outputs for controlling the system. The trainer can be used online with a computer. This option sends data back to computer and allows almost real-time remote monitoring of the trainer. The manual of the trainer describes all the input and output options of the unit. The manual also presents a sample program that covers several programming options and provides the status of all memory locations. Along with the manual a 3.5" floppy disk is supplied. The disk contains the sample program listed in the manual. The trainer is designed with a powerful processor and is very flexible.

I. Introduction

A PLC is a digital controller that can be interfaced with industrial processes for control purposes[1-2]. It has discrete ON/OFF inputs for accepting various DC voltages and analog inputs for accepting voltage and current signals. Outputs can be in the form of ON/OFF DC and AC signals or as different DC voltage levels. Through computer programs status of various inputs can be identified and based on these information decisions are made to produce the required outputs for controlling a system.

Commercial educational PLC trainers are usually expensive and lack the flexibility of a complete PLC. They are commonly structured with fixed modules, limited interface options, and older PLC processors.

The purpose of this undergraduate project was to design and construct a trainer which overcomes these limitations by using the full power and operational abilities of a PLC with a newer processor. Therefore, it was decided to incorporate the Allen Bradley commercial SLC-503 programmable logic controller into the trainer. This PLC was selected due to its 16K-word memory on board and its wide applications for controlling systems and processes in industry.

The project was assigned to an individual undergraduate student as a senior design project. The student had to meet the following requirements:

1. Utilize the full power of the SLC-503 PLC by integrating it with the main processor, I/O modules, A/D modules, and the power unit.
2. Provide inputs and outputs options with voltage levels of 5^V DC, 12^V DC, 24^V DC, 120^V AC, and variable voltage and current levels.
3. Provide select choice options for input and/or output connections with a latching toggle switch, a momentary push button, and a user supply input voltage.
4. Use LED illumination as an indicator for input and output states.
5. Design and construct the artwork for dressing the faceplate of a rack mount enclosure. This enclosure is used as housing for the PLC and attached modules.
6. Design the computer interface for communication with the trainer.
7. Develop a demo program to ensure the proper operation of the trainer and to demonstrate its features.
8. Create a manual that is easy for beginner to follow and enable them to develop the required skills for using the trainer.

II. Design and Construction

The PLC trainer is designed as a self-contained unit. The main component of the trainer is the SLC-503 processor with four replaceable modules in a rack. Two power supplies of 24^V DC and 5^V DC are used to provide the required power for the support circuitry. Multiple I/O options each with an LED indicator are considered for flexible visual interfacing between the trainer and the user. All modules are housed in a 19" rack mount enclosure.

The trainer is not a stand-alone unit. It has several support materials. It comes with a shielded programming cable. The cable connects the computer’s RS-232 port to the trainer’s RS-232 port. This cable allows programming of the trainer. Through software the trainer can be put online with the computer. This option feeds data back to computer and allows near real-time remote monitoring of the trainer. The trainer manual explains all the input and output options of the unit. The manual also presents a sample program that covers several common-programming options and it has a sample report that gives the status of all memory locations. Along with the manual a 3.5" floppy disk is supplied. The disk contains a program that can be loaded into the trainer for exploring the PLC commands.

The housing of the trainer is a 19" rack mount enclosure. The faceplate of the 19" enclosure is designed using AutoCAD. A careful consideration is given to placement of all holes and marking on the faceplate of the unit. The AutoCAD drawing was also used to create a silk screen for printing the markings on the faceplate. The faceplate is designed in such a way that all switches, jacks, indicators, and inputs are placed on the left and all outputs are located on the right of the front panel. Figure 1 shows the faceplate of the trainer. On the bottom panel of the enclosure some holes were added to aid mounting the 24^V DC and 5^V DC power supplies, the PLC, and the two relay boards.

Figure 1: The faceplate of the trainer

To power the PLC processor and its modules a special power supply was purchased from Allen Bradley. In addition to this power supply, a 24^V DC and 5^V DC supplies were designed and used in the unit. These power supplies were used to power additional circuitry, inputs and outputs LED indicators, and the relay boards. The use of these supplies was essential to reduce the risk of damage to the PLC's supply. Figured 2 shows the top view of the trainer.

The trainer is comprised of the SLC-503 processor module, a discrete input module, a discrete output module, an analog input module, an input/output analog module and a power supply unit. These various modules are interconnected with the faceplate, relay boards, and DC power supplies to complete the trainer. Figure 3 shows modules used in the trainer. The power supplies, relay boards, and the SLC-503 are solidly mounted in a sturdy 19" rack.

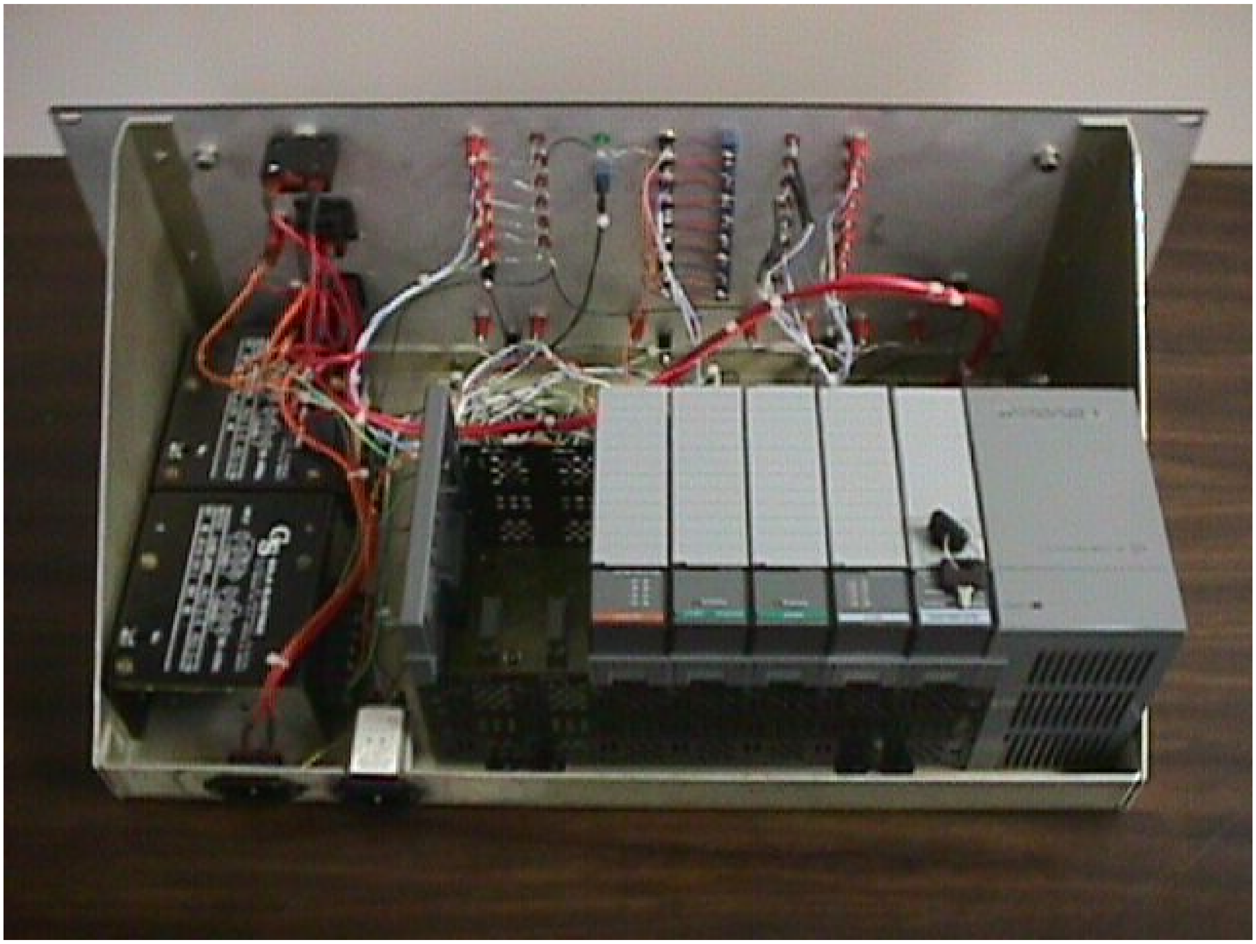

Figure 2: The top view of the trainer

III. Operation

To program the PLC trainer, Wintelligent Linx and RSLogix-500 software packages are required. The Wintelligent Linx is a communication software. It sets up the mode of communication between the computer and the trainer. The RSLogix-500 software is used for the development of programming projects. This software allows user-friendly visual writing of the programs. The program uses the ladder logic as its structure. The ladder logic has evolved from relay logic that was widely used to control processes until the PLC was developed. The program takes the data from the various inputs and uses that data to compute the corresponding outputs. The outputs are generated to control external circuitry or equipment. This process of accepting data and providing outputs can be observed on the computer as well as on the PLC modules. When the PLC is located away from the programming computer, the PLC can send near real-time data to computer and allows remote monitoring of the trainer. This situation can be simulated using the software and the interfacing RS-232 cable.

Discrete inputs (I1-I8) are accepted by the PLC's discrete input module. These inputs are also required as source inputs or active low. For easier interface, it was decided the input should be active high. This was accomplished with input relay board. The input relay board has 8-inputs each of which drives two 5^V relays. Three voltage level inputs of 24^V DC, 12^V DC, and 5^V DC are available for the user. The 5^V DC inputs can drive the relays directly while the 12^V DC and 24^V DC inputs must activate the relay through a dropping resistor. When an input is supplied, both relays are engaged. One of them provides 24^V DC to turn on the indicators and the other one supplies ground signal to be used as the input for the input of the PLC module.

The outputs (O1-O6) are obtained through the isolated relay module. Each relay in the module has separate user supplied inputs. This is done within the trainer. The relays associated with O1 and O2 have been supplied with 24^V DC allowing 24^V DC to be present on the front panel at the jacks O1 and O2. The relays associated with O3- O6 have 5^V DC applied which allow 5^V DC to be presented at the front panel jacks O3- O6 outputs. The output relay board also contains two 120^V AC, 15^A relay. Each relay is independently driven as outputs O7 and O8. As O7 and O8 are activated the associated relay is activated too, thus, supplying 120^V AC to a receptacle and lighting the indicator.

Figure 3: The trainer's modules

The analog inputs and outputs module consists of six inputs and two outputs. Four inputs are variable voltage inputs and two are variable current inputs. The two outputs are variable voltage outputs. These inputs and outputs allow interfacing of transducers, signal samplings, and signal generations.

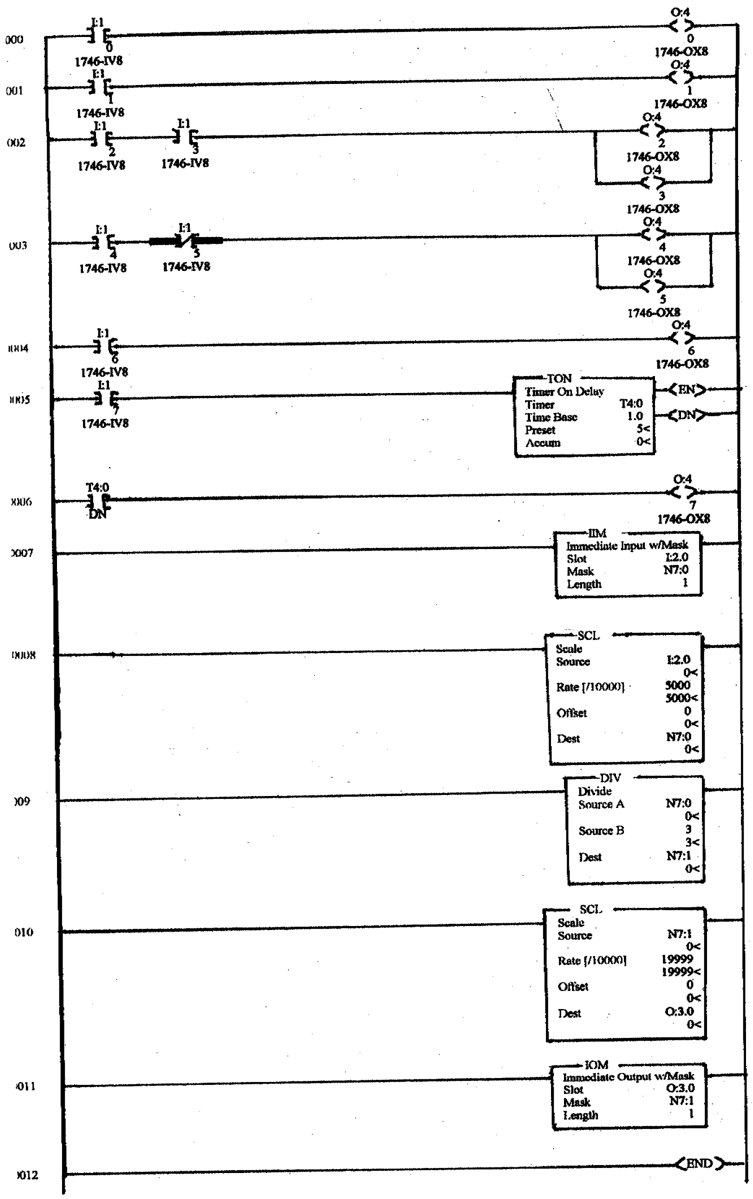

Figure 4: A sample program for the trainer.

There are two AC power cords. The first one is EMI/RFI shielded and fused. It supports the PLC and the two DC power supplies. The second AC connection delivers power to the O7 and O8 outputs. When O7 and O8 are activated, individual AC relay is engaged. A resetable 15^{A} circuit breaker is located before the relay. In case the current delivered to load exceeds the rated current of the unit, circuit breaker will shut down the current flow. This is useful for diagnosing the malfunction part of the system before the breaker is reset.

The program on the computer can be down loaded via the RS-232 to the trainer. The program can be tested using the I/O options. The inputs and outputs can be activated using the switches and indicators that are located on the faceplate without a need for any external circuitry.

External circuitry such as transducers, switches, motors, and lights can be interfaced with the trainer by making connections on the faceplate with various banana jacks and AC receptacles. Figure 4 shows a sample program written for the trainer.

IV. Conclusions

The project was a successful undergraduate design work with many benefits. The education experiences were enormous for the student. He gained valuable insight of systematic approach to design process and implementation of many disciplines offered in our Electrical Engineering Technology Program. The key advantages of this design project over existing ones are:

- The SLC-503 remains a complete full functioning PLC and is not modified in any way.
- The additional 24^{V} DC and 5^{V} DC power supplies provided power for all inputs and outputs of relay boards and indicators. This arrangement frees the internal SLC-503's power supply to power only the processor and the corresponding installed modules.
- Each discrete input has three options of a toggle switch, a momentary push button, and a user supplied input. The user-supplied input allows for 24^{V} DC, 12^{V} DC, and 5^{V} DC. When an input is applied, a LED indicator goes on and lights up.
- The trainer is flexible and has a newer processor.

References:

1. Webb, J.; Programmable Logic Controller: principals and Application, 4Th edition, Prentice Hall, 1998.
2. Simpson, C.; Programmable Logic Controller, Prentice Hall, 1994.

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Dr. Fotouhi is a Professor of electrical engineering technology at University of Maryland Eastern Shore. He received his Ph.D. in power System Engineering from University of Missouti-Rolla, M.S. from Oklahoma State University and B.S. from Tehran Polytechnic College. He has been conducting a practical research on the growth and characterization of the dilute magnetic semiconductor since 1985. He is a member of Eta Kappa Nu Honor Society. He was chairman of Student and Industry Relation and Host Committee member of IEEE Conference on Power Systems Computer Application in 1991. He also was chairman of Student Relation and Host Committee member of the IEEE Power Society Winter Meeting in 1996.

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