Student Projects in PLC Networking

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Abstract:

A case study of Programmable Logic Controller (PLC) networking in the classroom and its implementation during the laboratory session will enable students to better understand the subject. In this paper, we will present a PLC network project that was part of an honors contract program in a flexible automation course. Students who participate in the university honors program can complete the project as partial fulfillment of their honors program's curriculum.

Three main elements are involved in a PLC networked system. These elements are: 1) Network Connection Topology, 2) Transmission Medium, and 3) Network Access Control Scheme. The way a network is connected is referred to as, "Network Connection Topology". There are different methods used to physically connect PLCs and computers in a Local Area Network (LAN). The transmission medium or wiring type used to connect each network's nodes is critical in setting the actual distance, number of nodes (LAN stations), and frequencies of transmitted signals in the network system. Another important aspect of the LAN considers the way equipment in the network communicates. This is referred to as the network access control scheme. A brief explanation of the machines and components mentioned above, and the specific method employed by the Allen-Bradley Series 500 Small Logic Controller (SLC500) network system will be part of the paper. The manuscript will focus on essential topics that should be included in an Industrial Networking Laboratory.

Students who participate in Honors Program at the University of Cincinnati must maintain a 3.2 Grade Point average and complete 36 Quarter credit hours of Honors level coursework. The 36 Quarter credit hours must include a minimum of 9 credit hours of Honors Special Topics courses. The remaining credit hours can be obtained by the Honors Contract or Independent Study courses. This project was part of the Honors Contact course for the student(s) who participated in the Honors Program. The students participating in the honors program connected a four-station network system in the PLC laboratory during the spring 2004 quarter. Stations consisted of one PC computer, and three Allen Bradley SLC 500 series programmable logic controllers. Students first learned how to set up the hardware component of an industrial network system. Then, they were required to configure the network protocol where one PLC is configured as the Initiator station, and the other two PLCs are configured as the Responder stations. Finally, students wrote the ladder logic diagrams for implementing the control regime

that emulates operation of an industrial plant. This project was intended to familiarize students with hardware/software set up of an industrial network system. It also acquaints them with programming skills needed for a network PLC environment in a process control system.

Introduction:

Programmable logic controllers (PLCs) are designed to carry out industrial control routines and replace the older relay logic controller panels. Relay logic controllers were previously used to manage and control electromechanical devices in manufacturing plants and material handling industries. Starting in the eighties, PLCs are frequently networked in industrial plants so that control software and data acquisition could be managed through a centralized computer system. An Electrical Engineering Technology (EET) graduate who is hired to work in an industrial plant is expected to be informed about these topics. In most schools the topic of Programmable Logic Controllers (PLCs) is taught in two-quarter or two-semester classes. Typically, a semester is sixteen weeks long, while a quarter session is only eleven weeks long. During the second quarter or second semester one must be able to introduce and explain important topics on networking PLCs in industrial plants. An introduction to industrial network theory and programming should be an essential part of any advanced Programmable Logic Controller (PLC) course.

Modern Programmable Logic Controller (PLC) devices have sophisticated instruction sets, larger memories and more Input/Output ports [1]. These PLCs are programmed to control robots, conveyors, and electromechanical machines. In a networked environment, PLCs communicate with each other in the plant, and the computers located in the control room. Computers are used to download new control programs into the networked PLCs [2]. These computers are also used to record and manage the data flow in and out of the PLC Input/Output ports.

In this paper, we will present a PLC network system that is used to control the rate of frequencies at which pilot lights may be turned on and off. Required hardware devices and wiring connections of the system will first be explained. Then, a control regime will be devised for the system. Finally, the software that is used to manage the system will be described.

Problem Statement:

As part of the Honors contract, students were given the following problem. Connect three PLC stations in a local area network. Then, program the PLC Network Systems as stated in the following paragraph.

The Master PLC (Initiator Node) program will have two Message Functions. When the green pushbutton on the Master PLC station is pressed, it should use a latch function to go to the first Message Function. This Message Function will read the status of the Timers that are on the Slave PLC (Responder Node) station #1. Then they will release the green pushbutton in order to Unlatch and exit the Message Function. When the red pushbutton on the Master PLC station is

closed, it will use a latch function to go to the second Message Function. This Message Function will read the status of the Timers that are on Slave PLC station #2. They will then release the red pushbutton in order to Unlatch and exit the Message Function. All the data gathered by the Master PLC station will reside in memory locations N7:0, N7:1, etc. of the Master PLC. Each individual Slave PLC station will have a program that will continuously implement the following tasks: 1) Green light is on for five seconds while the red light is off, and 2) Red light is on for eight seconds while the green light is off. When students completed the first part of the project, then they are asked to Modify the program on the Master PLC station specified for the aforementioned PLC network, and add Write Message functions in order to vary the duration of time that the red lights and the green lights on the Slave PLC stations stay on. Note that, there should be two Write Message Functions in the Master PLC program. Two switches will be used to activate the write message functions.

Hardware Devices and Connection of the Network system:

Figure 1 displays an Allen-Bradley programmable logic controller Local Area Network (LAN) schematic diagram that was connected in the laboratory. Four LAN stations or LAN nodes are in this network. The LAN stations are: 1) Personal Computer (PC), 2) Allen-Bradley SLC503 Master PLC, 3) Allen-Bradley SLC500 Slave PLC, and 4) Allen-Bradley SLC503 Slave PLC. The personal computer (PC) is at the node address zero (Network Station #0), the SLC500 Slave PLC is at the node address one (Network Station #1), the SLC503 Slave PLC is at the node address two (Network Station #3), and the SLC503 Master PLC is at the node address three (Network Station #3) [4].

Figure 1- Local Area Network Connection for Allen-Bradley SLC500 Series System

The network stations displayed in Figure 1 are connected in a Bus Topology [3]. The transmitted signals in a Bus Topology are copied by the target stations, and the signals are absorbed by the terminating point resistor. A personal computer is used for downloading the ladder logic programs into the PLCs, and monitoring the data flow during the program executions.

In this network, Belden #9842 Shielded Twisted Pair (STP) wires are used to connect the PLC network cards. Allen-Bradley Asynchronous Interface Connector (1747-AIC) isolation link couplers are the network cards. Two of the most often used twisted pair (TP) wires, as specified by their transmission speed, are the sixteen Mega bits per second (16Mbs) TP, and the one hundred Mega bits per second (100Mbs) TP. The 16Mbs twisted pair typically has three or four twists per foot and carries data at lower speeds over shorter distances. The 100Mbs twisted pair typically has three or four twists per inch and carries data at faster speeds over longer distances. The shielded twisted pair of wires used in this network transmits data at the speed of sixteen Mega bits per second (16Mbs).

The computer is connected to the PLC devices via the Peripheral Interface Communication (1747 PIC) card. We also utilized the proprietary cables manufactured by Allen-Bradley (1747-C10 and1747-C11) to connect the SLC500 devices to the network transmission media.

The WIN95/98/NT/2000/XP based Rockwell International's RSLogix software is used to program the Allen-Bradley SLC500 Programmable Logic Controllers (PLCs) [5]. We must first load and run the RSLogix software on the personal computer (PC) station in the network (Network Station #0). Next we activate the "Who Active" function in the Communication command group. We then turn on the Master PLC station and assign it to the node address three (Network Station #3). Following that, we turn on the Slave PLC Stations and assign them to node addresses one and two (Network Station #1 and #2).

Finally, we must "cycle power" to the processors in order for changes to occur. Turning the processor off, and then on is called "cycling power" to the processor. If there is more than one slave PLC in the network system, we must repeat the aforementioned steps for all the PLCs in order to assign network nodes to all the units connected in the Local Area Network (LAN) system.

Networking Technologies:

The PLC network presented in this paper utilizes a Master-Slave (i.e., Initiator-Responder) communication routine with a Token Passing access control scheme. This means that the master PLC has control of passing the token to its associated slave PLCs. In the Token Passing network a signal package called "Token" is passed around from one station to the other. The "token" consists of the present station address, the predecessor station address, and the successor station address. The station that needs to have access to the network for receiving and transmitting data will hold on to the token for a pre-determined amount of time. Otherwise, the token is passed to

the next station. In the Master-Slave network with a token passing access control scheme, the initiator station is called the Master PLC. It will "poll" the responder stations called Slave PLCs. This "polling" action is used to see which station in the "polling list" is trying to gain access to the network highway. Figure 2 displays a typical Allen-Bradley Master-Slave communication dialog box [2]. Once the connection between the Master PLC and the Slave PLC is established, data will flow between the two PLCs.
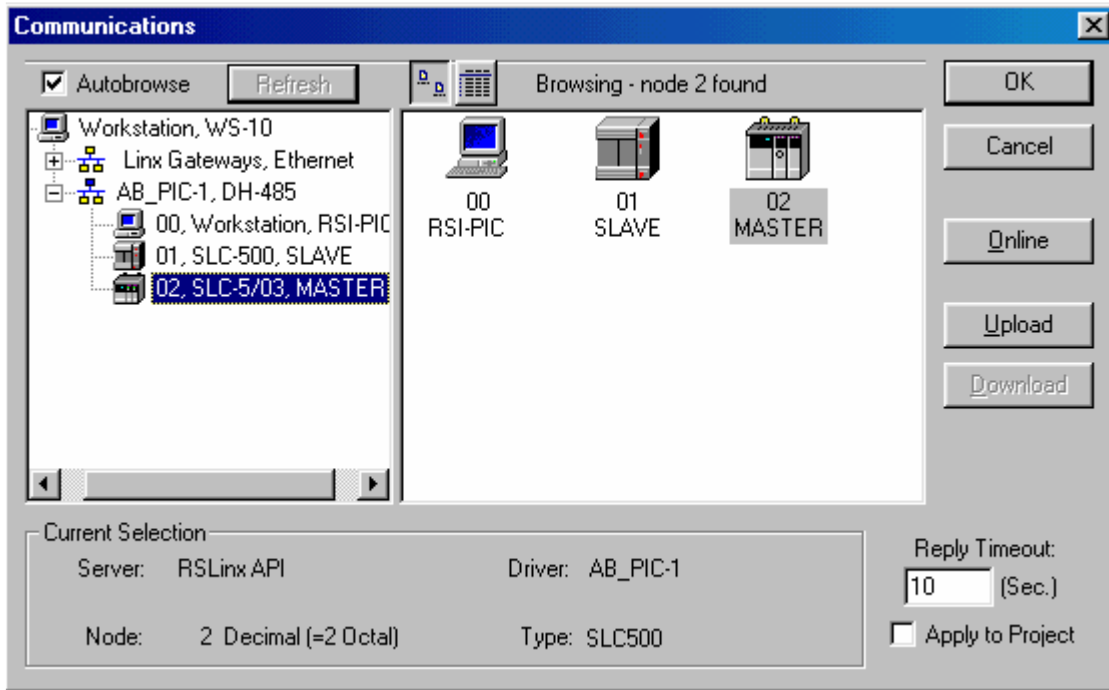
Figure 2- Allen-Bradley Data Highway 485 Communication Dialog Box

After the networked system is connected and configured, a realistic and practical problem is presented to the students. Students are responsible for programming of the stations in the LAN system. In the following sections we will describe the steps required for solving the case study.

PLC Input / Output Assignments:

Figure 3 displays the Input/Output address assignment of the Master and Slave PLC stations. There are four input devices connected to the Master PLC station. These input devices consist of two pushbuttons and two switches. There are two (2) output devices connected to each slave PLC stations. Each PLC station has one red and one green pilot light connected to it.

| Master PLC Station		Slave PLC Stations	
Green Pushbutton @ N#3 (G_PB)	**I:1/1**	Switch #1 @ N#2 (SW_1)	**I:1/0**
Red Pushbutton @ N#3 (R_PB)	**I:1/2**	Green Pilot Light @ N#2 (G_LT)	**O:2/0**
Switch #1 @ N#3 (SW_1)	**I:1/3**	Red Pilot Light @ N#2(R_LT)	**O:2/1**
Switch #2 @ N#3 (SW_2)	**I:1/4**	Switch #1 @ N#1 (SW_1)	**I:0/0**
		Green Pilot Light @ N#1 (G_LT)	**O:0/0**
		Red Pilot Light @ N#1 (R_LT)	**O:0/1**

Figure 3- The Master and Slave PLC Input/Output address assignments

The Control Routine:

Figure 4 displays a flow chart of the program to control the data flow. Appendix A, Appendix B, and Appendix C contain the PLC ladder logic diagrams for the Master and Slave PLC stations. The input ports are first scanned by the master PLC station. If an input is activated, then a decision will be made to see which network message should be serviced. Otherwise, the input ports are scanned again.

The message function in our system is configured for peer-to-peer type, using local (i.e., hardwire) connections (see Appendix A). There are two Read and two Write message functions in the Master PLC program. Each message function requires fourteen (14) control words. For example, in the first Read message function we are reserving data files N7:40 thru N7:43 for the control tasks.

The message (MSG) dialog box for each message function should be completed in order to set up the proper data communication protocol. Figure 5 displays the message (MSG) dialog box for the first Read message function. Notice that the function is setup to read the data file N7:0 from node #1, which is the SLC500 slave PLC station into the data file N7:0 in SLC503 master PLC station.
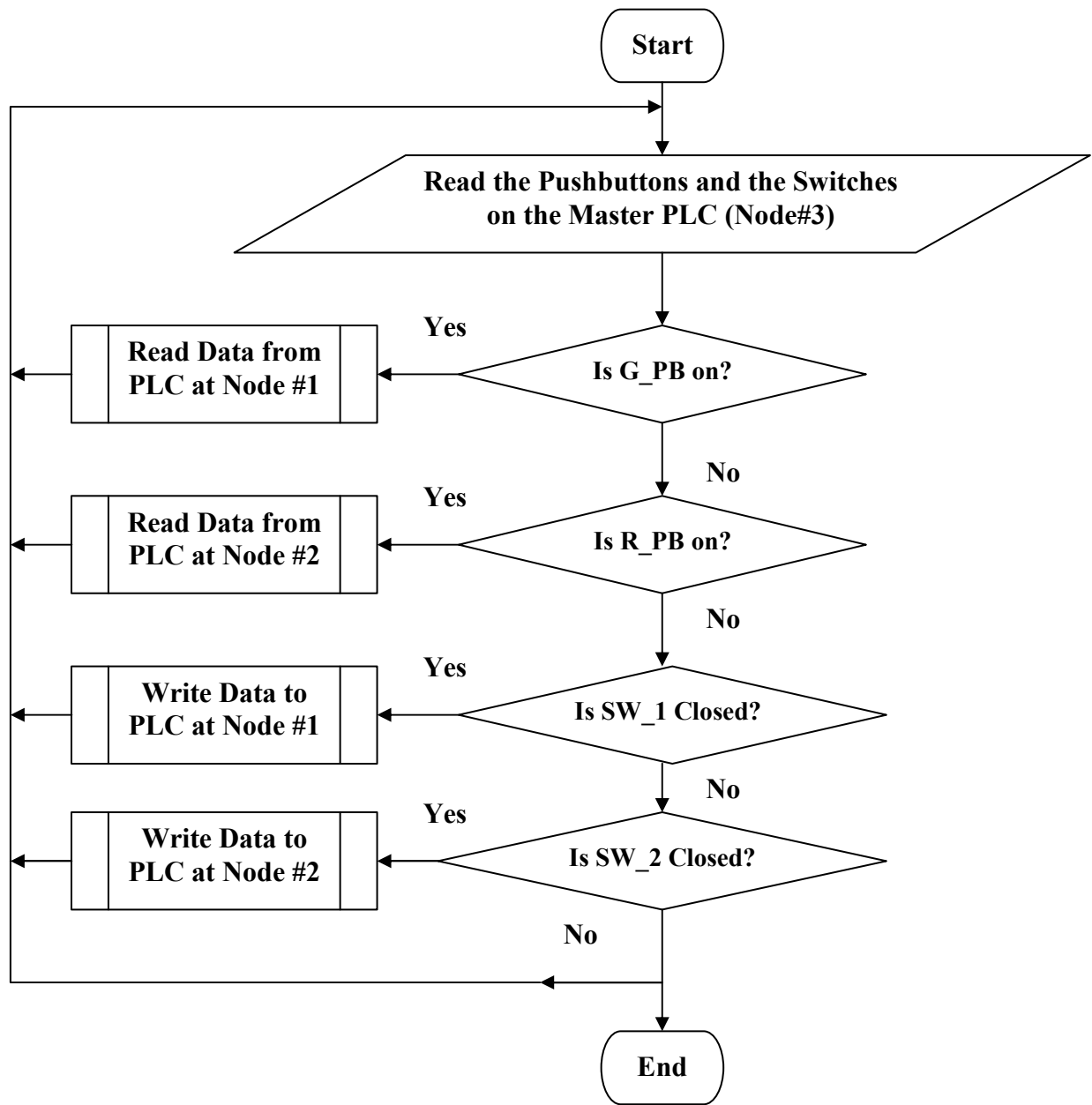
Figure 4- Flow Chart of the Master PLC Ladder Logic Diagram
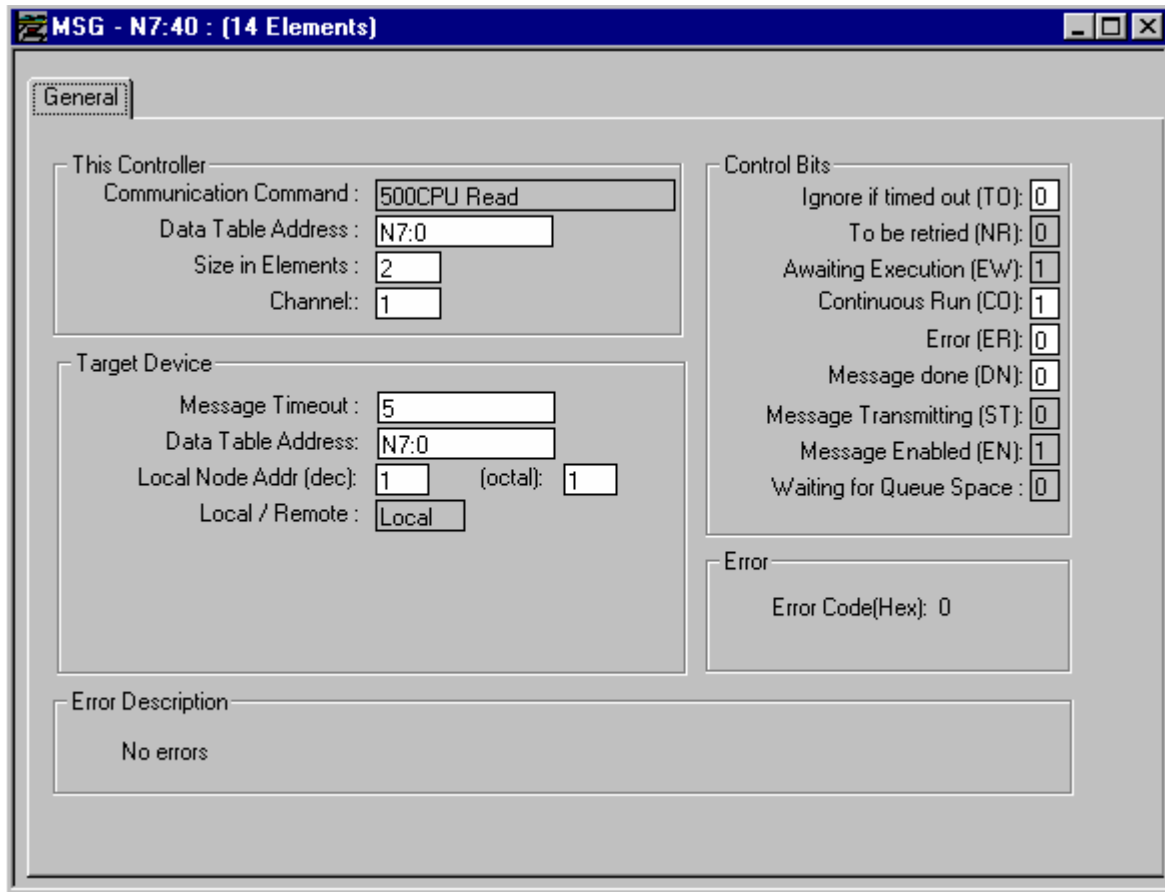
Figure 5- The Control Setup Screen for Read Message #1

Conclusion:

This paper demonstrated how to connect programmable logic controller (PLC) devices in a network environment. It also explained how to use software such as Rockwell International's RSLogix500 in order to incorporate commands for control of an industrial network. Network systems similar to the one discussed in this paper are used to control electromechanical devices, hydraulic/pneumatic systems, and manufacturing robots/conveyors in industries. Students involved in a project similar to the one presented in this paper will gain valuable industrial programming knowledge. In fact, this faculty member has had positive feedback from students who completed this honors contract project and are employed in the industry for their co-op program.

This is a direct code from one of the students who completed the Honors contract described in the paper; " I found the PLC networking project both educational and enjoyable. It built off of the course by describing how PLCs interact with each other and PCs in a networked environment. This project was of particular relevance to CET/EET students because it bridges

the gap between the electronic and computer oriented topics within the majors. I have found that these types of skills are highly valued by the employers."

In engineering technology programs, instructors need to encourage students in junior and senior level courses to design and emulate realistic industrial examples. This will familiarize the students with control settings in industrial and manufacturing plants. Students who are somewhat familiar with realistic industrial systems have a better chance of getting a co-op job or being employed after graduation.
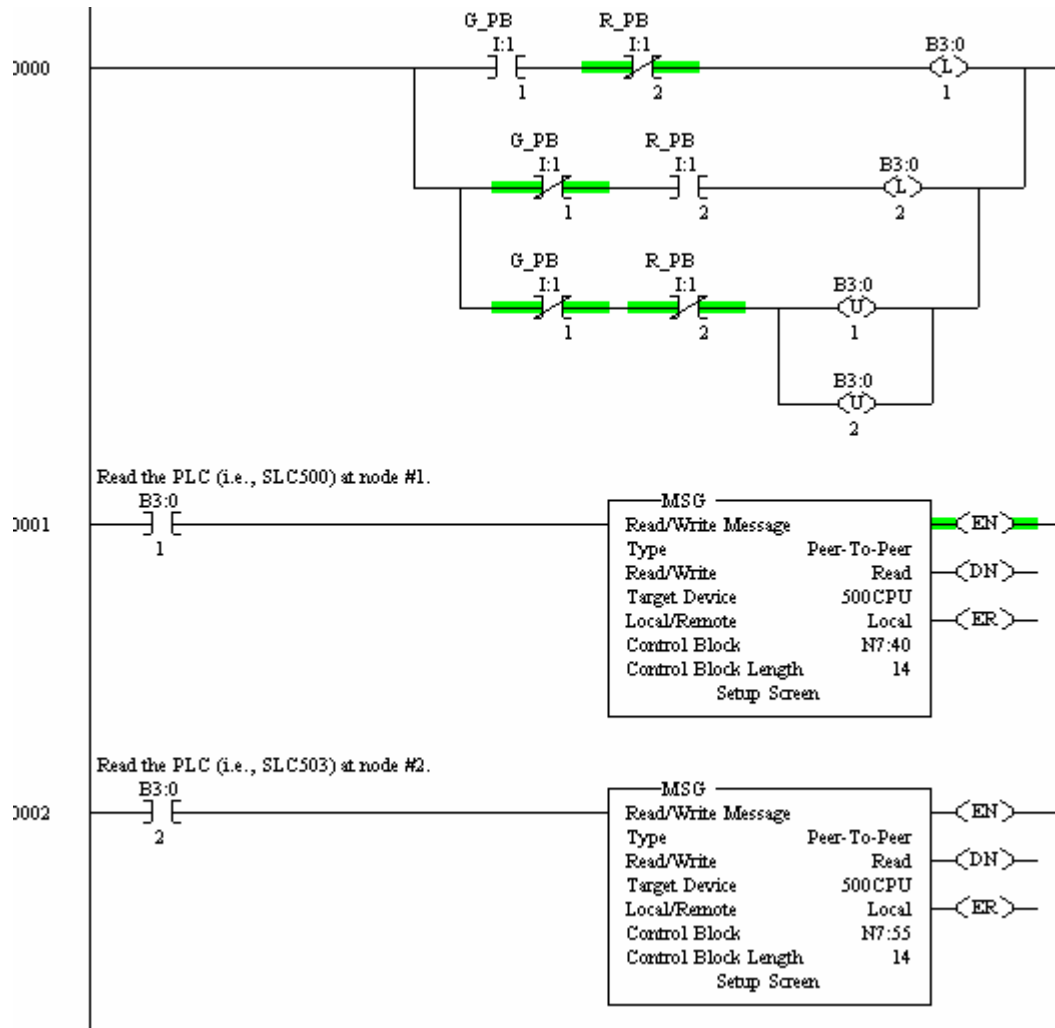
Bibliography

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3. *Thompson, Arthur, Understanding Local Area Networks: A Practical Approach, 2000, Prentice-Hall Publishing Company, Upper Saddle River, NJ.*

4. *A-B Reference Manual: Allen-Bradley SLC500 and MicroLogic 1000 Instruction Set, 2002, Rockwell Automation, Milwaukee, WI.*

5. *RS-Logix User Manual: Win95/98/NT/2000 RS-Logix Programming Software, 2002, Rockwell Automation, Milwaukee, WI.*

Biography

Max Rabiee earned his Ph.D. in Electrical Engineering from the University of Kentucky in 1987. He is a Professor of Electrical and Computer Engineering Technology (ECET) at the University of Cincinnati. Dr. Rabiee is a registered professional engineer, and a senior member of the Institute of Electrical and Electronic Engineering (IEEE). He is also a member of the American Society of Engineering Education (ASEE), the Eta Kappa Nu Electrical Engineering Honor Society, and the Tau Beta Pi Engineering Honor Society.

Appendix A Part I:

The Master PLC station Ladder Logic Diagram for Node #3 showing the read message functions.


0000

```
        G_PB          R_PB
        I:1           I:1                           B3:0
0000  --] [--       --]/[--                        --(L)--
         1             2                               1

        G_PB          R_PB
        I:1           I:1                   B3:0
      --]/[--       --] [--               --(L)--
         1             2                     2

        G_PB          R_PB
        I:1           I:1           B3:0
      --]/[----------]/[--        --(U)--
         1             2             1

                                    B3:0
                                  --(U)--
                                     2
```

Read the PLC (i.e., SLC500) at node #1.

```
        B3:0                      --------MSG--------
0001  --] [--                     Read/Write Message            --(EN)--
         1                        Type            Peer-To-Peer
                                  Read/Write              Read   --(DN)--
                                  Target Device        500CPU
                                  Local/Remote           Local   --(ER)--
                                  Control Block          N7:40
                                  Control Block Length      14
                                          Setup Screen
```

Read the PLC (i.e., SLC503) at node #2.

```
        B3:0                      --------MSG--------
0002  --] [--                     Read/Write Message            --(EN)--
         2                        Type            Peer-To-Peer
                                  Read/Write              Read   --(DN)--
                                  Target Device        500CPU
                                  Local/Remote           Local   --(ER)--
                                  Control Block          N7:55
                                  Control Block Length      14
                                          Setup Screen
```

Appendix A Part II :

The Master PLC station Ladder Logic Diagram for Node #3 showing the write message functions.
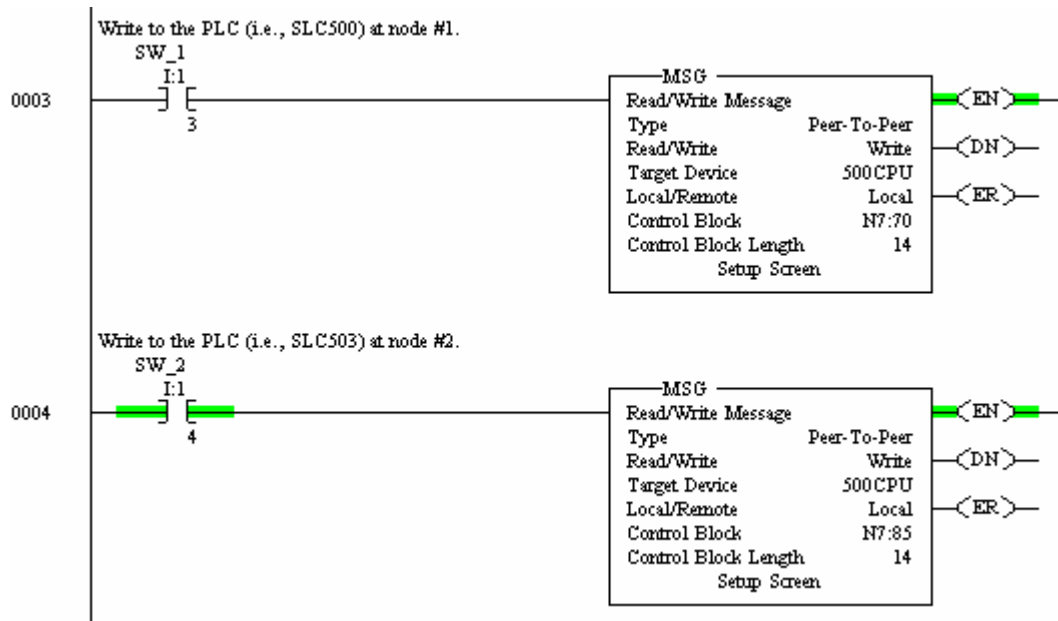
Appendix B:

The Slave PLC station Ladder Logic Diagram for Node #2.

Slave PLC (i.e., SLC503) connected to node #2.
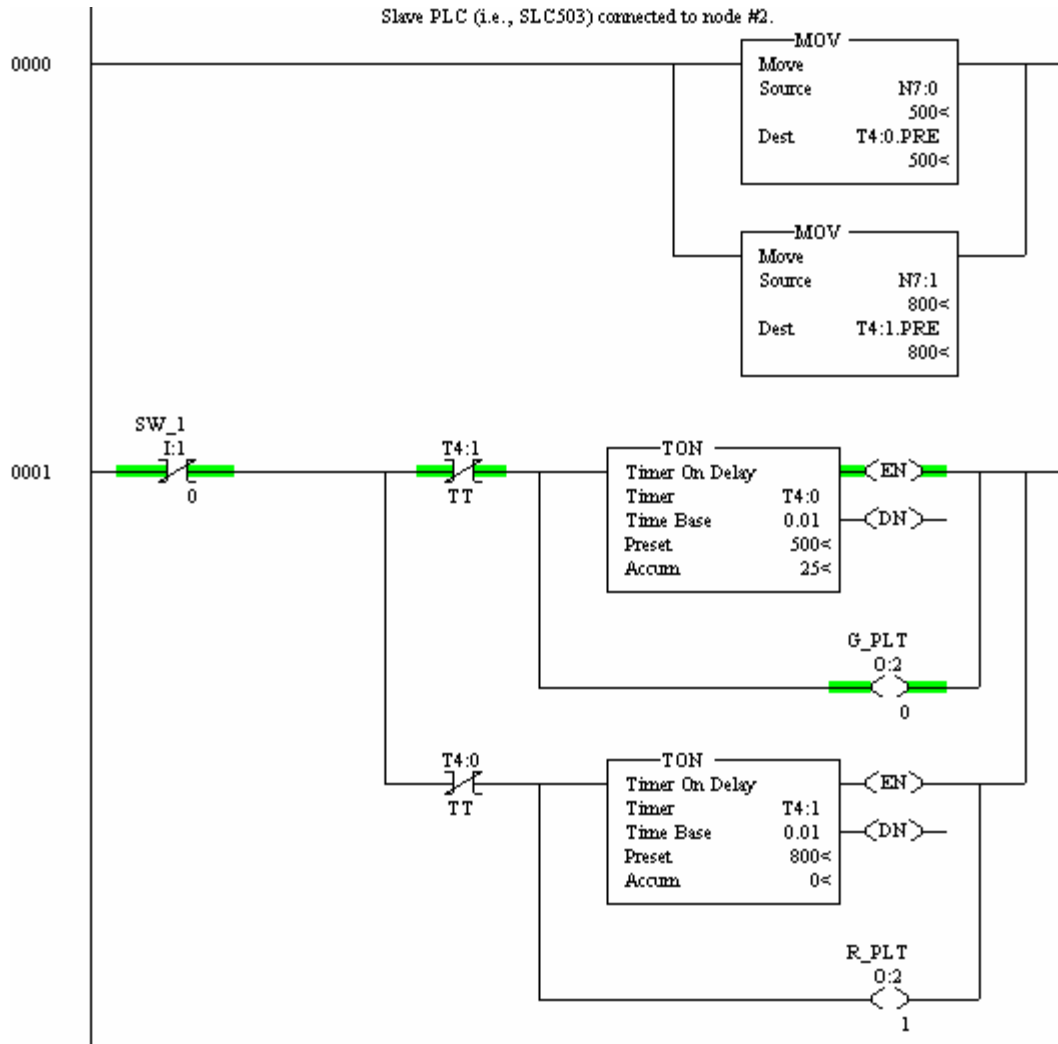
Appendix C:

The Slave PLC station Ladder Logic Diagram for Node #1.

Slave PLC (i.e., SLC500) connected to node #1.