Introduction:

There is a growing demand for individuals in the field of Industrial Automation with an emphasis on programmable logic control, robotics, industrial networks and project management. This program will prepare individuals to competitively challenge for a variety of positions in the automation and control systems areas. Niagara College students will be well trained automation specialists with highly skilled expertise.

Prerequisites:

Students must be familiar with Windows software and have the ability to navigate through Windows software. Since the ControlLogix is a big brother or sister to the Allen-Bradley PLC 5 and related to the SLC 500 PLC, any past experience with these two Allen-Bradley platforms will help the student transition into the world of ControlLogix.

ControlLogix Software:

- Studio5000
- RSLinx
- Factorytalk View

ControlLogix Hardware for Lab Exercises

Slot 0	1756-L71S	Logix5571 Controller
Slot 1	1756-L7SP	Safety Controller
Slot 2	1756-IB16 /A	16 Pt DC Input Card
Slot 3	1756-IF16 I/A	Analog Input Card
Slot 4	1756-OF6 CI/A	Analog Output Card
Slot 5	1756-OW16 I/A	Relay Output Card
Slot 6	1756-ENBT/A	Ethernet Card

Lesson Plan:

NOTE: This schedule is under ideal conditions. There is a great deal of material to cover such that modifications of this schedule are possible. Changes will be posted. Other changes can occur due to holidays, snow days and other possible unforeseen disruptions.

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 1 2Sept19 Week 2 9Sept19	**ELNC9103 – Introduction and Lecture 2** **ELNC9103 – RSLinx Configuration (for Lab)** Introduction to PLC and Control Systems. • What is PLC? • History of PLC (Before and After) • Major components of PLC • Operational sequence of PLC • Basic Electrical Circuit and Elements • Logic Gates (Review posted on BB) • Ladder logic • Example of starting and stopping of a motor • Advantages / Disadvantages • Application – Elevator example This lesson covers the basics of electrical circuits and set the expectation for the remainder of the course. Student watch a video on a Relay Controlled Elevator which is a good demonstration of relay control. Video was chosen since the Relays and Contacts are visible along with Limit Switch and Floor Sequencer. Basic of Inputs and Outputs are covered. It should be noted that there may be students without an Electrical Background which need to be instructed to do extra research and reading to catch up, especially if anything covered by the current slides is not familiar. Introduction to the textbook used throughout the course: *Introduction to the ControlLogix Programmable Automation Controller, Gary Dunning.*	Slides: Intro: 1 to 34	Assignment #1 Basic Binary Numbers and Logic Reading/Docs ELNC9103 - Number Systems.docx - Logic Gates.docx - Relays.docx

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 1 2Sept19 Week 2 9Sept19	Lab 1 – PLC Communication (done in lab) • Includes instruction material in the form of a Powerpoint to step the student through RSLinx Setup and Connection to the PLC. • Uses an existing PLC File for Demonstration Purposes • Demonstrate Lab Hardware (connected I/O) • Demonstrate Printing as an XPS File • Demonstrate how to change Display and Print Colors of Elements and Comments Students answer questions in Lab = does not have to be submitted. **Instructor Files:** Demo uses Flasher.ACD posted on Blackboard	Slides: Lab: 1 to 12	Lab Demo

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 3 16Sept19	**ELNC9103 – Lecture 2 – Hardware** Introduction to PLC Hardware – Focus on Rockwell. Along with the introduction Lecture, this material is intended to give the student an insight into the Hardware that is necessary or used in Today's Modern Control PLC. - Focus on Rockwell PAC (Programmable Automation Controller) - Identify different members of the ControlLogix family - Identify ControlLogix controllers and their features - Select I/O modules by their part numbers - Understand the differences between the modular ControlLogix and the members of the CompactLogix family - Identify ControlLogix communications modules Powerpoint lesson contains many diagrams and photos to assist students in their conceptual understand of what a PLC, what Hardware is Involved and how it is structured. Although this is still covering the basics of the architecture, there must be some Electrical or Controls understanding of the concepts involved.	Slides: Hardware: 1 to 67	Chapter 1 *Introduction to Hardware* Assignment #2 Reading/Docs ELNC9103 - Ladder Logic Examples.docx

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 3 16Sept19	**Lab 2 –** PLC Communication and Ladder Creation (done during lab) • Includes instruction material in the form of a Powerpoint to step the student through creating of a New PLC Program • Review of Lab 1 – RSLinx Connection • Detailed instructions in Powerpoint on how to create a new project • Rack Building and Configuration • Module Keying (Major and Minor Revisions) • Student to create basic program to mimic standard logic gates Students are required to hand-draw the ladder logic and answer basic questions in to give them a basic understanding the logic. Hand-drawing is necessary to emphasis that logic must be planned, not just programmed and made up on the spot. Ladder Logic Examples posted on Blackboard **Instructor Files:** Using ELNC9103_Lab2.acd	Slides: Lab: 1 to 20	Lab 2 (Design and test ladder logic. Deliverable is hand drawn logic.)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 4 23Sept19	**ELNC9103 – Lecture 3 – Software** **ELNC9103 – Lecture 3 – ControlLogix Project Organization** **ELNC9103 – Lecture 4 – Tags (Alias)** **ELNC9103 – Lecture 5 – Control Logix I/O Config** **Software:** • Introduce RSLogix/Studio 5000 Software • Identify RSLogix/Studio 5000 Toolbars • Introduce The PathTool Bar • View and Modify Controller Properties • Turn On and Customize Toolbars • View and Modify Workstation Options This lecture offers a more in-depth look at the Studio 5000 Software. The student will learn how to navigate the menu, understand what the selections mean and gain insight into the Software Setup and Configuration. Some of the screens and setting should already be familiar as this Lecture occurs after Students have already had a chance to run and interface with Studio 5000 in the lab. **Project Organization:** • Understand project organization • Create and modify tasks, programs and routines • Understand program scheduling • Introduce unscheduled programs • Identify subroutines • Introduce and identify a fault routine The complexities of todays PLC software makes this type of Lesson imperative. The Student needs to understand the integration that is available and how to recognize the various components and how to find where Tasks and Routines are located. The basic GUI Configuration for Studio 5000 is closely resembles many updated Professional Packages giving the Student a good base of understanding. Although there are many slides to get through, the presentation is rather quick since the slides represent a step by step instruction which is not complicated. Navigation is very similar structure to the Standard Windows Environment.	Slides: Software: 1 to 26 Project: 1 to 52 Tags: 1 to 35 I/O: 1 to 23	Chapter 2: *Introduction to Software* Chapter 4: *RsLogix Project Organization* Chapter 5: *Understanding Addressing* Chapter 6: *Modular Control Logix I/O Configuration* Reading/Docs ELNC9103 - Tags, Comments, Timers, Counters – reference.docx

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 4 23Sept19	**Lab 3 –** Analog Input Module • Required Tags / Alias for Inputs and Outputs • Follow instructions • Demo Part one to Instructor • Finish Assignment including providing written answers Demo portion is to ensure all Students are able to read the Analog Input Module Value. This allows for some Students to work at their own pace an provides time for the Instructor to help those who have problems getting the Analog Value into the Controller. Posted Document from Rockwell: Analog Input Modules **Instructor Files:** ELNC9103_Lab3.acd - Sample with comments - Could be cleaned up and consolidated ELNC9103_Lab3_Unlatch.acd - Had ladder with Unlatch Message to clear Analog Card Limit Latch		Lab 3 (Lab requires both a Demo to the Instructor and an assignment)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 5 30Sept19	**ELNC9103 – Quizz / Test (50 min)** **ELNC9103 – Lecture 4 – Tags (Alias)** **ELNC9103 – Lecture 5 – Control Logix I/O Config** (Continue Lecture 4 and 5 as needed) Tags: • Understand format of ControlLogix I/O tags • Identify local discrete and analog I/O tags • Identify remote I/O tags • Interpret I/O Configuration for local and remote hardware Basic Tag and Alias Structure is discussed. This discussion should only take 15-20 minutes as the subject is relatively simple. Slides are also provided for reference in case the Student has questions after the lab. Once the Tag layout is discussed in the initial slide set, the remain slides are just variations of the same theme. Modular ControlLogix and Compact Logix I/O Configuration: • Understand terminology associated with modules and their configuration • Perform a digital diagnostic input and output-module configuration for a modular ControlLogix and CompactLogix • Perform an analog input and output-module configuration for a modular ControlLogix and Compact Logix • Download your completed project and monitor tags This is basically a review of what was already discussed during the lab session so there should not be much that students have not been exposed to. A good review and placeholder for information.	Slides: Tags: 1 to 35 Config: 1 to 22	Chapter 9: *Creating and Monitoring Tags* Chapter 7: *Compact Logix I/O Configuration* ELNC9103 - Ladder Logic Examples – Part 2.docx

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 5 30Sept19	**Lab 4 –** Toggle Function Test / Simulated Logic • Follow instructions • Demo Part one to Instructor • Finish Assignment including providing written answers Demo portion is to ensure all Students are able to understand how the Toggle Function from the Quiz functioned and to verify a Truth Table. Using the Monitor functions of the PLC Software, this is a good exercise to not only show how to test and debug but also that some bits can not be monitored due to how quickly they change state. In this exercise, the overall reset bit is only on for one scan which required a TOF to capture the change in state. Two programming exercise are difficult to test without a more definitive plan Part 2 – Packaging Line and Part 2 – Batch System should be set up to make grading easier. Having students load programs for testing is time consuming and frustrating for students waiting to get a grade before moving on to the next assignment. Uses question from the Quiz to program and test in Lab. **Instructor Files:** ELNC9103_Toggle_Lab4.acd - Proper Toggle Function programmed into Ladder ELNC9103_Toggle_Lab4_Test Error.acd - Incorrect Toggle Function from Original (ie: previous professor's) Exam that did not function correctly Note: Should go back and revisit Toggle Function and create an exam question that is separate from the lab. The lab could start with the incorrect version of the Toggle Function that the Students have to debug. Would be a good idea to create multiple programs for both the Quiz and the Lab so Students can not copy off of each other.		Lab 4 (Lab requires both a Demo to the Instructor and an assignment)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 6 7Oct19	**ELNC9103 – Lecture 6 – Ladder Logic Programming** Programming: • Logic Organization • Documentation • Code Re-use • Version Control • NPN versus PNP • AC and DC Inputs and Output • Relay, Transistor and Triac Output • Siemens versus Rockwell Logic Organization and Documentation is very important in any programming environment and many Engineers and Technicians do not do a very good job at tackling these tasks. Planning is essential to creating a structure that is well written and able to be understood by future programmers. Task creep and spaghetti programming is one of the biggest problems with coding so it very important that a programmer or troubleshooter understand that there is going to be good code and badly written code. Some time should be taken to discuss the various types of Input and Output Hardware that exists to interface with the Real World. Students should have some basic understanding of Relays, SCRs, Traics and Transistors … how they work and when to use each of them. Should also cover the review for midterm at this time.	Slides: Programming: 1 to 29	Chapter 13 *Adding Ladder Rung Documentation*

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 6 7Oct19	**Lab 5 –** Toggle Function Test using Function Blocks (two week lab) • Follow instructions • Create an Event Driven Subroutine • Create and Schedule Programs • Create the Toggle Program using Function Blocks This assignment can be challenging for the students as it takes a basic ladder and converts the program into Function Blocks. Basically this is the reverse of how Functions (ie: AND, OR) were used to develop Ladder Logic, now the Student much work to create the equivalent Boolean Code. Not only is the coding important but the order of the Blocks Determine the order the Logic is Solved. The power of Ladder Logic is evident once the Student Learns that Loops required the Function to be explicitly instructed to make assumptions of the Input Status. Questions form the assignment portion of this Lab. It should be noted that Class Assignments are rolled into the Lab during this time. Based on Chapter 4 and Chapter 10 in the Text **Instructor Files:** ELNC9103_Toggle_Lab5.acd - This file contains Ladder, Function Block, SFC and ST version of the Toggle Function. - SFC and ST versions are created in class as part of the Demo – should use Blackboard Collaborate and get the students to follow at the workstation. - Home version of this file was used to test the programs on another CompactLogix PLC Lab5_Part3_Step1 (oxps and pdf) - Function Block with Intermediate Tags Lab5_Part3_Step2 (oxps and pdf) - Function Block without Intermediate Tags		Lab 5 (Lab requires both a Demo to the Instructor and an assignment)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 7 14Oct19	**ELNC9103 – Midterm** Due to holiday scheduling, the Midterm has to be moved to the week after reading week. As such the schedule had to be modified to fit. There was no class this week but the review was covered during the regular lab sessions.		
Week 8 21Oct19	READING WEEK		

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 9 27Oct19 (Exam) Week 10 3Nov19	**ELNC9103 – Lecture 7 – HMI Modernization** HMI Modernization: • Introduction to Human Machine Interface • Block Diagram • Before / After Examples • Growth and Advancement • Use of Information • IIOT (Industrial Internet of Things) • Benefits (Studies / Examples) • Visualizations / Alarms / Messaging Start the lecture with a discussion regarding Logic Organization and Documentation being very important in any programming environment. Unfortunately, experience has demonstrated that many Engineers and Technicians do not understand the need to address the "why" of the interface. It is important to address the need to solicit requirements from the Customer by showing some examples of HMI Conversations …. is it necessarily the right thing to convert to an HMI. The answer is, of course, that it "depends" on the requirements. Discussion regarding the use of information of which the HMI plays an important role. Advantages and disadvantages of using HMI in Industry. Good time to also start a discussion regarding the use of Graphics and Colors. The main point to make here is that HMI Design needs to concentrate on the needs of the operation. In other words, does the Graphic or Use of Color or other Displays of Information benefit the Operator. Does it provide more information or are Graphics a distraction? Refence some examples from companies: https://www.wausaucoated.com/ https://www.loram.com/ Also touch on IIOT and the Globalization and Distributed use of Data.	Slides: HMI: 1 to 30	TBD Some good examples should be made available.

Week 9 27Oct10	**Lab 6 –** HMI • Demo by Instructor using the submitted PowerPoint (Although not done using the development of this course, it would be much better to use Blackboard Collaborate and have the Students follow alone with the instructions provided in the Presentation.) • Review Questions from Quiz and provide Introduction to Lab • Review Lab Instruction and Assign • Follow instructions • Create a Simple HMI Screen • Attach the Provided PLC Program to HMI Questions form the assignment portion of this Lab. It should be noted that Class Assignments are rolled into the Lab during this time. Important to emphasize that the display element does not necessarily mean the PLC bit is ON or OFF. This seemed to be a difficult concept for Students to grasp so more should be spent on this idea. The HMI need to focus on function or logic … ie: is the Permissive in the Correct State and that State could be a "1" or "0". Posted FactoryTalkView – User Guide on Blackboard (over 600 pages … reference only) Instructor Files: D:\ …. \Labs\Lab 6\Lab6TestV1 *(Directory for FactoryTalk View HMI Files)* → requires the PLC Code stored under Lab 7 since it has the Boiler Tags. Note: Currently, there is no project with the Lab6 HMI. The homework start with a sample HMI (or suggested layout) that was created in Word.	Lab: 1 to 20 (needs to be completed and updated)	Lab 6 (Lab requires both a Demo to the Instructor and an assignment)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 10 3Nov19	**ELNC9103 – Lecture (see notes above – some rescheduling of lecture and labs may be required F20 depending on scheduled class)** Week 4 is pretty heavy … suggest splitting week 4 and moving lectures. Lab can also follow lecture by inserting another programming lab which would be a good idea considering that the students struggle to keep up.	Slides:	
Week 10 3Nov19	**Lab 7a –** BCD Counter and Display by Segment • Demo by Instructor • Review Questions from Quiz and provide Introduction to Lab • Review Lab Instruction and Assign • Follow instructions • Create a Simple HMI Screen • Attach the Provided PLC Program to HMI Posted Video of working LED 7 Segment Display Simulation on Blackboard **Instructor Files:** D:\ …. \Labs\Lab 7\LED Display Decoder\ *(Directory for FactoryTalk View HMI Files)* → requires the PLC Code stored under Lab 7 (same as used for Lab 6)	Lab: 1 to 20	Lab 7a (Demo and Students work on their own – no assignment due)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 11 10Nov19	**ELNC9103 – Lecture 8 - Introduction to Arrays** Arrays: • Understand how array data is stored inside ControlLogix • Identify different types of arrays • Create arrays • Understand what happens when an array is overflowed • Alias off an array element • Program array tags and array alias tags on ladder rungs In this lesson, we introduce grouping data together in a block called an array. An array can be multidimensional: one, two, or three dimensions. We will see how arrays can be used as a way to become more efficient as well as increase organization of tags in an a Studio 5000 project. It is important for students to understand that arrays are a great tool for programmers to utilize. Given that a factory may have processes that are very similar but different locations, such as a roller conveyor line (sections of conveyor that are essentially the same but have different locations), arrays are superb for making sure code is the same for each section of conveyor AND providing the ability to use one block of code in a loop to evaluate every section of conveyor.	Slides: Arrays: 1 to 51	

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 11 10Nov19	**Lab 7b –** Display Code by Segment (two week assignment) • Review Lab Instruction and Assign • Requires Array and Checksum for Error Proofing Posted Video of working LED 12 Segment Simulation on Blackboard (Included Checksum and Pass / Fail Status) This lab is very similar to Lab 7b with the exception that it is very difficult to determine of the process is working as designed. In the first lab, all the student has to do is watch the 7-Segment Display simulated on the HMI to check functionality, however, this lab creates a set of symbols that are not easily recognized. Now it is easy to understand why planning and the creating of the truth table are so critical. As an added feature, a Checksum is added to verify the automatically generated table and compare to numbers entered by the programmer. To pass this lab, the student must be able to describe the operation, create a fault by entering the wrong Checksum and also create a fault by generating in incorrect symbol. **Instructor Files:** D:\ …. \Labs\Lab 7\LED Display Decoder\ *(Directory for FactoryTalk View HMI Files)* → requires the PLC Code stored under Lab 7 (same as used for Lab 6)	Lab: 1 to 20	Lab 7b (Students work on their own – Lab includes a required demonstration as well as some material to be handed in.)

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 12 17Nov19	**ELNC9103 – Lecture 9 – UDT** **ELNC9103 – Lecture 9 – Comparison Instructions** UDT • Understand the purpose of a user defined data type • Create a User Defined Data Type • Apply a user Defined Data Type to a tank farm • Identify tags associated with User Defined Data Type User Defined Data Types (UDTs) are an extremely powerful feature in the Studio 5000 platform that improves the maintainability, uniformity, and readability of routines and programs. UDTs are groups of base data types such as Bool, Real, INT, DINT, Timer, and Counter which can be defined and re-used. For years now, Object Oriented Programming paradigm (or OOP) has been a commonly used programming practice, and has of course found its way into industrial automation. Most PLC manufacturers have found ways to make the programmers life easier by introducing User Defined Types or UDTs. Allen Bradley ControlLogix series of PLC's, together with Studio 5000 programming software, makes it very easy to work with these UDT's …. and since the introduction of RSLogix version 17,it is now even possible to edit your UDTs while online with a running system. [1] Comparison Instructions • Describe the function of the common comparison instructions • Identify RSLogix comparison instructions • Explain two ways to program the Limit Test instruction • Create and interpret ladder logic containing comparison instructions • Incorporate comparison instructions into a project (Lab) Comparison instructions are input instructions that test two values to determine if the instruction will be true or false. Comparison instructions include equal, not equal, less than, less than or equal, greater than, greater than or equal, masked comparison for equality, and the limit test, all to test one value against another. Most comparison instructions have two parameters, source A and source B. Typically source A must be a	Slides: UDT: 1 to 19 Compare: 1 - 16	Chapter 15 *Comparison Instruction* Chapter 14 *Control Logix Counter Instructions*

	tag, while source B can be a tag or a constant. As an example, using an equal instruction, source A could be a counters accumulated value while source B could be a constant such as 10. When the counter accumulated value is equal to 10, the instruction will be true. On the other hand, if source B is a tag, then when the value stored in the tag is equal to the counters accumulated value are equal the instruction is true. Comparison instructions can be used to pick multiple presets off instructions like timers and counters. The limit test instruction can be used to limit the range of data an operator can enter for time, temperature, pressure or speed. [2]		

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 12 17Nov19	**Lab 8 –** Working with UDT • Review Lab Instruction and Assign • Follow instructions • Create a Simple HMI Screen • Attach the Provided PLC Program to HMI Questions form the assignment portion of this Lab. Reference Document for Students: ELNC9103_Lab8_System Time.docx	Lab: 1 to 20	Lab 8

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 13 24Nov19	**ELNC9103 – Lecture 10 – Use of GSV and SSV** **ELNC9103 – Lecture 10 – Data Handling Instructions** Use of GSV and SSV: • Introduce GSV and SSV Instructions • Use of a User Defined Data Type • Identify the GSV and SSV instructions • Explain usage of the GSV and SSV instructions • Interpret GSV and SSV instructions • Program ladder logic utilizing GSV and SSV instructions • Create a fault routine and use GSV and SSV instructions in a fault routine If a programmer requires information that would have traditionally been stored in a status file, a Get System Value, or GSV instruction is programmed to get desired information from the controller wherease to send the controller information will require a Set System Value, or SSV instruction. Both of these instructions are outputs and will execute each scan the rung remains true. Consideration as to how often the instruction is executed is important. As execution of these instructions can occur each and every scan, input logic could include a push button, logic including a one- shot instruction or using a timer to trigger instruction execution only when the information is needed. [2] Data Handling: • Zero tags data using the Clear instruction • Clear array tags containing old data, using the File Fill instruction • Explain the difference between a Move instruction and a Copy instruction • Determine the data resulting after execution of a Masked Move • Extract mixed data coming in from a network • Extract data using the Bit Field Distribute instruction • Program a Copy instruction to copy recipe data from one array to another • Program a Swap instruction to correct extracted data value errors Good opportunity to discuss one of the advantages of programmable controllers over relay control systems is the ability to easily data-handling capabilities. Advances in PLC flexibility and control have created vast instruction sets, including some that allow the PLC	Slides: GSV: 1 to 24 Data: 1 to 28	Chapter 17 *Introduction to GSV & SSV Instructions* Chapter 16 *Data Handling Instructions*

	to store huge amounts of information pertaining to the manufacturing process. For example, stored data could include numerous recipe sets, one set for each of the different products produced; logs of production data from many products or batches; and operator production data. Data-handling instructions allow stored data to be moved or copied from controller memory for use in ladder logic instructions for the process currently being controlled. Network input or output data can be systematically organized into a block for efficient transfer across the network. [2]		

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 14 1Dec19	**ELNC9103 – Review Session** - Review of material covered and class and the Lab - Exam Prep.	Slides: Review: 1 to 15	

Lesson	Power Point / Topics	Power Point	Homework / Tests
Week 15 8Dec19	**ELNC9103 - Exam**		

Disclaimer:

[1,2] Most of the material contained in this document was written by myself. However, there is some content loosely paraphrased from the Text and Various sources on the internet such as www.plcdev.com. As this constitutes a small percentage of material as noted.