

## Automation Laboratory Development With Design Implementation Scheme And Simulation Software

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### Abstract

This paper describes the development of the Automation Control Lab in the Mechanical Engineering Technology Program of the Engineering Technology Department at Old Dominion University. The reorganization goal of the development is to help students design, test, and implement their automation designs effectively. Three processes are adopted to achieve this goal: (1) floor-plan design and inventory control of the components, (2) using Automation Studio to dynamically check each design, and (3) using industrial Programmable Logic Controllers (PLC) controllers to download PLC programs.

### 1. Introduction

The course of Automation and Controls offered in the Mechanical Engineering Technology Program of the Department of Engineering Technology at Old Dominion University has the objective of teaching students:

- (1) Pneumatic components and pneumatic circuit designs.
- (2) Feedbacks from electrical sensors and related ladder diagrams.
- (3) Introduction to Programmable Logical Controllers (PLC) and PLC<sup>1,2</sup> programs.
- (4) Integration of pneumatic, electrical, and/or hydraulic components with PLC programs.

To let students have hands-on applications in this course, a two-hour/week lab is also offered to train the students to integrate mechanical, pneumatic, and electrical components with ladder diagrams or PLC programs. The lab basically includes three main sessions: (1) four weeks of pneumatic applications, (2) four weeks of pneumatic components, electrical sensors, and ladder diagrams, and (3) five weeks of PLC programming using IDEC<sup>3</sup> and TRiLOGI<sup>4</sup> PLCs. In addition, the simulation software of Automation Studio<sup>5</sup> is used in each project so that students can check their designs before implementing their projects. Depending on the number of students enrolled in each lab, several small groups are formed so that they can work together for each assignment. In this paper, the following steps are adopted and proposed to effectively manage the lab:

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- (1) Implementation of the floor plan.
- (2) Management of the components.
- (3) Use of Automation Studio.
- (4) Use of TRiLOGI and IDEC PLC controllers.
- (5) Interfacing with inputs and outputs.

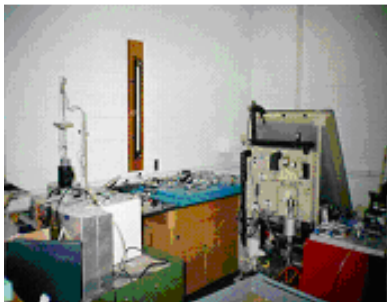
When compared to other automation labs developed for similar purposes<sup>6,7,8</sup>, this paper presents an effective way for the students to design, check, modify, and implement their projects. A student project is given to explain the implementation of the design scheme.

## 2. Implementation of the floor plan

To effectively use the space and components available for the lab, two steps are applied in this stage: (1) Floor-plan design and (2) Inventory control on the components.

### 2.1 Floor-Plan Design

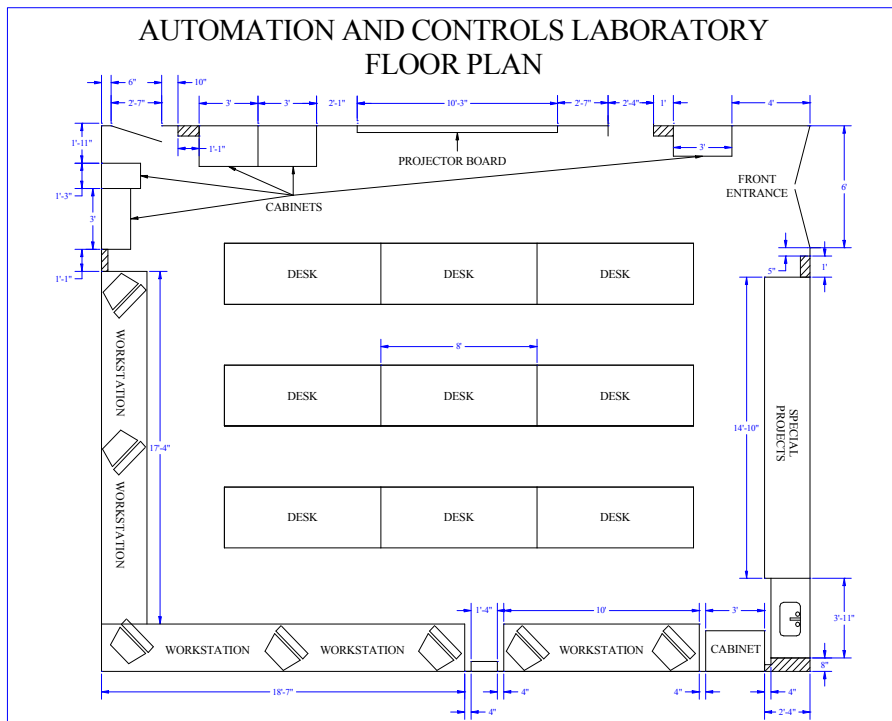
As the lab facility has been utilized various lab courses for years, there were pieces and parts in the room without clearly knowing their functions and why they are located there. Figures 1 and 2 show the situation of the original arrangement in the lab. Therefore, a clean up, inventory control for the parts, and a redesign of the floor plan is completed by a group of students<sup>9</sup>. Figure 3 shows the top view of the floor-plan design for construction of eight workstations, which includes support equipment, PCs, storage for pneumatic components, and central space for group discussions. A space is also reserved to conduct any special or advanced project. Figures 4 and 5 show the space for new workstations and special projects respectively. Figure 6 shows a workstation with PC and electrical cables.



**Figure 1.** Original arrangement –I.



**Figure 2.** Original arrangement -II.



**Figure 3.** Floor-Plan Design.



**Figure 4.** Newly-designed support for workstations.



**Figure 5.** Newly-designed support for special projects.



**Figure 6.** A PC workstation with cables for ladder diagram and PLC programs.

## 2.2 Inventory Control

An inventory was taken on all parts. Parts that were no longer functional were cannibalized to repair others. Figures 9 and 10 show the inventory control of the components. Functional tests were performed on all existing parts to verify their operability. A parts list was generated to order new parts, which will provide the need for eight small groups<sup>6</sup>.



**Figure 7.** Inventory control for electrical components.



**Figure 8.** Inventory control for pneumatic components.

## 3. Automation Studio

To increase the effectiveness of each lab, the simulation software of Automation Studio is used in each design group. Automation Studio is an innovative schematic capture,

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simulation and project documentation software package for automation and fluid power systems design. Based on a sound and proven concept that has gained a worldwide acceptance in the fields of engineering and training, Automation Studio is a modular package that integrates all the necessary features for elaborating systems, from small to large. It is intended to be used by engineers and instructors in a wide variety of related fields<sup>5</sup>.

### 3.1 A Student Project

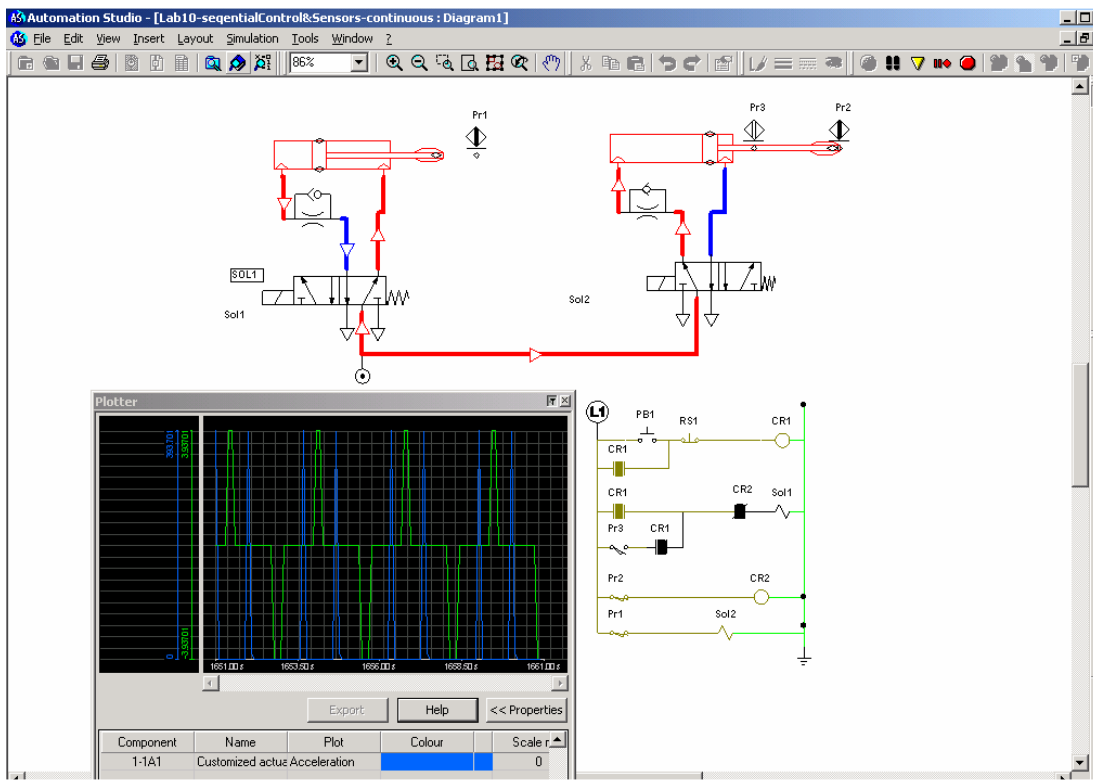
A student project is given to perform the following tasks using this simulation software:

1. An NO push button (which will be immediately opened when released) is to start the operation and extend Cylinder A at an adjustable speed when Cylinder B is in the retract position, which is sensed by a proximity sensor Pr3.
2. Cylinder B starts to move forward slowly when Cylinder A is fully extended and is sensed by a proximity sensor Pr1.
3. Cylinder A remains in fully extended position, but when Cylinder B is fully extended and is sensed by a proximity sensor Pr2, Cylinder A starts to retract at regular speed.
4. Cylinder B remains in fully extended position, but when Cylinder A starts to retract, so does Cylinder B.
5. The operation will be continuously repeated until another NC Push Button is pressed.

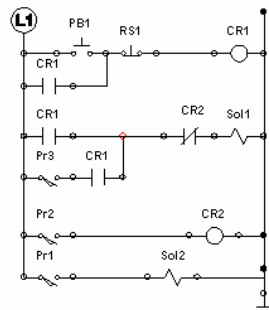
Figure 9 shows the solution of this design and simulation with graphic illustration of acceleration, velocity, and cycle time. Using Automation Studio has the following immediate advantages:

- (1) See the immediate results of design, which including pneumatic, hydraulic, and electrical circuits, in a dynamic way.
- (2) Check the cycle time, which is critical in the automation processes.
- (3) Maintain good documentation for the parts required in each project.

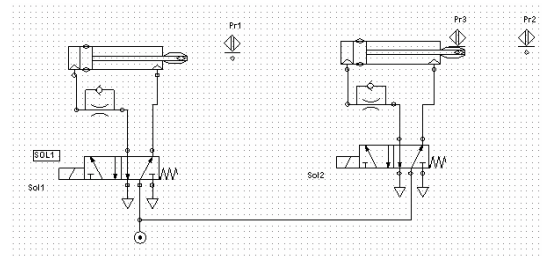
Because of these advantages, students can check their design before implementing their hardware circuits. The instructor can also save grading time for each project by using the simulation capability of the software. Figures 10 and 11 shows its electrical circuit and pneumatic circuit respectively. Figure 10 can be easily converted to a PLC program when a PLC is available.



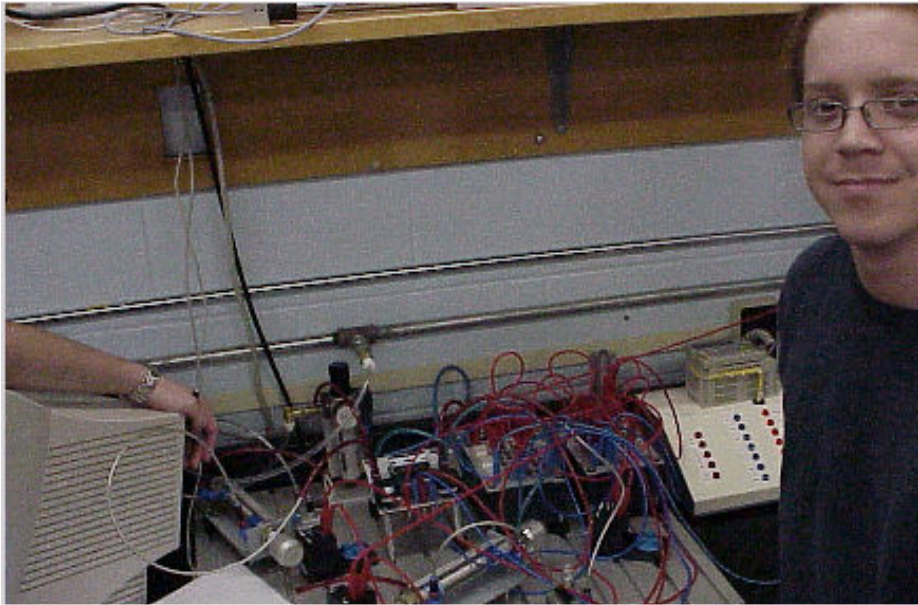
**Figure 9.** Solution of the student project using Automation Studio.



**Figure 10.** Electrical circuit design of the student project using Automation Studio.



**Figure 11.** Pneumatic circuit design of the student project using Automation Studio.



**Figure 12.** Hardware implementation of the student project.

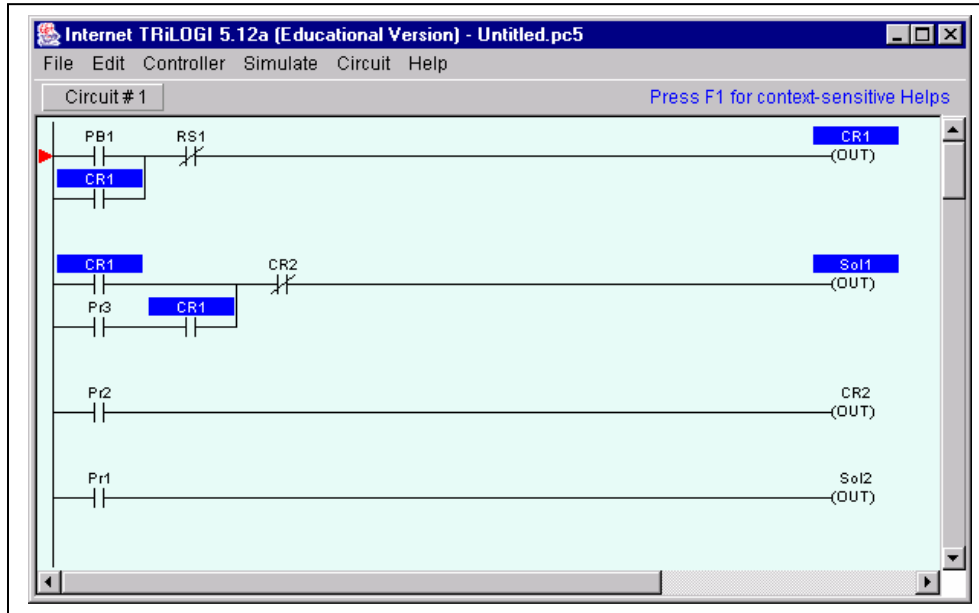
#### **4. PLC Controllers**

While Automation Studio has many advantages, it does not have the capability of converting a design circuit diagram to a specific Programmable Logic Controller (PLC) program. To solve this problem, two PLC software programs are used in the lab: TRiLOGI and IDEC Controllers, as they are both user friendly and affordable.

##### **4.1. TRiLOGI Controller**

"TRiLOGI" is the name of the ladder or ladder+BASIC programming software for the E, H and M-series of PLCs. There are several versions of the software available. The M-series super PLCs are programmable using either the Windows version 5.1 or the DOS version 4.13. The E10s and H-series PLCs are only programmable using the DOS Version 3.3 of TRiLOGI program. All TRiLOGI versions have a built-in simulator, which allows a ladder or ladder+BASIC program to be simulated on a PC without purchasing the PLCs<sup>4</sup>.

Figure 13 shows the PLC program of the student project. The software is very user friendly and has many logical components including AND, OR, NOT, NO and NC internal relays, counters, and timers. Students can check their designs through on-line simulation software. If the program is correct, students can download the program to the PLC controller immediately for implementation.



**Figure 13.** TRiLOGI PLC program for the student project

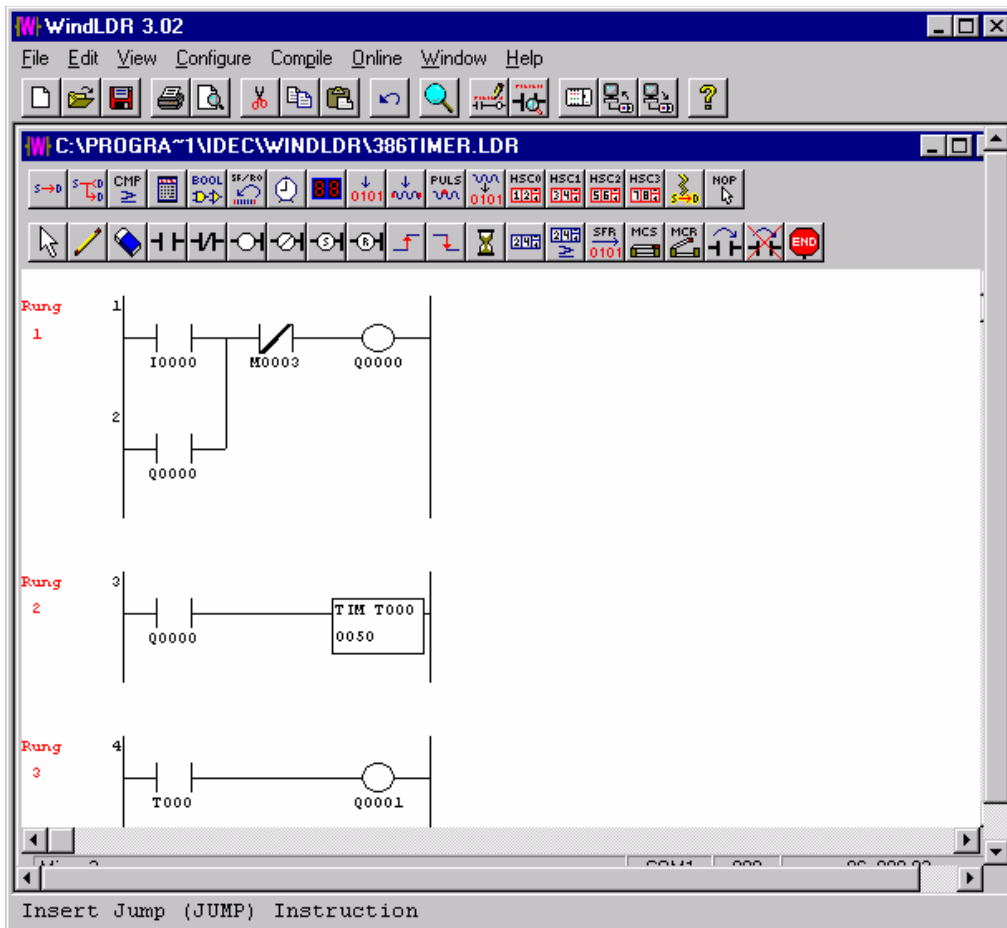
## 4.2 IDEC Controllers

Similar to TRiLOGI controller, IDEC is another affordable software which is used in the automation control lab. It provides a software called WindLDR, which has the following capabilities<sup>10</sup>:

- (1) Programs all IDEC PLCs from the Micro1, Micro<sup>3</sup>, Micro<sup>3</sup>C, FA1J, FA2J, FA3 Series to the new OpenNet Controllers.
- (2) Presents improved features such as cut and paste, cross reference and program comparison. The on-line monitoring is considerably enhanced with new batch monitoring capabilities.
- (3) Gives users the power to choose the right IDEC PLC, from the inexpensive Micro-1 for small relay timer replacement applications, to the powerful OpenNet Controller for more complex applications.

Figure 14 shows a PLC program using IDEC controller.





**Figure 14.** A PLC Program using WindLDR for IDEC controllers.

## 5. Lab course description

Figure 15 shows the syllabus of the Automation Control Lab. Each small group includes three to four people with a group leader, who is in charge of task assignment for each project. Students are asked to be responsible to do their own inventory control of components during the whole semester. They are asked to take turns to perform initial design, simulation check using Automation Studio, hardware implementation, ladder-diagram design, and PLC program implementation. As each group has its own space in the lab, they can also complete their projects beyond their lab hours when a project is too complex to finish during the lab hours. Tests are given every four weeks to check students' performance.

**MET 386 LABS - Syllabus**

**Rules:**

1. Four people in a group.
2. Actual implementation of your design with successful demonstration.
3. Each project completed with the use of major components provided.
4. Inventory control of the components in your group.
5. Instructor's signature for each lab completion.
6. Lab report(s) due at the beginning of next lab, with discussion.
7. Lab exam will be given at end of course.

**Content:**

Week No	Topic
1	Single Acting Pneumatic Cylinder.
2	Double-acting cylinder – Lifting Machine.
3	Roller-Track with Sensors and Speed Control.
4	Wood-Cut Machine – And/Or Functions
5	Double-Acting Cylinders with Pneumatic Sensors.
6	AND/OR Ladder Diagrams.
7	Pneumatic Cylinder with Electrically-Activated Control Valves.
8	Memory Circuits.
9	Discrete Sensors on a Ladder Diagram.
10	IEDEC PLC Programming with Memory Circuits.
11	NO and RESET Buttons for PLC Program.
12	PLC Programming with Timers.
13	Flashing Circuits.
14	PLC Programming, Pneumatic, and Sensors.

**Figure 15.** The Syllabus of Automation Control Lab.

**6. Learning effectiveness of this lab**

After the implementations of the floor plan in Spring 2004 and management of the components, students have more space and can easily locate the components for each project. Figure 16 shows students working on a project. Figure 17 shows a student is using Automation Studio to check his design before the implementation. Results indicate that when both pneumatic and electrical circuits are complicated, students can save more than 50% of the time by using the simulation software first to verify their setup before assembling their systems.



**Figure 16.** Working on a project.



**Figure 17.** Implementing circuit using simulation software.

## 7. Summary

Results show that after the implementation of the scheme, students can locate the components for each project easily and instructors can order any missing or bad part, based on the design of the storage area. The simulation capability of the Automation Studio does provide an immediate feedback to students of their designs and help build up their design capability for systems that may be part of senior projects. The dynamic simulation can also save the grading time for instructors. Using the PLC software, students can easily create a program by using the user-friendly symbols available at the system and can automatically download their PLC programs to PLC controllers.

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## Biography

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Cheng Y Lin is an Associate Professor of Engineering Technology at Old Dominion University. Dr. Lin is a registered Professional Engineer of Virginia. He teaches Machine Design, CAD, CNC, and Robotics and is active in local industrial research and consultation. He earned his B.S. and M.S. degrees of Mechanical Engineering from National Cheng-Kung University in 1975 and 1977 and a Ph.D. of Mechanical Engineering from Texas A&M University in 1989.

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Gary R. Crossman, Professor of Mechanical Engineering Technology at Old Dominion University, Norfolk, Virginia, has 33 years of experience in engineering technology education. He holds a Bachelor's degree from the U.S. Merchant Marine Academy and a Master of Engineering degree from Old Dominion University. He has been very active in the Engineering Technology Division and the Engineering Technology Council of ASEE, holding several positions in ETD, including chair. He has also been active in TAC of ABET, as a commissioner and the American Society of Mechanical Engineers.