

## **Realistic Laboratory in an EET Controls Course**

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### Abstract.

Prior to the addition of simulation and miniature models, the laboratory exercises consisted of realistic design problems. These problems were then implemented using an Allen Bradley SLC500 programmable controller. The programs were verified by using Rockwell 500 Emulation software, or by downloading the programs into the PLC. The downloaded programs were verified by watching the lights on the output module.

Even though the problems were realistic, the implementations of the problems were not. The students dissatisfied because the only way that they could determine if the program was working properly was to watch the output lights. As a result of this dissatisfaction, a search was conducted to determine if miniature models or PLC simulation software was available that could be implemented in the laboratory.

The results of the search resulted in the purchase of two different models and a simulation software package. This paper describes in detail the hardware, the simulation software, and the student evaluation of the updated laboratory experiments.

### Objective.

It is unrealistic to expect an industrial controls lab to be equipped with actual industrial machines. The cost, space requirements, and power requirements are a huge detriment for using actual industrial machines. A search was conducted for both realistic models and PLC simulation software that would provide a realistic substitute to be used instead of actual hardware.

### Hardware selection.

Several realistic miniature hardware models were found. A choice was made to purchase models from two different companies. We purchased three modules from Tim King Electronics<sup>1</sup>. The modules purchased were the raw material bins, the flexible processing line, and the finished goods bin. The Tim King models use Fischertechnik parts. The total cost of these three modules was \$4500. We also purchased a model car wash from Staudinger for \$4750. The car wash line was purchased from Germany because it was cheaper than if purchased from the USA distributor, Model A Technology<sup>2</sup>.

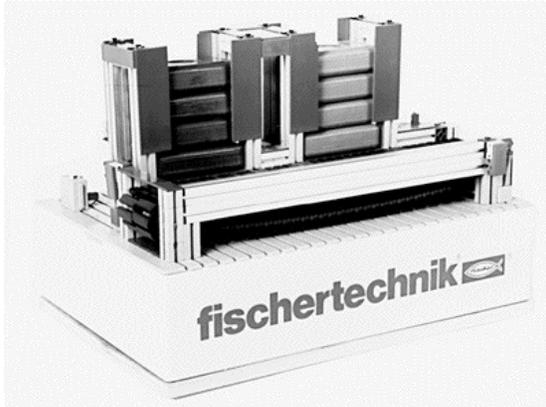


Figure 1. Unload Station.



Figure 2. Drill and Mill Stations.

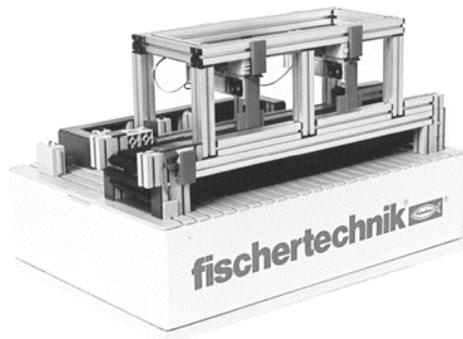


Figure 3. Unload Station.



Figure 4. Car Wash Model.

Simulation software selection.

An evaluation was made of LADSIM<sup>3</sup>, PSIM 2000<sup>4</sup>, TriLogic PLC Ladder Program<sup>5</sup>, Your personal PLC tutor site<sup>6</sup>, PLCtrainer<sup>7</sup>, LogixPro<sup>8</sup>, and RSLogic Emulation 500<sup>9</sup>. The software selection was made using two criteria: (1) the naming convention should be similar to the Allen Bradley SLC 500. The naming convention criterion was used because the lab is equipped with SLC 500 PLCs. We saw no reason to teach one naming/numbering convention for the simulation software and another for the actual SLC500 hardware. (2)The software should cost less than \$50. This would allow the students to purchase the software and run the simulation problems on their own personal computers outside of the scheduled laboratory time.

After the evaluation, LADSIM, PSIM 2000, TriLogic PLC, and the PLC tutor site were eliminated because they were not compatible with the Allen Bradley SLC 500 naming convention. The RSLogic Emulate 500 (\$750 per station) and the PLC Trainer w/PLC Logix (\$105 per station) were eliminated because it was deemed they were too expensive.

The LogixPro software was selected and is available in two versions. One requires a key serial number to be installed on the computer where the software is installed. This allows the software to run on one computer. The cost for this option is \$24. The second version comes with a CD that must be in the drive when the software is

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running. You can run this version on any computer. The cost for this version is \$32. We installed the first version on all the computers in the control lab. Most of the students purchased the second version. This allowed them to run the software on their computers both at home and at work.

Implementation of Simulation exercises.

The laboratory exercises were re-written to include five simulation experiments. These lab experiments were:

1. Introduction to the software and the Input/Output modules.
2. Door simulation. The following graphic shows the program simulation.

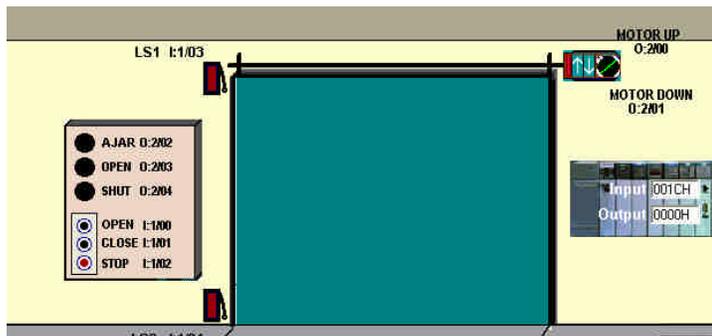


Figure 5. Garage Door Simulation Graphics.

3. Batch mixing simulation. The following graphic shows the program simulation.

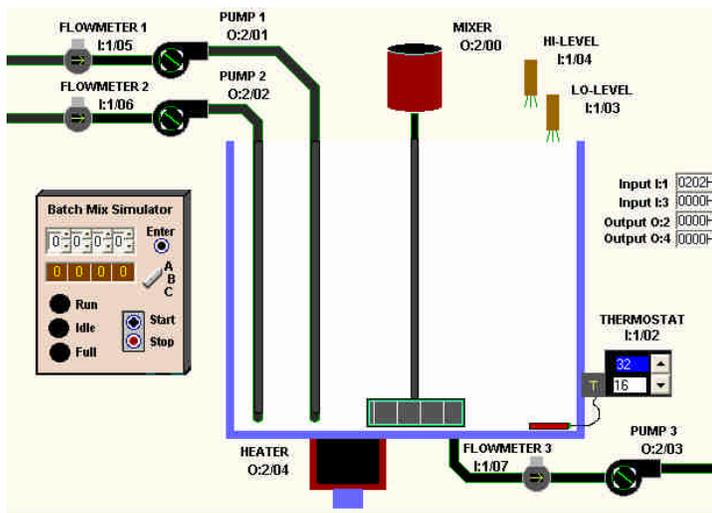


Figure 6. Mixer Simulation Graphics.

4. Silo simulation. The following graphic shows the program simulation.

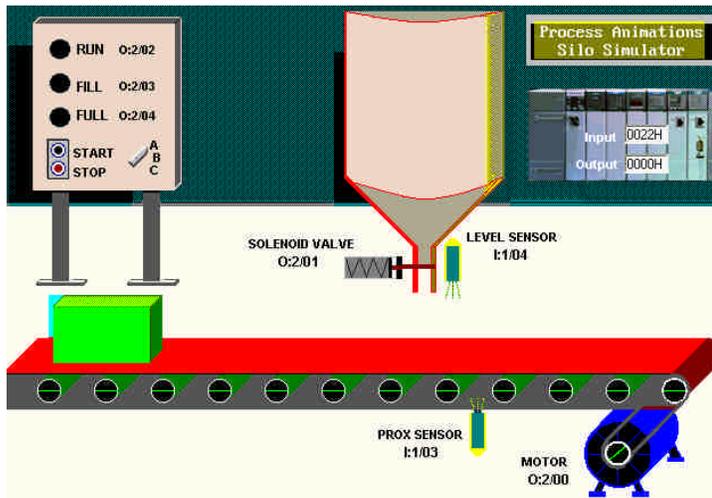


Figure 7. Silo Simulation Graphics.

5. Stop light simulation using a sequencer. The following graphic shows the program simulation.

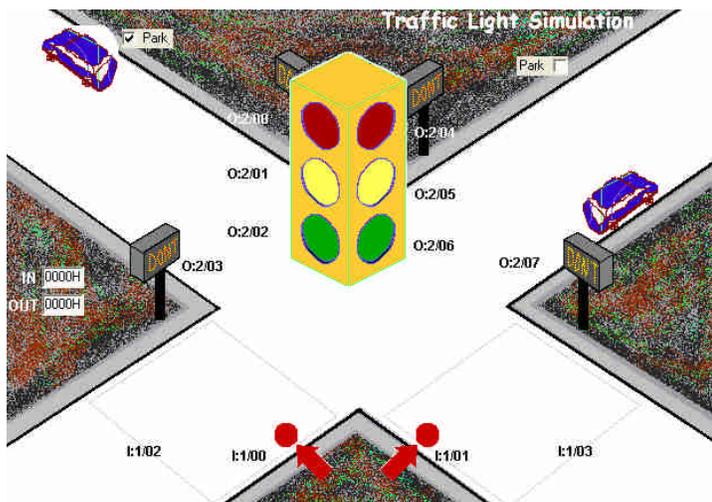


Figure 8. Stop Light Simulation Graphics.

During the five weeks where the laboratory consisted of the simulation experiments, the students were not required to attend the laboratory if they had completed the simulation at home prior to the lab time. If they chose not to attend lab, it was a requirement that they send me a copy of their completed simulation program. I could then verify that their solution met the design criteria. Several students were extremely pleased with this option because they lived 40 miles from campus and the lab was scheduled from 8:30 – 10:30 p.m. Some of the students worked on their design problems both at home and in the lab, some used only the scheduled lab period to work on their designs.

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There was consensus in the course evaluation that the software simulations were a success. The students liked that they were able to see the results of their control designs.

The ProSim-II Silo Simulation experiment design criteria.

The design criteria and the graphics for the silo simulation laboratory experiment that was given to the students are shown below:

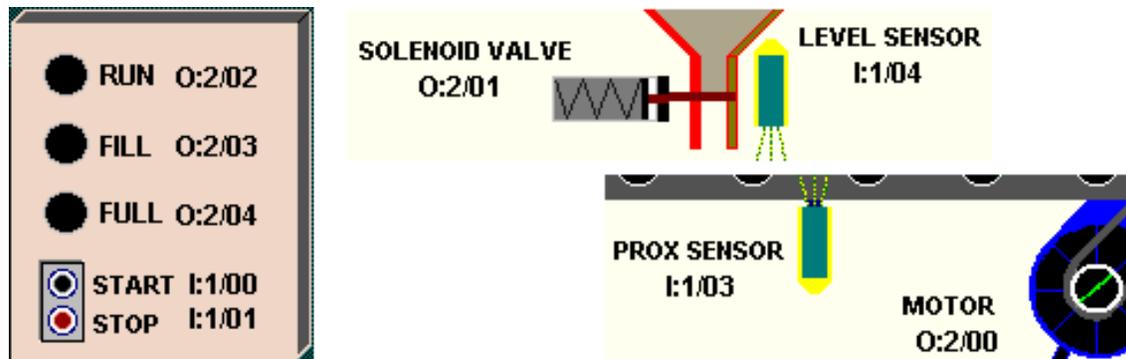


Figure 9. Silo Simulation Showing I/O Numbering.

Design and de-bug a ladder diagram control circuit that will automatically position and fill the boxes that are continuously sequenced along the conveyor. Ensure that the following details are also met:

1. The sequence can be stopped and re-started at any time using the panel mounted Stop and Start switches.
2. The RUN light will remain energized as long as the system is operating automatically.
3. The RUN light, Conveyor Motor and Solenoid will de-energize whenever the system is halted via the STOP switch.
4. The FILL light will be energized while the box is filling.
5. The FULL light will energize when the box is full and will remain that way until the box has moved clear of the prox-sensor.

Miniature model hardware implementation.

The Tim King modules were used as part of a three week design project at the end of the semester. Each two-member lab group was assigned one of the five modules. The group was to design the controls for the module.

At the conclusion of the project, five programs were placed in a common program to run the complete system. Each group was given the operational specifications and the input/output diagram. There was a video of each section placed on the course web site. So the groups could observe the operation of their section and of the entire system.

There were design problems that resulted in burning out several motors. The motors in the system will not tolerate being stalled. Electronic current limiting will be

installed for each motor prior to the project next semester. This will eliminate the equipment problems that were experienced.

This project has been assigned once. All the groups were successful in making their section of the system run. The students were excited about their success. The course evaluations indicated that:

1. The students were enjoyed designing the project.
2. The students didn't think the project was easy.

Conclusion.

The results indicated that the laboratory was much more realistic than the previous labs. Prior to purchasing the miniature modules and the simulation software, the student projects were observed by using switches wired to the input terminals and watching the output lights. The Tim King modules will have to be rewired to include current limiting so the motors will not burn out when they are stalled.

The car wash is currently being used as a show piece for prospective students and their parents. The initial control design was created as a senior design project. It shows what our graduates are capable of doing. This controls project is one that most people can understand. We are in the process of making a decision about implementing this model into the course as a design project.

Overall, the miniature model project design was very successful. We may have to purchase another model to eliminate the backlog that develops for those waiting to test their current solution. The students were given fifteen minutes at a time to test their software design.

The students would like for more of the projects to be implemented using the software simulation program. At the present time, this is impossible because of the limited variety of simulations that are available in LogixPro.

Both the simulation software and the hardware models were a success. I would recommend that they be considered for any PLC programming course.

References.

1. Tim King Electronics, Inc., 14595 Oceana Street, Allen Park, MI 48101, (313) 928-2598, <http://www.phoenix.org/tking.mod.html>
2. Staudinger kits, Model A Technology, 2420 Van Layden Way Modesto, CA 95356, (209) 575-3445, [http://www.techeducation.com/html/staudinger\\_industry.html](http://www.techeducation.com/html/staudinger_industry.html)
3. LADSIM, Bytronic International Ltd, The Courtyard, Reddicap Trading Estate, Sutton Coldfield, West Midlands, B75 7BU United Kingdom, <http://www.bytronic.net/ladsim.htm>
4. PSIM 2000, A. Palmer Animated Training, 20 Davenport Ave, Fall River, Nova Scotia, Canada B2T1A2, <http://www.apalmertraining.com>
5. TRiLOGI PLC Ladder Programmer, Triangle Research International, Inc. 6172 Bollinger Road PMB141, San Jose, CA 95129, <http://www.tri-plc.com>
6. Your personal PLC tutor site, <http://www.plcs.net>
7. PLCTrainer, Koldwater Technologies, LLC, PO Box 701, Mannford, OK 74044, <http://www.PLCTrainer.com>

8. LogixPro, The Learning Pit Dot Com, 709 King St. Whitby, Ontario L1N5A2, Canada, <http://www.thelearningpit.com>
9. RSLogic Emulate 500, Rockwell software, <http://www.software.rockwell.com/rslogixemulate>

Biography.

WILLIAM R. CONRAD

Professor Electrical and Computer Engineering Technology, Indiana University Purdue University Indianapolis. Professor Conrad has a BSEE from Purdue University and a MEng from The Pennsylvania State University and is currently teaching the introductory controls course. He has extensive industrial experience in control design.