EET Course Common Lab Experiments

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Abstract

A number of lab experiments have been developed that are common among a number of EET courses. The experiments have the intent of quick change-over from one course to another and a low relative cost so that multiple stations can be used simultaneously in the same room.

This paper will outline with some technical content the courses served, the lab experiments and the equipment. An outline of costs will be included.

Courses include courses in PLCs, embedded systems, database applications, C programming and automatic controls. Experiments will include simple one-week experiments as well as longer multiple week experiments requiring programming or in-depth diagnostic measurement.

Introduction

A request for collaboration on building of inexpensive controls labs occurred a couple years ago on the ET list-serve. This request was interesting in that it showed a genuine desire for instructors in computer, PLC, auto controls and other similar coursework to come together and share common experiences using less expensive laboratory equipment.

The lab experiences outlined here are generally able to be used in a number of courses. The goal is that they be able to be quickly stored and retrieved so that one lab is not tied to one course indefinitely and that they are less expensive and can be used by multiple groups in a lab setting.

These lab experiences try to accomplish these objectives. Some are more successful. They have all been a joy to design and build or watch others design and build. Some originally were the product of capstone groups. Some were the product of MSEE students' projects.

They include:

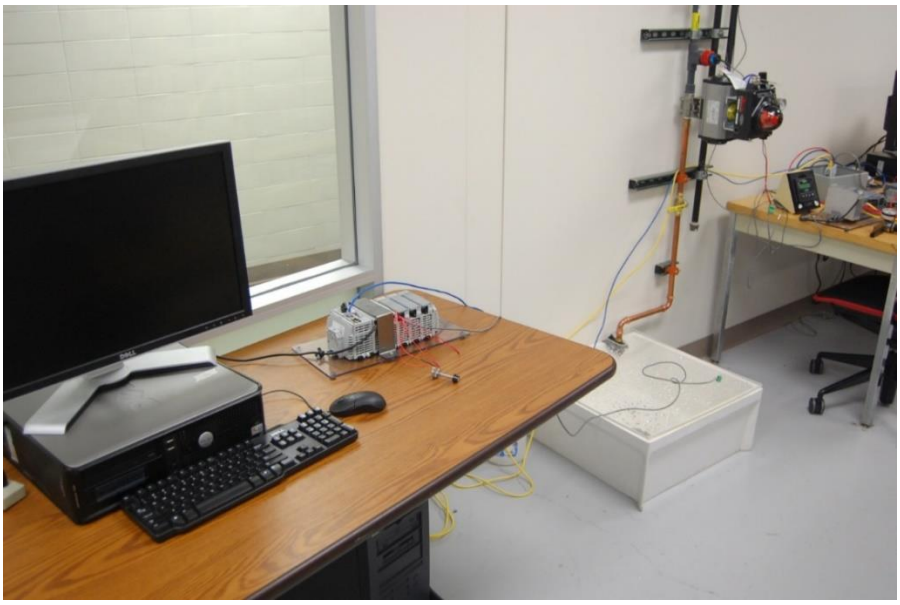
Water Flow Lab
Servo Lab
Stepper Lab
Liquid Batch Lab

Ball-in-Tube Lab
DC Motor Position Control Lab
Toilet Paper Rewind Lab
Tank over Tank Level Control Lab
Conveyor Lab
TWS Strobed Number Lab

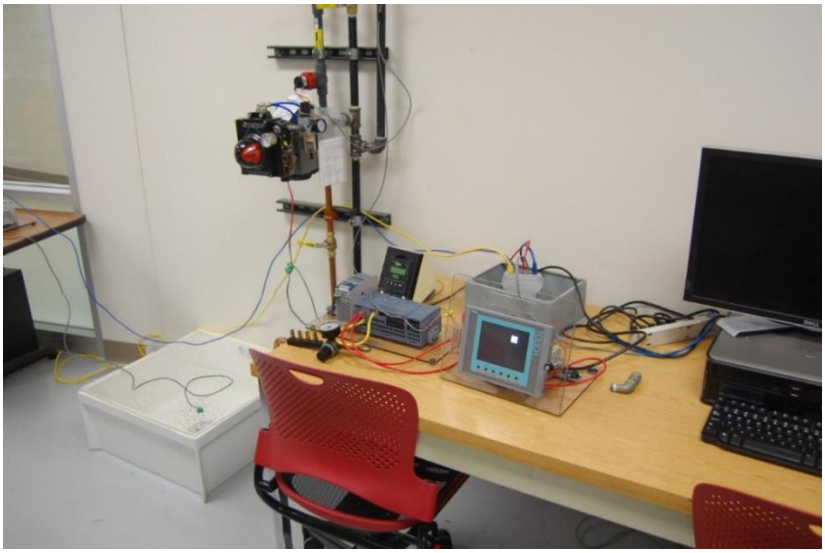
These labs are reviewed with a brief description of the lab experience, cost and courses served. Most can be stored and retrieved from a shelf. Not all can be moved including the first lab, the Water Flow Lab.

Water Flow Lab

The Water Flow Lab uses city water in a ¾ in pipe as a source to control flow of the water. The valve was purchased commercially and includes a flow transmitter. Both signals are 4-20 mA. Industrial air is required to power the water valve. The cost of the assembly is <$1000. Two were installed in the room. Both have the ability to be used by two different groups with cabling shared between the groups. The courses served include the advanced PLC or Mechatronics II course. A main advantage of this system is that tuning can be done manually with stability problems if the valve is not tuned precisely. Stability/instability problems can be experienced in this lab by slight changes in the tuning variables. Also, the splash guard and catch basin are extremely important in that the flow can reach 90 gpm from this valve. Yes, a lot of water.

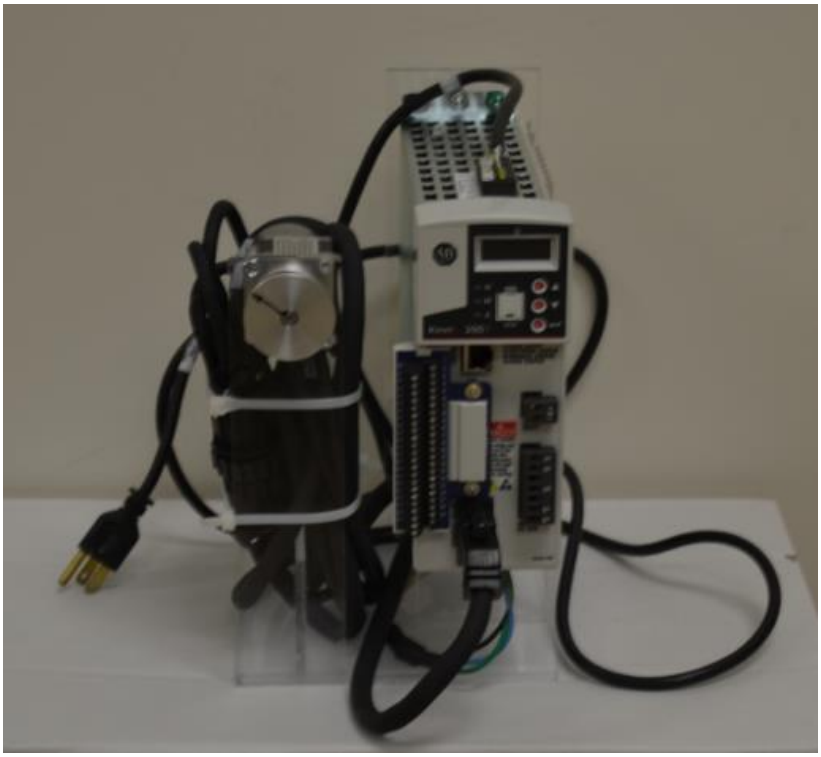


Flow Valve on Wall



Servo Lab

The Servo Lab gives the student an experience with single axis motion control. Automation uses for single axis motion include indexing machines and grinders. The lab is provided to a point with students expected to expand the base program to include advanced concepts. Developing a useful HMI is a part of this lab. The student is required to provide a motion action with the capability of automatic and manual control.



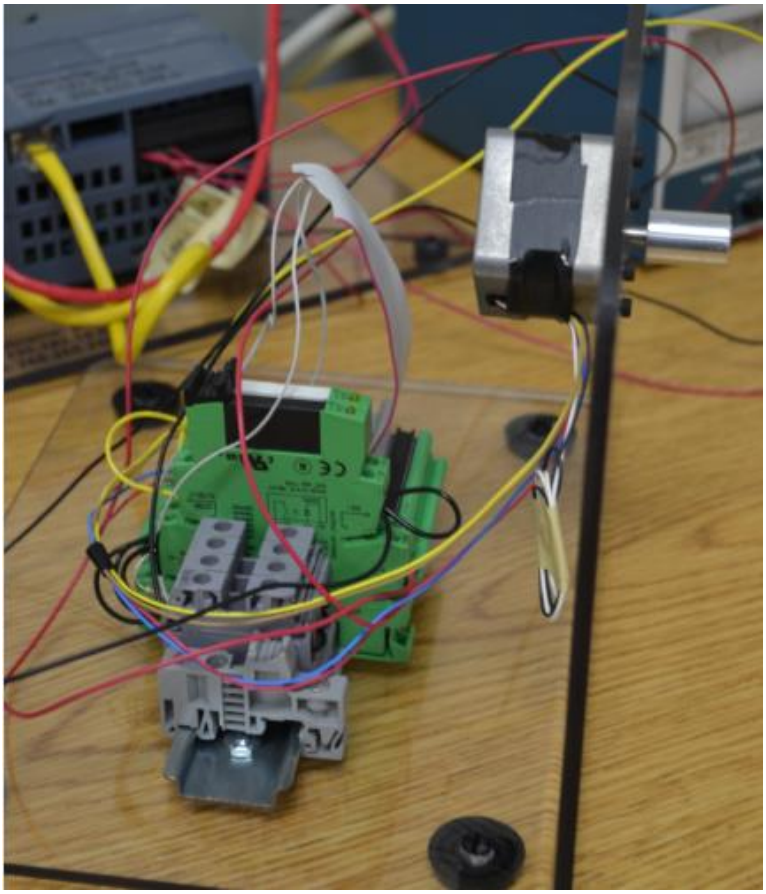
Servo Motor and
Motor Controller
Allen-Bradley

While the servo shown is Allen- Bradley, several servos from Siemens are also in the final stages of being purchased. The cost of these servos is approximately $1000/each. The servo communicates with the PLC via Ethernet. The goal is eight Allen-Bradley stations and four Siemens stations. These units can be stored on a shelf between labs.

Stepper Lab

While this lab is still used, it will probably be phased out as soon as the servo labs from Siemens come online. While this stepper lab is are important, a later lab using multiple stepper drives is preferred. This single axis stepper control was first designed to interface with an Etch-a-Sketch. That design didn't work well due to limitations of the Etch-a-Sketch.

The present design has similar requirements to the servo in that a starter program was given with the student required to enhance the program with a HMI program as well as control of the motor in auto and manual.



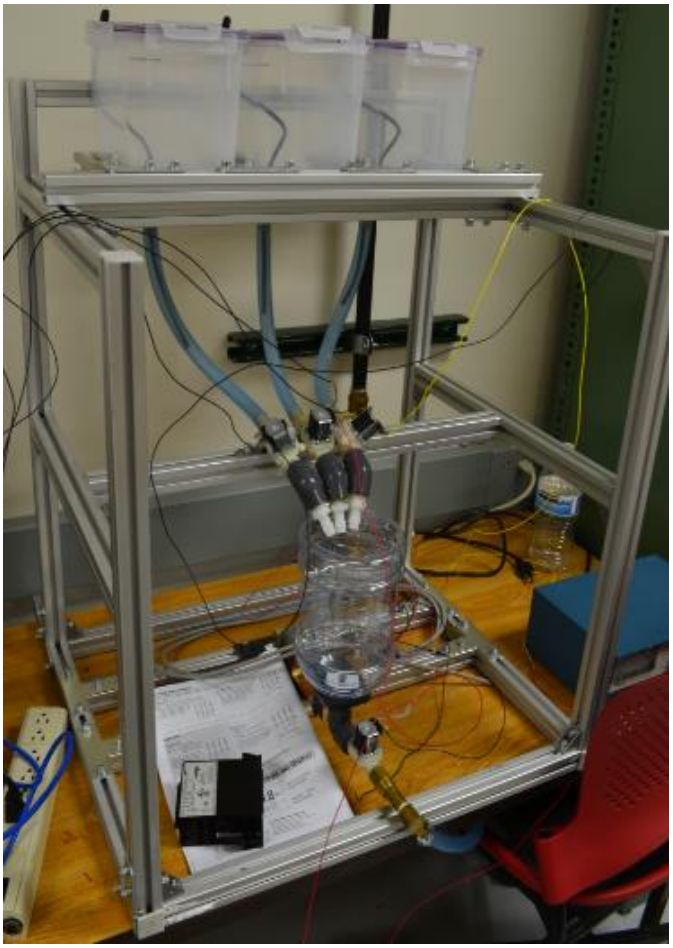
Stepper Motor and Controller
Hybrid system using custom boards and Siemens PLC

One of the design components of this lab was the green Phoenix Contact interface devices. It was felt that students should be introduced to common devices used by industry rather than trying to build the interface on a breadboard. Cost does increase with this design with the cost of

each of the interface devices >$100. The concept of off-the-shelf parts is an important one for the student to learn, however.

Liquid Batch Lab

The lab was first built by a capstone group with a total cost of about $500. Since then, it has been used by a second capstone group as well. It has been in storage at other times and is rather large.



Three Ingredient Batching System – Liquid Ingredients

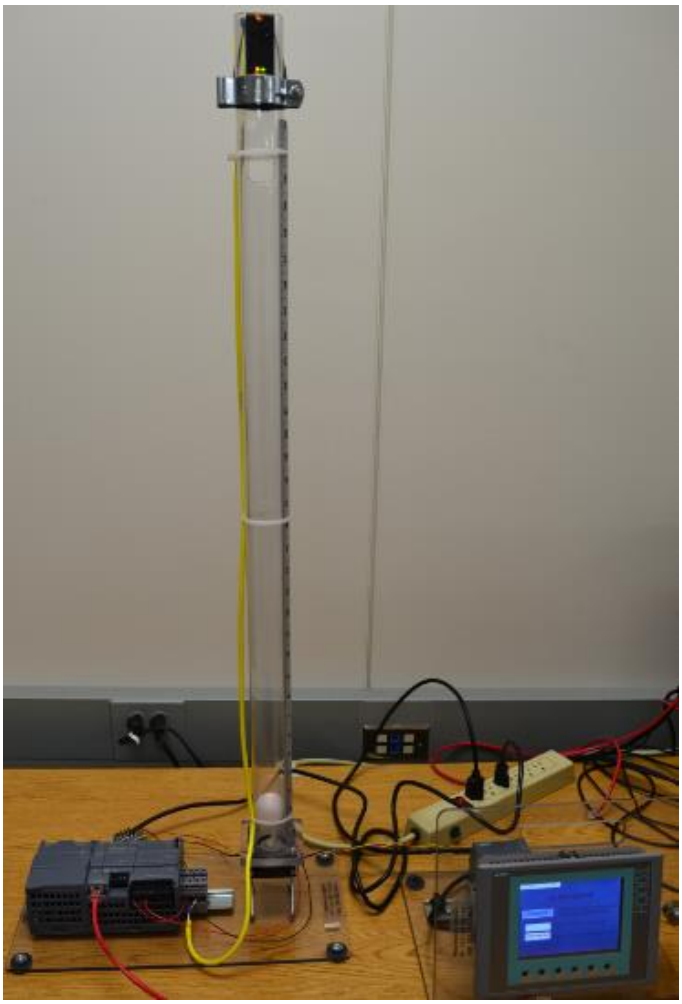
This lab incorporates the mixing of three liquids weighed individually in the mix tank at the bottom. A load cell reports the change in weight through a Red Lion load-cell control interface. This interface outputs a linear weight in volts. The controller then is used by a PLC or computer to create a mixed batch.

The students in both groups used the PLC and HMI to create a totally automated batching system. One used Allen-Bradley equipment. The other used Siemens.

This system is rather heavy and hard to move from room-to-room. It is difficult to store and only one was made. It will probably not be expanded to 8 units since the cost and size is prohibitive.

Ball-in-Tube Lab

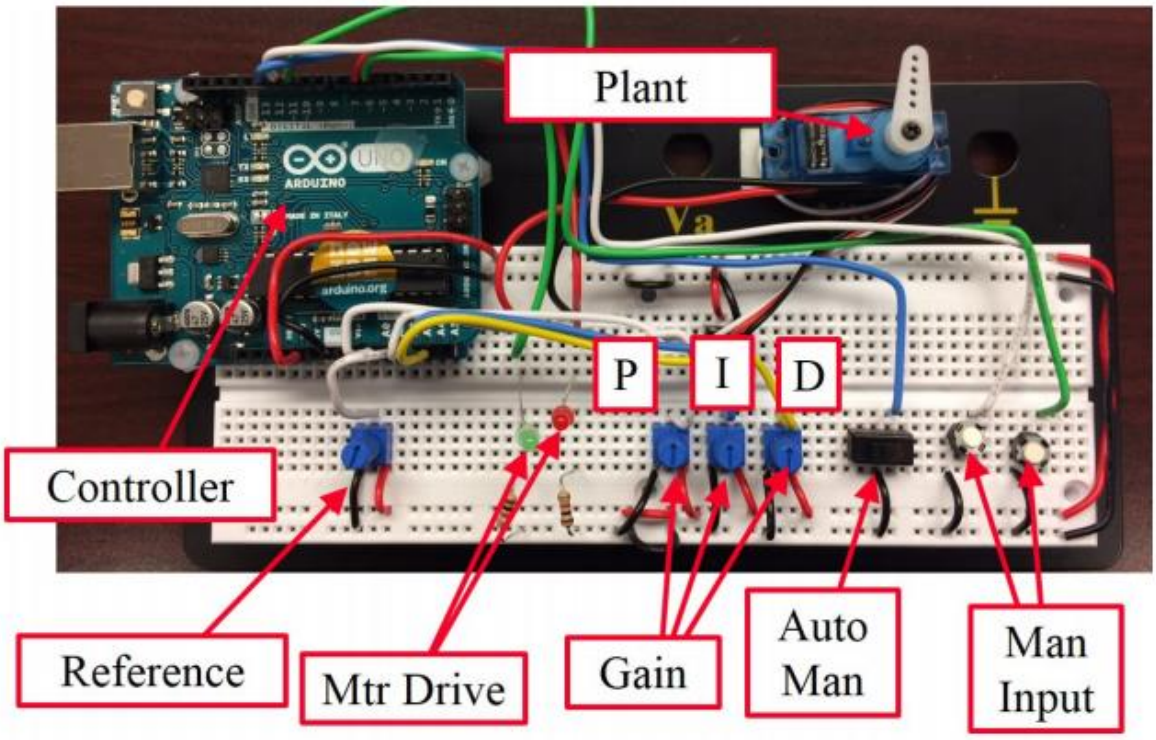
This lab is one of the more successful labs. It is used by the PLC courses as well as the automatic controls course. These courses can use the lab separately in the same day and not interfere with the other. These are extremely good characteristics for a lab and much planning has gone onto the present labs to accomplish these goals. The cost is approximately $500. This cost has dropped somewhat in the past years due to the decreased cost of lasers used as the feedback device. The planning for this lab has been ongoing. The most recent change included a separate PLC for the auto-controls lab. While the tube is very cumbersome and difficult to store, protecting the ball in the tube is an important part of the lab. The ball must be suspended slightly above the fan in order for it to take off. The tube can be removed from the base for shipment as necessary.



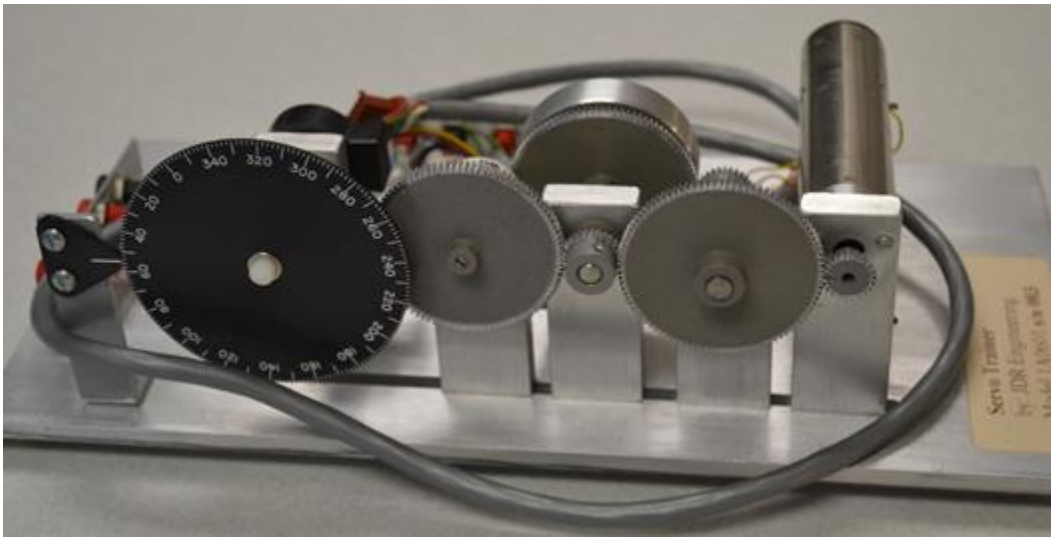
Flow Control
Levitation of a Ball
using Fan with Laser
Feedback

DC Motor Position Control Lab

This lab has a history from a number of previous developers. One was the original lab for the Auto Controls course manufactured by a former instructor in EET, John Rich. Another was a paper "A Low-Cost Control System Experiment for Engineering Technology Students" by Dr. Curtis Cohenour Ph.D., P.E. P.E., Ohio University. Dr. Cohenour's implementation is shown here:

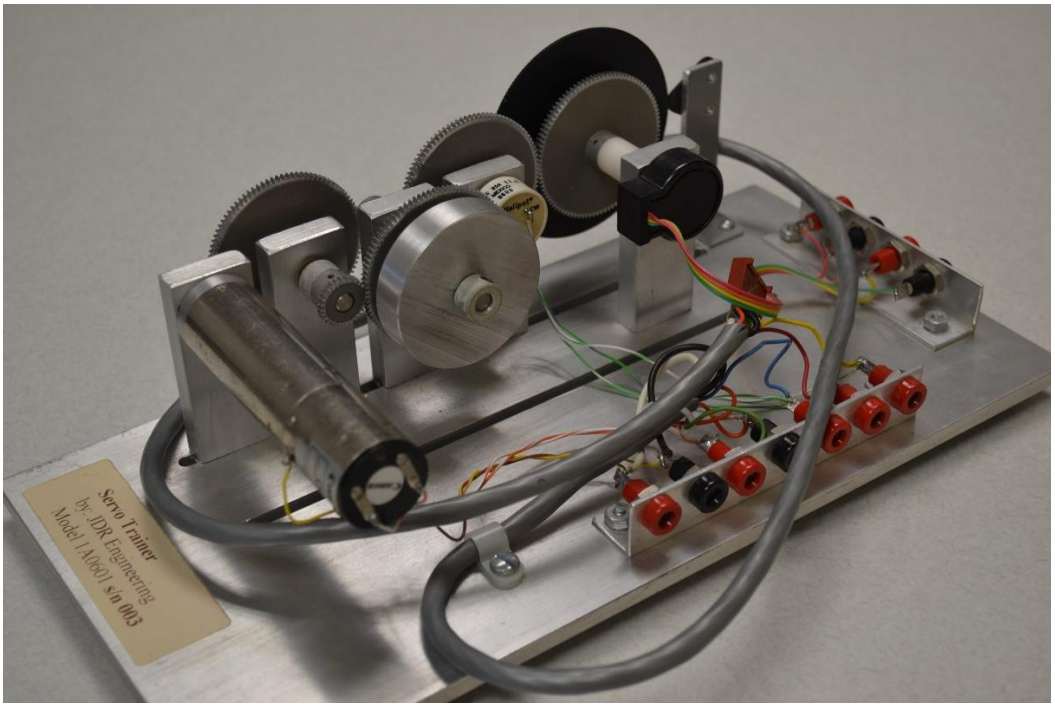


Prof. Rich's design is shown next:



Speed and Position Control of DC Motor

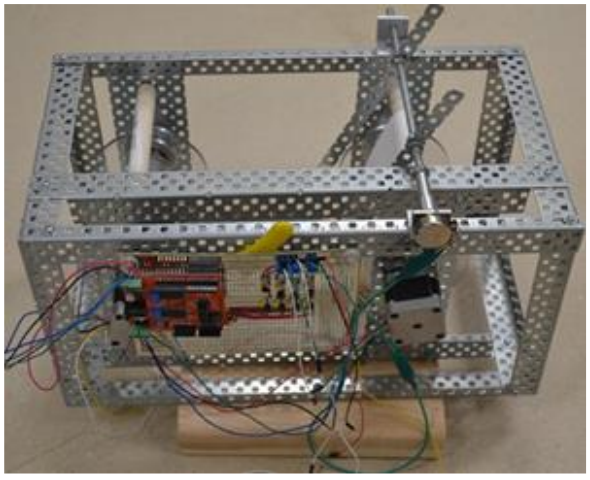
and here.

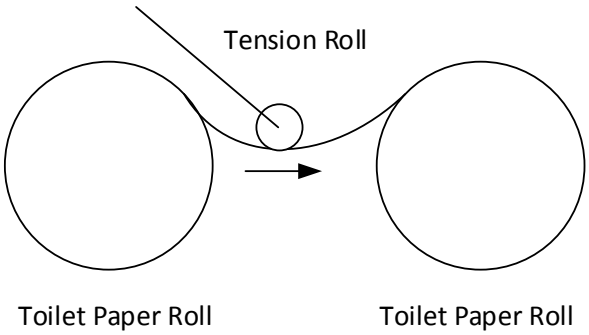


At present, the EET faculty are busy designing a hybrid of the two. The servo motor was very small and deemed not rugged enough for students. The Rich design was good but expensive to replicate and in need of a controller.

Present plans have a small dc motor attached to an Arduino and an encoder. This design will be expanded in the future to add position control with a potentiometer similar to both designs above.

Toilet Paper Rewind Lab



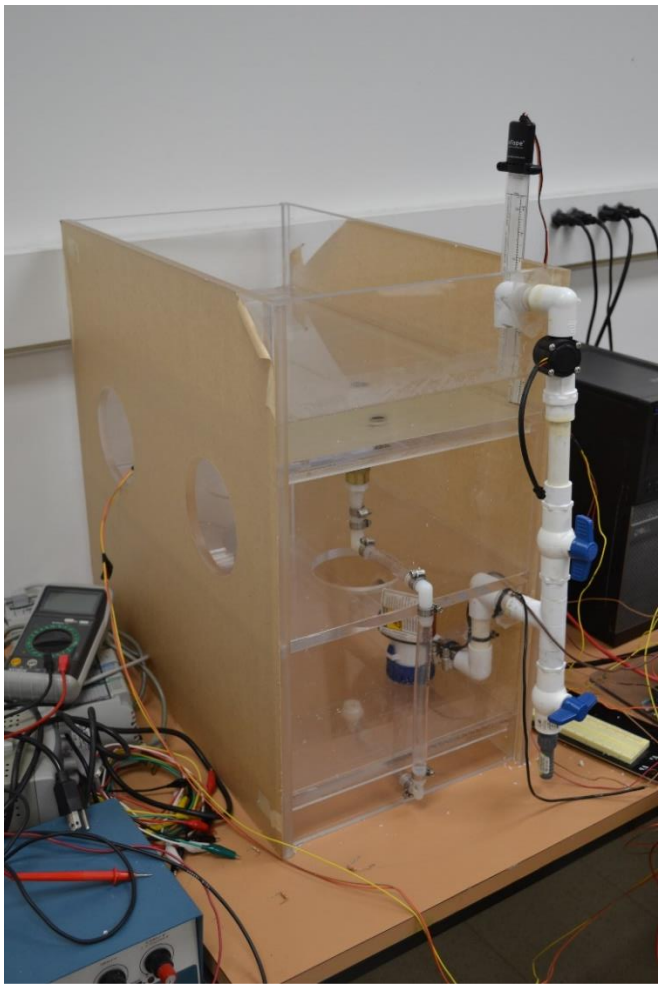


The design of a two-axis motion system with feedback control between the two has been an objective of a lab experience for some time. The present design is nearing completion and may be ready for PLC control this semester. The lab involves two stepper motors and a PID loop feedback between the two. Tension control is to be maintained. It is anticipated that many rolls of toilet paper will find the bottom of a waste can because of this lab.

Tank over Tank Level Control Lab

The lab pictured below is in the development stage. While the student is working toward his MSEE degree with thesis satisfied by successful completion of this project, the lab development has not proceeded as hoped.

The major cost is the plastic of the system – roughly $1000. The cost and weight of the unit are high enough that it may not be one to be replicated for eight groups. That said, it may be one that will be replicated due to the multiple loop control system and the visual nature of watching level maintained while operators vary the drain openings.



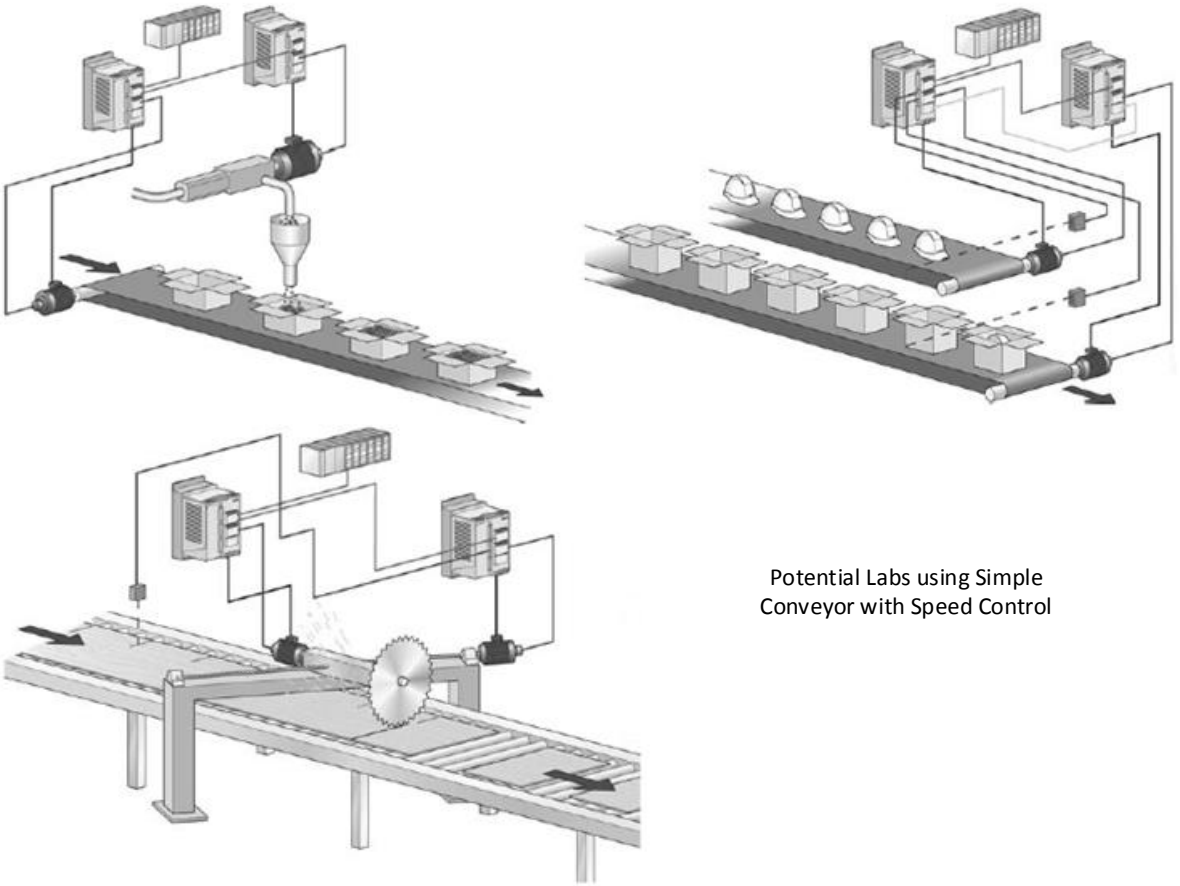
Level Control of Upper Tank with Multiple Drains and Feedback from Level Sensor

Conveyor Lab

The conveyor shown below is a Bruder toy conveyor (apx $35) with two aluminum pieces attached with screws to the side. At the far lelt is a 24 V gear motor attached to the drive instead of a toy hand crank. This was given to a capstone group for Spring 2018 with the charge to embellish it and provide a laboratory experience from it.

Cost Effective Conveyor with Gear Motor

Some of the potential lab experiences using the simple conveyor above include the three processes pictured below. A computer or PLC are the preferred method to control the conveyor.

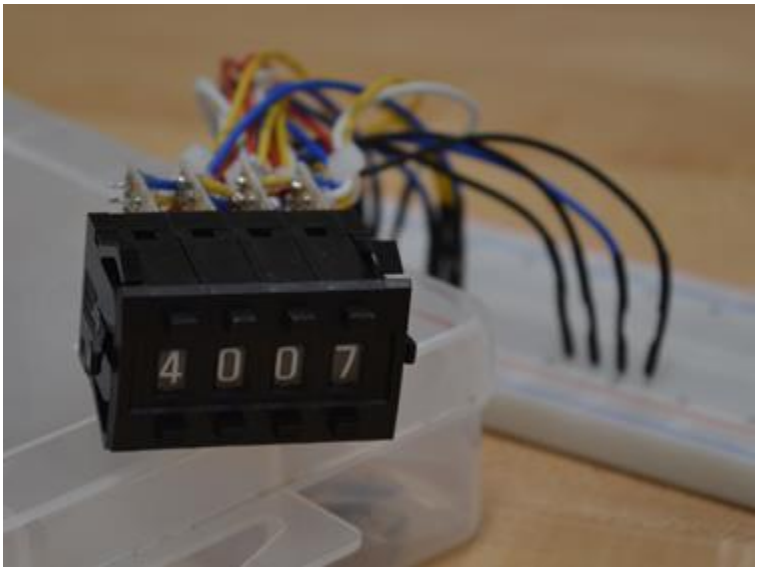


Potential Labs using Simple Conveyor with Speed Control

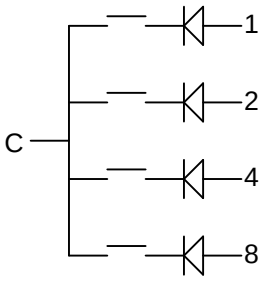
TWS Strobed Number Lab

This lab was discovered accidentally when the PLC's changed from true-low inputs to true-high. The thumb-wheel-switch assemblies at the time were designed for true low with the diodes pointing toward the switch (left picture below). The I/O was changed and the lab experience started. The students couldn't achieve the result of the lab which was to introduce the number displayed on the tws in the PLC as a number. Thus a strobe is required and the bits are multiplexed into the PLC/computer a bit at a time and the number re-built in the software. This lab works although there are no moving parts (other than a tws). It is an easy lab to check in that the number on the display should match the number in the program. It is not easy, however, to program and requires understanding of timing diagrams.

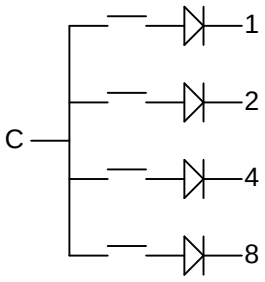
It is also a lab that students spend a great deal of time without much success only to have the correct result achieved very quickly.



Thumb-Wheel Switch Assembly used in Mux Lab



TWS with diodes installed



TWS with diodes reversed

Summary

The labs outlined have been challenging both to build and use. Students have benefited from these labs significantly. The courses using these labs continue to increase as instructors see the finished labs in use. A room has been re-furbished specifically to house the labs discussed in this paper. The encouragement of the university to support the development of these labs has been an encouragement to faculty and students.

The labs outlined are economical to build and maintain. They are in general simple to use and flexible to modify. They have provided hours of enjoyment for faculty as well as students as they were first constructed.

The instructors of these lab experiences are encouraged to expand and build more of these kinds of labs while continuing to expand their technical skills in the area of automatic controls and automation.

Bibliography

[1] B. Ray, "An Inexpensive Control System Experiment: Modeling, Simulation, and Laboratory Implementation of a PID Controller-Based System," in Proceedings of the ASEE's 123rd Annual Conference and Expositiion, New Orleans, 2015.

[2] A Low-Cost Control System Experiment for Engineering Technology Students" by Dr. Curtis Cohenour Ph.D., P.E. P.E., Ohio University, Proceedings of the ASEE's 125rd Annual Conference and Expositiion, Columbus, Ohio, 2017.

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