Virtual Software and Hardware Environment Provides Enhanced Learning for Mechatronics Engineering Technology Majors

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VIRTUAL SOFTWARE AND HARDWARE ENVIRONMENT PROVIDES ENHANCED LEARNING FOR MECHATRONICS ENGINEERING TECHNOLOGY MAJORS

Abstract:

Virtual software tools such as National Instruments' LabVIEW, Rockwell Automation's SoftLogix 5800, Studio 5000, and FactoryTalk View Studio are extensively used for development of electronic products, mechatronics systems, manufacturing automation systems, and especially used in designing packaging machinery system. They have become almost essential to follow concurrently engineering principles to meet desired standards such as: high quality, robustness, low cost, time to market, and customer satisfaction.

In order to achieve modular design, serviceability, upgradeability, and disposability, virtual software tools are of utmost importance during development cycle. They play an important role for modeling, simulation, prototyping, including deployment cycle.

Introducing these tools to mechatronics engineering technology courses exposes student to today's real world practices and provides enhanced learning environment in laboratory. In addition, introduction of these tools will allow laboratory environment to become less dependent on difficult-to-maintain and expensive laboratory hardware setups. Because of their virtual nature, a reliable computer station and software licensing is all that is necessary to provide the knowledge. **The intention of this work is not to eliminate the hardware coupled with hands-on activities, rather to be less dependent on them (the laboratory hardware) to carry the concepts and provide theoretical and practical background to students.** The virtual laboratory hardware and software system complements the real laboratory hardware and provides enhanced learning environments for the students. It is much more productive not to lose a 3-hour laboratory session and instead use a virtual hardware in case of non-availability of actual (real) hardware system. This virtual nature of laboratory also allows comparatively large laboratory class sizes as compared with those restricted by actual work stations (number of

students in a laboratory class). This is also economically advantageous to ever changing world of improved hardware, hardware with new features, and of course cost of buying them and maintaining them in a university or college laboratory setting. This approach will also allow instructor to provide individualistic laboratory assignment to each student in the class and that in turn helps students enhance their problem solving ability. These types of problem solving ability coupled with proficiency in using industrial grade software and virtual hardware tools will enhance students' preparation for the real world environments. This paper explains the software used for the virtual laboratory, three examples using the software, and finally some results/conclusions related to how the virtual laboratories enhanced student understanding of the concepts.

INTRODUCTION

Among the virtual tools mentioned above, LabVIEW is mostly used for Mechatronics devices and system modeling. Power of this software tool can be unleashed very easily because of its user friendly environment.

Concepts such as For Loop, While Loop, Sequence Structure, Equation Node, discrete logic, mathematical function, Control Design and Simulation are just a few among many graphical programming structures for various levels of work that could be learned and implemented through LabVIEW. The software tool can be effectively used to introduce the fundamental concepts ranging from a high school student to more advanced concepts for a graduate degree seeking student. Simple digital and analog control can be implemented in a few steps of programming. For example, a Proportional Integral and Derivative (PID) controller can be designed, tuned and demonstrated to students in a few steps. This tool can be used to model an electromechanical device such a servomotor system that consists of a servomotor, a servo drive, an encoder, a gearbox, and a load. The virtual model setup in turn would carry the whole concept through graphical demonstrations including timing. Furthermore, this software tool can communicate with simple real world hardware such as a switch and a light bulb to a very complicated hardware like a hydrocarbon based fuel reformer.

SoftLogix 5800, Studio 5000, and FactoryTalk View Studio software tools are used little differently. They are used to develop ladder logic control for Programmable Logic Controller (PLC) and dynamic Human Machine Interface (HMI) screen for a real life manufacturing and packaging systems. SoftLogix™ Chassis Monitor (virtual PLC) allows ladder logic control developed for a packaging system using Studio 5000™ software to execute without the presence of a hardware PLC and other real world hardware of the packaging system. HMI screen can also be added in the control loop for demonstrating the real world operation of the manufacturing or packaging process.

In addition, a ladder logic program developed using Studio 5000 can be downloaded into a real life ControlLogix™ and CompactLogix™ hardware PLC. Also HMI screen developed using FactoryTalk™ View Studio can be downloaded in to real life PanelView™ HMI unit. Thus the time spend in developing ladder logic control and HMI screen for the virtual packaging or manufacturing system are not wasted. They can be used for the real system with little modification. This helps system integrator and product developer with rapid prototyping, time to market, and non-availability of certain hardware parts during rapid prototyping cycle. Following are few examples of how use of software tools can enhance laboratory learning of students.

EXAMPLES USING LABVIEW SOFTWARE TOOLS

Problem One Description:

In the theory class, students' were given extensive background about discrete control system design logic expressed in ladder diagram format for Programmable Logic controllers. Students were exposed to sequential circuit design process using Boolean equation and AND/OR logic gates. Students were also given adequate background about how a frost free refrigerator works. As their laboratory assignment, students were asked to design controls for an auto defrost refrigerator. The problem statement is as follows:

Design an auto defrosts two door refrigerator control system using a discrete state logic gates. Refrigerator has two doors, cooler and freezer side. Only one light for the cooler side door and the light turn on when cooler side door is opened. Temperature set point controller and temperature indicator on both cooler and freezer side. A Frost detector sensor is used to simulate frost condition in the evaporator coil. A frost eliminator heater couple with a fan needs to be included in to the logic. One compressor connected with an evaporator (cooling coil) coil. A baffle between freezer side and cooler side needs to turn ON/OFF to control the temperature of the cooler side.

Solution to Problem One:

The discrete-state Input Variables:

1. Door: Open/Close
2. Cooler Temperature: High/Low
3. Freezer Temperature: High/Low
4. Frost Eliminator Timer: Timed out/Not Timed out
5. Power Switch: ON/OFF
6. Frost Detector ON/OFF

The discrete-state Output Variables:

1. Cooler Light: ON/OFF
2. Compressor; ON/OFF
3. Frost Eliminator Timer: Started/ Not Started
4. Frost Eliminator Heater and fan: ON/OFF
5. Cooler Baffle: Open/Close

LabVIEW Front Panel and Block Diagram are shown in Figure 1 and Figure 2, respectively. Front Panel shows all the inputs and outputs and their operations. Block Diagram shows the control logic using AND, OR, NOT, Comparators, Mathematical Operations, Timer Counters, Case Structures and For Loops.

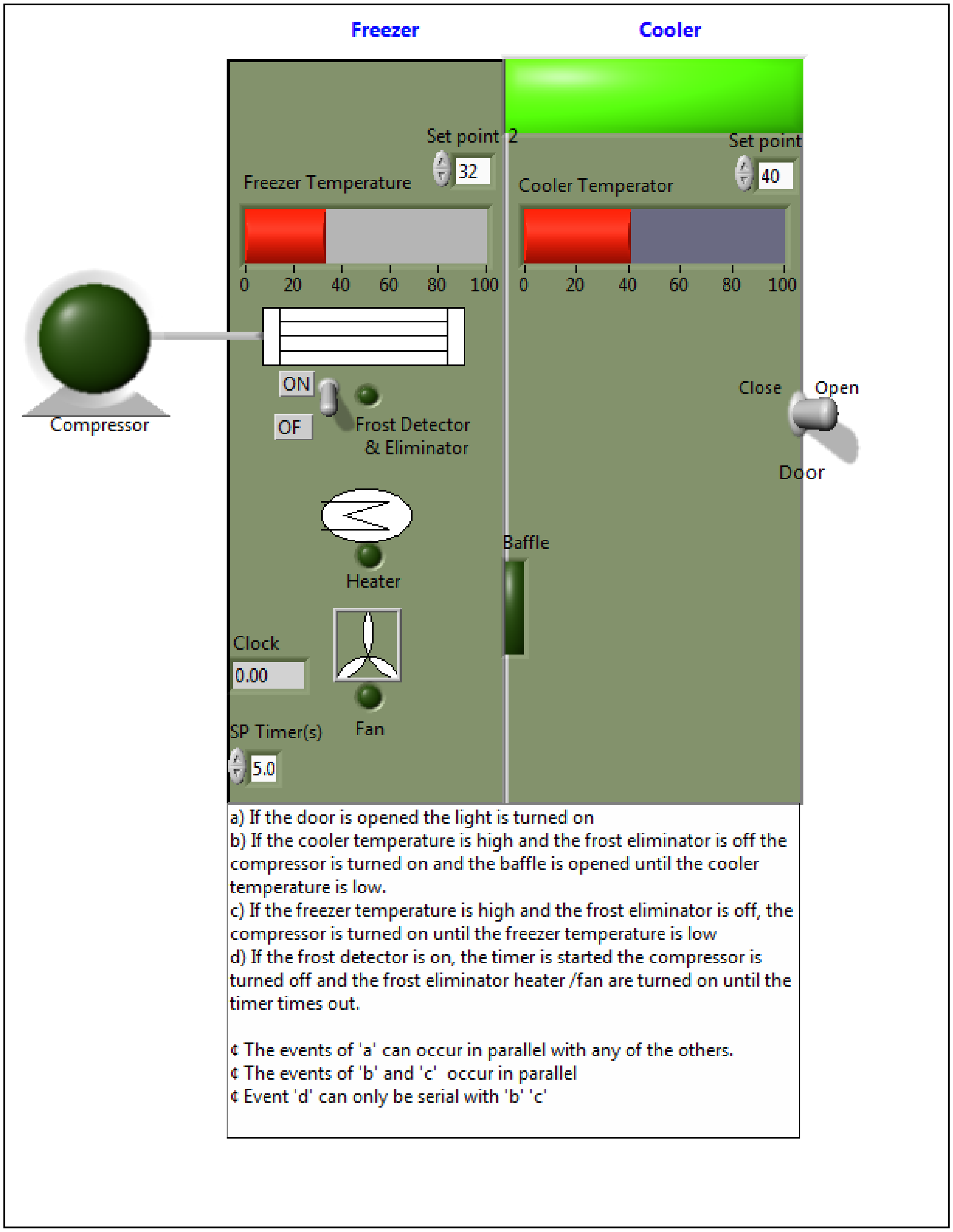


Figure 1: Front Panel of the Auto Defrost Refrigerator Control System

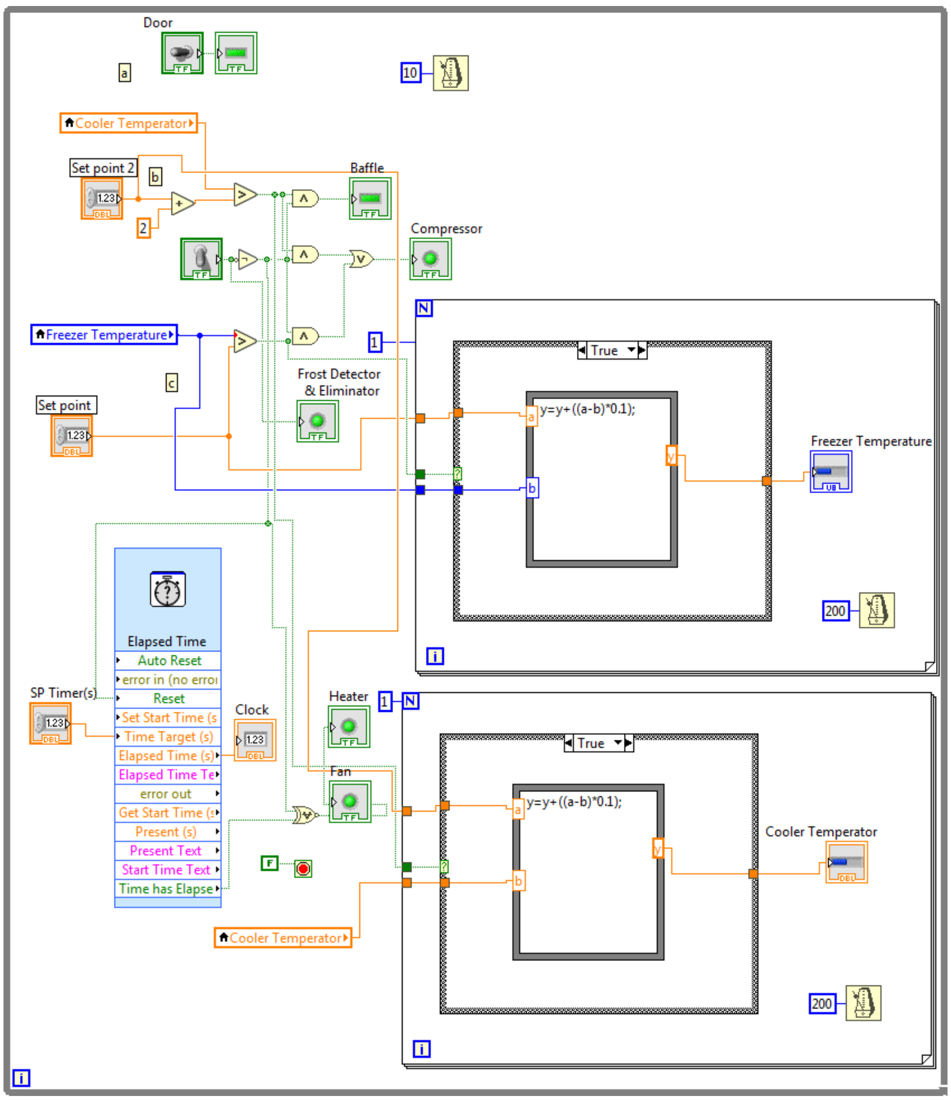


Figure 2: Block Diagram of the Auto Defrost Refrigerator Control System

Problem Two Description: Design and tune a PID controller for a closed loop control system that controls tank level. Transfer function of the servomotor controlled final control element (valve) that controls the liquid flow in to the tank and the transfer of the controller signal transmission to the final control element are as follows:

Transfer function of servomotor controlled final control element: $\dfrac{10}{s^2 + 20s + 2}$ and

Transfer function of controller signal transmission to the final control element: $\dfrac{6}{s+1}$

These two transfer functions indicate tank level control system dynamics and can be changed with a little effort. If changed, tuned values of K_P, K_I and K_D will result a different value for the PID controller when properly tuned.

Solution to Problem Two: In the theory class, students' were given fundamentals of PID controller parts and their tuning process using Ziegler and Nichols process reaction method. They were also given the theoretical understanding about sustained oscillation and one quarter decay ratio as criteria for good control for a step disturbance in the system.

A LabVIEW Front Panel and Block Diagram presented here was developed using Control and Simulation Loop for the solution. A laboratory test was given in order to verify the proper understanding of the controller tuning process. In the test each student was given with a slightly different value of the transfer function of the final control valve.

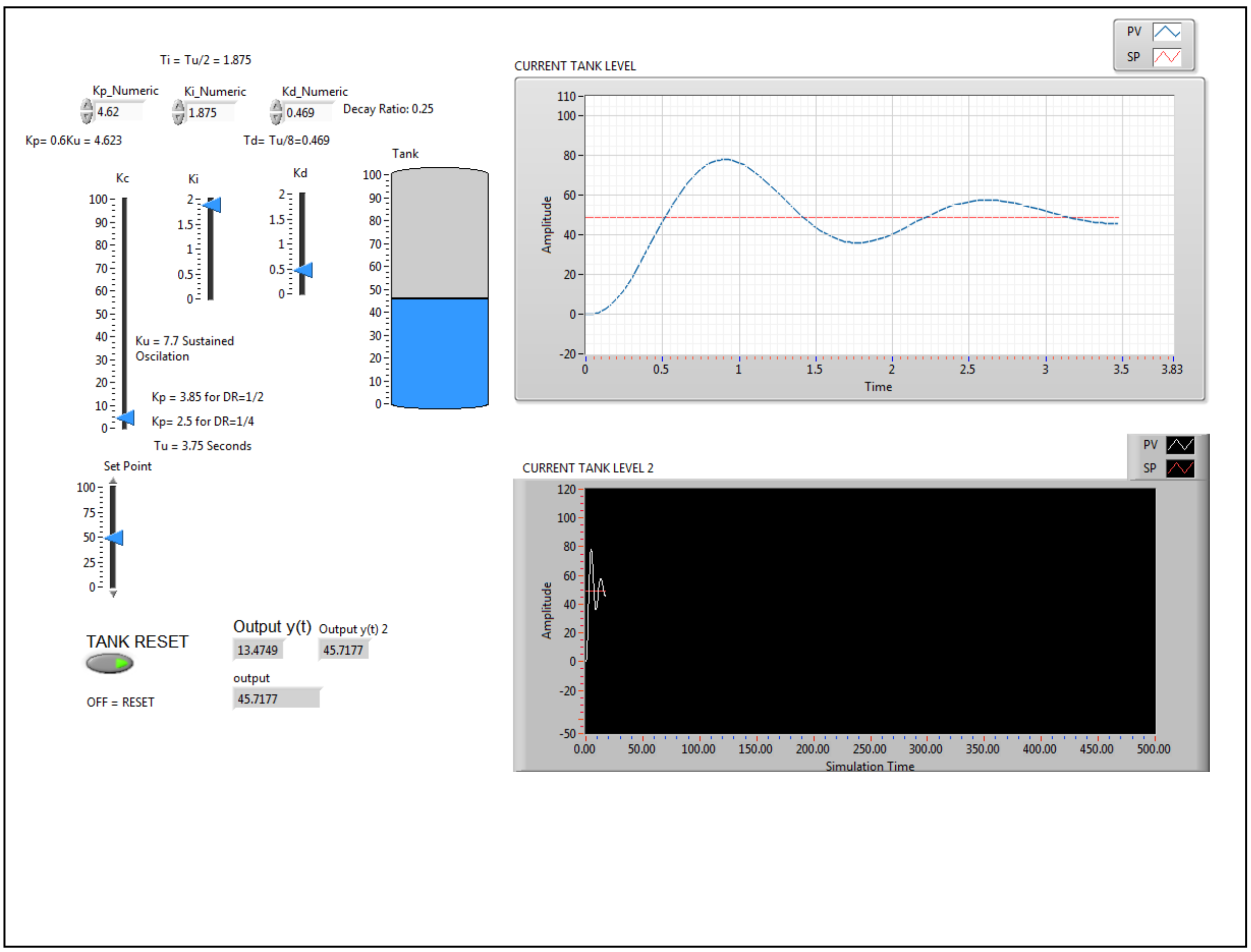


Figure 3: Front Panel of the PID Controller and Level Control System

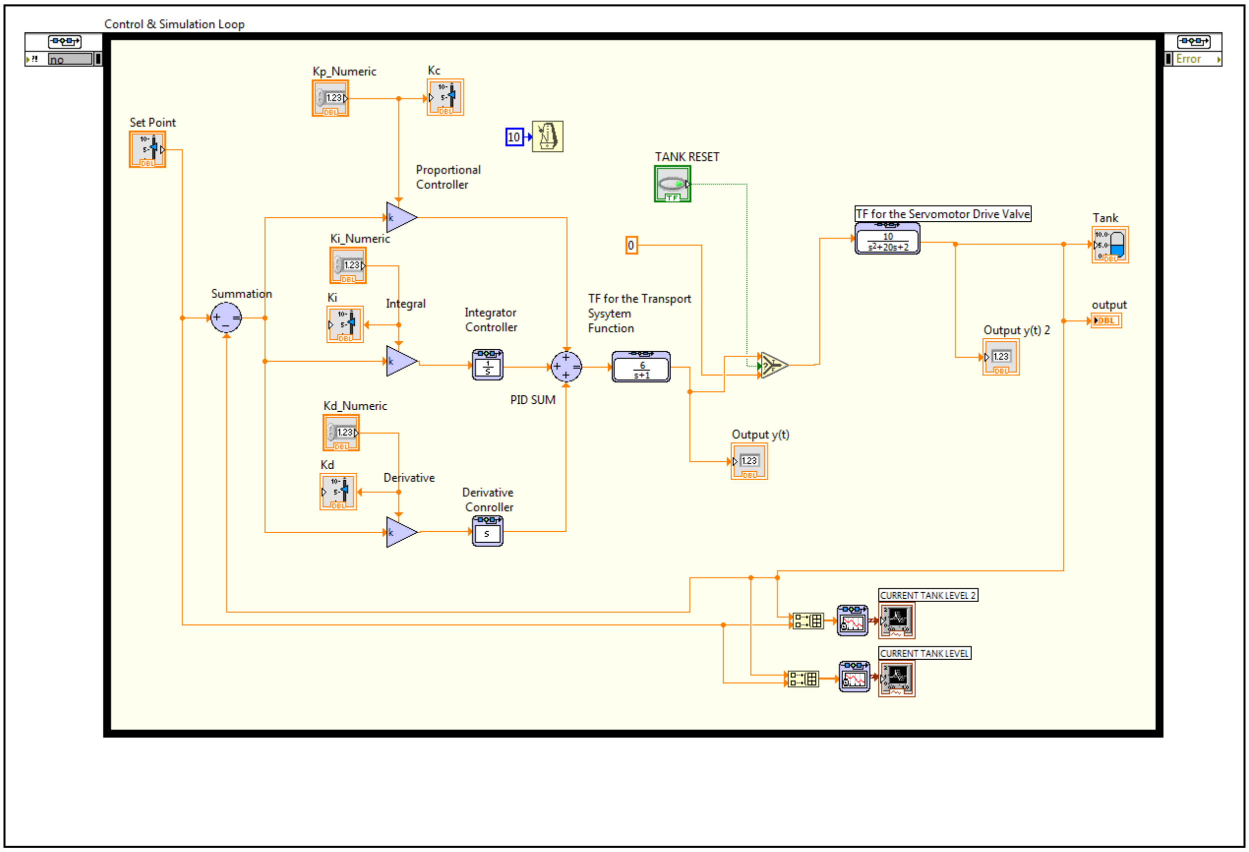


Figure 4: Block Diagram of the PID Controller and Level Control System

EXAMPLES USING SOFTLOGIX 5800 SOFTWARE TOOLS

Problem Three Description: Design a packaging system both PLC ladder diagram and HMI screen animation where a milk bottle is to be filled with 2% chocolate milk then put a cap on the bottle and then put a label that says "2% chocolate milk". Everything must run without the presence of real hardware PLC and HMI Screen hardware. However, PLC ladder logic and HMI Screen animation must be downloadable in to a real ControlLogix™ or CompactLogix™ PLC by Rockwell Automation and HMI animation must be downloadable in to PanelView™ HMI unit. Use the following software tools to implement the logic and HMI animation:

1. SoftLogix 5800 Virtual PLC Chassis
2. Studio 5000 ladder editor
3. FactoryTalk™ View Studio for HMI screen animation design

Solution to Problem Three:

In the theory class students were given adequate background about how to create ladder logic diagram for a packaging system using Studio 5000 software tools and an HMI animation and how to couple them together for seamless operation of the HMI animation screen. **Figure 5** shows the SoftLogix Chassis Monitor with ControlLogix Processor in Slot 2 and in Remote (REM) operation mode selected. **Figure 6** shows the HMI Screen animation diagram and **Figure 7** shows ladder part of the ladder diagram

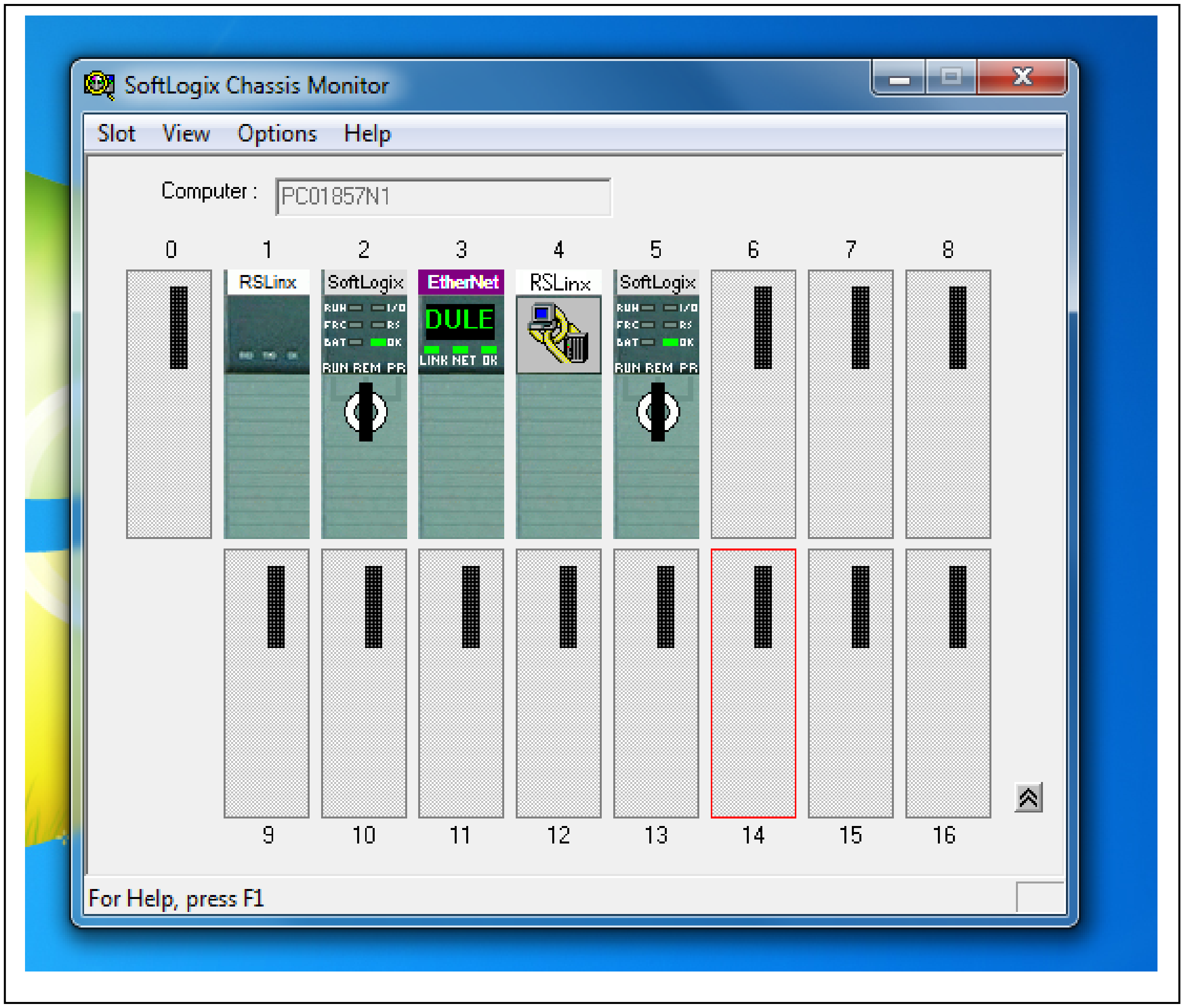


Figure 5: SoftLogix™ Chassis Monitor with ControlLogix™ Processor in Slot 2 and the Controller is in Remote (REM) operation mode selected Chassis Monitor

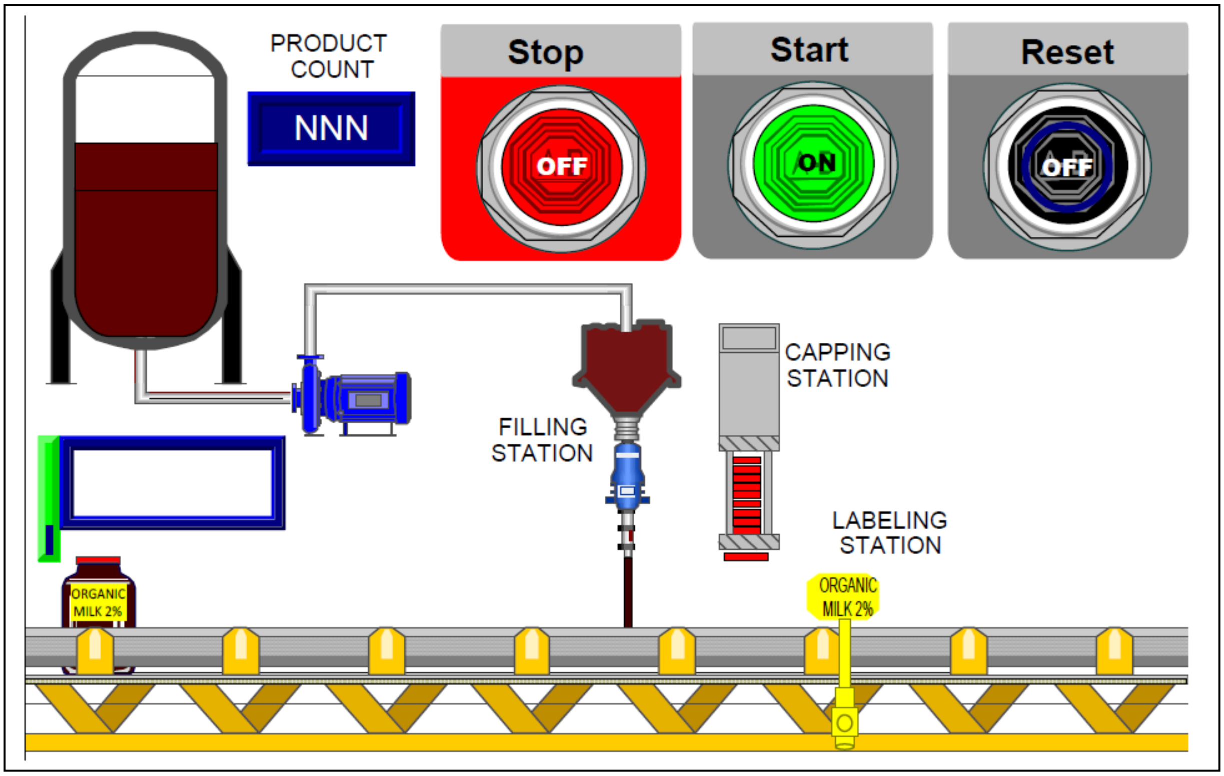


Figure 6: HMI Screen Animation Diagram

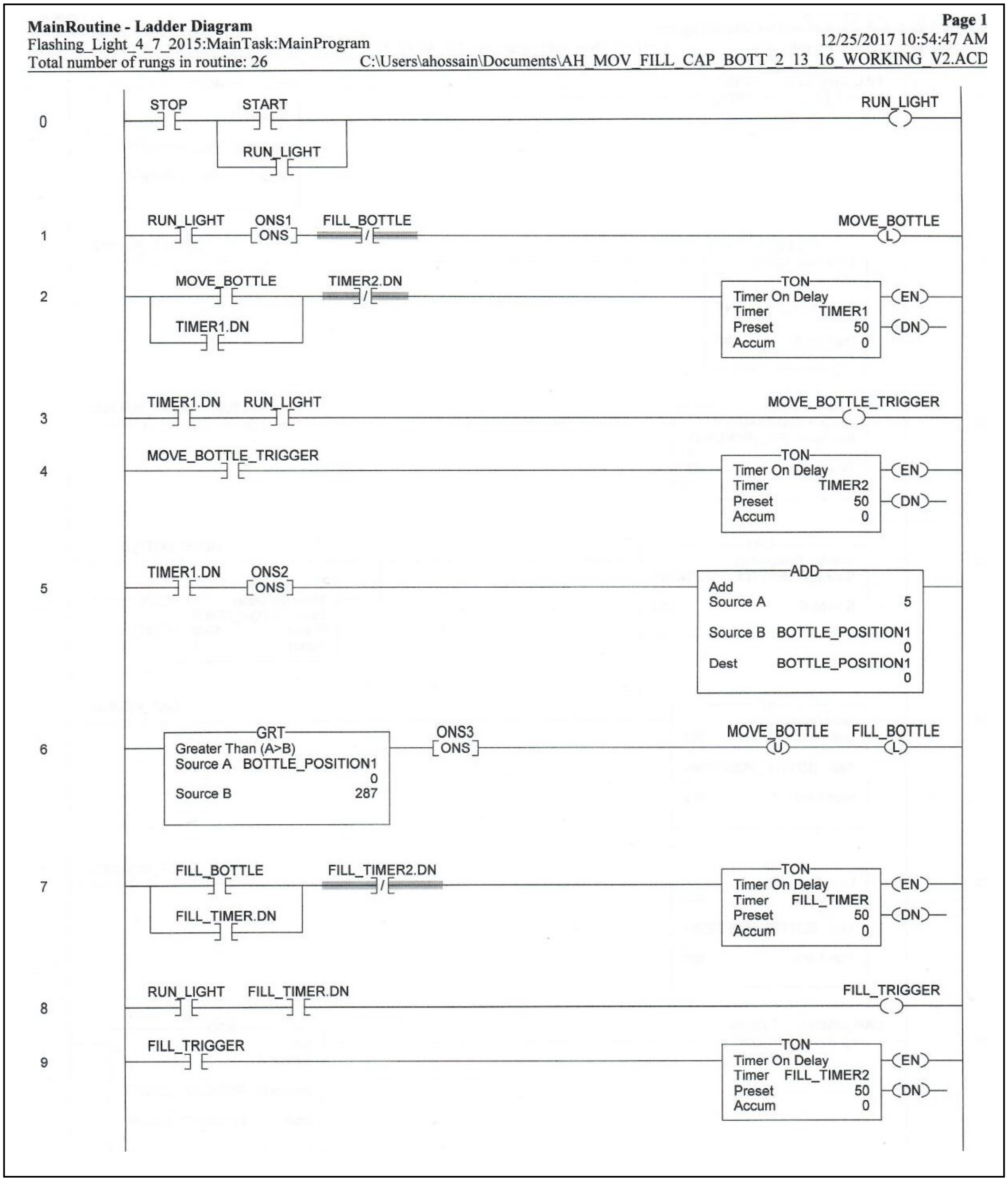


Figure 7a: Page 1 of Main Routine of the Ladder Control Logix Diagram

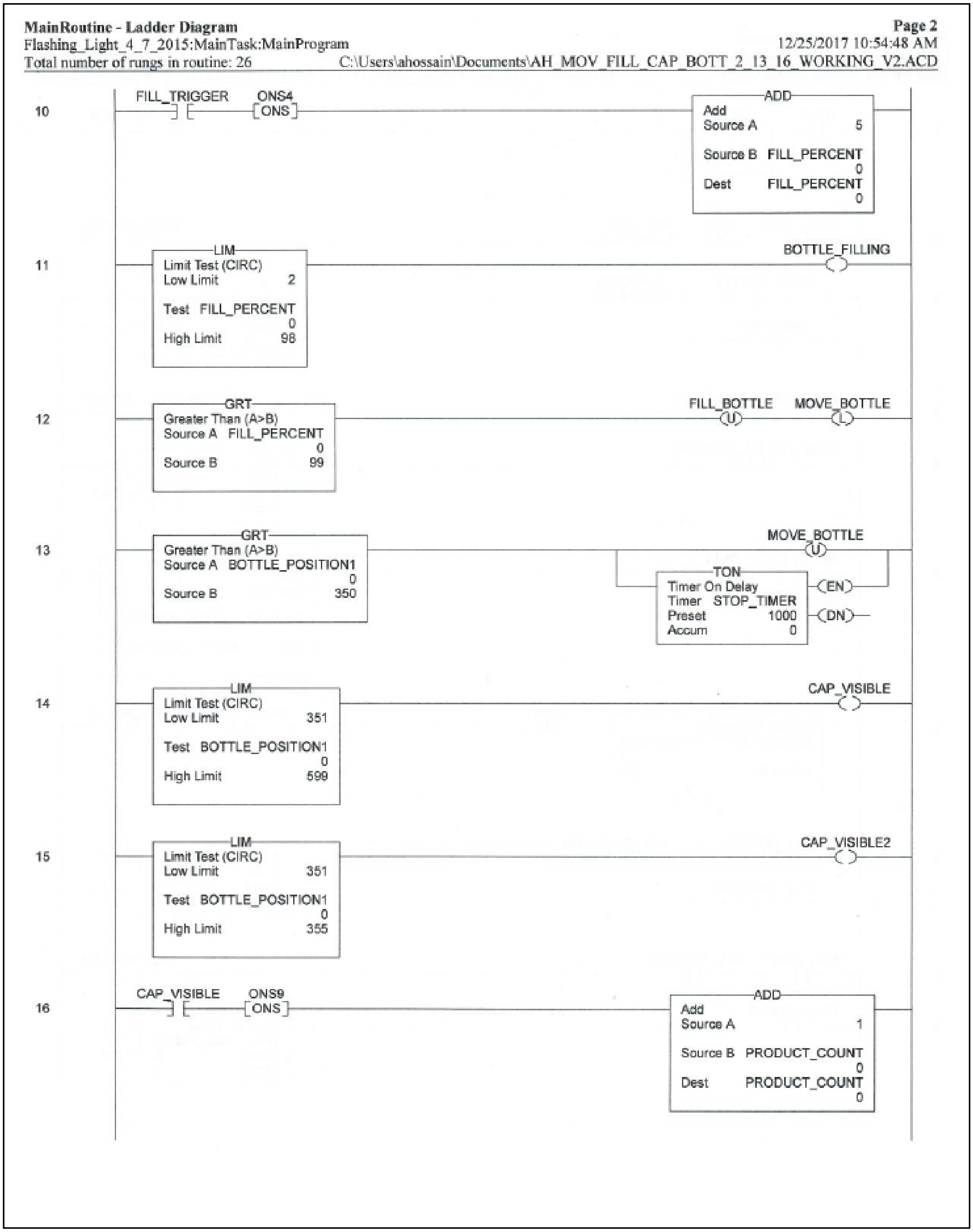
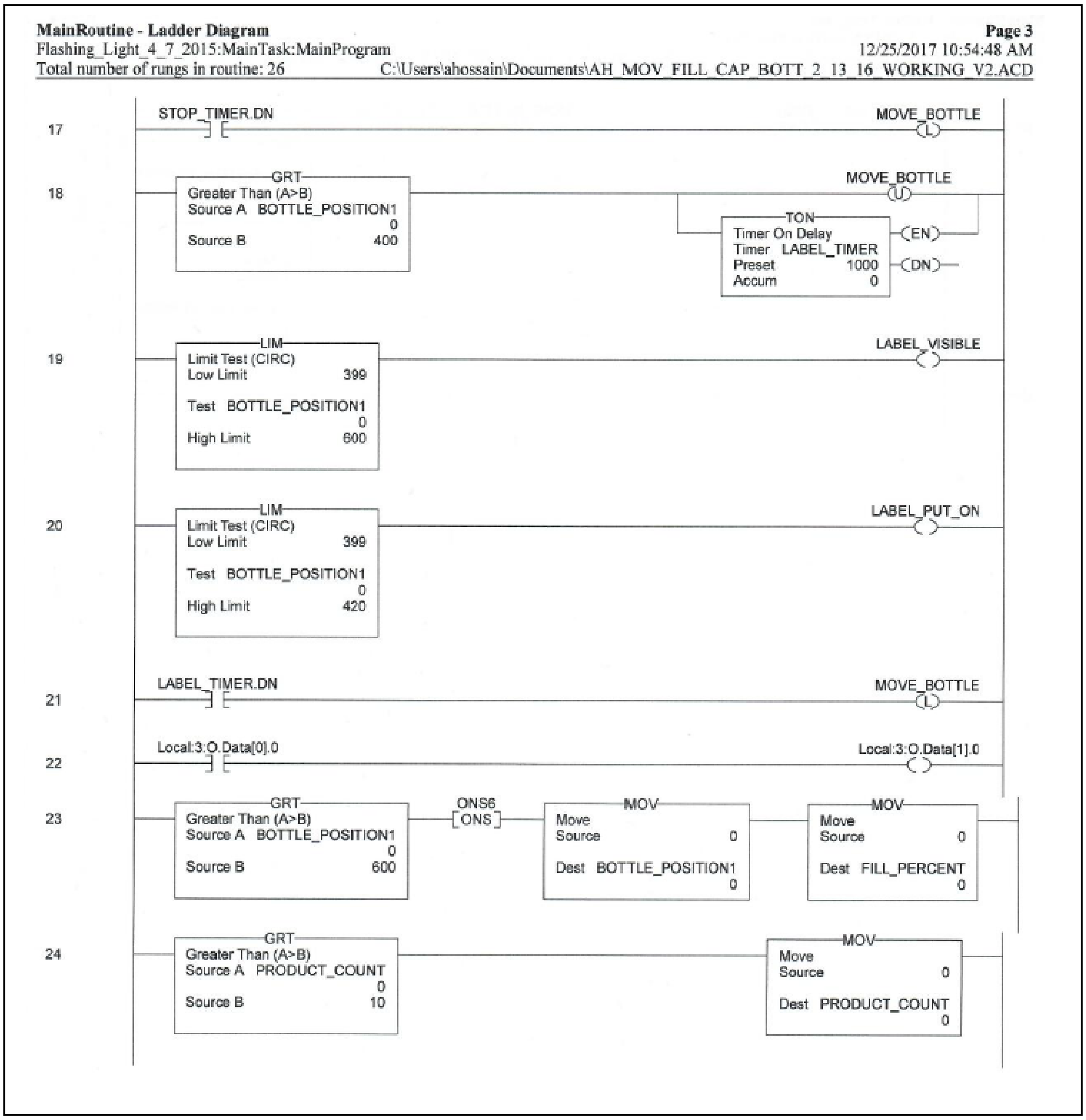


Figure 7b: Page 2 of the Main Routine of the Ladder Control Logix Diagram



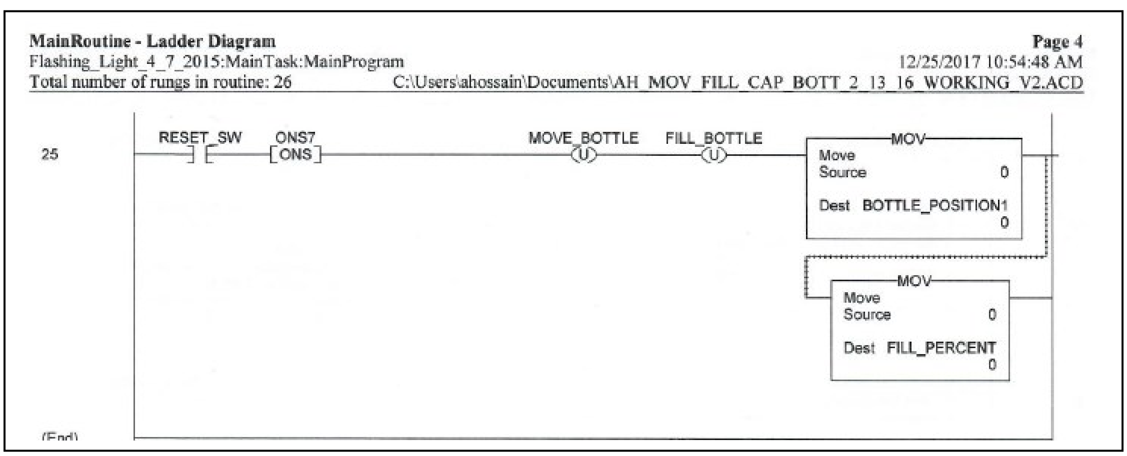


Figure 7c: Page 3 and 4 of the Main Routine of the Ladder Control Logix Diagram

DISCUSSION OF THE RESULTS

By introducing the virtual tools to the students in a senior level course, a number of laboratory issues are resolved and students' understanding have significantly improved. Most hardware laboratory assignments have procedures for students to follow to get the desired result. However, for virtual software tools assignments, there are no procedures to follow and only problem statements and expected solutions are given. This requires students to understand the actual problem and find a solution by following their intuitive methods. This is the industry approach to problem solution. When problem is assigned to an engineer, there are no step by step procedures provided for the solution. An engineer in many cases needs to start from a very vague description of the problem and refine desired outcome at a later time.

Following results and observations make the case for and show the benefits of virtual software and hardware tools for laboratory experiments:

1. Less dependency on the "functioning hardware" resulted 90% of enrolled students to successfully complete the laboratory assignments - **Proven Result**
2. More students could be accommodated in a laboratory session because all that is necessary is a computer terminal and function software tool for each student in the laboratory – **Proven Result**
3. Success rate in laboratory activity has improved considerably. There were 35 students enrolled in the class and they were divided in two laboratory session. Over 85% students successfully completed Assignment 1. Over 98% students successfully completed Assignment 2. Over 75% students successfully completed Assignment 3. - **Proven Result**
4. Since the students are exposed to current practices by the industry they are more likely to find a job or an internships quite easily - **Not measured yet**
5. Since each student is actively involved in solving the assignment and these assignment could be slightly different for each student, their understanding about the problem and its solution has improved significantly – **Proven Result**
6. In the example cited above of a PID controller, students learned not only how they are used and tuned using Ziegler and Nichols process reaction method, but also learned

what they are made of and the effect and characteristics of each part. Therefore, if later in their career, they need to design one, they are better prepared with deeper understanding of concepts about the PID Controllers.

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