AC 2008-240: USING LOGIC CONTROL IN A SAFETY AND FIRE PROGRAM FIRE ALARM SYSTEM ENGINEERING COURSE

Harry Franz, University of Houston-Downtown

Prof. Harry Franz is an Associate Professor in the Control & Instrument Electronics Design Program and Safety & Fire Program at the University of Houston Downtown (UHD) in Houston, Texas. He has a BSEE and MSEE from the University of Pittsburgh. He holds a current P.E. and is a member of the NSPE and TSPE. He has worked in industry for sixteen years. He is a member of the IEEE and advisor to the UHD IEEE Student Organization. He is also a member the ASEE and ISA. He has been very active in the Tau-Alpha-Pi national ET honor society.

Using Logic Control in a Safety and Fire Program
Fire Alarm System Engineering Course

Abstract

The purpose of this paper is to describe the use of programmable logic controllers in a Safety and Fire program Fire Alarm System Engineering course (ENGR-1403) of a four-year university. The students in the course accomplish programmable logic control by using Automation Direct programmable logic controllers. The students achieve knowledge of generic logic control through the use of ladder logic, logic statements, and functional block diagram programming techniques. The students use a variety of software in the course that includes circuit software and LabVIEW. The LabVIEW software is used for both the design and simulation of fire alarm logic systems. In addition, the students use Honeywell commercial fire alarm control processors to perform practical system setup programming for vendor specific applications. The focus of this paper is on the programmable logic control teaching techniques that are used in the ENGR-1403 course and the respective student exercise and project work

The students in the ENGR-1403 course have various levels of experience and academic backgrounds. Students in the course often have experience in the installation or maintenance of fire alarm systems. Typically the preponderance of the class students does not have a significant amount of experience using programmable logic. While some students may have limited programmable logic experience, their course entry experience most usually is not enough to allow them to program more advanced exercises or projects.

Discussed in this paper are the learning strategies and teaching methods that are used to impart knowledge of programmable logic control to the fire alarm systems engineering course students. First the fundamentals of basic logic are given in the course with special applications to fire alarm systems. Next, programmable logic methods are put forth. Ladder logic is then given and the respective mnemonic statements for the ladder logic are presented. Finally, functional block diagram logic programming is given. At all stages of learning relevant applications to fire alarm system are used.

Strategies that are used in the course to increase the student knowledge of fire alarm logic are taken from both engineering courses and from industrial training courses. Most of the class students have not taken a digital logic course. Therefore, logic gates, truth tables, Venn diagrams, and logic statements that are typically found in digital logic courses are presented in the fire alarm systems class. In addition, hands-on and industrial training methods are used. It is allowed for students to help each other perform exercises, but more often than not, few students in the fire alarm systems engineering class initially have enough prior knowledge of programmable logic to help the others. As the course progresses, however, students that advance more rapidly help support the others. Finally, it is very important to note that the knowledge of programmable logic control gained in the fire alarm system class is a very valuable asset for students when they become employed in fire and safety or in many other areas of industry. Student exercises and group projects will be given that use programmable logic control.

Introduction

The goal of the ENGR-1403 course is to have the students gain both theory and application. First, basic theory is completed that includes logic symbols, logic gates, truth-tables, logic statements, logic manipulation, and basic combinational logic examples. The next approach used is to impart knowledge of the application of logic control. This is done in a manner to allow a student to use, understand, and even design a fire alarm system control unit. This is accomplished by having the students learn and use the more general logic software packages first and then learn the programmable logic software. The understanding of logic programming enables the ENGR-1403 students to design systems in addition to performing the application of a preprogrammed and pre-engineered fire alarm signaling control systems.

The students learn logic theory through the use of educational software that includes LabVIEW. Because the students that enroll in the ENGR-1403 class are not required to have a previous knowledge of the LabVIEW software, the basics of LabVIEW are taught within the ENRG-1403 course. Fundamentals of LabVIEW and examples are given in both the classroom and lab.

The ENGR-1403 students are also not required to have previous knowledge of programmable logic and software. The students learn programmable logic controller software and hardware applications through the use of programmable logic controllers that are in the ENGR-1403 course lab. Note that only smatterings of students in the ENGR-1403 course, mainly those that work in industry, do have some limited experience with programmable logic.

A fire alarm system systems laboratory is used in the ENGR-1403 course with the lecture. This fire alarm signaling systems laboratory has programmable logic controllers that allow fire protection systems to be designed from scratch. This is in contrast to the mostly preprogrammed commercial fire alarm signaling systems control panels that are also used in the ENGR-1403 lab. The use of the ENGR-1403 lab programmable logic controllers also acquaints students with programmable logic control which is an important tool that is used in industry. The students first learn to program logic by using functional blocks and logic diagrams in LabVIEW. The students then use the lab logic controllers to program mnemonics and logic diagrams for fire alarm systems.

Background

The ENGR-1403 course of the Engineering Technology department contains the design, installation, maintenance, and utilization of fire appliance and pre-engineered systems. The course also contains the operational capabilities and utilization requirements of the fire detection and signaling systems. In addition, the course contains demonstrations and computer simulation of hazardous detection systems.

Background *(continued)*

As mentioned previously the ENGR-1403 students are not required have prerequisite knowledge of LabVIEW. The rational for the use of LabVIEW rather than Visual Basic software in the ENGR- 1403 class is that most students find LabVIEW easier to use to create logic control panels for systems in a more direct and faster way than by using the Visual Basic software. Even students that have much experience with Visual Basic software most often prefer to use LabVIEW rather Visual Basic to make control panels and logic diagrams for the fire alarm signaling systems. The functional block programming of the LabVIEW software is also most often preferred by the ENGR-1403 students rather the use of the use of mnemonics.

As mentioned previously the ENGR-1403 students are also not required to have prerequisite knowledge of programmable logic. The Automation Direct logic units and software are used in the ENGR-1403 course because they are easy to learn to program and can be used for various applications. The Automation Direct industrial software is designed to create logic diagrams either directly or by using standard logic mnemonics that are used in industry. That is the Automation Direct software allows the students to learn the use of a tool that is required by industry.

Methodology

The ENGR-1403 course students are required to work individually on the basic exercises, but work in groups on the projects that are relatively large. Both the LabVIEW software and Automation Direct software packages are available on the fire alarm signaling lab computers. The Automation Direct software is also available in the form of mnemonics on the lab logic controller hardware units. The hardware units in the fire alarm signaling labs vary from logic controller "bricks" which are single self-contained smaller units to larger logic controllers with modules. Student versions of the LabVIEW software are also available in the university bookstore.

To acquaint students with the basic fire alarm logic software, lectures are given in the course on logic control using LabVIEW and Automation Direct software. Examples and demonstrations are given in the lab. The students work along with the instructor and then work independently. In addition, professional training methods are used in the course. These methods use a varied set of lectures, demos, labs, and student group action to keep the course moving and interesting. As the level of work progresses students are then assigned to work in groups rather than individually for the more complex larger projects.

Discussion of Student Work

As previously noted the students are required in the earlier part of the course to work individually on exercises, but in the later part of the course work in groups on larger projects. . The group size varies with the class size. Student *group* projects are discussed below and then are shown in figures.

Fire Detection, Alarm, and Suppression System for an Industrial Gear Unit Factory Project

A student group programmable logic controller project assignment is shown in *figure 1-A*. The actual student group work hardware board is shown in *figure 1-B*. The hardware board uses an Automation Control "brick" logic controller for detection and notification for the factory fire alarm system project. Note that the hardware board with the Automation Direct programmable logic controller in *figure 1-B* is a "brick" logic controller shown with input, output, and wiring.

The gear factory has initiating device detectors for fire signatures that include smoke, high-heat, chemicals, and flames that use a UV detector. The factory has notification appliances that include horns and sirens for local alarms, general alarms, and evacuation alarms. The logic is performed by the controller program created by the students for inputs, logic, timing, outputs, and other functions. The program made by the students uses mnemonic statements.

Fire Detection, Alarm and Evacuation System for Office Building Project

A student group LabVIEW project is shown in *figure 2-A.* This project has been made by the students using LabView. The view shown is the front panel view.

The evacuation system directs occupants to the nearest exit away from the fire, not to the nearest exit which may be the location of the fire or close to the fire. Fire signature detectors are shown with notification appliances that include directional guide arrows to direct occupants away from the fire to the nearest exit. The students have programmed the logic using function blocks.

Note that this evacuation project also has served as a guide for a hardware board. The hardware board created later uses a programmable logic controller and other hardware for a larger more sophisticated evacuation system. A sample of the programmable logic controller logic mnemonics used for the hardware board is given in *figure 2-B.*

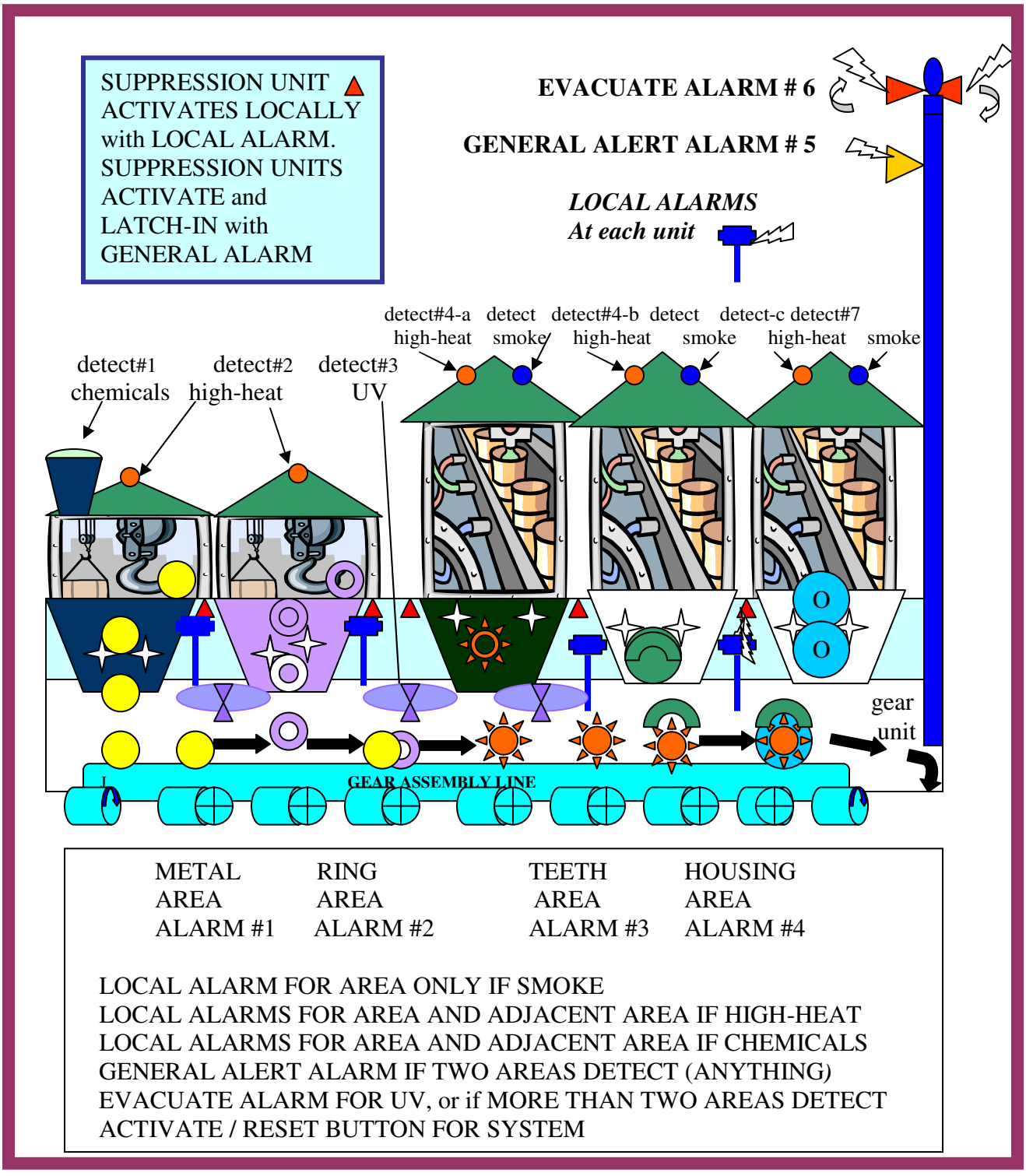
Fire Detection, Alarm and Evacuation System for Two-room Building Project

A student group LabVIEW project with combined analog and digital functions is shown in figure *3-A* the front panel view and in *figure 3-B* the functional block diagram view. Logic equations are shown in *figure 3-C.* The high-heat detection system compares analog data supplied by each of the thermometers to the respective set point for each room. If either room has a high temperature then both of the alarms will notify. The suppression will activate only for the respective room with the high temperature.

Examples of Student Work

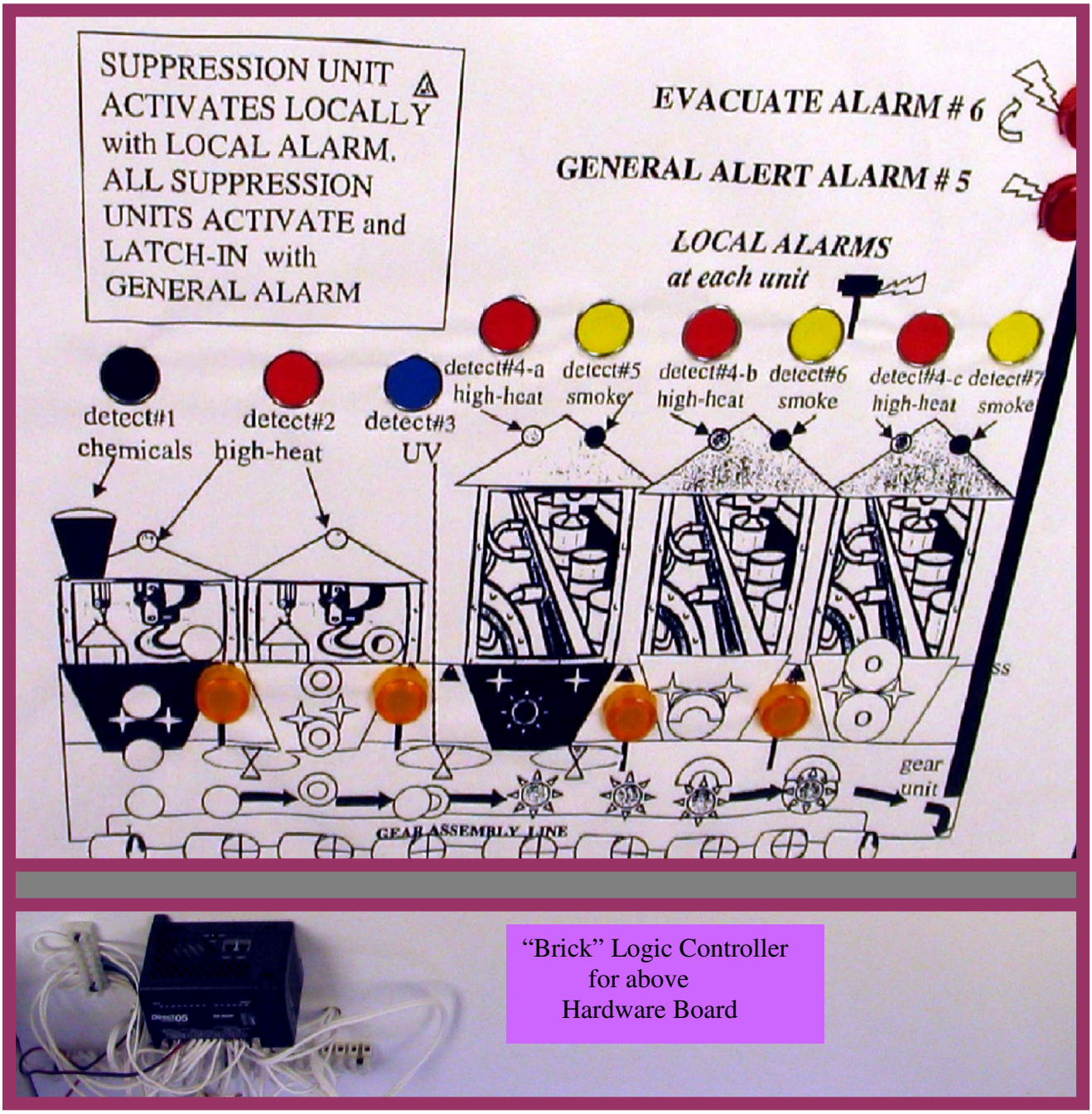
Figure 1-A

Student Assignment
Fire Detection, Alarm, and Suppression System for an Industrial Gear Unit Factory Project



Examples of Student Work *(continued)*

Figure 1-B
Student Work Hardware Board with Logic Controller
Fire Detection, Alarm, and Suppression System for an Industrial Gear Unit Factory Hardware



Examples of Student Work *(continued)*

Figure 2-A
Student LabVIEW Project Work Panel View
Fire Detection, Alarm, and Evacuation System for an Office Building Project

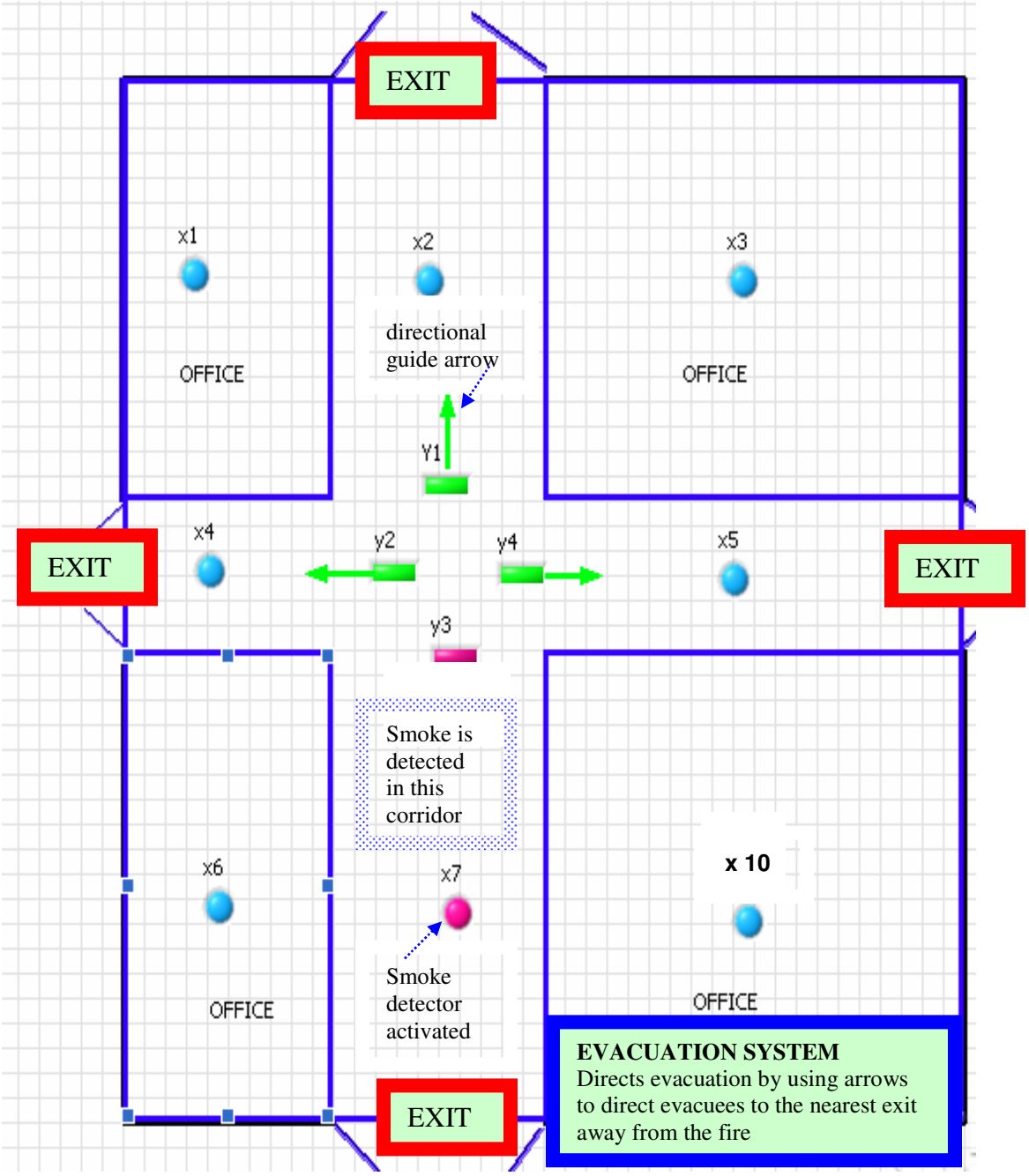


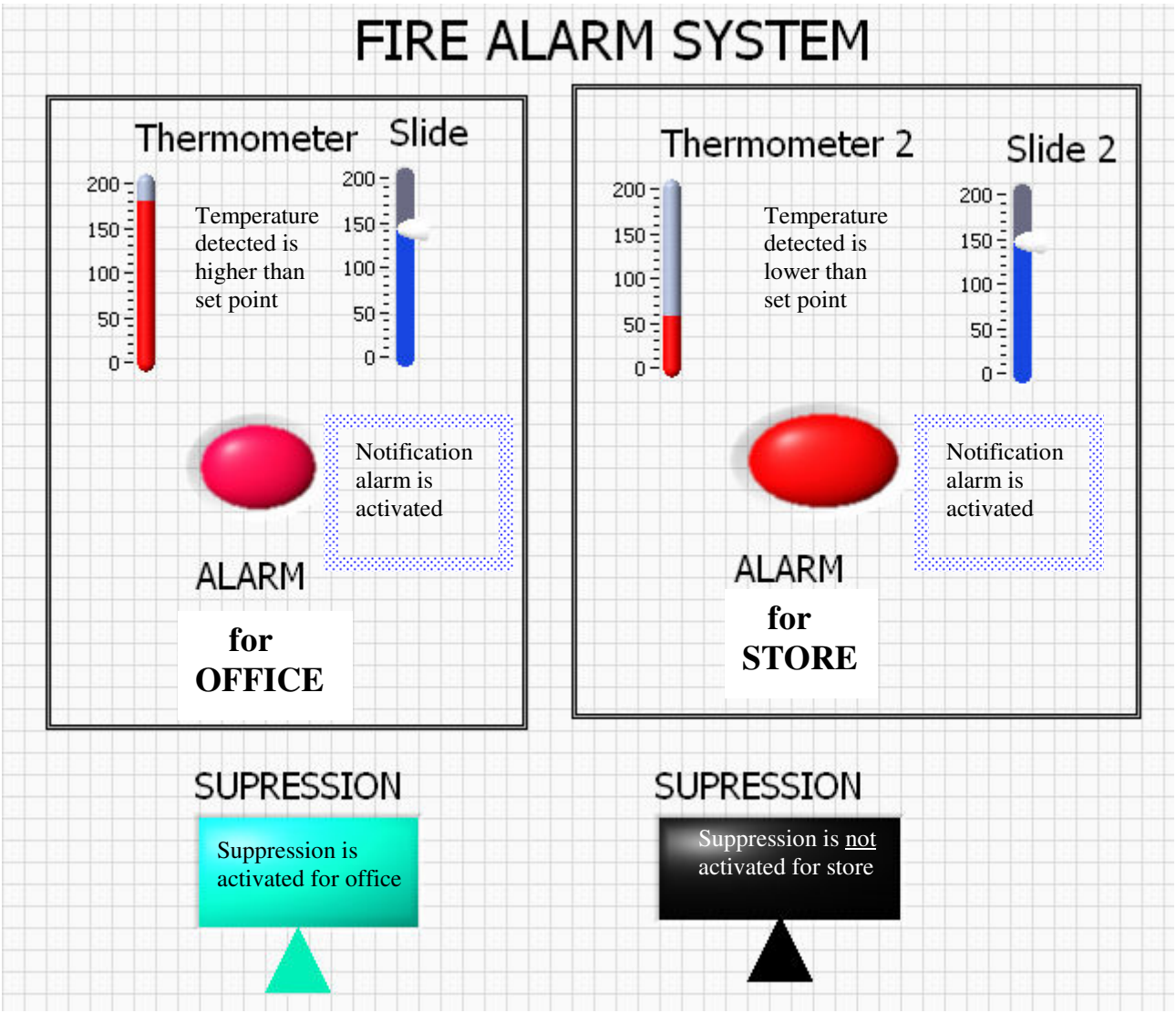
Figure 2-B *Programmable Logic Controller Logic Mnemonics*

STR X4	OR X7	STRN X1	ANDSTR
OR X5	OR X10	ANDN X2	OUT Y1
OR X6		ANDN X3	(*where N≡ NOT)*

Examples of Student Work *(continued)*

Figure 3-A

Student LabVIEW Project Work Front Panel View
Fire Detection, Alarm, and Evacuation System for a Two-room Building
One room is used as a store for sales and the other room is used as an office



Examples of Student Work *(continued)*

Figure 3-B

Student LabVIEW Project Work Functional Block Diagram View
Fire Detection, Alarm, and Evacuation System for a Two-room Building

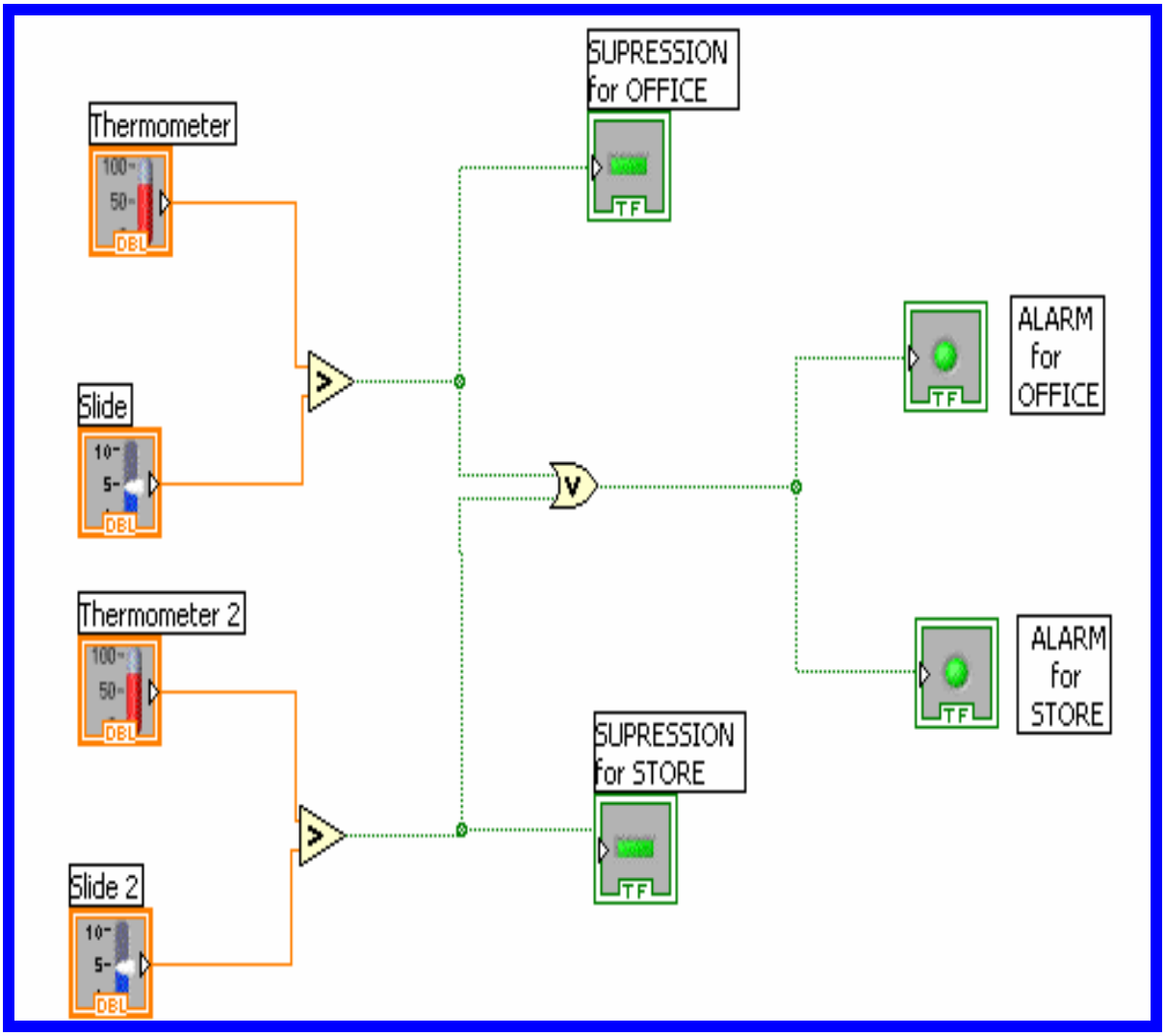


Figure 3-C
Logic Equations for above Functional Bock Diagram

IF Thermometer G.T. Slide ➔ Office Suppression *(where G.T. ≡ greater than)*
IF Thermometer 2 G.T. Slide 2 ➔ Store Suppression

(IF Thermometer G.T. Slide) OR (IF Thermometer 2 G.T. Slide 2 ➔ Alarm Office
(IF Thermometer G.T. Slide) OR (IF Thermometer 2 G.T. Slide 2 ➔ Alarm Store

Student Work Feedback

The students have reacted to the use of logic control in the ENGR-1403 course in more than one positive way. Note that the course students in the ENGR-1403 class are typically either firefighters or non-fire fighter students that are taking the course as an elective for a program other than safety and fire.

First, for reference the students especially fire fighters have been very interested to learn the aspects of the National Fire Alarm Code, NFPA 72, and how to apply the Honeywell commercial alarm control box and addressable alarm control box to various fire alarm systems. The firefighter students in the course have stated that the knowledge of the Honeywell fire alarm system control boxes makes them a better informed firefighter and a more aware firefighter. In addition, practically all of the ENGR-1403 course students stated it was a valuable experience to be able work on the design and installation of actual commercial fire alarm signaling systems.

Second, for the focus of this paper most of the students including those that are fire fighters have stated that they have been very grateful to learn the aspects of applying programmable logic control to the subject area of fire alarm system design. In addition, most of the students have stated that the knowledge of programmable logic is a very useful and vital tool for the understanding and design of fire alarm control systems as well as a vital tool for industry in general.

Summary and Conclusions

The students in the ENGR-1403 Fire Alarm Signaling course benefit from the use of both the LabVIEW and Automation Direct software. The ENGR-1403 course projects require knowledge of fire alarm signaling systems and knowledge of programming. Knowledge of programming by function blocks using the LabVIEW software and knowledge of programming logic controllers in mnemonics or logic diagrams are given in the course. It is important to note again that the Automation Direct Logic Controllers are actual units used in industry and the use of these controllers is a valuable learning experience for the ENGR-1403 students.

Bibliography:

1. UHD Undergraduate and Graduate Catalog 2007 / 2008 edition
2. UHD ENGR-1403 Students Projects
3. LabView 8 Student Edition National Instruments, Prentice Hall
4. Automation Direct Programmable Logic Control Manuals