2006-116: COMPUTER-BASED INSTRUMENTATION PROJECTS

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Computer-Based Instrumentation Projects

Abstract
Student-initiated projects as part of an instrumentation and data acquisition course for sophomore-level electronics engineering technology students are presented. The three instrumentation projects reported in this paper are: an automated parking garage system, an automated draw-bridge control system, and an intelligent traffic light controller. All three projects focused on instrumentation system development integrating multiple sensors and actuators, data acquisition hardware, interface electronics, control logic implementation in LabVIEW software, and wood/metal work in departmental shop. These projects were carried out during the final four weeks of the semester after eleven weeks of lecture/laboratory sessions.

Introduction
The ability to conduct and design experiments is rated as one of the most desirable technical skills of engineering and engineering technology graduates[1]. Specifically, the referenced survey indicates that employers want graduates with a working knowledge of data acquisition, analysis and interpretation; and an ability to formulate a range of alternative problem solutions. Additionally, potential employers of our EET graduates are in the automated manufacturing and testing sector of the industry; and that motivated the creation of an instrumentation and data acquisition course[2]. Students have had courses in electrical circuit analysis, electrical machines, and analog and digital electronics before taking this course. The first three weeks of the fifteen-week semester are primarily devoted to LabVIEW programming. During the next eight weeks, the concepts and integration of sensors and actuators, interface electronics, and data acquisition and instrument control hardware/software are covered. The final four weeks are dedicated to student-initiated laboratory design projects[3-6]. This paper focuses on some of the instrumentation projects implemented by students during the spring-2005 semester.

Early in the semester students develop project topics with appropriate feedback/guidance from the instructor. A feasibility report is required of each group by the eighth week of the fifteen-week semester. The feasibility study is quite detailed as it requires preliminary ideas supported by circuit schematics, parts list, LabVIEW program flow chart, and project completion schedule. Students are in charge of selecting the necessary sensors and actuators, and are required to use the well-equipped departmental shop for fabrication and metal/wood work in support of their projects. A formal presentation and a final report are also part of the project experience. The basic lab setup available to students includes a PC with LabVIEW[7] software and data-acquisition board[8], and GPIB/RS-232 interfaced instruments such as triple output power supply and digital oscilloscope. The following sections describe the implementation of automated parking garage, automated draw-bridge control, and intelligent traffic light controller projects.

Automated parking garage system

The objective of the automated parking garage system is to constantly monitor the availability of parking spaces in an eight-spot garage in order to control the flow of vehicles into the garage including automated operation of entrance and exit gates and parking fee (coin) collection. A block diagram representation of the system is shown in Figure 1.

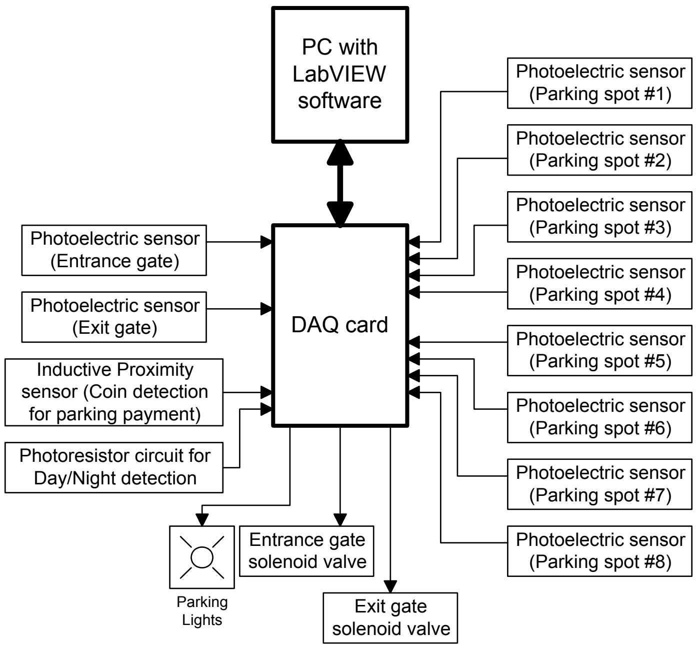


Figure 1 A block diagram representation of the automated parking garage system.

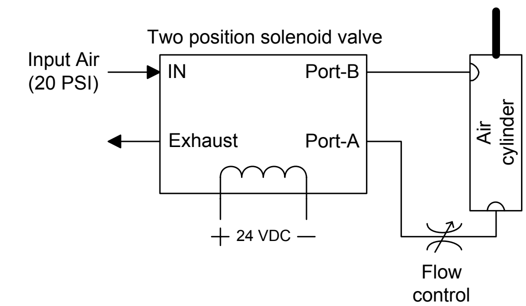


Figure 2 Pneumatic solenoid valve and air cylinder configuration.

Availability of parking spaces is monitored using eight separate photoelectric sensors[9] mounted right below the parking spots numbered one through eight. Two additional photoelectric sensors are used for monitoring the presence of cars at entrance and exit gates. These infrared emission based diffused photoelectric sensors have an operating voltage range of 10-30 VDC and a sensing distance of 400 mm. The coin collection system at the exit gate uses an inductive proximity sensor[10] to control the open/close position of the exit gate; this sensor is also capable of operating from 10 to 30 VDC and has a sensing range of 3 mm. The lighting control for the parking garage uses a photoresistor based voltage divider circuit to turn-on and turn-off the lights for a calibrated day/night condition. Altogether, there are twelve inputs to and three outputs from the data acquisition board. The three outputs are: a signal to turn on the parking lot lights, a signal to open/close the entrance gate, and a third signal to open/close the exit gate. As shown in Figure 2, two-position pneumatic solenoid valves[11] along with double-acting air cylinders[12] are used as actuators for opening and closing the entrance and exit gates. Air flow control devices were needed to be used to achieve a relatively smooth opening and closing operation of the gates. Figure 3 shows a pictorial view of the implemented system including the entrance and exit gates.

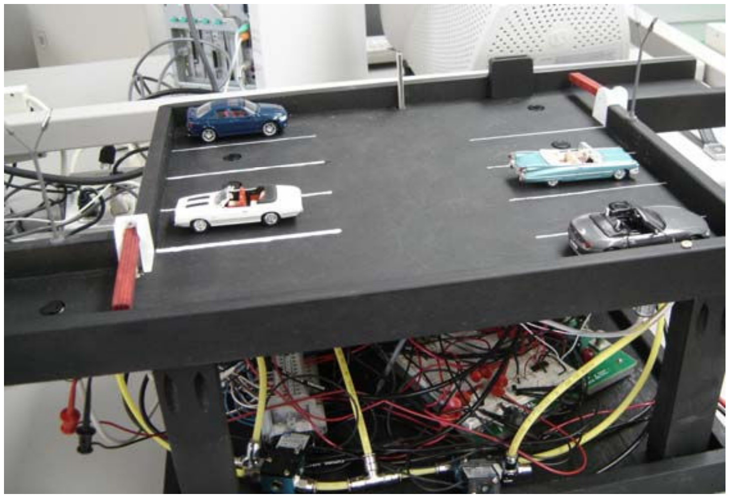


Figure 3 A pictorial view of the automated parking garage system.

All of the control logic was implemented in LabVIEW software. A view of the front panel display for the automated parking garage system is shown in Figure 4. The corresponding block diagram for implementing control logic functions is shown in Figure 5, whereas the subVI used to monitor the availability of parking spaces is shown in Figure 6. Major LabVIEW function blocks used are *case structure*, *sequence structure*, *for loop*, various array functions, string functions, and analog and digital I/O functions. The programming was relatively straight forward; however, a few timing issues were encountered and it took some time to get them resolved.

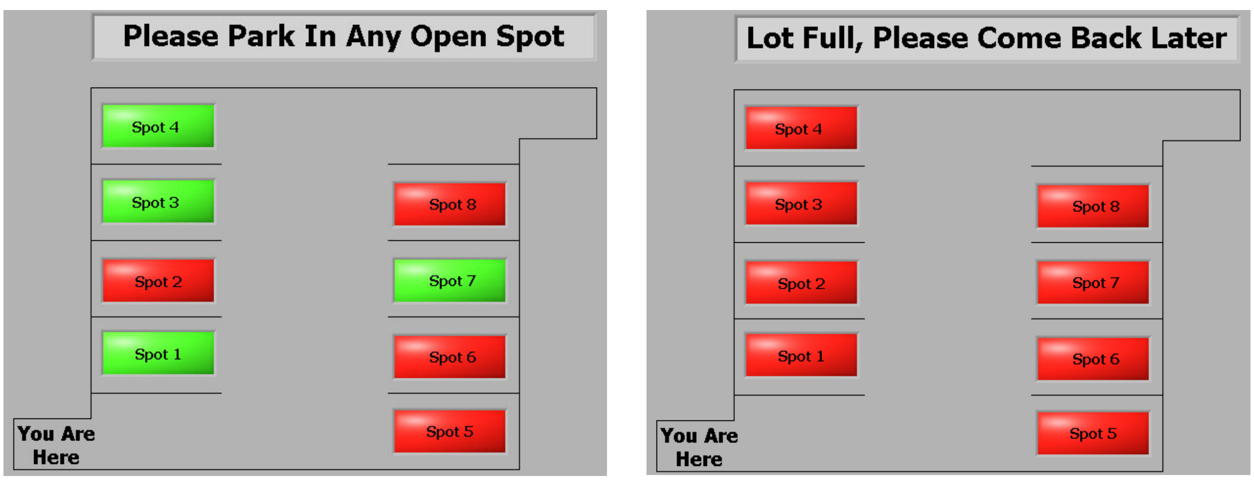
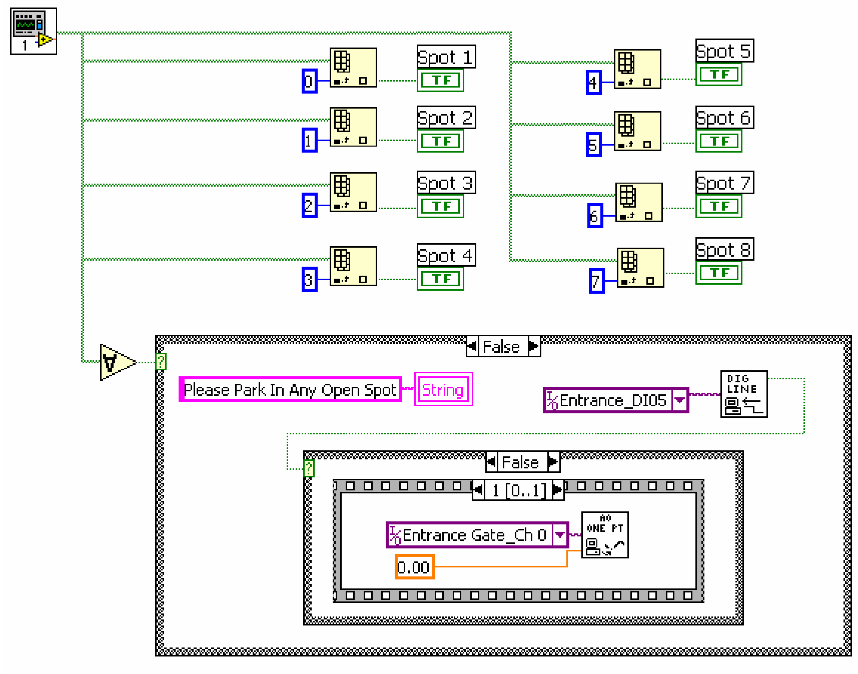


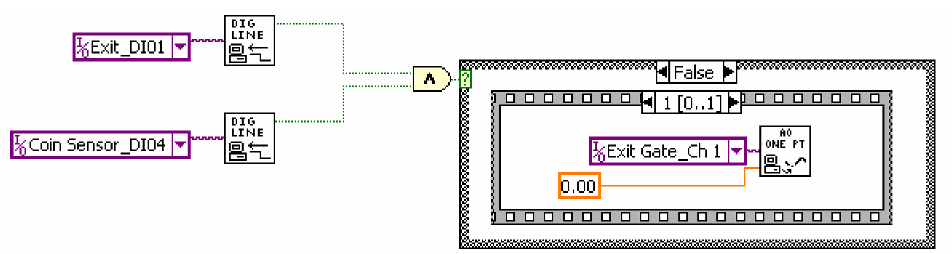
Figure 4 A front panel view of the display system.

In the area of hardware design, operation of entrance and exit gates didn't include the use of flow control devices in the original plan. During the testing phase, it was realized that an airflow control device is a must in getting the gates open and close in a smooth and acceptable manner. Also, the coin collection and release system design using an inductive proximity sensor took more time than originally expected primarily due to mechanical aspects of the design. Overall, the project progressed well and the final system worked without a flaw.

Parking spot scanner subVI



(a) Parking space availability and entrance gate control logic



(b) Exit gate control logic

Figure 5 LabVIEW implementation of parking garage control logic functions.

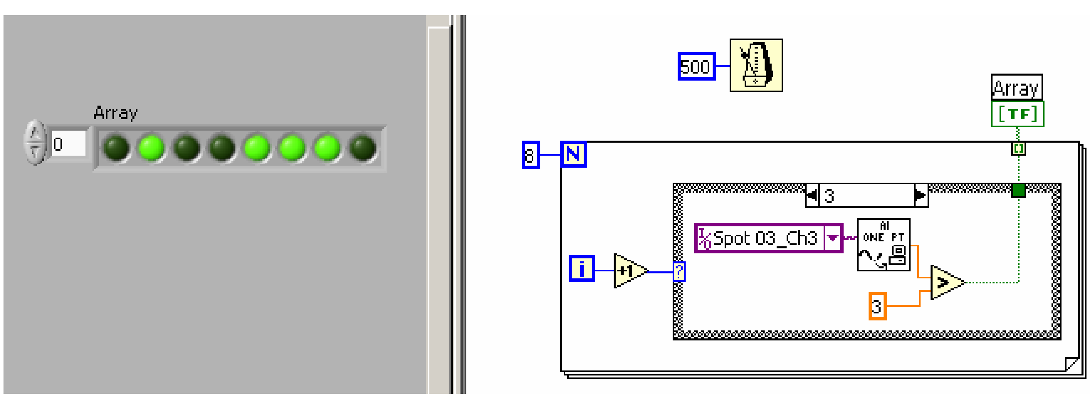


Figure 6 Parking spot availability scanner subVI.

Automated draw bridge control system

The focus of this project was to design and implement a draw bridge system that will rise when a ship approaches. The ship is detected using sensors which will in turn actuate motors to raise the toll bridge and control traffic lights for bridge traffic. A block diagram representation of the project is shown in Figure 7. Four photoelectric sensors[9] are used to detect an incoming ship, and the control program activates the green traffic light in the absence of an incoming ship. When the boat trips the second sensor, the green light is turned off and the yellow light is turned on. When the ship trips the third sensor, yellow light is turned off and the red light is turned on to stop traffic flow. The program is designed such that when the ship blocks the third and fourth sensors the motors are turned on for opening up the bridge. A pictorial view of the draw bridge system is shown in Figure 8. The bridge actuation drive system and the corresponding motor rotation reversal H-bridge circuit are shown in Figure 9.

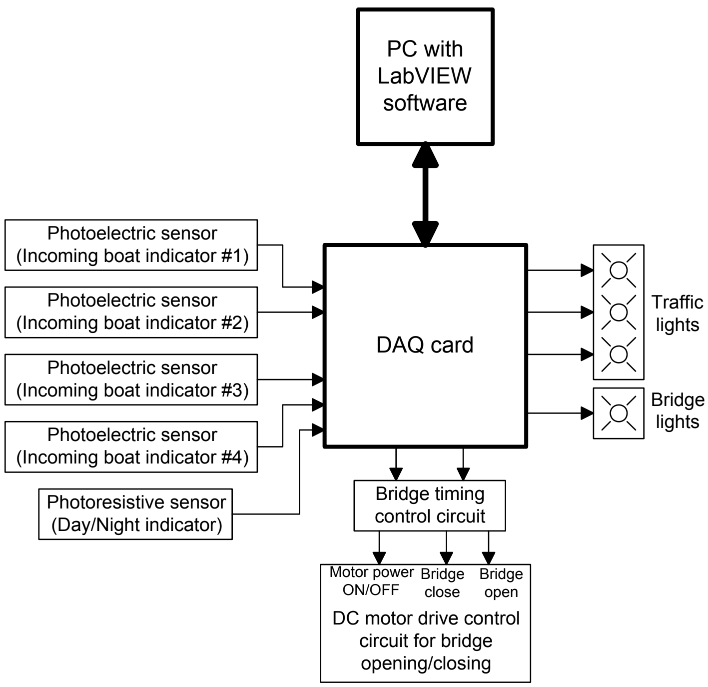


Figure 7 A block diagram representation of the draw bridge system.

Figure 8 A pictorial view of the implemented draw bridge system.

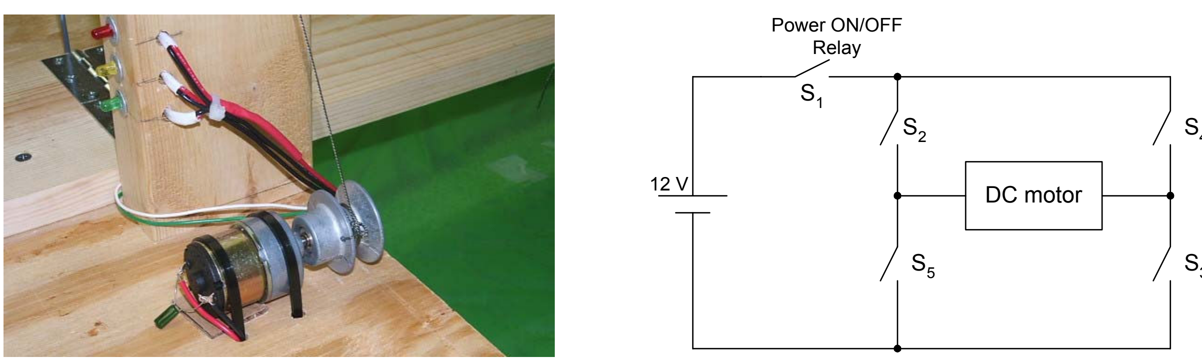


Figure 9 Pictorial view of the bridge actuation system (left) and the motor reversal circuit (right).

The implementation of the control logic is shown in Figure 10 which uses the Motor SubVI shown in Figure 11. This subVI runs on a sequence loop whereby one motor is slightly delayed from the other so that each part of the bridge can lay flat together when down. The motors are timed so that they run for 0.1 seconds which takes the bridge almost the whole way up. The program then waits for 15 seconds before the motors run in reverse. The bridge comes down and after a slight delay the red LED turns off and the green LEDs come back on. A completely independent set of input and output channel is used to control the bridge lighting system using calibrated photoresistor based day/night condition detection. The project was completed successfully even though resolving the timing issues between software and hardware took much more time and effort than originally planned for.

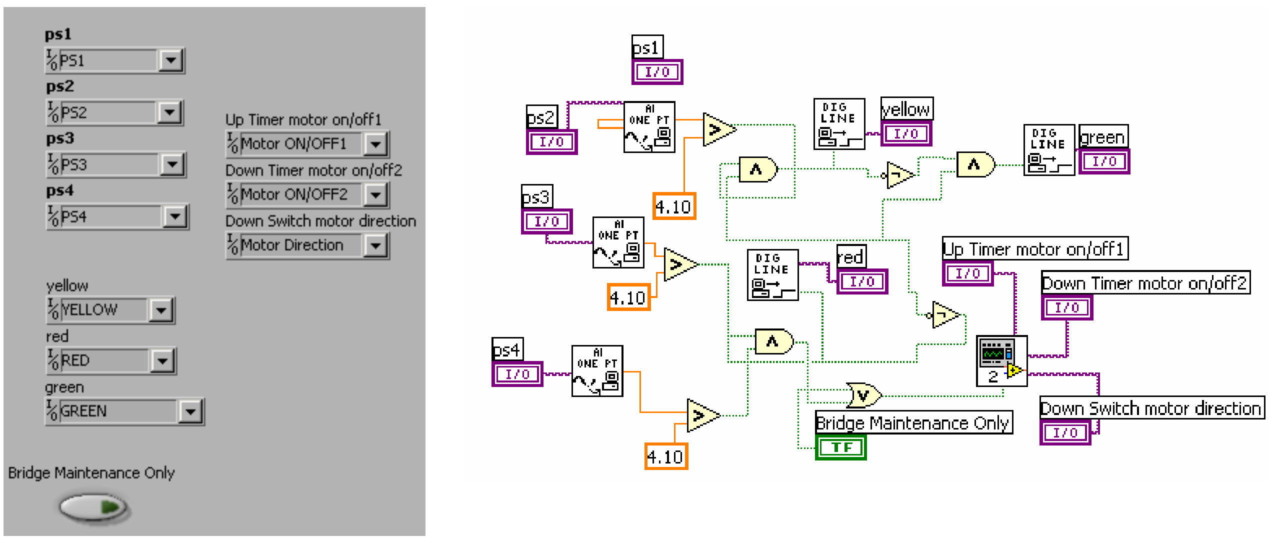


Figure 10 Implementation of the draw bridge control functions.

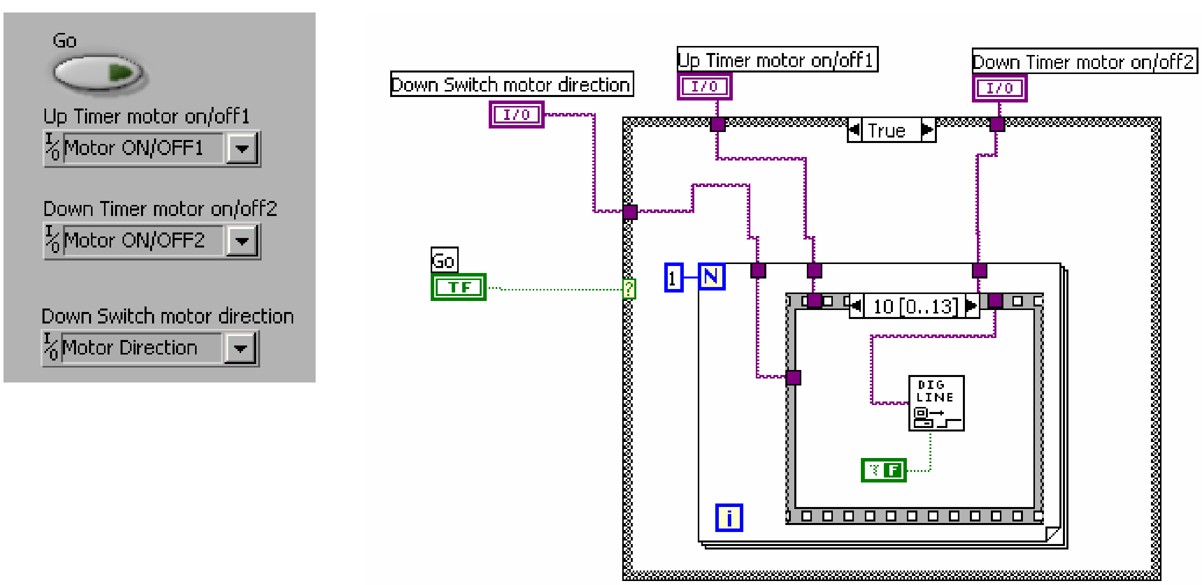


Figure 11 Motor subVI based on a sequence structure.

Intelligent traffic light controller

The goal of this project was to design an intelligent traffic light controller that will speed up or slow down light cycles to maximize traffic flow using traffic flow sensors. Additional features included are: pedestrian walk signal, automatic street lamp lighting system, and night time flashing operation to accommodate low traffic flow pattern. A block diagram representation of the complete system is shown in Figure 12; and pictorial views of the traffic light junction and control interfaces are shown in Figures 13 and 14, respectively. A total of six input signals were used: four photoelectric sensor[9] signals for traffic flow in N/S/E/W directions, one push-button switch signal for pedestrian walk request, and one photoresistor input for sensing calibrated day/night condition.

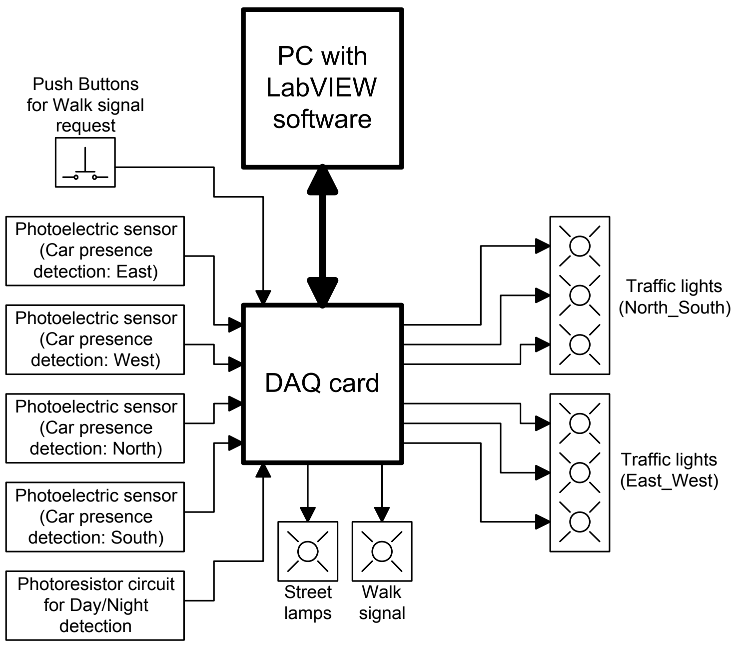


Figure 12 A block diagram representation of the traffic light controller.

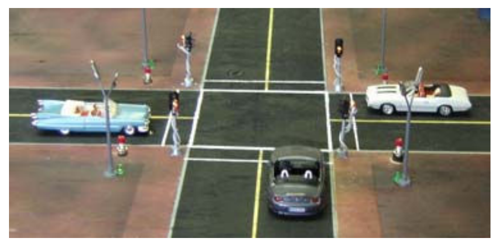


Figure 13 A pictorial view of the traffic light junction.

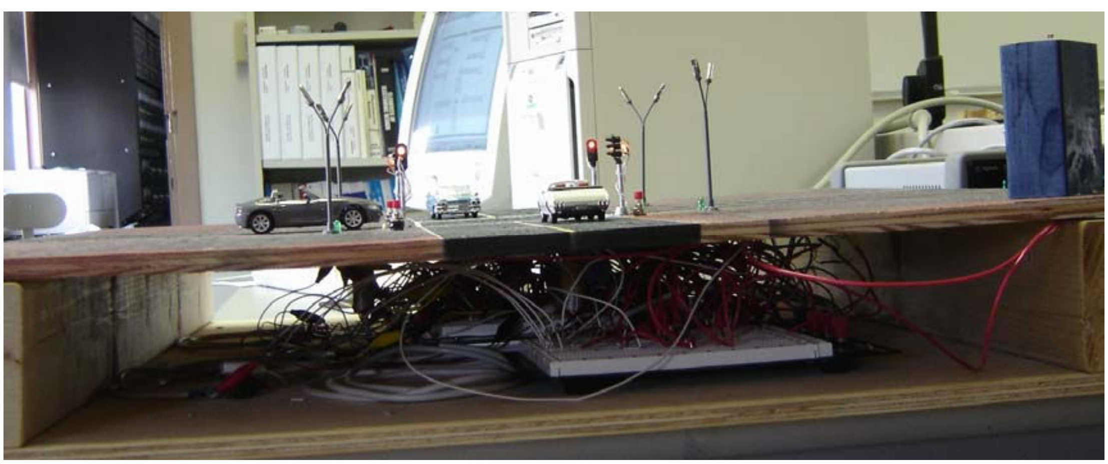


Figure 14 A pictorial view of the traffic light control interfaces.

There are a total of eight output signals from the DAQ card: six signals for traffic light control (three each for N/S and E/W directions), one for walk-signal light, and one for street lighting control. All of the control logic was implemented in LabVIEW software; a typical front panel display of the controller is shown in Figure 15 whereas the implementation of the control logic functions is shown in Figure 16.

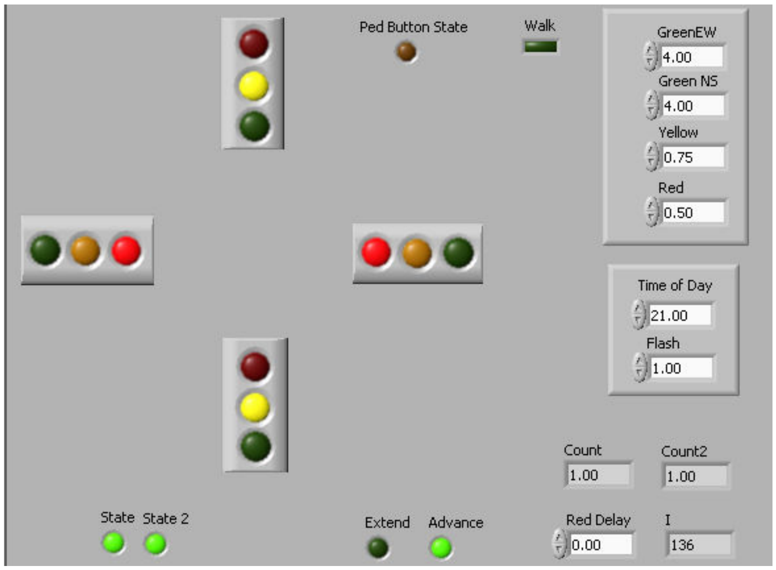
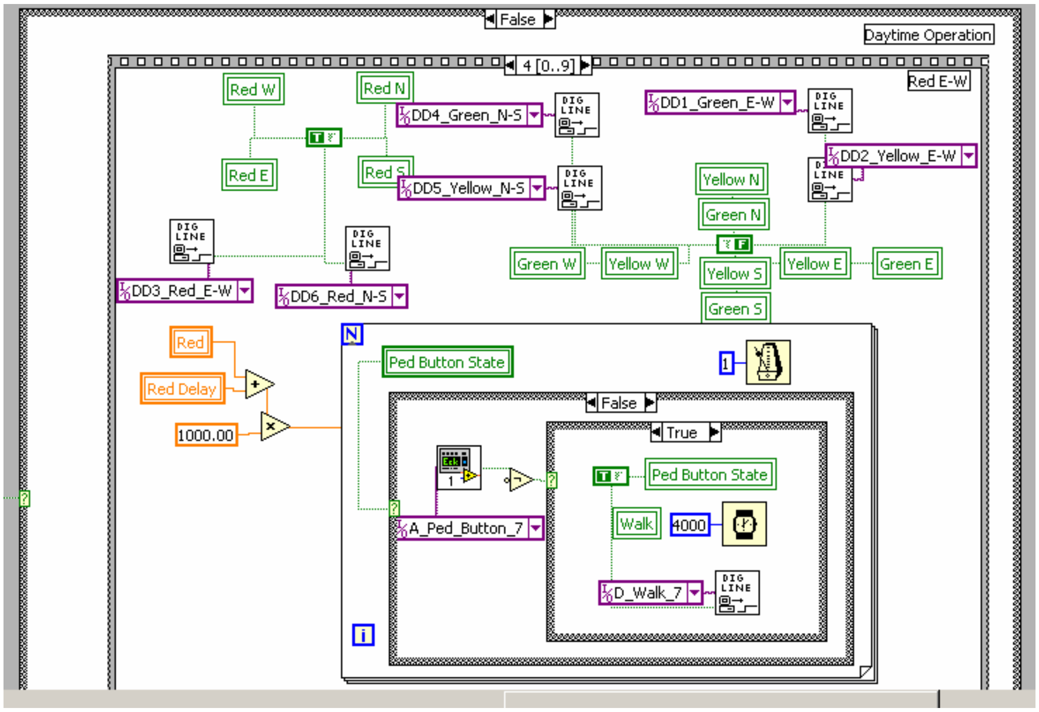


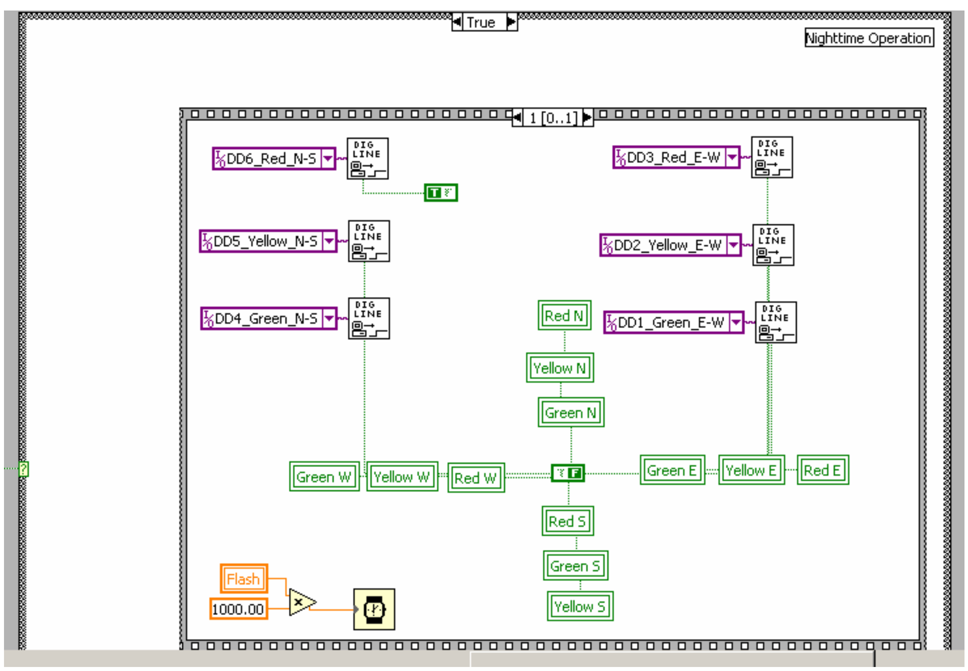
Figure 15 Front panel display of the traffic light controller.

The project started with a basic single-mode traffic light simulation using sequence structures to turn on and off the lights. The first feature added to the program was the pedestrian crosswalk button. Four push-buttons were used in parallel to generate a single walk request signal. Next feature added was sensing the traffic flow using four photoelectric sensors. East-West traffic was assumed to be the primary traffic such that the green lights for this road would be of extended duration if a heavy traffic flow is sensed while no cars are waiting in the North-South direction. A green light advance feature was also added for the cars waiting at a red light in the East-West direction when there is no traffic flow in the North-South direction. The third feature added was sensing the day/night condition using a photoelectric sensor to turn-on the street lights and switch over the program mode to flashing red/yellow under night condition. This mode was later modified to include a day time operation during the night time if the traffic flow increased above a predefined threshold. The timing issue was the problem that had to be resolved several times during the process of control logic development due to multiple *for loops* and *sequence structures* usage. In terms of hardware and interface development, no major problems were encountered. The final program and the designed hardware did work flawlessly with the features built-in as discussed above.

A useful feature that could have been added is an emergency vehicle mode. Sensing an incoming emergency vehicle, the controller would be able to stop traffic flow by turning on all of the red lights while letting the emergency vehicle go through. The program could then switch over to normal mode of operation.



(a) Daytime operation



(b) Nighttime operation

Figure 16 Control logic implementation of the traffic light controller.

Student feedback on project experience

The process of developing, implementing, and testing a project from scratch was an excellent experience for most students. The majority of students were pleased with the project structure, though a few suggested that the project duration within the instrumentation and data acquisition course be extended to at least five weeks instead of the currently allocated four weeks. Qualitative feedback from students is presented below through their comments.

- ✓ *Liked working with software and hardware integration*
- ✓ *Enjoyed working with partner*
- ✓ *Applying classroom knowledge to real-world situations was interesting*
- ✓ *Just getting to do a self-developed lab project was fun*
- ✓ *Very interesting course……making me lean towards computer-based automation career*
- ➢ *Reliance on partner was a problem*
- ➢ *Allocate more time to the coverage of interface electronics design*
- ➢ *Include some biomedical measurements application*

Summary

Experience with student-initiated projects within the instrumentation and data acquisition course is presented. A few students struggled at the beginning of the four week long project period in defining the scope of their work, as this was their first experience with project-based learning. It was also observed that many students had not had to design, debug and test a system that had multiple functional blocks in previous courses. Most students had difficulty breaking the design into functional modules and designing and testing them separately before putting them together. Improving student competence in this area will be incorporated at the next offering of projects. Overall, the experience has been very rewarding and challenging for the students as well as the instructor. More assessment data needs to be gathered to ensure that the defined learning and teaching objectives are met.

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