AC 2008-718: COMPUTER-CONTROLLED INSTRUMENTATION PROJECTS BY SOPHOMORE-LEVEL EET STUDENTS

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Computer-Controlled Instrumentation Projects by Sophomore-Level EET Students

Abstract
This paper presents student-initiated projects as part of an instrumentation and data acquisition course for sophomore-level electronics engineering technology students. Project objectives and associated assessment methodologies as well as general project management concepts are discussed. Two sample instrumentation projects reported in this paper are an automated street parking system and a computer-controlled bowling game system. Both 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 for prototype development. These end-of-semester course projects were carried out during the final four weeks of the semester after eleven weeks of lecture/laboratory session.

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 providing additional motivation for an instrumentation and data acquisition course[2] at the sophomore level of a four-year EET program. This course consists of two hours of lecture and three hours of laboratory per week. 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 devoted primarily 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 general approach to implementing end-of-semester course projects and associated assessment tools used to assess the project objectives. Technical details of two sample instrumentation projects, an automated street parking system and a computerized bowling game system, implemented during the spring-2007 semester are also presented.

Course project objectives and the associated assessment method

The learning and teaching objectives for the project experience are listed in the next page. A list of questions was prepared based on the stated objectives, and the survey was conducted at the end of second and fourth week of the four-week project experience as an indirect assessment tool. The results of the first survey was used to improve the project experience during the second half, and the results of the second survey is to be used to improve the next offering of the instrumentation project experience in spring-2008. Students are also assessed using direct assessment tools for teamwork, oral presentation, final report, successful operation and demonstration of the completed project, and design review meetings. Example rubrics used to assess teamwork and oral presentation are shown in *Appendices A* and *B*, respectively. Results of direct and indirect assessment instruments are archived for use as an input to the course continuous improvement process and also as part of display materials for program accreditation visits.

Project Learning Objectives	*Project Teaching Objectives*
• Gain experience in interpreting technical specifications and selecting sensors and transducers for a given application	• Foster discovery, self-teaching, and encourage desire and ability for life-long learning
• Understand terminologies associated with instrumentation systems	• Provide experience in designing instrumentation system based on specifications
• Gain experience in developing computerized instrumentation systems for industrial processes using multiple sensors, interface electronics, data acquisition hardware, and GPIB and serial instruments	• Develop soft skills including teamwork, open-ended problem solving, formal report writing and oral presentation

Project management

Early in the semester students start developing potential project topics with appropriate feedback and guidance from the instructor leading to a required pre-proposal submission by the fifth week of the semester. Upon approval of the pre-proposal, students are required to submit a formal proposal for a specific project topic by the ninth week of the fifteen-week semester. Use of a minimum of four sensors/transducers and four actuators is required as part of any project. The required proposal is quite detailed as it includes project implementation ideas supported by major outcomes and specifications, I/O interface drawing, circuit schematics, parts list with vendor and price information, LabVIEW program flow chart, and project completion schedule including a Gantt chart. An example student-generated Gantt chart is shown in *Appendix C*, prepared using *Vision Professional*. For implementation of the project, 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. Each group of two students is allocated a nominal budget of $200 for purchasing project-specific parts not normally available in the laboratory. Project deliverables include pre-proposal, proposal, preliminary design review, critical design review, final report, and a formal presentation. Student presentations and final reports are archived for use as part of the display materials for future accreditation visits.

Laboratory setup

Each station is equipped with a PC, and GPIB/RS-232 interfaced instruments such as digital multimeter, triple output laboratory power supply, arbitrary function generator, and two-channel color digital oscilloscope. The instrumentation and data acquisition specific software and hardware are briefly described below.

Software: LabVIEW 8.5 from National Instruments[7]

Data acquisition (DAQ) board: Model 6024E from National Instruments[8]

- 16 single-ended or 8 differential analog input channels, 12 bit resolution, 200 kS/s
- 2 analog voltage output channels, 12 bit resolution, 10 kHz update rate
- 8 digital I/O channels with TTL/CMOS compatibility; and Timing I/O

GPIB controller board:

- IEEE 488.2 compatible architecture (eight-bit parallel, byte-serial, asynchronous data transfer)
- Maximum data transfer rate of 1 MB/sec within the worst-case transmission line specifications

Signal conditioning accessory:

- Model SC-2075 from National Instruments
- Desktop signal breakout board with built-in power supplies, connects directly to 6024E DAQ board

Sample Project: Automated street parking system

The objective of the automated street parking system was to implement a prioritized parking system with prepayment and post payment options including a boot system for parking violators. For this street parking management system, three categories of cars are considered: resident, frequent, and visitor. A resident car can be parked for an unlimited amount of time without accruing any fines, a frequent car can be parked on a daily basis for a limited number of hours to be billed for parking fees on a biweekly basis, and a visitor car would need to pay upfront for parking. Additionally, activation of a boot system from under the street upon expiration of parking credit and/or other violations was an integral part of the system.

A block diagram representation of the I/O interface for the street parking system is shown in Figure 1 and a pictorial view of the system is shown in Figure 2. This prototype system consisted of three parking spots along a street. A total of eight analog inputs were used in implementing the system: three inputs for detecting the type of car, three inputs for parking spot availability status, one input for spot selection for prepayment, and an additional input for coin collection system. The coin collection system was based on an inductive proximity sensor[9] while the other seven input signals were based on simple voltage divider networks and/or photoresistors. An example voltage-divider based interface for prepayment spot selection is shown in Figure 3.

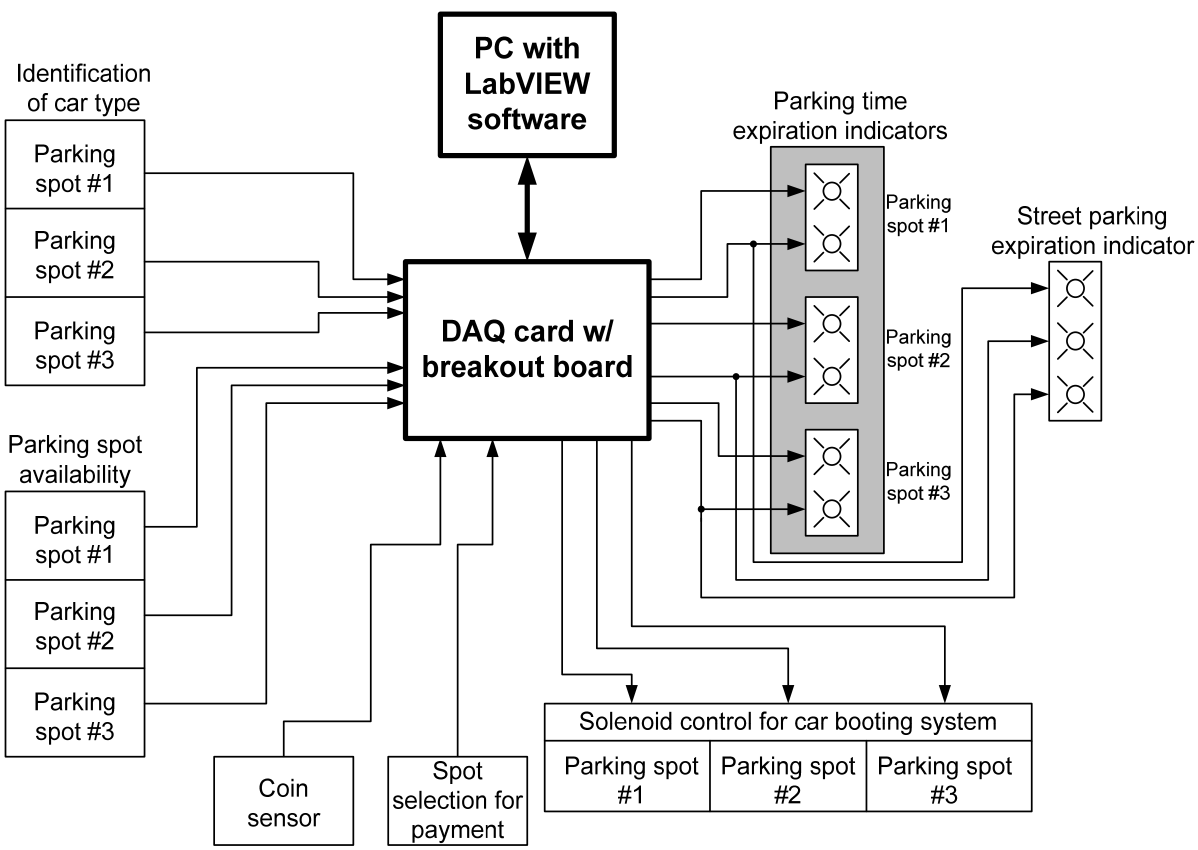

Figure 1: A block diagram representation of the I/O interface for the automated street parking system.

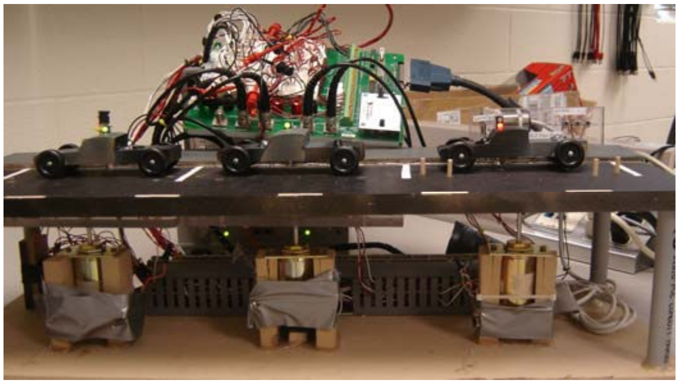

Figure 2: A pictorial view of the automated street parking system.

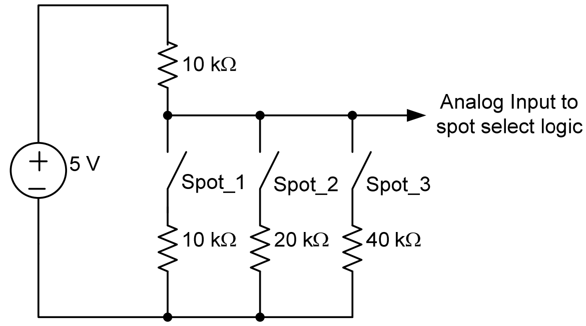

Figure 3: Implementation of the spot selection logic for prepayment.

The parking system used a total of nine outputs: six digital outputs for various parking status indicators and three analog (but used as digital) outputs for driving the solenoids for the boot system. In case of malfunctioning of the car type detection system for a given spot, the status light will turn red and draw attention of the police via the end of street display lights. This end of street display and the boot system get activated in case of an unpaid visitor car in a spot. For an activated boot deployment system, only the police personnel can release the boot system. After the car is removed from the spot, the system resets itself for the next car to be parked.

The control logic for this system was implemented in LabVIEW software. A typical front panel display for the automated street parking system is shown in Figure 4 and it includes status monitoring of the following subsystems: parking spot, boot activation, prepayment, coin collection, and prepaid parking timer. The corresponding block diagram for implementing the

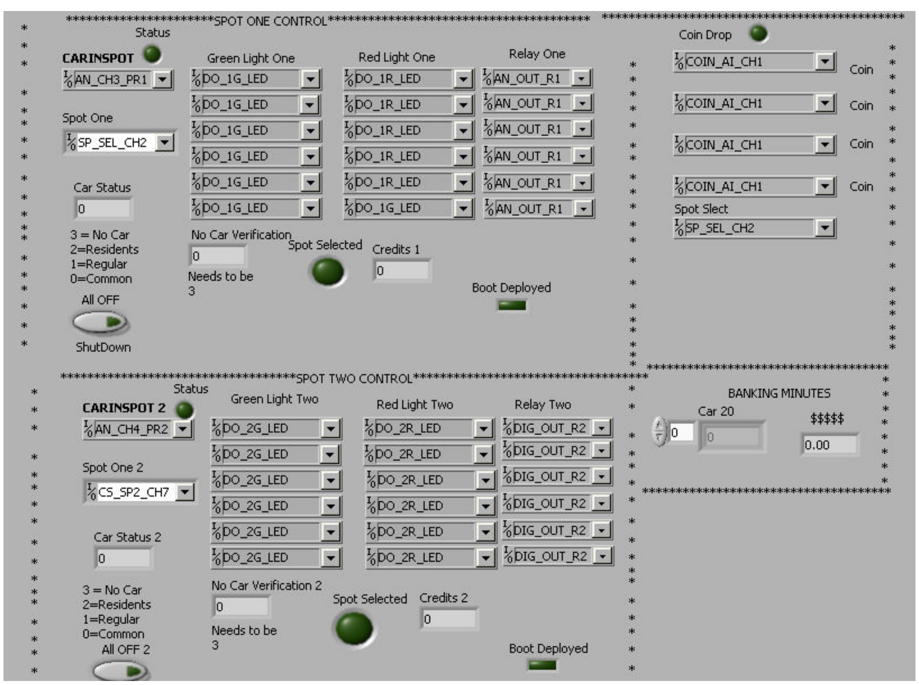

Figure 4: A typical front panel display of the automated street parking system.

parking spot logic functions are shown in Figure 5. The major LabVIEW function blocks used are case structure, sequence structure, for loop, subVIs, local variable, various array and string functions, and analog and digital I/O functions. The programming was relatively straight forward; however, a few timing issues encountered took a great deal of debugging effort in getting them resolved.

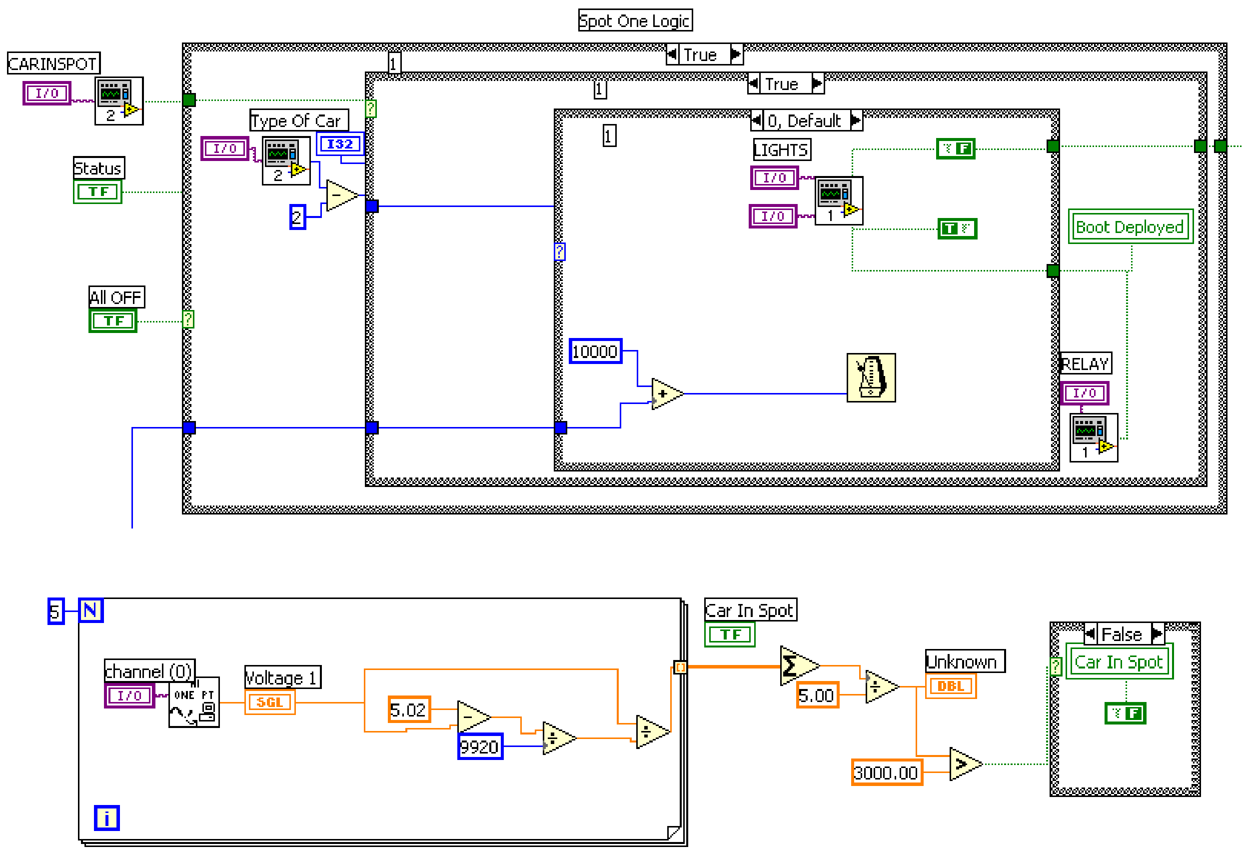

Figure 5: A partial view of the parking spot logic implementation in LabVIEW environment.

In terms of major problems encountered during the implementation of this project, the initially purchased non-latching solenoids didn't work out due to maximum on time limitation. Additionally, their lift force wasn't sufficient for the application. This problem was resolved by using continuous-time tubular solenoids capable of providing sufficient lift force. The timing issue with the coin collection system was resolved by implementing two inputs: an inductive proximity sensor for coin detection and a separate spot selector switch for the visitor. Overall, the project was completed successfully and it provided an opportunity to define and specify a given application incorporating hardware and software integration. Ability to resolve unexpected problems and good time management skills were of critical importance in getting the project completed in a timely manner.

Sample Project: Computer-controlled tabletop bowling game system

The goal of this project was to design and implement an automated tabletop bowling game system under complete control of a computer. The system included the ball launching, scoring, ball return, and ball pickup/launch positioning subsystems. A block-diagram representation of the I/O interface and a pictorial view of the complete system are shown in Figures 6 and 7, respectively. The ten inputs to detect the status of the pins are implemented using ten photoelectric sensors[10] placed underneath each pin location. The ball launching and ball return solenoids are controlled by two independent digital output signals. Finally, the linear track based ball pickup/launch positioning system is controlled by two digital output signals (one for forward and the other for reverse movement). Most of the interface electronics for I/O signals are based on discrete components such as transistors and relays. As an example, Figure 8 shows the circuit schematic for controlling the forward/reverse positioning of the linear track based ball pickup/launch subsystem. The linear track actuator[11] uses a 24 V permanent magnet DC motor and provides a nominal linear speed of 0.5 inch/sec, and the 12 VDC non-latching solenoids used for ball launching and return provided sufficient force for proper operation of the system.

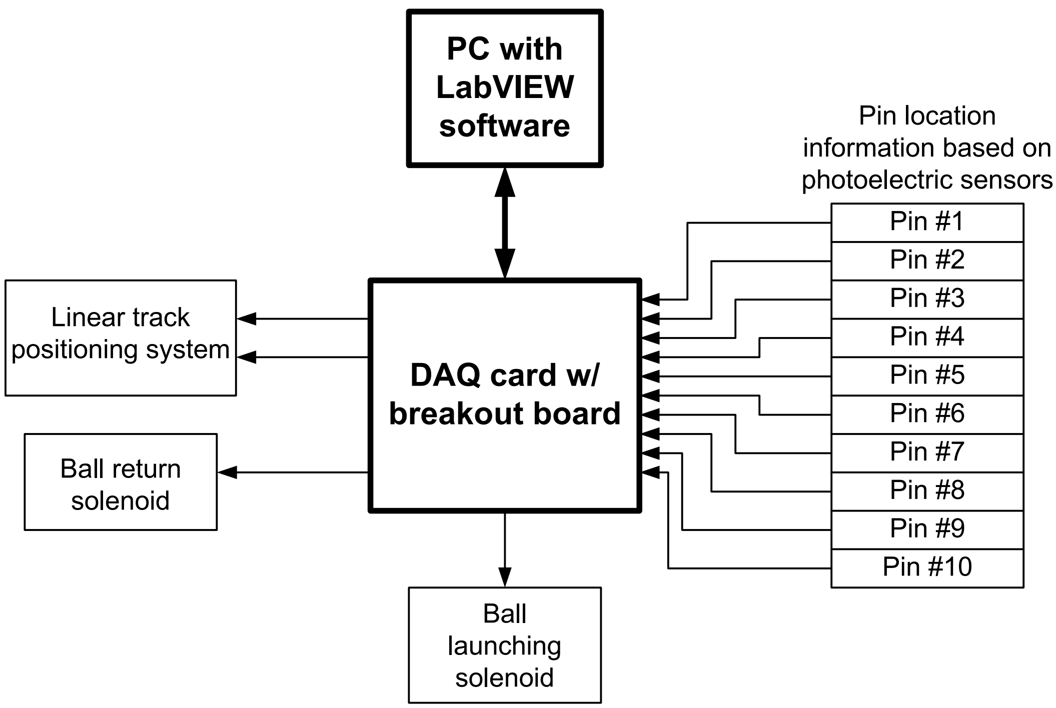

Figure 6: A block diagram representation of the I/O interface for the computer-controlled tabletop bowling game system.

A front panel display of the scoring system is shown in Figure 9. The LabVIEW program keeps the score for an entire game of ten frames, and scoring for each frame necessitated the use of roughly ten sequence structures; one such structure is shown in Figure 10. Use of sequence structures allowed easy adding of score from one frame to that of the next one and helped implementing a scoring system similar to that of professional bowling. Strikes and spares were also integrated into the scoring system.

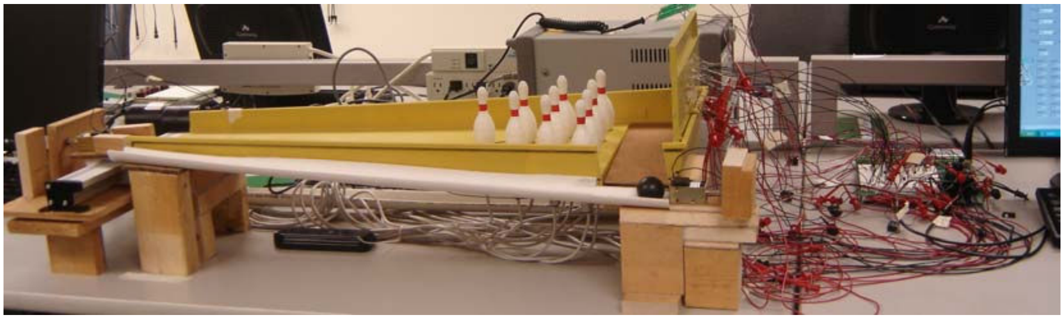

Figure 7: A pictorial view of the tabletop bowling game system.

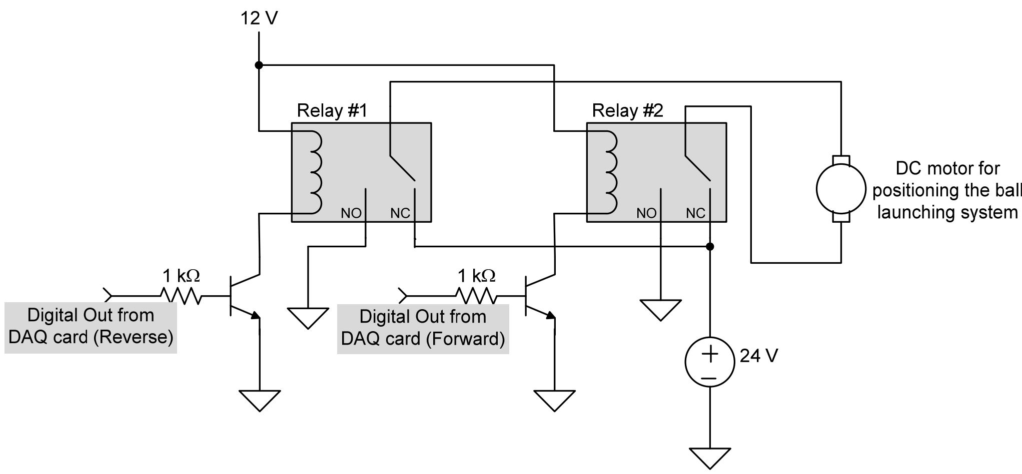

Figure 8: Circuit schematic for forward/reverse control of the linear track positioning system.

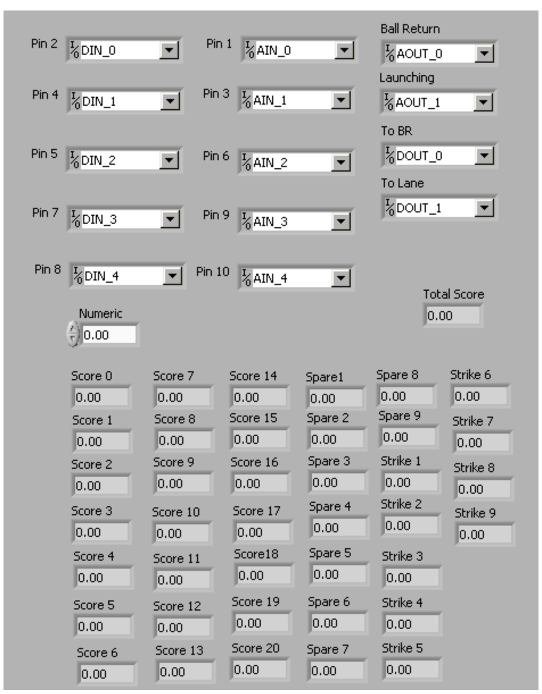

Figure 9: A typical front panel display of the tabletop bowling game system.

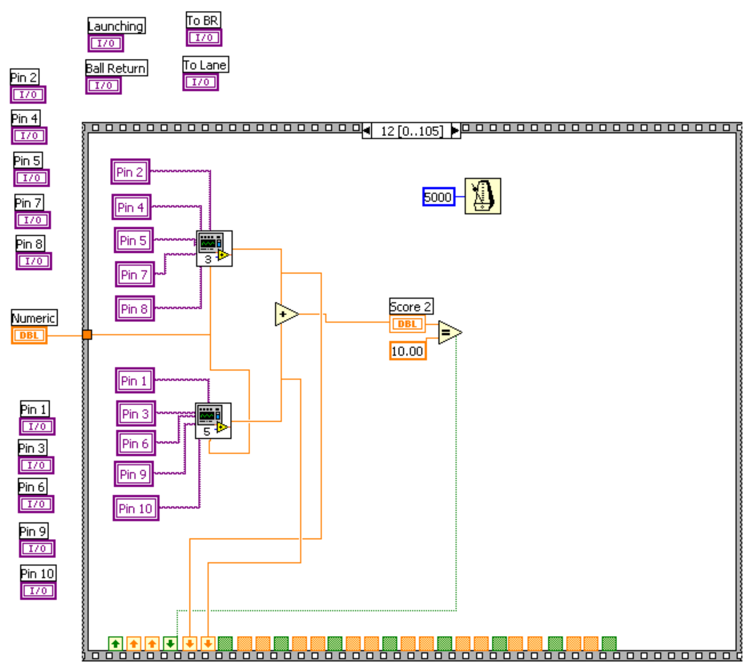

Figure 10: A partial view of the scoring system block diagram for the bowling game system.

As shown in Figure 11, if there is a strike rolled then there will be no second roll in the frame, thus the outer case structure will be true and the ball will be returned to the center of the lane. If a strike is not bowled then LabVIEW will compare whether the number of digital inputs is less than or equal to the analog input. The timing for positioning of the solenoid will then adjust to move the solenoid to one side of the lane or the other to produce the highest score with the next roll.

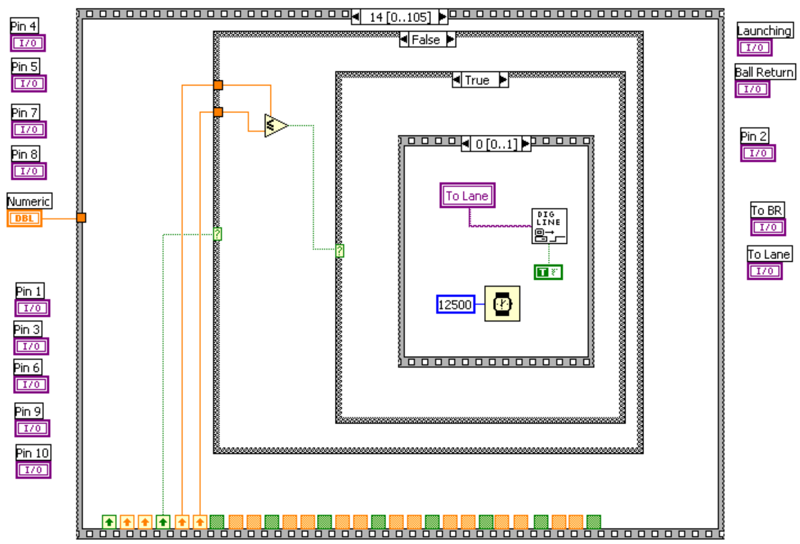

Figure 11: A partial view of the scoring system in case of a strike for the bowling game system.

The major problem encountered in implementing the bowling game system is the timing coordination among various subsystems such as the scoring system, ball launching and return solenoids actuation, and linear track positioning for ball pickup and release. The different positioning requirement for the linear track between first and second strikes made the logic implementation challenging. A lot of testing for various striking and scoring conditions provided useful inputs to the development process of an effective algorithm. The project was completed successfully even though resolving the timing issues between software and hardware took a much closer look and more effort than originally planned for.

Student feedback on the course 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 management structure, though a few suggested that the project duration within the instrumentation and data acquisition course be extended to 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*
- ✓ *Taking ownership of the project was a great experience*
- ✓ *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*
- ➢ *Need to 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 was presented. A few students struggled in defining the scope of their work at the beginning of the four-week project period since this was their first project-based learning experience. It was also observed that many students had not had to design, debug and test a system that had multiple functional blocks in their prior coursework. This contributed to students' difficulty in breaking the design into functional modules and designing and testing them separately before putting them together. Improving student competence in this area will be a goal for the next offering of the course. Overall, the experience has been very rewarding and challenging for the students as well as the instructor. Additional assessment data are being collected to ensure that the defined learning and teaching objectives are met.

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Appendix A: Teamwork Evaluation Rubric

Bloomsburg University of Pennsylvania
Electronics Engineering Technology (EET) Program

Teamwork Evaluation for *58-241 (Electronic Instrumentation and Data Acquisition)*

Instructor: ___________________

Title of Work: *End-of-semester course project*

Student Team Members: ____

Project Title: ____

Semester: *Spring-2007* Date: *May xx, 2007*

Skills	Criteria			Performance
	10 9 8	**7 6 5**	**4 3 2**	
Participating: The instructor observed each student contributing to the project	Almost all of the time	Most of the time	Some of the time	
Persuading: The instructor observed the students exchanging, defending, and rethinking ideas	Almost all of the time	Most of the time	Some of the time	
Questioning: The instructor observed the students interacting, discussing, and posing questions to members of the team	Almost all of the time	Most of the time	Some of the time	
Sharing: The instructor observed the students offering ideas and reporting their findings to each other	Almost all of the time	Most of the time	Some of the time	

Instructor Comments:

Appendix B: Oral Presentation Evaluation Rubric

Bloomsburg University of Pennsylvania
Electronics Engineering Technology (EET) Program

Oral Presentation Evaluation for *58-241 (Electronic Instrumentation and Data Acquisition)*

Instructor: ____________________ Title of Work: *End-of-semester course project*

Student Team Members: ____

Project Title: ____

Semester: *Spring-2007* Date: *May xx, 2007*

Skills	Criteria			Performance
	10 9 8	**7 6 5**	**4 3 2**	
Organization	Student presents information in a logical and interesting sequence which audience can follow	Student presents information in a logical sequence which audience can follow	Audience has difficulty following presentation because student jumps around	
Content Knowledge	Student demonstrates full knowledge (more than required) with explanations and elaboration	Student is at ease with content, but fails to elaborate	Student is uncomfortable with information and is able to answer only rudimentary questions	
Delivery	Student used a clear voice, and technical terms correctly; used multimedia techniques very efficiently	Student's voice is clear, and used most technical words correctly; used multimedia techniques efficiently	Student used technical terms incorrectly and multimedia techniques inefficiently; and audience members have difficulty hearing presentation	

Instructor Comments:

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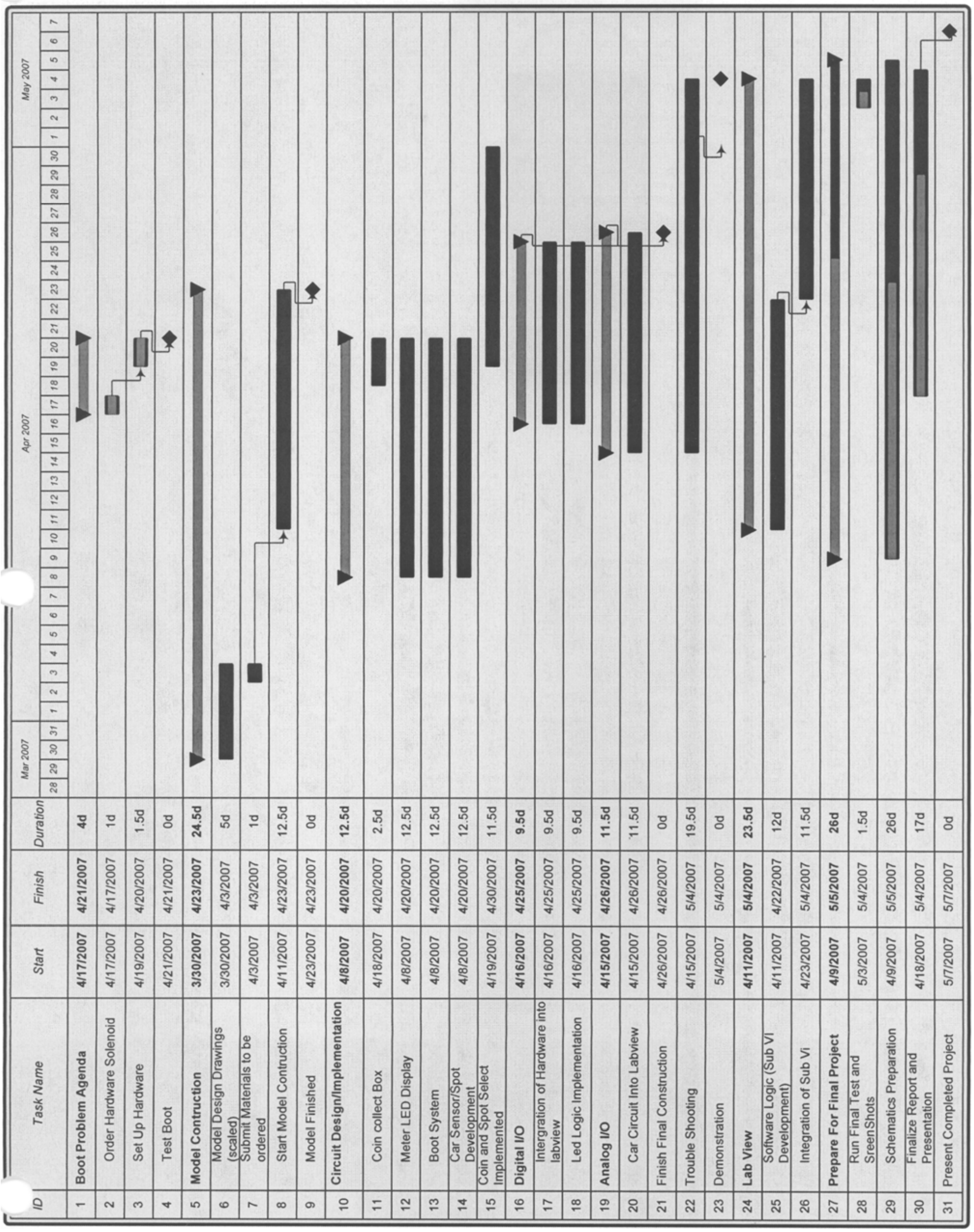
Appendix C: An Example Student-Generated Gantt Chart



ID	Task Name	Start	Finish	Duration
1	**Boot Problem Agenda**	**4/17/2007**	**4/21/2007**	**4d**
2	Order Hardware Solenoid	4/17/2007	4/17/2007	1d
3	Set Up Hardware	4/19/2007	4/20/2007	1.5d
4	Test Boot	4/21/2007	4/21/2007	0d
5	**Model Contruction**	**3/30/2007**	**4/23/2007**	**24.5d**
6	Model Design Drawings (scaled)	3/30/2007	4/3/2007	5d
7	Submit Materials to be ordered	4/3/2007	4/3/2007	1d
8	Start Model Contruction	4/11/2007	4/23/2007	12.5d
9	Model Finished	4/23/2007	4/23/2007	0d
10	**Circuit Design/Implementation**	**4/8/2007**	**4/20/2007**	**12.5d**
11	Coin collect Box	4/18/2007	4/20/2007	2.5d
12	Meter LED Display	4/8/2007	4/20/2007	12.5d
13	Boot System	4/8/2007	4/20/2007	12.5d
14	Car Sensor/Spot Development	4/8/2007	4/20/2007	12.5d
15	Coin and Spot Select Implemented	4/19/2007	4/30/2007	11.5d
16	**Digital I/O**	**4/16/2007**	**4/25/2007**	**9.5d**
17	Intergration of Hardware into labview	4/16/2007	4/25/2007	9.5d
18	Led Logic Implementation	4/16/2007	4/25/2007	9.5d
19	**Analog I/O**	**4/15/2007**	**4/26/2007**	**11.5d**
20	Car Circuit Into Labview	4/15/2007	4/26/2007	11.5d
21	Finish Final Construction	4/26/2007	4/26/2007	0d
22	Trouble Shooting	4/15/2007	5/4/2007	19.5d
23	Demonstration	5/4/2007	5/4/2007	0d
24	**Lab View**	**4/11/2007**	**5/4/2007**	**23.5d**
25	Software Logic (Sub VI Development)	4/11/2007	4/22/2007	12d
26	Integration of Sub Vi	4/23/2007	5/4/2007	11.5d
27	**Prepare For Final Project**	**4/9/2007**	**5/5/2007**	**26d**
28	Run Final Test and SreenShots	5/3/2007	5/4/2007	1.5d
29	Schematics Preparation	4/9/2007	5/5/2007	26d
30	Finalize Report and Presentation	4/18/2007	5/4/2007	17d
31	Present Completed Project	5/7/2007	5/7/2007	0d