Use of Digital Systems Fundamentals to Teach Design in a Freshman Engineering Design and Graphics Course

Author:

Sohail Anwar, Penn State University, Altoona College, Altoona, PA, sxa15@psu.edu

Abstract *– ED&G 100 is an introduction to engineering de sign course for all freshman baccalaureate degree engineering students at the Altoona College of the Pennsylvania State University. This three credit -hour course consists of three components. The first component of ED&G 100 introduces students to computer application skills using CAD. The second component deals with manual graphic and drafting skills. The third component of this course emphasizes team -based engineering design. This paper presents a detailed description of the design component of ED&G 100. T he paper also presents description of an assessment tool used to measure the effectiveness of the instructional approach used to teach the design component of ED&G 100.*

Index Terms *– Digital Systems, Engineering design, Freshman engineering, Problem solv ing.*

INTRODUCTION

Engineering design is the communication of a set of rational decisions obtained with creative problem solving for achieving certain stated objectives within prescribed constraints [1]. The use of engineering design projects provides students with a broad context to the material presented in the lectures [2]. Engineering design engages both the intellect and the imagination of the designer.

INTRODUCTION TO ENGINEERING DESIGN AT ALTOONA COLLEGE

ED&G 100 is a project-based introduction to engineering design course for all freshman baccalaureate degree engineering students at the Altoona College of the Pennsylvania State University. In this three credit-hour course, an engineering approach to problem solving is taught with an emphasis on team work, communication, creativity, ingenuity, and computer-aided design tools. Upon completion of this three credit-hour course, students should be able to:

- Use computer software packages to assist and document the design procedure.
- Communicate effectively through oral and written presentations.
- Demonstrate basic lab work skills such as data collection, report writing, and teamwork.
- Carry out the design process from problem statement to final design.

ED&G 100 consists of three components with each component meeting for a single two-hour period once every week.This gives a total class meeting time of six hours per week. This gives a total class meeting time of six hours per week for fifteen weeks. The first component of ED&G 100 introduces students to computer application skills using CAD. It also develops student design competencies in the topical area of communication. Topics covered include internet navigation, website design, word processing, MS Power Point presentations, and computer aided design and drafting using AutoCAD.

The second component of the course deals with manual graphic and drafting skills. Students are introduced to the fundamentals of orthographic projection. The topics covered include multi-view projection, dimensioning, lettering, oblique and isometric projection, sectional views, tolerances, scales, and selected topics in descriptive geometry.

The third component of ED&G 100 focuses on team-based engineering design. Several mini-projects have been developed to teach the design component of ED&G 100. These mini-projects are designed to introduce students to the basic concepts of electrical and electro-mechanical engineering. The focus of most of the mini-projects is digital electronics.

Topical areas taught in digital electronics include combinational logic circuits, minimization of logic functions, and digital system design. Completion of a team-based major design project is an essential requirement. The major design project allows students to pull together previously learned concepts to design, build, and test a digital system in order to control a material handling process. In addition, there are several team presentations, lectures, exercises, and case studies presented throughout the semester.

DESIGN COMPONENT OF ED&G 100

Over the past several decades, digital systems have been incorporated into many different types of products [3]. Most modern industrial machinery and many commercial products are controlled by some type of digital system. Due to the proliferation of digital systems, it is important for all engineering students to develop conceptual knowledge and practical experience in digital system design. The digital systems concepts covered in the design component of ED&G 100 are integrated into several mini projects conducted by students. The specific outcomes associated with these mini projects are as follows:

1. Students will understand the Boolean algebra and Karnaugh map (K-map) method
2. Students will understand the operation of logic gates.
3. Students will be able to analyze and design combinational digital circuits.
4. Students will understand the operation of flip-flops, registers, and counters.

In order to achieve the above-mentioned outcomes, students conduct the following mini projects involving digital systems:

1. Interpretation of Data Specification Sheets – students learn how to use data specification sheets of digital integrated circuit (IC) chips provided on the internet by IC chip manufactures such as Texas Instruments
2. Testing of Digital Logic Gates – students learn how to test basic digital logic gates (OR, AND, NOR, NAND, XOR, NOT,and NXOR) using logic probes and IC chip data specification sheets.
3. Design and Construction of a Combinational Digital Logic Circuit – students learn how to use digital logic gates and DIP switches to design and build a digital burglar alarm system.
4. Additional Practice in Design and Construction of a Combinational Digital Logic Circuit – students are logic probes, digital logic gates, light emitting diodes (LEDs), and DIP switches to design and construct a simple chemical process control system.
5. Minimization of Digital Logic Functions – students use logic function minimization techniques to design and build a digital control system for a lumber cutting machine.
6. Design and Construction of Timing and Waveshaping Circuits – students use 555 timers and various electronic components to design and build timing and waveshaping circuits such as monostable and astable multivibrators.
7. Design and Construction of Counters – students use flip-flops to design and construct various digital counters.

All the mini projects are conducted by students in teams. Students are required to demonstrate competency in skills such as effective communication, report writing, team presentations, use of appropriate computer software packages, and engineering design.

MAJOR DESIGN PROJECT FOR ED&G 100

In addition to the mini projects, students conduct a major design project to meet ED&G 100 course requirements. The major design project involves design and construction of a digital system to control a material handling system. A description of this engineering design problem is as follows:

A conveyor system brings raw material in from 3 different sources. The 3 sources converge into a single output conveyor. Sensors mounted adjacent to each source conveyor indicate the presence of raw material. All four conveyors have separate motors so they can be individually controlled. Each source conveyor can have a different speed. The output product flow rate is fixed; it can be turned only on or off. The output product rate must match the source conveyors' flow rates. To accomplish this objective, the following conditions must be met. If source 1 has product, then sources 2 and 3 must be turned off; if source 1 is empty, then either 2 or 3 or both can be turned on. In the event that no product is available from the 3 sources, the output conveyor must be turned off. If no product is available, the respective source conveyor must be turned off.

For the engineering design problem listed above, student teams are asked to:

1. Identify input and output binary variables

2. Develop a truth table.
3. Develop a switching equation from the truth table.
4. Simplify the switching equation using K-maps.
5. Using AUTOCAD, develop a logic diagram.
6. Using AUTOCAD, develop an IC CHIP diagram.
7. Using an appropriate computer software, develop a picture of this industrial process which shows all the elements of the process. For example, show the conveyor system, motor, sensors, etc. From your previous learning experience, recommend suitable sensors for the industrial processes mentioned below.
8. Using appropriate hardware, implement the IC chip diagram developed in 6.
9. Test the hardware implemented above.

Students are required to work on the major project in teams of 2 individuals each. Student teams are required to implement the project design on a bread board. The project must be tested for functionality before it is submitted to the course instructor.

COURSE ASSESSMENT

During Spring 2004 semester, a questionnaire was administered to ED&G 100 students at the Altoona College of Penn State University. The objective of the questionnaire was to obtain students' comments regarding the quality of instruction delivered by the course instructor in support of the design component of ED&G 100. The questionnaire consisted of three subjective items:

1. What did you like best about the course?
2. What did you like least about the course?
3. What suggestions do you have for improving the course?

Summarizing students' comments regarding the instructional approach used to teach ED&G 100 course during Spring 2004, it appears that they liked the hands-on- mini-projects conducted by them. Students also liked conducting the major design project. Most of the suggestions for the improvement of ED&G 100 called for allotment of additional laboratory time for the completion of final/major design project.

CONCLUSION

The use of digital systems fundamentals to teach engineering design to freshman engineering students was introduced for the first time in ED&G 100 course in Spring 2004 semester. This instructional approach was well received by ED&G 100 students. This approach will be used again in the Fall 2004 and Spring 2005 semesters to teach engineering design in the design component of ED&G 100 course.

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