ORGANIZATION OF A CAPSTONE DESIGN COURSE

Glenn K. Heitman and Rachid Manseur[1]

Abstract *The approach to engineering design varies from one school to the next but all engineering programs understand and emphasize the importance of design in their curriculum. This article presents an approach to a capstone senior design course that strives to duplicate a real industrial design project experience for the students. Accordingly, team projects are favored and encouraged, and students are held to strict project specifications, deadlines, and deliverables.*

INTRODUCTION

Experience in engineering design is an important part of engineering education. Many different approaches to design education exist and are implemented in one form or another in every engineering school. Design is often a part of several courses in the curriculum that include assignments that are in fact small design problems. The importance of design is such that additional design courses are sometimes offered as electives to improve the students' training and experience [1] [2].

The objective of a Capstone Design Course is to provide an opportunity for the student to clearly demonstrate an ability to integrate the engineering knowledge gained from undergraduate coursework, and to provide a practical solution to an engineering problem. The ability to start, design, and develop a product is what most engineering employers are looking for in their engineers.

At the University of West Florida, the Electrical and Computer Engineering Program was established in January 1994. The development of an entirely new electrical engineering program provides a unique opportunity to improve on established courses. The faculty of the program decided to establish a course that provides students with a senior design experience that closely matches an equivalent project in industry. In other schools, the level of organization of the senior design course varies from a simple agreement between a student and a faculty member to an elaborately organized class in which a project is agreed upon by the whole class and teams of students all work on the same project. The faculty of Electrical and Computer Engineering Department at UWF took a middle-of-the-road approach, as explained below. It should be pointed out that the ECE Department at UWF is small—there are six faculty and approximately ninety undergraduate students. On average, 10–15 students are enrolled in the design course during any term. One reason that the UWF design course is organized as described in the next section is that it *can* be so organized in a small department.

THE UWF DESIGN COURSE

In general, a minimum of two faculty is involved with every project. One faculty member serves as the design course coordinator, whose duties are to maintain the evaluation paperwork for each project, establish the design calendar for the semester, and serve as second examining faculty member on all project reviews. The second faculty member is the students' chosen project mentor. The main features of the UWF design course are:

Project selection. Students have freedom to choose projects of interest to them, with guidance from the faculty if needed. Initial project selection starts with a discussion with a faculty mentor chosen by the student. Most often students address a faculty member known to have expertise in the area of the project they have chosen. Once a project is pre-approved by the faculty mentor, it is presented by the students at a preliminary design review to the whole department faculty and to all other students enrolled in the senior design course. The brief presentation is followed by a questions and answers period. The department faculty discusses each project, and changes to the project topic are often suggested to insure that the project is of suitable breadth and complexity.

Industry-based projects. Many ECE students at UWF participate in the university's cooperative education program; occasionally students working for an engineering company suggest topics that are relevant to their work or present an interest to their employers. Industry-based projects of the type described in [1], in which students work in teams on an industrial project sponsored by a company are allowed. In such cases, the faculty may request that a company representative be present at the project discussion to ascertain the level of company sponsorship and to insure availability of company resources and support for the project.

In some Engineering Schools, the Capstone Design Course is successfully organized primarily through Industrial partnerships as described in [3]. One drawback of industry-based projects is that a large part of the design project control is taken from the faculty and given to the industry

[1] Electrical and Computer Engineering, University of West Florida, Pensacola, FL 32514

0-7803-6424-4/00/$10.00 © 2000 IEEE **October 18 - 21, 2000 Kansas City, MO**
30th ASEE/IEEE Frontiers in Education Conference

sponsoring the project. There have been cases where such projects ran into difficulties caused by the company's inability to provide equipment or support as promised.

Team projects. Students are encouraged to work in teams of two to four students but solo projects are allowed. The preference for team projects originates in the fact that real industrial projects are most often completed by engineering teams and very rarely by a lone designer. Another major reason is the Accreditation Board for Engineering Technology (ABET) requirement that engineering programs must demonstrate student exposure to teamwork.

Project schedule. It is always recommended that students start thinking about a project topic during the semester preceding the senior design course enrollment. Preliminary discussions with a faculty advisor insure some level of suitability of the project and a prior commitment from a faculty member to be a mentor for the project.

The students are generally advised to complete our Microprocessor Applications and Advanced Electronics courses before attempting the design course—most projects involve a combination of circuit design and microprocessor programming and interfacing.

An important feature of the UWF design course is the realistic review process—each team must undergo preliminary and critical design reviews, acceptance tests, final acceptance, and submit a final written report. There is a strictly enforced timetable for these events, and grade penalties are imposed for failure to complete an event on time. The details of the review process are (this is based on a 15 week semester):

Orientation (Week 1) The design Course Coordinator meets with all of the students enrolled and explains the procedures and regulations of the course.

Preliminary Design Review: (Week 3) Before the design review, each team submits a short written proposal of its project which contains preliminary specifications, responsibilities of each team member, and a list of project deliverables. Then at the preliminary design review each team makes a short oral presentation of its proposal to the entire faculty, the other students enrolled in design, and any other interested students. The main objective is to convince the faculty of the project's feasibility. After the presentations the faculty meet to discuss the projects; most projects are approved, possibly with minor modifications, because each faculty mentor has already proposed the project to the rest of the faculty before the preliminary design review.

Critical Design Review: (Week 6) At this review, the team meets with the project mentor and the course coordinator, and any other interested faculty; no other students are present. At this review, the students present detailed design plans, circuit schematics, software flow charts, and any other information so that the faculty can ensure that the design specifications are met. At this time the students commit to the final design.

Project Development: (Week 6 to Week 14). This period is devoted to the development, testing, wiring, and general construction of the senior design project. Frequent consultation and discussions between the students and their faculty mentor occur on an informal basis during this period. In some cases, design modifications become necessary due to factors beyond the students' control. An example of such factors is the unavailability within a reasonable delay of an important component in the original design specification. Minor design changes can be approved by the faculty mentor. Major changes are discussed with the other Department faculty.

Final Acceptance Test: (Week 14) At this time the teams must demonstrate the completed project and submit an outline of the final report. The faculty will determine compliance with the design specifications, and any deficiencies will be recorded on a punch list and must be corrected before final acceptance.

Final Acceptance: (Week 15) The course coordinator verifies correction of the project deficiencies and signs off the punch list. At this time, the teams submit draft copies of their final reports to their mentors and to the course coordinator; the edited drafts are returned to the students within two workdays.

Final Report: (Final exam week) The final, corrected, report is submitted. The faculty mentors, in conference with the course coordinator, assign the course grades. (See Grading, below.)

The reasons for the strict schedule include the faculty effort to model a real industrial design experience as closely as possible, the benefit of a disciplined approach to design, and an avoidance of the all too familiar procrastinate-and-crunch technique. The students are taught that delays in design translate into costly delays in production and delivery of the product and therefore represent a loss for the company. A grade penalty is assessed for missing important deadlines. In addition, there is a severe penalty imposed for not completing all of the requirements of the design course by the end of the semester. At the final acceptance test the students are informed if the project will not receive a passing

grade (a grade of C or above is passing); the students have the option of re-taking the design course with a new project, or submitting a petition for an incomplete and a time extension on the current project. The petition is reviewed by the entire faculty; if it is denied, the students must re-take the design course, but if it is accepted they are allowed one calendar month to complete the project with a penalty of one letter grade.

Project deliverables. Students are required to provide partial results on their projects at each step of the schedule listed above. In addition, they provide an informal oral report and partial demonstration of project subsystems as they become available.

Project Notebook. Students are required to maintain a Patent-style notebook throughout their design project. All activities related to the senior design projects are entered into the notebook and carefully dated. Both the course supervisor and the faculty mentor examine the notebook at regular intervals. The course supervisor verifies the notebook at the preliminary review, the critical review, and at the final acceptance test. The project mentor would normally also check the notebook at his discretion. The notebook provides evidence of regular progress and work on the project and discourages procrastination.

Grading. Grading is distributed according to the following table:

Activity	Weight
Preliminary Design Review	5%
Critical Design Review	20%
Final Construction	10%
Design Notebook Maintenance	10%
Final Report	15%
Mentor Evaluation	40%

All faculty members may be involved in a project, but each project has a faculty mentor, whose responsibility is to be the chief source of technical advice to the team and the project's primary evaluator. The course coordinator serves as second evaluating faculty member for each project, mainly as a means of ensuring uniformity and fairness in the evaluation process.

Design Laboratory. The students are given twenty-four hour access to a laboratory dedicated to the design course. This gives them access to necessary measurement equipment, including digital storage oscilloscopes, spectrum analyzers, logic analyzers, digital VOM's, arbitrary function generators, and power supplies. Each station in the design lab also has a networked PC running Matlab, Mathcad, Pspice, and other computer engineering software.

ADVANTAGES OF THE UWF ORGANIZATION

There are several advantages to the organization of the design course at UWF, due mainly to the small size of the program. The first is the involvement of the entire faculty at the preliminary design review and proposal acceptance stage. This helps to provide uniformity in project quality and complexity. Second, the students are able to have a close mentoring relationship with their faculty advisor. Third, the students learn the necessity of meeting design project deadlines, and how to deal with the accompanying pressure.

ROOM FOR IMPROVEMENT

The authors see several aspects of the capstone design course that need improvement, the primary ones being:

- More formal cost analyses; at present project cost analysis is done on an *ad hoc* basis.
- More formal safety analyses.
- More cooperation with local industry. There is a large co-op program on the UWF campus in which many engineering students participate, but only a few of those students have tailored their design projects to their work. This cooperation must be done with care because sometimes a company's priorities can change in the middle of the project and support for the project can be suddenly withdrawn.

Conclusion

In this article the organization and principal features of a capstone senior design course have been described. Since its inception in January of 1994, the Electrical and Computer Engineering Department slowly matured to the level of course organization described here. The course provides students with a design experience similar to what would be expected at a small engineering design company where teamwork, a disciplined schedule, and timed deliverables are essential. About ten students usually enroll in the senior design course every semester and a very small number of students (about 1 in 20) end up taking a grade penalty for failing to complete their design work within the allocated schedule.

APPENDIX: A SAMPLING OF UWF DESIGN PROJECTS

As discussed above students have the freedom to choose their senior design project topic. In the past two years several of our students have chosen a project related to a National or Regional Hardware competition. One example is the Student Hardware competition organized annually at the IEEE SouthEast Conference. The 1999 Student

Hardware Competition required the design and development of a robotic vehicle able to accomplish the following tasks:

1. Mobile vehicle
2. Able to track a line
3. Able to push a button
4. Pick up a precisely located metal ball
5. Drop the ball at a different location
6. Climb up and down a 15° incline
7. Push open a door
8. Navigate a path in the dark

MORE DETAILED INFORMATION ON THIS DESIGN TOPIC CAN BE FOUND IN [4]. A TEAM OF SIX STUDENTS DESIGNED TWO ROBOTIC VEHICLES, ONE OF WHICH EARNED FIRST PLACE MAKING UWF THE CURRENT CHAMPION IN THIS COMPETITION. FIGURE 1 SHOWS A PICTURE OF THE TWO DESIGN PROJECTS.

In light of the success of this project, twelve students have decided to undertake a design project related to the 2000 IEEE South East Conference Student Hardware Competition taking place in April 2000. Reference [5] provides more details on the project specifications. It is important to note the senior design requirement is independent of the project performance at the competition.

SOME OTHER PROJECTS THAT HAVE BEEN COMPLETED ARE LISTED HERE TO HIGHLIGHT SOME OF THE FEATURES OF THE UWF DESIGN COURSE.

Wireless Stereo Extension. This was a two-person project in which a transmitter and receiver were designed and built to provide a wireless connection between a CD player (or other audio source) and powered stereo speakers.

Fiber Optic Intercom and Relay Control System. This three-person project involved the design and construction of a microprocessor-based system that controls relays from a remote location, with a separate audio communication channel. Data and voice communication are over a fiber optic cable.

Six Zone Home Security System. In this individual project, the student designed and installed in a home a microprocessor security system. The microprocessor monitors door and window switches, motion detectors, and vibration detectors, and offers several modes of operation. It includes battery backup and siren.

Guitar Preamp System. This individual project originated with the student's avocation of electric guitar playing. A preamp, stereo imager, and 5 band graphic equalizer were designed and built.

Autonomous Underwater Vessel. The two students on this project built an autonomous submarine (using the 40-inch hull from a model sub kit) that follows a preprogrammed course 3 feet under the surface. The onboard microprocessor reads in the course from an external laptop, and it controls 3 servomotors for the dive planes and rudder and one propulsion motor. The microprocessor reads its heading from a digital compass and its depth from a pressure sensor.

Figure 1.

Miniature Surface Mount Synthesizer and Automated Test Set. This is an individual project conducted with the cooperation of a local company; an engineer from the company also served on the student's review committee. The student designed and built a miniature surface mount programmable frequency synthesizer; his company provides the facilities for laying out the integrated circuit. The synthesizer operates in the range 900-930MHz in 25kHz steps. The student also designed an automated test fixture since the company intends to put the part into production.

REFERENCES

[1] Developing and Conducting an Industry Based Capstone Design Course. C. O. Rudd & V. J. Deleveaux, IEEE/ASEE Frontiers in Education Conference, Pittsburgh, PA, Nov. 5-8, 1997

[2] A Course in Design for Quality. J. Weaver. IEEE/ASEE Frontiers in Education Conference, Pittsburgh, PA, Nov. 5-8, 1997.

[3] A Successful Undergraduate Design Center. J. C. Sutton, III. IEEE/ASEE Frontiers in Education Conference, Atlanta, GA, Nov. 2-4, 1995.

[4] 1999 IEEE SouthEast Conference Student Hardware Competition. http://www.eng.uky.edu/student.orgs/IEEE/Southeastcon_99/

[5] 2000 IEEE Southeast Conference Student Hardware Competition. http://www.tntech.edu/life/orgs/ieee/secon/.